PASSENGER CASUALTIES IN NON-COLLISION INCIDENTS ON BUSES AND COACHES IN GREAT BRITAIN

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ABSTRACT

Of all the killed or seriously injured (KSI) passengers on buses or coaches in Great Britain, a surprisingly high proportion, 64.3%, are injured in non-collision incidents. A KSI casualty distribution of this sub-sample identifies that 74.2% of the casualties are female and a large proportion, 58.0%, are elderly casualties 60 years of age or over.

INTRODUCTION

Two major bus safety reports have recently been completed at Loughborough. Firstly the 'Assessment of Passenger Safety in Local Service PSVs', for the Department for Transport (DfT), assesses the impact of the PSV Accessibility Regulations made under the Disability Discrimination Act (DDA) (1995) and the Disabled Persons Transport Advisory Committee (DPTAC) (established under section 125 of the 1985 Transport Act) recommended specifications on bus travel. Secondly 'Real World Bus and Coach Accident Data from Eight European Countries', for Task 1.1 of the Enhanced Bus and Coach Occupant Safety project (European Commission 5th Framework Project no. 1999-RD.11130), is a collation of European data that identifies the important issues in bus and coach occupant safety. It has become evident during these projects that non-collision incidents are an important part in the injury experience of bus casualties, especially for elderly occupants.

By consideration of both national statistics and in-depth cases a picture has been formed of the bus and coach casualty population and the types of incidents in which these people are injured. These statistics are presented, along with possible reasons for such a high proportion of casualties occurring in non-collision incidents and recommendations have been made that would lessen the risk of these injuries occurring, through better design and operational changes.

These injuries occur due to a combination of factors. Occupants can fall due to slipping or tripping on poorly designed floor surfaces or in wet weather conditions, or falls can occur due to acceleration forces as the bus brakes or pulls away. When these falls occur the design of the interior can present an injury risk.

In recent years bus design has changed as a result of new regulations to allow a wider population to use buses, especially with the introduction of low floor access. These features promote easier boarding and alighting and allow less mobile members of the population to make use of bus travel. Unfortunately this accessibility to travel may also increase the likelihood of these more vulnerable people receiving injuries on buses.

Many of the issues addressed are particularly relevant to elderly people, small children and the people who accompany them.

Keywords: Non-collision, DDA, DPTAC, PSV, Bus, Coach.

METHODOLOGY

This study uses British national road accident data, commonly called 'STATS 19', to investigate bus and coach accidents. The overall criteria for an accident to be included in the records are that a person must have been injured in an accident on a public highway. These accident forms are submitted to the Department for Transport (DfT) by each of the 50 police forces in Great Britain.

The definitions of injury severity used in the database are:

Fatal Injury: Includes only those cases where death occurs in less than 30 days as a result of the accident.

Serious Injury: Hospital in-patient, e.g. fracture, internal injury, severe cuts and lacerations, crushing, concussion or severe general shock. Injuries to casualties who die 30 or more days after the accident from injuries sustained in that accident.

Slight Injury: Receive or appear to need medical treatment, e.g. sprains, bruising, cuts judged not to be severe and slight shock requiring roadside attention.

The authors feel that the level of reporting of injuries to bus and coach occupants in Great Britain is high at all injury levels, due to the responsibility of the driver to report incidents to the operator.

There is also a legal obligation to report incidents to the Vehicle Inspectorate, an agency of DfT. This high level has been evident in the monitoring of police accident reports (received as part of an ongoing injury study) in the Nottinghamshire and Leicestershire counties of Great Britain, from February 2000 to February 2001.

Data are available for Great Britain, which includes England, Scotland and Wales. Whilst a separate vehicle type code is given to buses and coaches unfortunately there is no way to distinguish between a local service bus or coach and a coach. The analysis therefore covers all buses and coaches that have 17 or more passenger seats (regardless of whether or not they are being used in local service operation).

As part of the study undertaken for the DfT, physical designs of the current bus fleet were examined. This provided information on the types of designs currently in use within the UK and the hazards associated with these designs. A task analysis was undertaken of the actual bus journey from the passengers' point of view. This identified the extent of which passengers would be exposed to any hazards during the journey including such things as boarding and alighting. As well as investigating the bus design, passenger issues were considered. These included the effects of sensory disabilities, slips, trips and falls and the characteristics of the bus user population. This work has been used in this paper to identify how and why injuries occur.

RESULTS

Overall Picture

This study uses data from 1999 to 2001. The distribution of injury severity, compared to car and taxi, and all road users is given in Table 1, averaged over these three years.

Table 1. Casualty Figures (ref. 1)

	Number of Casualties (Average per year 1999 to 2001)			
	Fatal	Serious	Slight	Total
Buses and Coaches (Passengers)	12 0.1%	511 5.6%	8,577 94.3%	9,100 100%
Cars (Occupants)	1,683 0.8%	17,986 8.8%	184,053 90.3%	203,722 100%
All Road Users	3,427 1.1%	38,129 12.0%	276,411 86.9%	317,967 100%

These figures show that when a passenger is injured in a bus or coach they are less likely to receive a fatal or serious injury than overall road users (5.7% against 13.1%).

Figure 1 gives the overall picture of killed or seriously injured (KSI) road user casualties in Great Britain. Casualties on buses and coaches represent 1.4% of all KSI casualties (1.26% passengers).

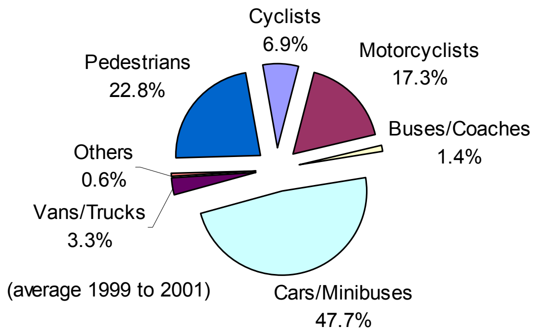

Figure 1. Proportion of KSI Casualties by Road User Type

Whilst this percentage is low, and analyses of exposure indicate that bus travel is one of the safest modes of transport, this study identifies issues that should make local bus transport even safer. Recent experience in the UK concerning rail crashes indicates that the public has a keen awareness of the safety of public transport and an expectation of very high levels of safety if they are to use public transport.

Also, as new low floor buses make travel more viable for less physically mobile passengers it is important to make sure that these people are not suffering injuries inside the vehicle, which will make the overall proportion of bus casualties higher. It is also important to look to the future with most governments encouraging the greater use of public transport, especially in congested cities.

Accident Circumstances

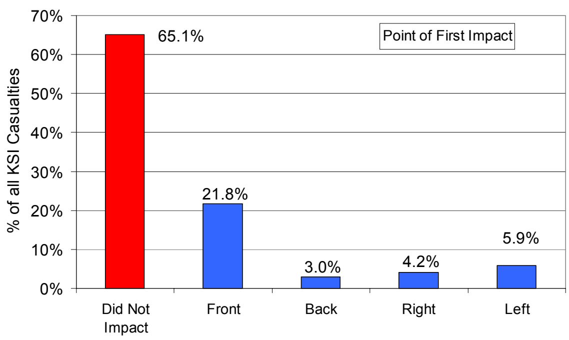

Figure 2. Location of First Impact when Passengers (KSI) are Injured

Figure 2 shows the location on the vehicle of the first point of impact (left and right are for an occupant sitting in a vehicle facing forward). While this is not necessarily impact direction, over the whole national database it is a good estimation of the type of accident. It can be seen that 65.1% of all KSI passenger injuries are in non-impact incidents.

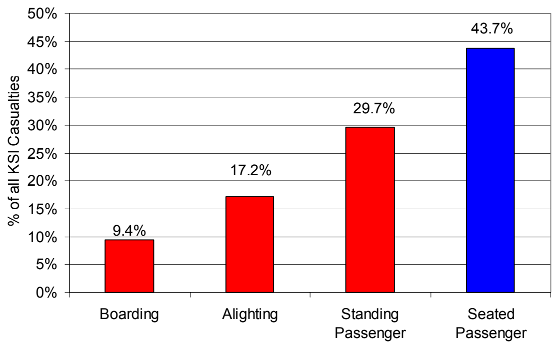

Figure 3. Position / Action of KSI Casualties*

*If a passenger is struck by a vehicle after safely alighting from a bus or coach they are counted as a pedestrian. If an injury occurs due to a fall onto or off the vehicle they are recorded as boarding or alighting as appropriate.

Figure 3 shows that 56.4% of all KSI passenger casualties are not seated when they are injured. Overall 49.0% of KSI casualties are both not seated and the vehicle does not have an impact. These are large proportions of the bus casualty population.

Non-collision incidents typically have a much lower number of casualties per vehicle, 1.14, when at least one injury takes place (the criteria for an accident to be recorded). For frontal damage accidents this figure is 2.05.

KSI Rate

'KSI rate' is used to describe the proportion of all casualties in a certain group which receive a serious or fatal injury. It is found that when a casualty is not seated there is an 8.3% likelihood of sustaining a KSI injury, compared to figures of 4.1% for seated passengers and 5.8% overall. More detail is given in figure 4.

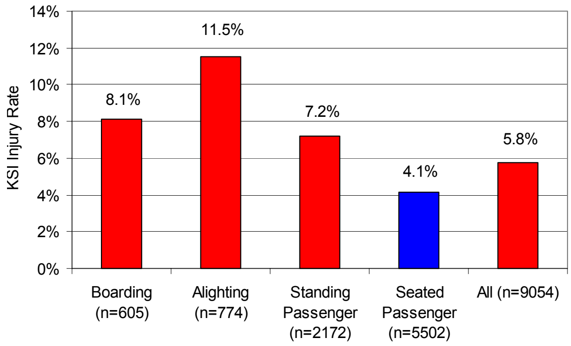

Figure 4. Percentage of KSI Casualties

(n=all severities per year)

Interestingly there are more casualties when alighting the vehicle than when boarding, with a shift towards a higher proportion of serious injuries. This could be due to drivers being less aware of these passengers or just the likelihood of falling down being greater. Also slight loss of balance can develop when standing quickly after a period of sitting on the vehicle and bifocal glasses, that do not give good distance vision when looking down, may also be a problem.

During the 3 years of data, 24 out of the 35 fatal casualties (69%) occurred when the passenger was standing, boarding or alighting the bus or coach. After studying some in-depth cases it is apparent that many of these fatal casualties in fact suffered from some kind of fall, trip or slip, whilst standing, alighting or boarding.

Of all casualties that are standing, alighting or boarding, 83.7% are injured in non-collision accidents and it is important to note that 40.4% of seated casualties are also injured in such accidents. For KSI casualties these figures are 87.0% and 36.9%.

Road Classification

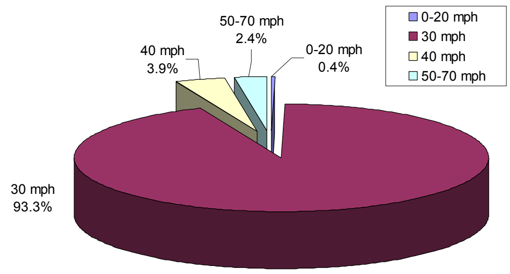

Figure 5. Casualty Distribution by Road Speed Limit

Looking at just the non-collision population it is found that 93.9% of all casualties occur on roads with a 30 mph (48 kph) speed limit and 3.9% on 40 mph (64 kph) roads, 94.1% and 3.4% for KSI casualties. This compares to figures of 83.6% and 4.6% for all casualties injured on buses and coaches.

Roads up to and including 40 mph speed limit are defined as built up areas by the UK government. In the data it is not possible to separate local buses and coaches but this high figure in built up / urban areas indicates that the majority of non-collision incidents are likely to occur on local service buses.

Who Is Getting Injured? The Non-Collision Casualty Population

Gender and Age

3 year (1999 to 2001) totals:
Male - 9 Fatalities
251 Serious
Female - 11 Fatalities
738 Serious

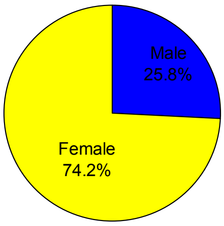

Figure 6. Gender Distribution (KSI)

Figure 6 gives the gender distribution for KSI casualties, injured when no collision takes place, with the split of 74.2% women and 25.8% men. Seated casualties have been included as the design of the interior can be just as important for them as it is for occupants trying to keep their balance when standing.

The data shows that there are almost three times as many female as male KSI casualties. This is likely to be both a function of greater bus use by females and a lower tolerance to injury.

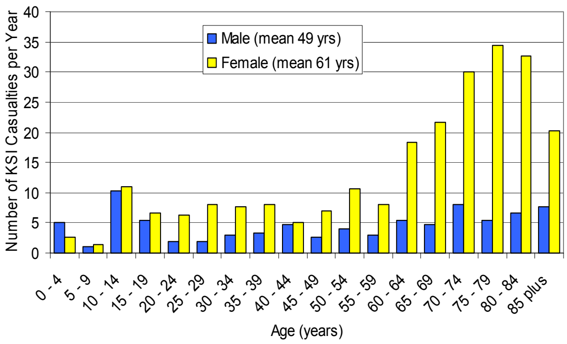

Figure 7. KSI Casualties by Age and Gender (per year)

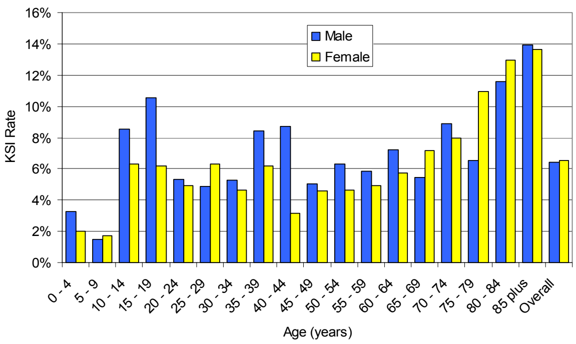

Figure 8. KSI Rate Across Age Bands

Figures 7 and 8 give age and gender distributions for KSI non-collision casualties.

In figure 7 a small peak is seen for school age children and there is a very obvious increase in numbers amongst elderly females. The mean age for female casualties is 12 years higher than that for males.

From figure 8, overall there is an increase in the likelihood of a serious or fatal injury to both males and females as their age increases. The increase is most prevalent after the age of 70. An increase is also evident for male teenagers. The risk of a KSI injury, when an injury has taken place, is lower for young children.

Exposure

Governmental surveys (ref. 2) show that generally women travel more on local buses than men for most types of area and age. This goes some way to explaining why women have a much greater representation as bus or coach casualties than men on the database. Overall it is estimated that in the 16 to 59 years old age group women travel 47% further on local buses than men.

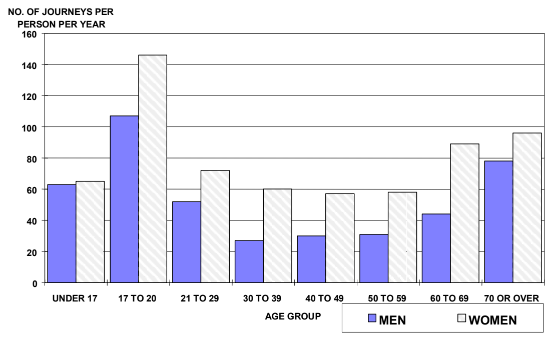

Figure 9. Share Of Bus Journeys By Age Group NTS 1996-98 (ref. 3)

This figure from the National Travel Survey shows that women of all ages also make more local bus journeys than men, whilst travelling further. This will give women higher exposure to injuries that occur whilst standing, boarding or alighting the vehicle, as they get on and off more often.

HOW AND WHY DO THESE INJURIES OCCUR?

This work has shown that 64.3% of all KSI bus passenger casualties are in non-collision incidents with a shift towards elderly female passengers. This section will discuss problems on buses that cause these injuries. Generally it is felt that most of these types of non-collision injury are taking place on local service buses, borne out by 94% of these injuries occurring on 30 mph roads. The rest of this paper will therefore concentrate on these vehicles.

Slips, Trips and Falls on the Vehicle

Caused by:
- Slippery floors,
- Weather conditions,
- Uneven floors,
- Unexpected or high steps,
- Steep slopes,
- Lack of visual cues,
- Physiology in older people.

Figure 10.

Figure 11.

There are a number of design issues on buses that can cause slips, trips and falls. Floors can also be slippery due to inappropriate or worn surfaces. More modern buses have textured floor surfaces which give a good grip but on older buses and especially those which have seen a lot of service, the flooring gets very worn and therefore smoother, which could present a potential slipping hazard.

Weather conditions present many variables that are impossible to remove whilst the vehicle is in operation. Rain, leaves, snow or even wet paper significantly increase the likelihood of an individual slipping on a floor. It is generally recommended that floors should be kept as clean as possible and non-slip surfaces should be used throughout.

Uneven floors, especially unpredictable or varying slopes on aisles can present tripping hazards, as they are not expected. New guidelines suggest that floors should not have a greater slope than 3 degrees inside the vehicle (figure 10) and 5 degrees around the door area. Buses with internal steps half way down the aisle can cause falls as passengers are busy trying to find an empty seat rather than looking at the floor (figure 11). The height of any steps within the bus should also be consistent.

It is important to mark any steps or floor obstructions on the vehicle to act as visual cues. There should be good marking of steps, good even lighting levels, and appropriate use of colour so passengers can quickly identify grab handles, steps, seats and exits. Steps also wear quickly and become slippery so good maintenance is required.

Generally older people are more susceptible to falls and the environment described above will increase the risk of falling. Older persons have stiffer, less co-ordinated and more limited gaits than younger persons. Posture control, body-oriented reflexes, muscle strength and tone, and height of step all decrease with age thus limiting the individual's ability to negotiate steps and obstacles whilst also impairing the ability to avoid a fall after an unexpected trip or when reaching or bending. Age-associated impairment of vision, hearing, and memory also tend to increase the number of trips and stumbles.

Slips, Trips and Falls whilst Boarding or Alighting

Caused by:
- Step to the kerb can be too high,
- Riser steps of different heights,
- Passengers can be encumbered.

Figure 12.

Boarding and alighting includes passengers being injured while stepping on or off the bus as well as falling over whilst standing as they make their way from or to a seat. This can be seen in the split between casualties when the bus is moving and when it is stationary. National Accident data is collected by individual police officers at the scene of accidents. Therefore there may be some overlap in the understanding of the definitions relating to standing as a passenger and those boarding or alighting.

Of all KSI non-collision passenger casualties, 35.3% are injured whilst boarding or alighting (Boarding 12.8%, Alighting 22.5%). Of these casualties 42.4% occur when the vehicle is stationary, 11.0% whilst the vehicle is stopping and 25.8% when the vehicle is starting off.

If there is a large initial step when alighting or boarding, or the step risers are different in height, passengers can lose their balance or misjudge the distance (figure 12). This is especially relevant to the elderly or the encumbered passenger, for example when carrying bags, children or pushchairs.

Differences in kerb heights at different bus stops is a difficult variable to control but this can exacerbate the problem. All subsequent steps on board the bus should be the same height to avoid loss of balance. A number of alighting cases have resulted in serious injury or even death as people have stumbled and fallen under the bus.

Operational Issues and Heavy Braking

Falls can occur from the mechanisms mentioned above but the operation of the vehicle can also initiate a fall on a bus.

Caused by:

Acceleration, vehicle pulls away before passenger reaches seat,
Deceleration, passenger stands to get off bus before bus has come to a halt,
Vehicles sometimes need to turn sharply into and out of bus stops,
Emergency manoeuvres.

Due to timetable constraints the bus can often start to accelerate away before passengers, especially the less mobile, have the time to reach a seat or find a place to stand safely and hold on. Passengers can also feel under pressure to stand up before the bus has halted at a bus stop as they fear that they will not be able to get off in time, or the driver may not stop at all.

Bus stops tend to be recessed which is good for traffic flow but if they are too small the sharp steering motion of entering and exiting bus stops can unbalance passengers.

These factors can cause boarding and alighting passengers to lose balance and fall against rigid parts of the bus interior.

The scenarios above are also relevant to standing passengers who haven't got a seat and 92.3% of standing passenger casualties are injured when the vehicle is moving. Standing passengers account for 39.0% of all KSI non-collision casualties.

The performance of buses in terms of engine power and braking is also improving which can increase the likelihood of injuries occurring due to the operation of vehicles, as they can accelerate and brake more quickly.

The obvious solution to this would be to avoid all standing passengers and ensure that all passengers are seated before the bus moves off from a stop. Likewise, alighting passengers should remain seated until the bus stops. It would be difficult though to not allow standing passengers when the use of public transport and buses is being promoted and operators want to use their vehicles at full capacity when needed.

Another solution would be for the driver to endeavour to avoid sudden manoeuvres and accelerate and brake more smoothly.

Passengers on vehicles also have a duty to reach seats as quickly as possible. Drivers can't be expected to wait if passengers are unnecessarily fussy about where they are sitting!

Driver Issues

In work carried out at Loughborough University one operator said 90% of complaints from injured passengers put the blame on the driver. But it is important to recognise workload is high due to:

- high levels of traffic congestion,
- pressure to keep to timetables,
- driver operated buses.

Since deregulation in Great Britain there is considerable commercial pressure to keep to timetables due to fierce competition. Also in Britain we are starting to see traffic commissioners banning operators from registering any more services and imposing fines if operators are not running to time (ref. 4a). Traffic congestion is much higher so to keep to timetables drivers must not spend too long at bus stops. Also to keep up with modern traffic, bus performance has improved in terms of acceleration and braking, which puts higher forces on any unbalanced passenger.

In addition it is now uncommon to find a conductor on a bus in addition to the driver. This means that the driver has to issue tickets, handle money and deal with any unruly behaviour on the vehicle. This adds to the driver's already stressful working conditions. Recently though, London Buses have carried out trials with conductors on a low floor route, with the Mayor of London committing to a significant increase in the number of conductors operating in Central London by 2004 (ref. 5).

The authors would like to see research into the workload of drivers and detailed analysis of the flexibility in bus timetables to examine whether longer stops are in fact an issue in the profitability of the bus service.

New provisions referred to under the 'Conduct of Drivers, Inspectors, Conductors and Passenger Regulations 1990' came into effect on October 1 2002 and refer to extra duties in providing that disabled passengers can travel safely on local buses (in addition to other points such that route numbers are always correct and illuminated appropriately) (ref. 4b).

INJURY CAUSATION

Poor Interior Design

What are the dangers when a passenger does slip, trip or fall? Why are injuries caused?

These pictures give examples of interior design that can lead to injuries when passengers make contact with internal parts of the bus. These are typical of the bus fleet.

Figure 13.

Figure 14.

There are unprotected metal grab rails in the areas where seated passengers' heads will naturally fall forward and passengers' upper extremities may hit if they fall over (figures 13 and 14).

Figure 15.

Figure 16.

Ticket machines tend to have hard metal edges that a standing passenger could easily fall forwards and hit, for example, during hard braking (figures 15 and 16). Likewise a boarding passenger could trip and strike the machine. Generally ticket machines, card readers, and bins are not integrated into the design of the bus, they appear to be bolted on afterwards depending upon the requirements of the operator. This inevitably causes them to encroach on the standing area.

Figure 17.

Also shown is an example of the hard metal joints used for the interior grab bars (figure 17).

The continuing problem of vandalism must also be kept in mind though. It is a challenge for designers to make parts compliant enough to lessen injury but also durable and not attractive to easy vandalism.

Example of a Non-Collision Casualty Case

The following example demonstrates the potential consequences that can result from some of the factors previously discussed, including standing passengers, operational issues and poor interior design.

A 52 year old female passenger stood up on the bus intending to alight at the bus stop shown here (figure 18). She had shopping bags in both hands.

Figure 18. Scene of Accident

Figure 19. Area of Head Impact

Before reaching the stop a dog ran across the road causing the driver to brake heavily to a halt. Figure 18 shows the bus in the position at which it came to a stop, so it can be seen that the passenger stood up whilst the bus was a good distance from the bus stop. During the braking action of the bus, the passenger fell forwards and received a fatal head injury from the interior contact shown in figure 19.

The shape of the head impact can clearly be seen in the grill with the main injury caused by an impact with the rigid metal surround.

DISCUSSION

Other European Countries

Internationally accident data is collected in slightly different ways but it has been found that the non-collision casualty situations in Austria and Germany broadly mirror Great Britain.

In Austria 32% of all KSI casualties are injured during an emergency braking manoeuvre (ref. 6).

A German in-depth study of city bus accidents, in Bavaria (Munich and Nürnberg), carried out as part of a thesis (ref. 7), revealed that 50% of the casualties in buses are due to non-collision bus incidents. In over 70% of the cases emergency braking was the main cause of the incident in the bus, 72% of these casualties were older than 55 years.

New Legislation

The Public Service Vehicles Accessibility Regulations SI 2000 No. 1970, which have been in force in the UK since August 2000, replaced the recommended specifications of the Disabled Persons Transport Advisory Committee (DPTAC). These are in line with the European directive on bus construction 2001/85/EC. Generally these regulations make access on and off vehicles easier and vehicle interiors safer.

Any new local or scheduled service bus first used on or after 31st December must be compliant with these new disability and access regulations, with all buses compliant by 2017.

These new buses have significant advantages on the ease of access for all passengers but especially the less mobile, allowing a wider population to access and use buses, thereby changing the bus user population characteristics. New buses will have low floor access, priority seats and crucially space for wheelchairs and push chairs (figure 20).

Figure 20.

It is perceived that the introduction of these vehicles will be accompanied by an increase in the safety of the passengers. Low floor access avoids, or goes some way to improving, the high step onto the vehicle, which can cause stumbles and falls both onto, and off, the vehicle. Other improvements include access lighting for wheelchair users, improved and more consistent step dimensions, bellpushes within easy reach of passengers and more frequent handrails. These features should lessen the likelihood of falls inside the vehicle.

Figure 21.

Figure 22.

New Vehicles

At the start of 1998 there where no low floor buses in London. As of Sept 2002, 4,486 of the peak vehicle requirement in London was covered by low floor buses making 75% of the fleet wheelchair accessible (ref. 8). Investment in new buses has increased year on year since the early 90's.

The BusPlus scheme in London is pushing for the introduction of low floor vehicles on all non-Routemaster services by the end of 2005 and the government has generally encouraged the average age of vehicles in the PSV fleet to decrease, at the moment it stands at just over 8 years, from a peak of 10 years in the mid nineties.

The Continuing Relevance of Non-Collision Injuries

Even though new legislation has been introduced recently, Great Britain will still have older buses for some time to come and all local buses in service will not have to comply until 2017 (single deck local buses in 2016). In 2001 the average age of the public service vehicle fleet in Great Britain was 8.4 years old (ref. 9)

Therefore the authors believe it is very important to still consider the issues raised in this paper as they will affect bus users for many years to come, especially outside London. Also whilst access regulations generally improve the interior design of the bus, interior contacts must be kept in mind during the vehicle design and operational issues throughout the life of the vehicle.

In fact an unfortunate by-product of some of these regulations is that the number of seats are reduced on the lower deck of double decker buses, (there can be as few as 20 seats in the lower saloon) which means that more people may be forced to stand or move upstairs, it is therefore just as relevant to consider falls, especially from bus operation, on these new buses as on older buses.

The 10 Year Transport Plan set a target in 2000 of a 10 percentage increase in bus patronage in England by 2010, although this has now been combined with light rail. There was a 1 per cent increase overall from 2000/01 to 2001/02, a 5.5% increase in London but a 1.6% fall outside London. This could be an indication of the improvement in vehicles in London and reflect increases that may occur elsewhere with new low floor vehicle introduction (ref. 10).

Generally bus patronage looks likely to increase and if the same types of injuries occur the absolute numbers of casualties will also increase.

Future Work

These studies have already identified the problems of non-collision passenger casualties. Further work should answer the questions of whether:

- newer local bus designs solve the non-collision injury problems that have been evident in the past,
- the operation of local buses can still be detrimental to the safety of passengers. Have these problems changed, become better or worse on newer, higher performance buses?
- has greater accessibility allowed more vulnerable people to travel on local buses, and if so will we in fact see an increase in casualty numbers?

Any future studies may also be able to take advantage of on board CCTV coverage that is becoming more and more common on new (and in fact some older) vehicles to combat vandalism, attacks on drivers and general anti-social behaviour.

CONCLUSIONS

- The majority of killed and seriously injured bus passenger casualties in Great Britain (64.3%) occur when the vehicle is not involved in a collision.
- It has been found that there is a high proportion of elderly female passengers in this casualty population and when they are injured they have an increased risk of a serious injury.
- Legislation is changing the design of buses and the authors obviously support those changes which make public transport more widely available. However legislation is improving access for all, enabling more vulnerable people, especially the less mobile, to travel on buses. These people will be both more susceptible to falls, and to injuries if they fall, whilst on the vehicle.
- New regulations are in force but they do not place requirements on good operating practice, also the vehicle fleet includes a large proportion of older vehicles and these new bus designs will not be commonplace for many years to come (especially outside London).

RECOMMENDATIONS

Regulations have improved access but better interior design is needed, especially around the ticket/driver area and near to the doors, to minimise contact injuries. Maintenance procedures should also ensure there is no compromise on safety.

The issue of pressure on operators, and therefore drivers, to achieve strict timetables in mounting congestion should be considered. A compromise between economic whilst passenger friendly timetabling should be reached, against which operators can be judged.

During busy times and on busy routes it would be beneficial to have a conductor accompanying the driver, collecting fares, helping passengers (especially wheelchair users) and dealing with unruly passengers, leaving the driver to concentrate on driving.

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