Research into the Safety of London Bus Passengers

Final Report

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REPORT AUTHORS

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Executive summary

The study was commissioned by London TravelWatch and was substantially funded by the Road Safety Trust. Additional funding was provided by London TravelWatch and in-kind support was provided by participating Bus Operators and Transport for London. The aim of the study was to independently review and explore the causation of injuries to bus passengers on the London bus network.

Over 5.04 billion bus passenger journeys were made in Great Britain in one year (2015-2016), and around half of the bus passengers in the UK are, in fact passengers of London buses. In 2015, 1,594 bus and coach occupant casualties were reported by the Metropolitan Police Service (MPS). However, some 6,096 incidents not requiring police intervention were also reported by London's Bus Operators to Transport for London (TfL) in 2016, suggesting that there is a more of a problem of passenger injury than is suggested by the MPS figures.

A multi-method approach was used to analyse quantitative and qualitative data to derive a better understanding of the nature and circumstances of injuries and how they can be prevented and/or mitigated. Additionally, countermeasures were developed in consultation with designers, engineering, human factors and vehicle safety experts. These were then presented to stakeholders to determine priority solutions i.e. those that would have the most impact on preventing bus occupant injuries together with the feasibility of implementing them.

The first phase of the study quantitively analysed five years of the STATS19 police collision data and the TfL Incident Reporting Information System (IRIS) database containing bus operator reported passenger incident data. The initial quantitative analysis identified that in London, reported passenger injuries have increased since 2012, rising from a 31% share of the STATS19 total in 2012 to 44% in 2016. Most passenger injury incidents resulted from non-collision incidents and would account for the disparity between STATS19 and the IRIS database numbers. There were notable variations both between the two datasets, and the quality of the information available for analysis. STATS19 data analysis allows identification of the passenger position in the bus in one of four categories and can also help to identify the bus movement at the time of the incident. The analysis identified that alighting and boarding mainly occurs when the vehicle is "waiting to go", "parked" or "moving off". However, injuries sustained while seated, which on average represent 41% of the casualties, most often occurred when the vehicle is "going ahead" or "slowing / stopping". Standing injuries, which account for half of the total casualties, occurred most frequently when the vehicle was "slowing / stopping", "going ahead", or "moving off". However, STATS19 data cannot identify in detail the reasoning or the circumstances of the incident and it only offers a limited option for classification of passenger injury severity as being 'slight', 'serious' or 'fatal'.

The IRIS data was expected to produce a richer source of data for analysis but suffered from inconsistencies and/or inaccuracies. Most injuries were 'minor' which included some descriptors such as cuts, abrasions or bruises. However, the injury descriptions could not be analysed in greater detail as some 35% of the recorded injuries were in fact, actual injury mechanisms including (e.g.) 'bump' or 'crush'. Where it was possible to analyse injury data at a sub-category level, the body regions at risk of injury were mainly head and face in children and face and lower/ upper extremity for elderly passengers. Most lower extremity injuries in the subcategory of data were caused in alighting and boarding incidents.

The second phase of the study qualitatively analysed bus operator incident reports and CCTV footage of incidents utilised semi-structured interviews with passengers injured on buses. At the root cause of many of the injuries was the harsh movements of the bus during braking and

acceleration which caused passengers to be 'thrown' around in the bus resulting in falls or contacts with harsh objects in the bus interior. There was also an expectation that passengers and drivers would behave in a certain way which would then be used to determine 'fault' of the injury occurring. Additionally, there were apparent pockets of 'problem' scenarios or areas within the bus that warrant attention. These included the seats forward facing into the wheelchair area in which case passengers are liable to be thrown forward and onto the floor; standing passengers not holding on; drivers pulling away before the passenger has sat down; non-emergency harsh braking and pushchairs toppling over. It was also found that the impact of injuries sustained by passengers was both 'psychological' as well as 'physical' with some not returning to bus travel for up to one year after the incident.

The final phase of the study involved identifying potential solutions to the problem of passenger injury and presenting these to stakeholders to identify priorities and to assess the feasibility of their implementation. A workshop was held at Loughborough University bringing together designers, engineers, vehicle safety and human factors experts to generate countermeasures to the problems identified during Phase 2.

A design research approach was used enabling freedom for the workshop participants to ideate against 'how might we' statements. A total of 170 ideas were generated and then re-classified which resulted in 51 solutions taken forward to a stakeholder workshop attended by bus operators, manufacturers, TfL, the Road Safety Trust and London TravelWatch.

It was identified that many of the solutions were feasible but to make realistic changes to passenger injury outcomes would require a shift-change in passenger and driver behaviour as well as a supportive environment to achieve such change.

Key recommendations

- Reduce harsh braking and acceleration incidents;
- Encourage the use of forward collision warning systems to assist drivers negotiating congested traffic;
- Enable passengers to sit down before bus pulls away from bus stops;
- Encourage passenger behaviour change using nudge techniques or additional information sources to enable them to stay seated until the bus has completely stopped before alighting;
- Encourage passengers to routinely hold onto grab-rails and seat rails whilst sat down;
- Raise awareness of the impact of a driver's behaviour and decision making on a passengers psychological and physical well-being through driver empathy training;
- Review the issue of the 'open' forward-facing seats into the wheelchair / buggy area to prevent passengers being thrown out of them in instances of harsh braking;
- Consider evaluating and increasing running times in the off peak-periods to enable drivers to accommodate the needs of older passengers to reach a seat on boarding and remain seated until fully stopped for alighting the bus;
- Promote the needs of drivers and passengers to increase the dialogue on buses and raise awareness of expected behaviours e.g. passengers must always hold on to handrails;
- Consider policy changes to enhance driver behaviour; particularly to not pull away until passengers are sat down; always kneel the bus and wait until bus has stopped before passengers stand to alight;
- Potentially consider gamification of bus drivers to rate their driving and provide awards

Recommendations to improve data collection

- Better reporting systems including more accurate injury data and injury causation information;
- Standardisation of language and parameters across incident reporting systems;
- Consistency with the IRIS database;
- In-depth case reviews of existing/historical cases involving major incidents and collisions on buses in which major injuries have been sustained by bus passengers/drivers;
- Development of a process for independent in-depth investigations of future major incidents and collisions on buses in which major injuries have been sustained by bus passengers/drivers.

The strength of this study was the approach taken by the researchers and despite the difficulties accessing data, an interpretation of the problem of injuries on London buses has been provided. Using a design research methodology approach to generate 'expert' solutions from 'how might we' statements proved to be an innovative approach to injury countermeasures. This approach identified a range of potential solutions, some of which were traditional and others unconventional, which were taken to stakeholders. This enabled stakeholder input into identifying the feasibility and priorities for implementing solutions to the problems identified. A stakeholder workshop approach was very successful in providing an immediate evaluation of the feasibility of the identified solutions.

It was evident from the study that problems and solutions are not confined to one area but require a systems approach to achieving a reduction in bus passenger injuries. This would involve passenger and driver behaviour change, vehicle design improvements, road infrastructure changes, legislative and policy updates and changes to the behaviour of other road users.

Acknowledgements

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Table of Contents

1 Introduction

There were an estimated 5.04 billion bus passenger journeys in Great Britain (2015-2016), and a high proportion of these were made in the city of London[1]. In total, over 300 million vehicle miles are travelled by the London buses per annum equating to some 6 billion passenger miles per year. Around half of the bus passengers in the UK are passengers of London buses with 1,594 bus and coach occupant casualties reported by the Metropolitan Police Service (MPS) in 2015. These were categorised as one fatality, 70 seriously injured and 1,523 slightly injured casualties as defined within the STATS19 reporting system of 'Slight', 'Serious' and 'Fatal' casualties[2]. Other incidents with injuries not requiring police intervention are reported by London's Bus Operators to Transport for London (TfL) and are published[3] on the TfL's website. In 2016, 6,096 injuries were reported on London's contracted bus services ranging from those described as 'injuries treated on scene' to 'fatalities'. These figures suggest that many more injury incidents occur beyond the officially reported STATS19 data.

1.1 Aims of the research

- To derive a better understanding of the nature and circumstances of injuries and how they can be prevented and/or mitigated;
- To provide an in-depth understanding of the safety issues which confront bus passengers in London and consider countermeasures to such safety challenges.

To achieve these aims the following objectives were identified;

1. A quantitative analysis of bus passenger incidents in the Greater London area using the STATS19 and TfL databases to explore the nature and circumstances of injuries that afflict bus passengers in London;
2. A qualitative analysis of a representative sample of Bus Operator incident reports and interview data from passengers involved in incidents;
3. Identify key causation factors in bus incidents and identify countermeasures to mitigate injury;
4. Dissemination of the results of the study to stakeholders of the road transport system through seminars/workshops and a bilateral one-to-one meeting with industry and TfL.

To meet the first objective to provide a quantitative analysis of bus passenger incidents access to relevant Greater London Area datasets was necessary as outlined in Table 1 below. Department for Transport STATS19 data is available freely online[4]; therefore, data for 2012-2016 (inclusive) was downloaded for analysis. It was decided not to analyse the linked police-hospital dataset involving STATS19 and HES (Hospital Episode Statistics) at this stage as the available dataset is relatively old and is not directly comparable to the STATS19 time period for this project. Permission was sought to access the TFL's Incident Reporting Information System (IRIS) incident data, which was released by Transport for London to analyse specific incidents and injury cases for the same 2012-2016 period. These datasets were used to achieve the first aim of providing a quantitative analysis of bus passenger incidents in the Greater London Area.

[1] Department for Transport accessed 24/04/2017 https://www.gov.uk/government/collections/bus-statistics
[2] http://content.tfl.gov.uk/casualties-in-greater-london-2015.pdf
[3] https://tfl.gov.uk/corporate/publications-and-reports/bus-safety-data
[4] https://data.gov.uk/dataset/cb7ae6f0-4be6-4935-9277-47e5ce24a11f/road-safety-data, accessed 14 Feb 2018

Table 1: Data sources for the project

Data Source	Availability	Source partner	Analysis	Data
STATS19	Publicly available	Loughborough	Quantitative - Loughborough	Year 2012- 2016
TfL	Available on request	London TravelWatch	Quantitative - Loughborough	Year 2012- 2016 (or what is available)
STATS19+HES linked data	Potentially available on request (DfT) permissions required	Loughborough	Quantitative - Loughborough	Available years if permission granted
Bus operator data – incident reports	Potentially available on request	London TravelWatch	Qualitative - Loughborough	~600 cases (represents 10% of TfL reported cases in 2016)
Bus operator CCTV – video analysis	Potentially available on request	London TravelWatch	Qualitative - Loughborough	CCTV for 10% of these cases (n=60) if available
Bus passenger - Interview data	Access required via bus operators	Loughborough conduct interviews	Qualitative – Loughborough	~60 case interviews (10% of the case reviews)

Other data sources were needed for the qualitative analysis of data and such data is held by Bus Operators. Meetings were initiated through London TravelWatch to enable Loughborough University to access this data. A preliminary meeting was held with Go-ahead to discuss the feasibility of a study of this kind. Discussions also centred around accessing additional necessary data, identifying potential pitfalls and examining the quality of the data that could be released for analysis. A subsequent follow up meeting organised by London TravelWatch involved representatives from three Bus Operators (Go-Ahead, Abellio and Stage Coach) together with TfL. At this meeting, the project outline was presented by Loughborough University and project requirements were stipulated with potential data access requirements determined for each of the Bus Operators. The Bus Operators agreed on the provision of several incident reports and CCTV clips that could be accessed (Table 2). Additionally, the operators agreed that they would undertake a 'mail-out' to all passengers identified in the incident reports to invite them to take part in a telephone interview with researchers from Loughborough University.

Table 2: Agreed data to be provided to Loughborough University

Phase	Data Type	Bus operator 1 Go Ahead	Bus operator 2 Stagecoach	Bus operator 3 Abellio
Phase 2 (expected to receive)	Incident reports	300	150	150
	CCTV footage	30	15	15
Phase 3 (expected to mail out)	Passenger interviews	300	150	150

For ease of presentation the project is presented in three distinct phases with the methods and results for each phase described in each section.

2 Phase 1. Quantitative analysis

Objective: A quantitative analysis of bus passenger incidents in the Greater London area using the STATS19 and TfL databases to explore the nature and circumstances of injuries that afflict bus passengers in London.

2.1 Quantitative Methods

2.1.1 STATS19 Data

STATS19 is the Department for Transport's (DfT) dataset of police reported personal injury road traffic accidents in Great Britain and is available to the public to downloaded from the government data repository website[5]. The project required data from the most recent 5 years to be analysed, so data from 2012-2016 (inclusive) was downloaded; the 2017 data was not yet finalised at the time of analysis.

The 'casualty', 'vehicle', and 'accident' STATS19 files were obtained for each year in the analysis sample and combined so that a trend analysis across the years could be carried out. A combination of SPSS and Microsoft Excel was used for all data manipulation and analysis. Since the STATS19 dataset is produced by the DfT with the intention of being publicly available, the data gathered from each police force is checked and 'cleaned' before it is released. Therefore, no further data 'cleaning' was required before analysing.

The complete STATS19 dataset was filtered to leave only incidents of interest to the current study. Four subsets of data were created for analysis:

- Accidents occurring between 2012-2016 in Great Britain involving at least one injury to a bus passenger [n=14,462]
- Accidents occurring between 2012-2016 in London involving at least one injury to a bus passenger [n=5,699]
- Casualties injured on buses between 2012-2016 in Great Britain [n=22,163]
- Casualties injured on buses between 2012-2015 in London [n=7,043]

These separate groups of 'accidents' and 'casualties' were distinguished since a single accident can result in multiple injured persons; analysis of accident-specific variables (e.g. time of day) was undertaken using the 'accidents' dataset so that only one instance per accident was included in the sample and an accident with multiple injuries did not therefore bias the results. Casualty-specific variables (e.g. age and gender) analysis was undertaken using the 'casualties' dataset so that all injured persons were captured in the results.

Drivers and casualties outside the bus (e.g. pedestrians and cyclists) were excluded from all datasets, as injuries to bus passengers was the focus of this study. It should also be noted that within STATS19 data, it is not possible to distinguish between 'bus' and 'coach' as these are grouped in the dataset; therefore, the sample analysed also included coach accidents.

Analysis was carried out using descriptive statistics only. For each variable considered the analysis was carried out in one of two ways, either; (1) the data were combined to give a 5-year average and the distribution of values within the variable was presented; or (2) the distribution of values within the variable was determined for each year and presented in addition to the 5-year average.

[5] https://data.gov.uk/dataset/road-accidents-safety-data accessed 14th February 2018

The first method was used to give an indication of how and when accidents occur that result in injuries to bus passengers; these analyses were intended to be indicative of the circumstances of such accidents and were used for variables where there was little variance between years. The variables analysed with this method were; collision partner, day of week of accident occurrence, month of accident occurrence, weather conditions at time of accident, light conditions at time of accident, road type at accident location, speed limit at accident location, junction type at accident location, and age and gender of casualty.

The second method was used to examine in more detail how some distributions of data change over the years and to look for any trends; for example, to examine whether casualty numbers are increasing or decreasing. The variables analysed with this method were; total number of accidents or casualties, accident severity, passenger location at time of injury, and vehicle movement at time of passenger injury.

2.1.2 IRIS Data

IRIS is the database used by Transport for London (TFL) to capture all incidents that occur on buses whilst operating a service using a consistent reporting methodology. The IRIS database includes road traffic collisions, slips, trips and falls, vandalism, assault etc. IRIS data for the years 2012-2016 (inclusive) was provided to Loughborough University for analysis for this study.

The raw data was initially 'cleaned' to remove (for example) duplicate records or blank rows in the dataset. The data was then further filtered to remove non-bus related passenger incidents such as assaults and bus-soiling. Finally, injuries to drivers or other non-passengers were removed so that only incidents that resulted in injury to bus passengers were included in the sample for analysis. Microsoft Excel was used for analysing the IRIS dataset.

As with the STATS19 analysis, two subsets of data were created in order to analyse variables on either an 'incident' or a 'casualty' basis:

- Incidents occurring on TfL operated buses between 2012-2016 [n=20,490].
- Casualties injured on TfL operated buses between 2012-2016 [n=21,998].

Analysis was carried out using descriptive statistics on the dataset as a whole; the distribution of values across the different variables was analysed and presented as a proportion of the total sample. The variables analysed were; total number of incidents or casualties, injury event type, sub-category of injury event type, age of casualty, type of injury, body region injured.

Additionally, cross-tabulations of some variables were analysed to give more detail on exactly where and how injuries were occurring and provide more insight on where to target countermeasures.

2.2 Results – Phase 1

The key highlights from the phase 1 analysis are reported below; the full results, including figures and tables, can be viewed in the interim report (Appendix 1).

2.2.1 STATS19 Analysis

In total between the years 2012-2016 (inclusive), there were 14,462 accidents reported to the police in Great Britain where at least one bus or coach passenger was injured. Of these, 5,699 (39%) were in the Greater London area. However, according to Department for Transport annual bus statistics[6], for the year 2016/2017, 45% of all bus journeys in Great Britain were in London (50% of all journeys in England only), so it would be expected that they would have a similar share of the accidents.

[6]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/666759/annual-bus-statistics-year-ending-march-2017.pdf (Page3, table BUS0103)

These accidents resulted in a total of 22,163 reported bus passenger casualties, 7,043 of which were in London (32%). This is an average of 1.5 casualties per accident in Great Britain (1.2 in London).

Over the past five years in Great Britain, there has been a general decrease in the number of accidents resulting in injuries to bus or coach passengers. However, in London the numbers of bus passenger casualties have increased since 2012, rising from a 31% share of the total in 2012 to 44% in 2016.

On average over the five-year period, only 0.1% of the accidents in London resulted in 'fatal' injuries. A further 7% resulted in 'serious' injuries and the remaining 93% in 'slight' injuries. Compared with all bus accidents in Great Britain, London had relatively fewer 'serious' and 'fatal' injuries.

Most of the accidents that resulted in injuries to bus passengers did not involve a direct collision. In these accidents, which comprise 81% of the total, it can therefore be inferred that the injuries were caused by other factors, e.g. slips/trips/falls or striking an object within the bus, possibly due to vehicle movements such as harsh braking or rapid acceleration of the bus.

On average over the past five years, 72% of bus accidents in London that resulted in injuries to passengers occurred at junctions which were primarily T or staggered junctions (Figure 8). The Department for Transport 'Reported Road Casualties Great Britain' published in 2016[7] showed that when all accidents in Great Britain are considered (all vehicle types), approximately 60% occur at junctions and 40% not at, or within 20m of a junction. This suggests that there may be an over-representation of bus accidents at junctions in London and measures relating to infrastructure and/or driver behaviour at junctions could be investigated as a possible method of reducing these accidents.

When all casualties in an accident are considered, over the past five years in general across Great Britain the number of bus passenger casualties has fallen; however, in London numbers have risen gradually since 2012. In 2012 London had 26% of the share of total casualties, rising to 38% in 2016.

Approximately two thirds of casualties are female (69%) and the age distribution of casualties is skewed towards older occupants. This is expected, and reflects the general demographics seen in bus passengers.

There appears to be an increase in injuries to seated passengers over the five-year period, mirrored by a decrease in standing passengers and slight decrease in passengers that were alighting or boarding. The vehicle movement at the time of injury also shows small trends between 2012 and 2016, with an increase in accidents while the vehicle was 'going ahead', a decrease when 'slowing or stopping', and a slight increase in 'moving off' and slight decrease in 'waiting to go'.

When examining these factors together, injuries sustained while alighting and boarding mainly occur when the vehicle is "waiting to go", "parked" or "moving off". However, injuries sustained while seated, which on average represent 41% of the casualties, are most often occurring when the vehicle is "going ahead" or "slowing / stopping". Standing injuries, which account for half of the total casualties, occurred most frequently when the vehicle was "slowing / stopping", "going ahead", or "moving off".

[7]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668504/reported-road-casualties-great-britain-2016-complete-report.pdf (page 50, table RAS10009)

Since standing and seated injuries account for such a large proportion, mitigation measures should focus on addressing the vehicle movements highlighted above, for example avoiding sudden deceleration movements.

2.2.2 IRIS Analysis

In total, there were 20,490 incidents involving passengers on London buses between 2012-2016, resulting in 21,998 injured passengers. The number of incidents and injuries has generally increased across time, albeit a slight reduction in 2013.

Table 3 presents a summary of the event types and subcategories which shows that 'slip trip falls' are the highest occurring event type.

Table 3: Original and condensed event types (IRIS data)

Original Event Type	Condensed Event Type	Proportion per event category
Slip Trip Fall	Slip Trip Fall	58%
Knock, Trip or Fall within bus		
Fall down Stairs		
Collision	Collision	9%
Collision Incident		
Alighting Incident	Alighting and Boarding	17%
Boarding Incident		
Personal Injury Event	Personal Injury Event	16%
Wheelchair/ Buggy Incident		
Struck by Object		

Most events involved adult passengers, followed by an even split between child and elderly passengers. Youths (16-25 years) are under-represented within the bus incident data. This is surprising given that according to 2015 TFL data, 71% of Londoners aged 24 and under use London buses as a form of transport[8].

For some of the data a further sub-category of event type was defined. When this data was analysed, the large 'slip/trip/fall' event now revealed that 27% of incidents are attributed to a 'fall on the same level'. Also, within the 'personal injury' event it was established that passengers are predominantly injured through being struck or hitting an object (14%) or trapping limbs (7%).

Furthermore, age was also compared across the event sub categories. The proportion of incidents in elderly passengers is high in the 'while boarding' (30%) and 'while alighting' sub-categories (25%) in comparison to children and youth. It is worth noting that the proportion of 'while boarding' incidents in elderly passengers is nearly the same as adults. Incidents in the 'on the same level' sub category are relatively high in elderly passengers, compared to children and youths.

Data on the body region where the injury was sustained was available for some of the data (approximately one fifth). the body region with the highest proportion of injuries was the lower extremity (24%), with injuries to the head also relatively common (22%).

There are interesting trends within the body regions affected in incidents when comparing ages of the passengers. For example, youths have the highest proportion of incidents involving the lower extremities, as well as injuries to the back. Equally, children have the highest proportion of head and face injuries of all the age categories.

[8] http://content.tfl.gov.uk/travel-in-london-understanding-our-diverse-communities.pdf, page 17

There are several interesting findings when comparing body regions affected between the condensed event types. A large proportion of the body regions affected in alighting and boarding incidents were the lower extremities and the same pattern was found in personal injury events. With slip/trip/fall events, the main body region affected was the head, with injuries to both upper and lower extremities comprising the majority of the remaining incidents in this event type.

2.3 Initial Conclusions

Overall the analysis of the data has shown that variances exist between the data collected in police reported incidents in STATS19 and the TfL reported incidents in the IRIS dataset. STATS19 reports on some 7,043 casualties in the 5-year period compared to the IRIS dataset through which 21,988 casualties were reported in the same time period. Notably most of all casualty incidents are reported as 'slight/minor' but whereas STATS19 provides no further detail other than this basic descriptor, IRIS has the ability to report the 'type' of injury sustained within the 'minor' category. Other differences exist with the expansion between the passenger locations in STATS19 as a choice of four descriptors but in the IRIS data there were 11 descriptors before being condensed into the 4 analysis categories. Furthermore, the use of subcategory events in the IRIS dataset provides additional specific event information of the event; however, some of these variables contained actual injury descriptors rather than the mechanism of injury or 'event' type. These discrepancies make it difficult to develop a full and broad understanding of injuries on London buses in any specific detail. It is envisaged that the qualitative analysis of actual collision incidents from the Bus Operators will help provide a better understanding of the types of events and injuries sustained in the context of the IRIS dataset.

A summary of the main findings from the STATS19 and IRIS datasets are presented below;

- Both data sets showed a small but distinct upwards turn in the number of people injured on buses in London over the 5-year period;
- Bus only (non-collision) incidents predominate in STATS19 data, mostly on single carriage roads, whereas 'slip trip fall' is the main injury event in the IRIS data;
- Passengers who were recorded as standing or seated dominated the passenger position at the time of injury in STATS19;
- It was difficult to assign passenger position in the IRIS data apart from the comparable alighting and boarding incidents;
- The use of sub-categories helped to specify some other events or injury types, but these were not complete across the whole IRIS dataset;
- When the injury data was recoded for analysis 'minor' injury dominated the type of injuries sustained and included cuts and abrasions or bruises. The injury descriptions could not be analysed in greater detail as some 35% were injury mechanisms; for example, 'trapped' or 'crush' or 'bump' but providing no injury details.
- STATS19 is not designed to capture injury data beyond the severity of the incident; in this regard it is similar to the IRIS data 'minor' injury which was the main type recorded;
- Analysis of sub category data identified specific body-regions to be at risk of injury; these were mainly head and face in children (probably from buggy falls) and face and lower/ upper extremity for elderly passengers. The majority of the lower extremity injuries in the subcategory of data were caused in alighting and boarding incidents.
- Age categories greater than 25 years represented a larger proportion of the data relative to younger passengers, though there is a need to tie this into usage to determine whether older people are more likely to be injured compared with younger people, or merely more likely to use the bus.

3 Phase 2: Qualitative analysis

Objective: A qualitative analysis of a representative sample of Bus Operator incident reports and interview data from passengers involved in incidents

Qualitative research was appropriate for this study as this phase aimed to undertake a broad exploration and understanding of the problem of injury causation on London buses (Creswell; 2007 p39). The data provided for the study enabled observations of passengers and drivers whilst travelling on buses from CCTV (i.e. what people do), incident reports (i.e. what people say they do) and interviews from passengers (i.e. what they think / feel / believe). The output from this phase of the study was to generate insights into the data from the perspective of the bus, passenger and driver and the specific attributes that cause injuries to help identify potential design solutions to the problems.

3.1 Qualitative methods

The benefit of using qualitative research methods enables the interpretation and understanding of the topic under study but must still be considered as reliable and valid. An audit trail of the process used was maintained and collaborative working further minimised bias to remove preconceptions of assumptions and ideas. Validity in qualitative research concerns the interpretation of the data, in other words is there complete data? Have restrictions been imposed on the analysis? And have all explanations been considered? (Robson 2002). To reduce these concerns multiple methods and different data sources were used in the research as well as utilising the experience of other researchers drawing on designers, vehicle safety, human factors and psychologists to enable triangulation of the data to provide corroborating evidence and rigour of the research.

All text data in this phase was coded into broad themes and more detailed sub-themes to ultimately provide an overall understanding of the problem (Boyatzis 1998 p161). The data was uploaded to the software package NVivo to enable coding of the qualitative data.

3.1.1 Incident data

The Investigation notes and driver statements from Stagecoach and the specific sections from GoAhead reports (summary, notes, passenger and driver) were analysed. The data varied between the sections and for both, the overall summary and investigation notes were the main focus of the analysis. To further aid the coding process the incident data were analysed in context of the 'bus', 'passenger' and 'driver' to understand how injuries are caused on buses.

The coding involved identifying certain traits in the data which were categorised into main codes e.g. braking and further sub-level codes e.g. harsh, collision avoidance, emergency using the terminology present in the incident reports (Figure 1). Further analysis of the data involved reviewing the codes and sub-codes to generate broad insights (themes) into the problem. This style of analysis could mean that one statement would be coded into more than 1 category / sub-category for example;

Example 1:

Driver served bus stop at (xx) station he was stationary **a male passenger tried to board the bus but** trips on the edge of the platform resulting in him falling on to the platform. He refused medical attention.

Coding key:
Blue; bus movement
Yellow; Passenger (main category)
Yellow; passenger action on bus (Passenger sub-category)
Yellow; passenger injury kinematics (Passenger sub-category)

Example 2:

Driver interviewed and has confirmed while he was concentrating in his mirrors, he failed to observe a vehicle in front,has stopped causing him to take evasive action and **brake hard to avoid colliding into vehicle in front.**

Coding key:
Blue; bus movement
Grey; Driver (main category)
Driver error; (sub-category)

Figure 1: Example of incident data coding

3.1.2 Available Data

Provision of data for the project was agreed by three bus operators at a project meeting held at TfL premises in which it was expected that all three operators would provide copies of their incident reports, CCTV clips and would be willing to invite passengers to undertake an interview through a mail-out (Table 4).

Table 4: Data available for the project

	Bus operator 1 GoAhead		Bus operator 2 Stagecoach		Bus operator 3 Abellio	
Phase 2	Agreed	Delivered	Agreed	Delivered	Agreed	Delivered
Incident reports	300	300	150	150	150	0
CCTV footage	30	24	15	56	15	0
Phase 3	Agreed	Sent	Agreed	Sent	Agreed	Sent
Passenger mail outs	300	~270	150	150	150	40 + follow up

3.2 Results - Incident Reports

Go-Ahead supplied an Excel datasheet of 300 cases of which 276 were non-collisions described as passenger injury or passenger incidents; 18 were collisions and 6 were considered as 'other event', for example vandalism. Additionally, they supplied the incident investigation forms containing general notes, summary notes and where available, driver and passenger notes. Fault in the incidents was attributable in 98 of the cases; non-fault in 118 cases and partial fault in 33 cases with the remaining having insufficient evidence or unknown fault attributable or vehicle defects (n=2).

Stagecoach supplied an excel datasheet of 200 cases which contained investigation notes and driver statement notes for passenger injury incidents. There were 171 'minor' injury and 29 'moderate' injury passenger incidents.

No incident reports were received from Abellio.

All text from the incident reports and summary of incidents were coded under the broad overarching themes of bus, driver and passenger and the results are presented accordingly. Sub-categories were identified for each theme for clarity of analysis and examples from the reports are used as illustrative examples. All examples use their original spelling and terminology and the bus operator group is anonymous. After each phase in the analysis insights and problem statements were generated and appear at the end of each section.

3.2.1 Bus Themes

The main manoeuvres associated with the reported incidents tended to be during braking / pulling into a stop and pulling away from a stop or accelerating with a proportion of incidents occurring when stationary (Table 5).

Braking

All braking incidents were by far the most reported bus movement identified during the analysis and (N=159) predominantly described mainly as 'harsh or sharp' braking (N=78). Interestingly relatively fewer incidents were classed as necessary if using the language of 'avoiding a collision' (N=33) or 'emergency' braking which was a result of a failure on the bus rather than driver decision (Table 5).

Table 5: Braking incidents

Braking incidents	**Count (N)**	***Examples***
Braking	38	*Driver brakes as cab changes lanes on roundabout then brakes because he is in wrong lane! - some customers are shunted on bus,*
Harsh	78	*the bus was coming up to a roundabout and the driver slammed his brakes really hard* *Bus was proceeding along the road the taxi on front has stopped but our driver doesn't respond until he brakes harshly causing passenger out of their seats.*
Avoid collision	33	*Driver did not anticipate that the vehicle in front to stop, and to avoid a collision our driver braked harshly causing TP child to fall forward hitting the hand rail.*
Late	9	*late braking by our driver, passenger falls from rear seat.*
Emergency	1	*While bus was proceeding the rear door opened causing the bus emergency brakes to apply.*
Total	**159**	

Pulling away

The other bus movement commonly identified in the incidents was that of 'pulling away' and in a few cases 'accelerating'. This movement as well as braking results in inertial forces which would influence passenger kinematics during travel and such passenger interaction on the bus will be explored later. It was notable that for a number of the 'pulling away from bus stop' incidents, there was an immediate associated 'sudden braking' movement due to a traffic hazard; example *'female fell as driver pulled away from stop then braked due to car in front (which was braking a long time before)'* (Table 6).

Table 6: Pulling away incidents

Pulling away incidents	**Count**	***Examples***
Pulling away	62	*Driver states that when he was pulling away from the bus stop he heard someone fall down the stairs.* *As the driver pulled out the passenger jolted forward and fell on her back, bruising her right arm and leg.* *Driver stopped to serve stop, two passengers were in the process of moving to the rear doors to alight when the driver shut the doors and pulled off from the stop causing one of the passengers to fall*
Accelerating	4	*Passenger appears to have been reaching for a hold at the top of the stairs just as the vehicle accelerated (not obviously excessively).*
Total	**66**	

Stationary

The other bus movements noted in the analysis were stationary incidents or assumed stationary incidents classed as 'door incidents' which were common. The associated 'stationary' problems were associated with the ramp, non-lowering of the bus, distance to kerbside, not being able to pull in at the actual stop and doors. However, there were some examples of passengers just tripping on the platform as they boarded the bus (Table 7).

Table 7: Stationary incidents

Stationary incidents	***Examples***
Platform	*Passenger tried to board the bus but trips on the edge of the platform resulting in him falling on to the platform.*
Lowering of bus	*driver failed to take reasonable precautions to ensure the safety of the customer by not lowering the bus and leaving a safe distance from the kerb for customers to alight safely* *The passenger is an elderly lady who was boarding the bus and has fallen forwards and cut her leg. She has stated that the driver did not lower the bus for her, and this is why the incident has taken place.*
Ramp	*CCTV shows wheelchair user boarding the bus and then lady pulling trolley comes up the ramp and as she was boarding the door closes catching her arm. Driver states that she told passengers waiting to board, to wait until she stowed the ramp away.*
Slipping on board	*footage shows that the bus was stationary at the bus stop when the passenger got up from the rear seat to alight, as she stepped down the step at the rear of the bus she appears to have slipped and fell onto the floor.*

Door incidents

Door incidents were common in boarding and alighting incidents where passengers either chose to board or alight late when the door was already in motion which was different to the incidents were passengers had arms or feet trapped behind an opening door because of where they were standing on the bus. Many of the door incidents tended to be drivers' errors where they appear to leave their hand on the button too long causing doors to close or close the doors 'by mistake' on boarding passengers.

> *driver opened doors for customers to board and then shut them by mistake catching elderly female in door*

3.2.2 Bus Insights

One of the main insights generated from the text content of the incident reports was the driver decision-making process which in many braking incidents appeared to be late, choosing to pull away before passengers seated, closing the doors on passengers and not kneeling or lowering the platform on the bus. The 'harshness' of the (mainly) air-braking capability of the bus appears to be problematic resulting in inertial forces on the passengers.

The main problems identified to be taken to the idea solution workshop are presented below.

Problems

- How might we prevent drivers from braking harshly;
- How might we prevent drivers from accelerating harshly;
- How might we prevent doors closing on passengers;
- How might we always provide a safe environment for boarding and alighting passengers;
- How might we prevent late decisions in boarding and alighting by passengers.

3.2.3 Effect on passengers

Falls

Braking incidents had one of the largest effects on passengers particularly causing falls; however, there were differences in fall descriptions and distances i.e. a few steps, downstairs and to the floor although in the latter it was not always clear if the passengers were standing or seated at the time.

> *"6 people can be seen being thrown forward. Two of them were thrown to the floor"*
>
> *"Suddenly has to brake harshly to avoid a collision causing the passenger to fall (badly)".*
>
> *"Bus is proceeding normally in his lane when a vehicle coming from opposite direction turns right causing our driver to pinch the brake sharply and passengers fall on bus".*

Overall 'falls' predominated as the cause of injury in the summary and investigation notes, but the data did not always provide explicit information as to where passengers were on the bus or what was their posture at the time of the incident. Other descriptors, such as fall off seat were common occurrences for passengers resulting from harsh braking, as were stair incidents with more falling downstairs rather than either upstairs or onto the stairs. Other common falls were out of pushchairs or push-chairs tipping over during braking which resulted in child injuries.

> *"This resulted in a passenger being thrown against the side and her buggy tipped over"*

Notably there were few cases which used the terminology slip or trip in the notes and to understand injury patterns on buses more comprehensively, ideally these terms could be separated out in data collection. The slipping incidents resulted from wet floors which were mainly weather-related. Tripping incidents were more likely to occur on boarding platforms, rear steps and other obstacles such as shopping trolleys or pushchairs positioned in the wheelchair/ buggy areas.

Acceleration / pulling away from stationary also caused falls to occur with a common thread in the data that in these incidents, the driver pulled away before the passenger sat down.

> *"While moving away from bus stop a lady fell and hit her arm and head".*
>
> *"As the driver pulled out the passenger jolted forward and fell on her back, bruising her right arm and leg".*
>
> *"Driver served stop in (XX) Street where female PAX with stick boarded, driver moved off before passenger was seated and pax fell"*

This problem is intertwined with the assumption that passengers are intending to sit down although some passengers choose to remain standing or choose to walk past empty seats, increasing the time spent standing.

> *"after boarding bus, the mother and her children remain standing in the aisle as the bus moves from the stop for over 20 seconds".*
>
> *"Our bus pulled away at slow speed. Just as the bus pulled away the lady was grabbing for the handrail. I feel that this accident was due to timing and a bit unlucky. Considering the lady had shopping bags she could have sat nearer the front".*

Non-falls

Not all incidents caused an actual fall to the passenger but generated a trajectory path instead where passengers encountered the internal structures on the bus. The language used to describe the passenger movements varied such as 'thrown, flung, jerked, jumped, fall forwards, shunted and surged'. Ideally consistent language would aid the analysis of these passenger events, but it can be assumed that there was some form of 'sudden' movement in a particular direction based on the bus movement at the time.

> *"Female fell on bus, driver appears to brake harshly causing the fall and others to be shunted forwards".*
>
> *"Driver is pulling away from stop and suddenly brakes sharply and the passenger is thrown forward and hurts her wrist".*
>
> *"A third-party car moves from one of the offside lanes and cuts across the front of our bus without warning. Our bus is forced to brake sharply. Some passengers on the bus can be seen to fall forwards in their seats".*
>
> *"Driver is pulling away from stop and suddenly brakes sharply and the passenger is thrown forward and hurts her wrist".*

The contact sources for this kind of incident tended to be the poles, seats, handrails and panels (described as glass, modesty, partition) and depended on whether and where the passenger was seated or standing at the time. However, it was difficult to establish where all passengers were situated on the bus as this information did not appear in the text for all incidents. Where it was stated, some more common areas were evident, for example behind the wheelchair area, doors, aisle, rear of bus.

> *"One female passenger who is standing by the wheelchair area is swung around and lands on the stairs".*
>
> *"As a result of the braking a child sitting on the seat immediately behind the wheelchair/pushchair area is thrown forward allegedly banging her face on the hand rail "damaging her teeth"*
>
> *"2 children sitting on the back seat on the upper deck are thrown from their seats and one of them hits his head on the back of the seat in front".*
>
> *"When our driver looks back, he has to brake to avoid colliding into the rear but as a result an elderly passenger is thrown from her seat in the wheelchair area. He suffered a bloody nose and complained of neck pain".*

3.2.4 Passenger Insights

It is apparent that passengers need to sit down as soon as possible but drivers also need to allow passengers to sit down before pulling away. There were some obvious mobility needs of passengers so the driver's decision to pull away before they were sat down needs to be questioned. Inertial forces feature frequently in passenger falls and non-fall movements. Furthermore, there might be a reason for the bus drivers to feel they have to move off from the stops quickly, possibly due to timetable restrictions. Passengers should not alight or board when the doors are closing which also appeared to be an issue in the stationary incidents. When a fall occurs, it is sensible to question whether there are any common features associated with them (for example more vulnerable seating or standing areas and contact sources within the internal bus infrastructure) that could exacerbate the fall outcome.

Problems

The main problems identified that will be taken to the idea solution workshop are presented below.

- How might we encourage passengers to sit down quickly and in appropriate and available seats;
- How might we prevent drivers pulling away before passengers are sat down;
- How might we enable drivers the time to allow passengers to sit down before moving away;
- How might we prevent passengers alighting and boarding once doors are activated;
- How might we keep passengers in seats during harsh braking / accelerating incidents;
- How might we create a softer impact on contact with the internal infrastructure.

3.2.5 Passenger Injuries

Identifying passenger injury and severity is difficult to establish from the incident summary and investigation notes as often it is reported that a passenger has 'hit' their head or 'banged' their knee or 'caught' their shoulder which indicates the body area that was injured. These descriptions do not allow for identifying full injury descriptions. Although assumptions could be made about general bruising, it is not adequate for determining the extent of injury severity sustained by the passengers. The example below illustrates an example where the Investigation notes suggest a foot injury but additional information on the full incident report provides a description of the injury sustained. However, this level of detail was only available for a minority of incidents.

> Investigation notes: '*passenger disembarking the bus when the rear, Doors closed catching her foot in the doors. She fell forward. Onto the floor with her foot still caught in the doors'.*
>
> Full incident report states *'damaged ankle ligaments'*

The following provides an example where additional injury information would be needed to determine injury causation and injury severity;

> Investigation notes: '*The customer has been seriously injured in the process'* . This incident *involved a bus driver on the XX route who closed the rear doors on his head as he was leaving the bus'*
>
> Additional injury information to corroborate a serious head injury is not provided.

Overall from the available data the commonly injured body regions were found to be the head / face, arms and legs with fewer reports of back or chest (torso) injury.

> *"Car slows, lights change to amber and car stops. Our driver is looking out of offside window and when he turns back sees car has stopped and brakes harshly causing customer to fall from seat and hit head on pole".*
>
> *"One passenger falls out of her seat into the aisle. The third-party passenger complained of pain in her left shoulder and knees".*
>
> *"the elderly female is seen with blood coming from her nose, the ambulance arrives and attends to the female who is taken to hospital".*

3.2.6 Injury Insights

Overwhelmingly, there is insufficient detail available in the incident reports to enable a full study of the types and severity of injuries sustained. Often there is only vague descriptors of 'bump' or 'hit' used which are not injury descriptors but vague indicators of injury mechanism and offer no insight into severity of injury or if injury was in fact sustained by the passenger.

Problem

- How might we improve injury data collection for analysis purposes

3.2.7 Passenger Behaviour Themes

Passenger behaviour was an identified theme in the analysis of the incident reports as being contributory to their injury causation. Previously it was noted that passengers make late decisions when boarding or alighting buses and are contacted by the doors. Other incidents where passenger behaviour contributed to the incident outcome were also identified which in some incidents would render the fault to be with the passenger and not the driver. These include not holding onto infrastructures, being out of position and pushchair misuse.

Not holding on

The main noted issue was that passengers were not holding on at the time and were therefore liable to be partially at fault for the injury sustained.

> *"It appears as the bus was approaching a bus stop and the male stood up to get ready to get off. It is unclear if he is holding on. The bus slows to the bus stop and the male falls to the floor".*
>
> *"CCTV shows passenger on her phone at the top of the stairs on her phone, she then finishes her call, and starts to walk down the stairs. The bus was stationary at a shred road crossing section, as the bus moves off the passenger is not holding on and falls down the stairs".*
>
> *"After passenger boards the bus she stands in the aisle due to the bus being very busy and crowded, the passenger does not hold onto the hand rails so when the driver pulls away from the stop the passenger had not secured herself properly and falls over".*

Out of position

Interestingly there were some incidents where the passengers are out of position which was considered to exacerbate their potential to sustain injury.

> *"Another (passenger) was in the process of standing up to alight because she pressed the bell. She also went forward and collided with the hand rail in front of her".*
>
> *"Passenger falls whilst sitting down on the rear of the bus. CCTV shows passenger was sitting with someone on a seat designed for 1 person. Not 2".*
>
> *"As the bus bears to the left at the lights at (xx) she loses balance and hits the window of the bus whilst still seated. ……. the speed was correct it was only that the customer had her legs crossed so had no stability in the seat".*
>
> *"CCTV confirms bell rung approx. 40secs before reach stop. Passenger on upper deck behind stairs but*

> *does not stand to alight until bus stops. Driver checks internal mirror and cctv for passengers alighting but does not see anyone. As pulls away is aware of passengers standing on upper deck by stairs and assumes they want next stop".*
>
> *"Customer injured as driver brakes for lights. Customer hesitant and should have taken a seat then when bus braked, she wouldn't have 'moved back'"*

Pushchair misuse

Several incidents occurred where pushchairs toppled over, and passengers found not to be holding them in place contributed to the problem in addition to hanging shopping or nappy changing bags on the handles.

> *"The buggy is parked in the wheelchair bay with the handles pointing towards the exit doors of the bus".*
>
> *"The woman stands between the buggy and the offside of the bus and is not holding onto the … bus turns right ….. and as a result the buggy tips over.*
> *Liability for the buggy tipping rests with the mother for failing to park the buggy safely and carrying shopping on the handlebars which renders the buggy unstable".*

Passenger expectations

Interestingly there is an expectation by the bus operators that passengers also must be responsible for some aspect of their injury sustained during the incident. Not holding onto pushchairs was mentioned as was the fact that passengers must not sit crossed-leg on the seats – a factor that is probably not common knowledge as is the fact that passengers are expected to hold on whilst sat down.

> *"CCTV footage would suggest that the sole cause of the accident was the customer's omission to take precautions to ensure her own safety on a moving bus, given that bus passengers are expected to hold on to available supports. Drivers are not required to monitor passengers who appear to be safely seated".*

3.2.8 Passenger behaviour Insights

Do passengers know that they are expected to behave in a certain way as a passenger on the bus and whether this would influence any compensation claim to the bus operators? How is this communicated to passengers? These are interesting questions and it would be enlightening to understand how effectively such expectations are communicated. Conversely there is an assumption of safe travel behaviour by passengers whilst on the bus.

Problems

- How might we prevent pushchairs falling over on buses?
- How might we enable passengers to take responsibility for certain safety behaviours on board the bus?

3.2.9 Driver Behaviour Themes

Driver behaviour was another main theme identified in the analysis and comprises decision making, reading the road, concentration/ attention and passenger interaction. Not waiting for passengers to sit down after boarding appeared to be a common factor contributing to passenger falls which was noted above, as were the decisions to close / open the doors. The decision making associated with this is crucial to identify and understand why they do not allow passengers (particularly the more vulnerable passengers) to sit down and at what point the door button should be pressed.

Decision making

Some incidents occurred when the bus driver possibly assumed that they were benefitting the passenger, for example letting the passengers on or off whilst not at the bus stop. It was apparent that the rear doors for alighting possibly led to poor decisions or poor assumptions by the drivers regarding passenger intentions.

> *P"ax didn't press bell to alight but was standing by exit door- bus stops just after bus stop in traffic and lets pax off - she is hit by cyclist - no rep inj - driver admits to "stupid" error".*
>
> *"Driver stopped to serve stop, two passengers were in the process of moving to the rear doors to alight when the driver shut the doors and pulled off from the stop causing one of the passengers to fall"*
>
> *"Unfortunately, the drivers driving standards leading up to this incident, is very poor and has left us wide open to an opportunistic claim".*

However, it also appears it might be difficult for drivers to see the doors as some 'failed to see' alighting passengers.

> *"CCTV shows this is clearly our dvr's fault as he simply fails to notice final boarding passenger and closes doors on her"*
>
> *"our driver failed to see a small child alighting the bus and closed the rear door".*
>
> *"While serving the bus stop going toward xxx, I was letting passenger on and off the bus I check my mirror to make sure there was no-one running for the bus. I pressed the button to close the doors when from a blind spot an elderly lady started run".*

Reading the road

There were a number of incidents where it was apparent that the drivers were not reading the road or driving appropriately for the traffic conditions.

> *"Customer falls as driver brakes hard to avoid collision - avoidable incident, driver should have slowed in anticipation for upcoming light".*
>
> *"learner did stop but was so far ahead with brake lights visible that our driver was way too late in braking and may have thought learner would pull off by the time the bus had reached it but no excuse - totally avoidable".*
>
> *"We are clearly at fault for not travelling a safe distance behind the vehicle in front to be able to stop safely in an emergency".*
>
> *"Our driver failed to heed in preparation when approaching a set of traffic lights resulting in harsh braking".*

Concentration loss / distraction

There were incidents of drivers falling asleep at the wheel which resulted in collision incidents not considered in this analysis. There was evidence of drivers losing concentration or not paying attention to the road or being distracted inside the cab.

> *"Customer injury - driver is not paying attention to road ahead. A TP vehicle stops and indicates to turn right. Our driver does not brake until late causing the majority of his customers to be thrown forward on the bus".*
>
> *"CCTV shows our bus driver looking up and doing something above his head, then he looks back to the road and sees a car in front of him and brakes hard. You see one person upstairs thrown to the floor".*
>
> *"Our driver is seen driving along his route as he does this, he reaches down to adjust his driver's seat which puts him off balance and he applied the brakes by mistake. This is when TP hits her arm while trying to stop her child falling".*

Passenger interaction

One of the interesting findings in the analysis was the number of passengers who do not report the incident at the time and only do so some time later. Additionally, the number of events that drivers are unaware of is interesting although in some cases the drivers know something has happened but have not taken time to find out what. In some cases, the drivers show no apparent concern following sudden braking or acceleration manoeuvres.

> *"No-one approaches driver to state they need medical attention. But additionally, driver doesn't ask them if they require any".*
>
> *"Driver should have slowed and been aware of their traffic in offside lane potentially stealing some of the bus lane. Driver does not get out of cab to enquire on customers welfare".*
>
> *"Driver had to brake sharply, when the driver was stationary at the bus stop, a female passenger approached the driver to inform him she had hit her head on a hand rail. Driver asked if she was ok which she replied yes and then got off the bus".*
>
> *"When the bus was approaching (xx) Street the bus driver did an emergency stop and myself and other passengers went forward from their seats,*
> *I went up to the driver to get his details, (which was xxxx), and he was surprised that I had fallen down as he wasn't aware, but he never got out of his cab to check if everyone was OK".*

3.2.10 Driver behaviour Insights

Overall, driver decision making is an issue and is linked to the need to concentrate and, considering the traffic volume and erratic driving behaviour of other road users in London would suggest that some means of driver assistance would benefit. The other difficulty that drivers seem to have is that many are unaware of incidents on buses and are reliant on passengers to inform them, which is not ideal for the driver to understand the impact of their actions on the passengers.

Problems

- How might we help drivers make better driving decisions?
- How might we inform drivers of incidents that happen on their bus?
- How might we keep drivers focussed on driving?

3.2.11 Other insights

What was noticeable in the analysis of the incident reports is the common use of the 'slip /trip/ fall' classification for injury description when the passenger did not present as a 'true' fit to any of these classifications. Many of these incidents use the language of 'thrown forward' which is not an actual fall, see example below.

> *"our vehicle is too close to stop and brakes harshly causing several passengers to be thrown forward into poles & panels in the bus".*
>
> *"Two passengers identified one hitting her right shoulder on an upright pole and another by the rear doors being thrown into a glass panel who has complained, also a male passenger informed the driver he had hit his knees".*
>
> *"Passenger is alleged to have banged her head on the glass screen, driver is said to have hit the brakes ~MCD~".*
>
> *"injury description banged head"*

3.3 Results - CCTV analysis

Data analysis of the CCTV data was undertaken in stages; initially the CCTV content was reviewed by a researcher and the incident isolated to capture the pre and post incident period from various camera angles. To direct the analysis the 'AEIOU' analysis framework was then used to analyse the incident event period considering 5 elements Activity, Environment, Interaction, Object, and User (Martin and Hanington 2012 p10).

- Activities were considered to be the passengers' intent during the incident.
- Environments included reviewing the overall space they were travelling in and what is happening around them.
- Interactions were reviewed as being between the passenger and someone or something else.
- Objects relate directly to the environment and how they relate to their activities.
- Users were the passengers and drivers whose behaviours were observed.

This method is commonly used in ethnographic studies and was broadly and loosely applied here to direct rather than restrict the analysis process. Rather than analyse incident details, the broader view was taken to generate insights into the causes of injury on buses. The analysis of the incident events was undertaken by at least 2 researchers for reliability and validity and insights generated during the analysis.

A total of 80 CCTV clips were received but following review of the clips, a total of 71 incidents were available for analysis with 75 passengers affected (Figure 2). A full interpretation of incidents is attached in Appendix 2.

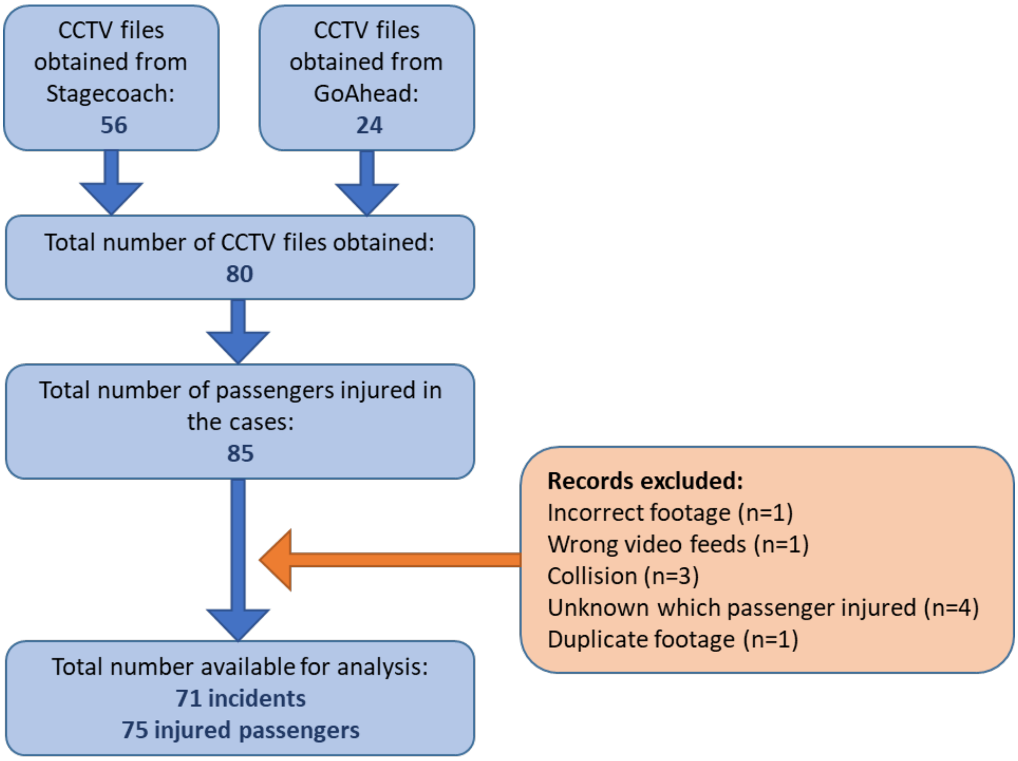

Figure 2: CCTV case flowchart

3.3.1 Overview of cases

There was a total of 71 bus incidents on the CCTV clips and 75 passengers affected an overview of the incident sample is presented below (Table 8).

Table 8: Overview of CCTV data incidents

Condition Type (n=71)		Count
Light Condition	Clear	4
	Dark	12
	Overcast	29
	Sunny	26
Weather Condition	Dry	58
	Wet	6
	Unknown	7
Location Type	Inner City	34
	Urban (non-residential)	26
	Urban (residential)	6
	Unknown	5

There was no real variation in times of days when the incident occurred for morning or afternoons; although the off-peak period 9am to 2pm has a 44% share of bus incidents and might reflect the fact that more elderly passengers are travelling at these times. There were very few incidents that occurred during the night-time hours 8pm-6am (Figure 3).

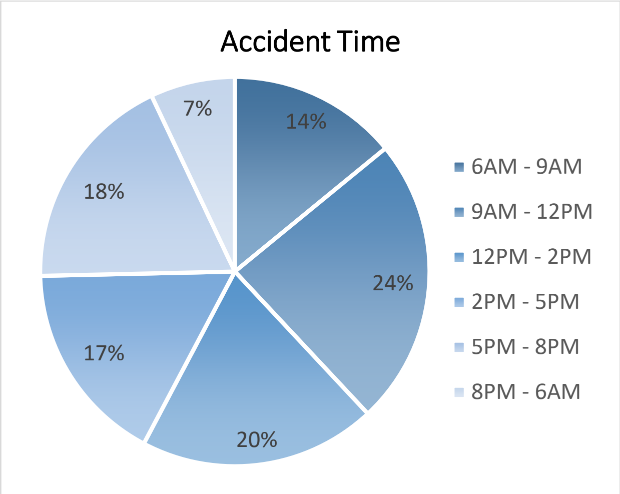

Figure 3: Time of CCTV bus incidents (n=71)

Most incidents were categorised as braking or slowing incidents (n=39) (Figure 4).

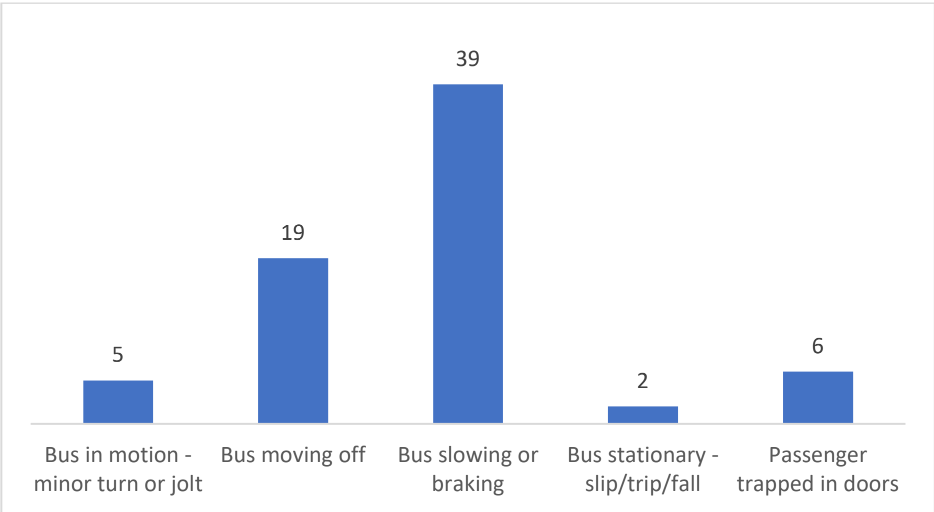

Figure 4: Distribution of bus incident types (n-71)

Interestingly the variation in speed and the three main bus moving incidents (n=61) were identified and notably that there was a larger average speed-change in the bus slowing and braking incidents (Table 9).

Table 9: Speed change of bus manoeuvres in CCTV incidents

Event Type	Average speed 2 seconds before event (mph)	Average speed at event (mph)	Average speed change over 2 seconds (mph)	SD of speed change over 2 seconds (mph)
Bus in motion – minor turn or jolt (n=5)	19.5	19.0	0.5	0.7
Bus moving off (n=19)	1.3	3.7	2.4	2.0
Bus slowing or braking (n=39)	13.1	7.4	6.5	5.5

Following the AEIOU method, analysis of CCTV data identified three main themes of passenger and driver behaviours and other insights.

3.3.2 Passenger Behaviour Insights

It was interesting to observe how passengers interacted with the environment during the journey and how they were perceived to behave and make choices.

Seats and seat choices

A number of the incidents analysed showed passengers sat in the seats facing forward into the buggy / wheelchair area (Figure 5).

Figure 5: Example of the forward-facing seats into the wheelchair area

They appear to be the seat of choice for many passengers with or without pushchairs or shopping trolleys; obviously the reason for this cannot be determined from the CCTV, but the passengers might view this as a convenient seat to alight the bus or is simply more spacious. Sometimes these are the first accessible seats after boarding dependent on the bus designs as some have an inaccessible high step up to the seats to the nearside of the bus immediately after boarding. Some passengers with shopping trolleys will hold onto these and not to handrails for support (Figure 6) whereas those boarding with a pushchair park them and do not hold on to them all of the time if they are sat in the seat.

Figure 6: Passenger seated with shopping trolley in forward facing seats into wheelchair area

However, some passengers choose to walk past empty seats to sit in these seats – it would be interesting to establish why they choose to do this. Also traversing the distance from the front doors to these seats can be problematic due to large distances between the hand poles, potentially creating unsafe situations for passengers when the driver pulls away from the stop without waiting for them to be seated.

Notably the horizontal handrails in front of these seats were varied in style and shape which either contained the passenger in the area when thrown forward or enabled the passengers to be thrown out of the seats into the buggy / wheelchair areas (Figure 7). One of the incidents involved a point of failure when the glass panel immediately in front of the seats shattered as the passenger was thrown forward (Figure 5) and a different design of handrail. The perception of these seats in the analysis is that they are potentially unsafe as passengers are thrown out of them onto the floor and some appeared to travel some distance before landing due to the lack of full handrail or panel. Rear seats were also considered to be problematic as passengers do not have something to hold onto when sat in the middle of the rear aisle causing them to be thrown forwards down the aisle.

Figure 7a: Example of passengers thrown forward and variation in handrail design

Figure 7b: Example of passengers thrown forward and variation in handrail design

Seat Preference

Generally, observations about the bus and passenger seat choice is that many passengers choose to sit near the aisle and not the window which obviously has a direct impact on other passengers' seat choices when boarding and selecting seats. Potentially this could create problems as it renders the nearest seats inaccessible causing passengers to have to walk further along to find a seat.

Passenger choice to sit upstairs is either enforced by a full downstairs area or a pre-determined action possibly because they can easily ascend the stairs, more seating is available, or it provides a better view and awareness of surroundings during the journey. There might also be a propensity for short distance journey's which makes ascending the stairs a non-viable option for that person.

Standing choices

From the CCTV, passengers were either forced to stand because of lack of seats or they chose to stand during the journey. The choice to stand appeared to relate to having a pushchair on board and the passenger stood with this in the buggy area. However other passengers chose to stand in this area despite free seats being available possibly because they had a shopping trolley, or in one instance a guide dog (Figure 8).

Figure 8: Passenger choosing to stand in wheelchair area with shopping trolley

Unfortunately, in cases of harsh braking, the passengers were thrown forward or fall to the floor as often they were leaning on the infrastructures and not holding onto any handrail or pole for support.

Standing in the aisle between the front doors and end of luggage rack in the narrow space was a regular choice for passengers predominantly because the bus was full; however, on most buses there is a distinct lack of poles to hold onto for balance and they tended to 'prop' themselves against the wall or luggage area. The horizontal handrail on the left side on entry onto the bus is then rendered inaccessible for boarding passengers to help them traverse down the aisle and is not even used by the standing passengers for support. The other problem with this is the proximity to the driver with potential for distraction and blocking of the driver's view of the rest of the bus.

Standing to alight

Obviously holding on whilst standing is not always going to be sufficient support to prevent passengers falling or being thrown around as the extent and aggressivity of braking determines the inertial forces on the passengers. This was evident in some incidents where people were standing during the journey and subsequently fell; however there is a problem of passengers standing in preparation to alight the bus who then fall or are thrown around (Figure 9).

Figure 9: Passenger choosing to stand early to alight bus and hold onto pole

In these incidents, the passenger's choice to stand is questioned as they could remain seated until the bus has pulled into the stop. However, it was evident that passengers tend to stand early to alight, but the reasoning behind this is not determinable from the CCTV. Those passengers alighting the bus from upstairs also tend to move early which suggests that not missing their stop is of prime concern - they fear that if they are not at the doors in time the driver will pull away. Whether the driver can see passengers on the stairs is difficult to establish from the CCTV, but it is assumed that this is not the case. The visibility of passengers on the stairs is then an issue for the driver if they are unaware of alighting passengers that could potentiate a "late" alighting incident involving the closing doors.

3.3.3 Driver Behaviour Insights

The CCTV analysis in most cases provided the driver's perspective from the cab and it was notable that one of the main challenges for the driver is negotiating congested roads.

Driving decisions

Not reading the road ahead appeared to be the biggest factor for the drivers resulting in numerous harsh braking passenger incidents. This reactive driving style probably causes more incidents than a proactive cautionary approach to driving in congested traffic would. The driver can be seen 'bracing' for the braking, but the passengers do not have the same warning to prepare and enable them to hold on or brace ready for the sudden change in speed. It was noted that the speed change during the braking episodes was rapid and probably accentuated the inertial forces because of the type of brakes (air-brakes) installed on most buses.

Doors

Drivers control the doors but there is an issue with doors closing on passengers and this can either be the fault of the driver or the passenger (Figure 10). What is evident is that once the doors are in the closing operation, they do not stop even if there is a person in the way and therefore it is assumed that sensors are not embedded in the doors. Furthermore, the view for the driver appears to be hampered in a crowded bus - particularly regarding alighting passengers from the rear doors and passengers descending the stairs. It appears there is a potential blind spot for the drivers if passengers' approach along the length of the nearside of the bus to board at the front doors.

Figure 10: Passenger boarding with closing doors

Pulling away

It was evident that drivers pull away from bus stops without letting passengers sit down and although not policy to do this there are apparent circumstances that would support the need for the driver to wait for passengers to sit down. It was observed that on occasions, the driver did not appear to wait for older people and those with an obvious walking aid to sit down resulting in subsequent falls and unnecessary delays in journey time due to the need for ambulance attendance (Figure 11). The decision to pull away before passengers had sat down did not appear to be driven by busy periods; for example when numerous passengers boarded the driver pulled away and this was the same for a few passengers boarding an empty bus with an obvious mobility aid.

Figure 11: Passenger with walking stick boarding bus; driver pulls away before they are seated

3.3.4 Other Insights

During the CCTV analysis there were other observations made about the passengers and potential for injury.

Children

It was noted that young children when sat on a seat tended to fly upward and forward impacting the seat in front or were thrown some distance onto the floor during harsh braking. This would suggest that their body weight does not help them stay seated compared to an adult.

Holding on

Many passengers do not hold onto handrails in general when they are sat down which suggests they feel no need to do this until the bus starts to brake in normal driving; however, in harsh braking the opportunity is lost because of the suddenness of the manoeuvre compared to normal driving mode.

Other passengers

Following an incident, other passengers tended to show most concern to the injured passengers through waiting with them for the ambulance, rather than the driver who in most cases was elsewhere (outside the bus). This could be operator policy since it may involve a potential insurance claim; however, this approach is not ideal for customer satisfaction. The long delay in waiting for ambulances and/or police to arrive must cost the bus operators in terms of lost revenue or non-meeting of route time-targets set.

It was also noted that some passengers sit in the 'priority' seats despite appearing not to need those seats or even remain seated when older passengers are standing (Figure 12).

Figure 12: Older passengers needing to stand on full bus

Drivers

In some incidents, it was observed that some drivers were not particularly concerned with the passengers on the bus even when there was an incident. Some drivers can be seen turning towards the back of the bus immediately, presumably to speak to passengers and others appeared unaware or unconcerned that harsh braking had affected the passengers. One driver was seen to continue driving whilst writing, presumably the start of the incident notification process which is an additional concern as the driver is then further distracted from driving.

Pushchairs / wheelchairs

Parking of pushchairs is of interest and in cases where numbers of pushchairs are parked at 90^o across the bus they appeared more stable compared to single pushchairs parked at 90^o or 45^o angles (Figure 13). It is noted though that some pushchairs do appear to have their handles loaded with shopping or 'nappy changing bags'.

One incident involved a mobility scooter parked at 90^o which toppled over - passengers helped to upright the passenger and scooter and the passenger then manoeuvred into a parallel position running along the offside of the bus.

The positioning of both pushchairs and wheelchairs is interesting as there are no markings on the floor to assist passengers to make the best decisions of how to park.

Figure 13: Pushchair tipping over sideways

3.3.5 Overall CCTV Insights

The forward-facing seats appear to be problematic as passengers who fall out of these seats tend to land on the floor rather than be thrown forward and landing back on the seat. Lack of handrails or the design of handrails in front of them appear not to help passengers 'hold on'. Ultimately these seats are the seat of choice for most passengers.

The distance that older or impaired passengers must walk to find a seat can be long based on the individual bus design and might add to the driver's decision to pull away. The wheelchair area does not help people with pushchairs to park them effectively / safely although it would be interesting to find out if manufacturers test the tipping point based on parked angles. Many passengers do not routinely hold to grab-rails whilst using the bus although from incident reports they are expected to. The drivers must negotiate traffic congestion and adapt their driving and anticipate the traffic dynamics better than they already do. There is an overall disparity between some drivers who seem to be aware of the passengers needs and others that drive on regardless.

Problems

- How might we help passengers to make better seat choices?
- How might we encourage passengers to hold onto handrails and poles all the time?
- How might we help drivers read the road and navigate congestion traffic
- How might we prevent harsh braking?
- How might we let passengers know of the bus intended movement?
- How might we encourage gentler braking for most road scenarios?
- How might we prevent doors closing on passengers?
- How might we help drivers make the decision to close the doors?
- How might we prevent passengers attempting boarding when doors closing?
- How might the bus be adapted to provide nearer seats for impaired passengers on boarding?
- How might we stop passengers falling out of the front-facing seats into the wheelchair area?

4 Phase 3: Passenger Interviews

Phase 3 of the study aimed to interview a sample of bus passengers who had been involved in a reported incident on a London bus operated by one of the three project Bus Operators. To ensure confidentiality, a letter was prepared by Loughborough University and the operators were invited to include their own Company letter to assure passengers that their personal data had not been given to the researchers. Occupants were invited to reply directly to Loughborough University by completing a short form and using the pre-stamped return envelope. The aim was to use a sampling frame to select a representative sample to interview; however, the postal return rate was too low to enable this approach. Therefore, all persons returning a form were contacted and were invited to participate in an interview.

Table 10 shows the expected mail-out stated in the original proposal to ensure interviews of 60 passengers (a 10 % return rate) and even with traditionally low return rates for questionnaire surveys, this was still considered a reasonable expectation. Letters were distributed to the bus operators but disappointingly the response rate was lower than anticipated at 6% (n=30) following a mail out of 460 invitation letters. Overall, the expected mail out was to 600 passengers but one Bus Operator (Abellio) only sent 40 letters based on the number of cases that had been reported to them in the previous 2 years. Prior to their mail out, it was agreed that a follow up letter would be sent and no letter from the Bus Operator was included.

Table 10: Postal mail out expected and delivered for Phase 3

	Bus operator 1 GoAhead		Bus operator 2 Stagecoach		Bus operator 3 Abellio	
Phase 3 – Passenger Interviews	Agreed	Sent	Agreed	Sent	Agreed	Sent
	300	~270	150	150	150	40 + follow up

Both an interview schedule and data collection sheet were developed to elicit information from passengers about their bus use, incident, injuries sustained and suggestions for improvement to passenger safety (Appendix 3).

4.1 Results – Phase 3

Following the mail out of 460 letters 33 envelopes were returned of which 31 respondents stated they were available for interview (2 duplicate returns; 1 refusal). All eligible 31 respondents were then contacted by phone; 3 people decided not to continue or were non-contactable and 1 person wanted to be emailed. Therefore, in total 25 passengers were interviewed by telephone including a mother of a baby who was injured and 1 was interviewed via email. All interviews were transcribed and entered on NVivo for analysis of the free text.

4.1.1 Passenger characteristics

The mean passenger age was 64 years (range 0-93 years), median age was 72 years and most passengers were females (n=20). Due to the older age of the participants (with 23 being over 60 years of age), most used a freedom pass to travel on the buses. They all recognised how the freedom pass enables them to travel probably more than they would without the pass. The affordability and convenience of bus travel provided the opportunity to have positive experiences including shopping, visiting friends, attending activities including keep fit, hospital visits, work and school-runs.

Bus use

Bus use frequency varied between the participants ranging between every day and monthly (Table 11).

Table 11: Frequency of bus use

Public bus usage per week (n=26)	Count
Less than once per week	2
1-2 times per week	2
2-3 times per week	3
3-4 times per week	4
5+ times per week	15

One participant used the bus daily stating he loved everything about travelling on the buses and the fact that bus travel gave him purpose.

> *"Every day, yes, almost every day, just to keep myself, cause I've to live, I don't want to die you see. I've got a, I've to get a telegraph from the Queen" (LU26)*

> *"not that often actually, because I still drive, and I mainly use the bus, if it involves a parking charge, or there's difficulty in parking. So I would … say a couple of times a month" (LU15)*

Very few used other means of public transport such as London underground, or trains which might simply reflect the fact that older-age citizens find the bus an easier and more convenient option.

> *"practically every day, apart from Sundays. Erm, and then there's the, journey to where I was going and the journey where I was coming back, I don't very often use the train, it's nearly always bus, sometimes it could be 2, 3 buses during the day" (LU21)*

4.1.2 Incident characteristics

Pulling away and braking were the most mentioned types of bus movements involved in their injury with one person stating they were at fault and tripped over on the bus and hitting the Oyster card reader (Table 12).

Table 12: Type of incident participants were involved in

Bus movement	Passenger position	Count
Pulling away	Boarding	11
Braking	Alighting	7
Stationary	At stop Doors Trip	6
Cornering / turning	Seated	2
Total		**26**

Pulling away

Similarly to support previous observations, pulling away is a problem for passengers and seven participants cited this as the cause of their injury with some believing that the drivers were not supposed to move until passengers are sat down.

> *"I'd got on the bus, and, went to sit down, and the bus started up, and I jerked and swang round, right round, and ended up in the door well, hit my head on the door" (LU05)*

> *"So I got on the bus, and they're supposed to, drivers are supposed to not start, until everyone is seated. So I made my way along, and it's difficult because I had the trolley in one hand and was trying to hold on with the other, and he jolted, pulled away. So I made a sort of dash to get to the seat, and I had to turn, because I had the trolley in my hand, so I had to turn to get into the seat, and that's when he jolted". (LU21)*

All considered the driver to be responsible for the incident as they stated that the driver should have been aware that they were not sat down and should have waited for them to do so.

Braking

Braking was a big problem and the fact that it comes without warning was a main concern for the participants. This suggests that they are unprepared for the sudden deceleration associated with harsh braking but also are unaware that this may happen when the drivers are pulling into a stop. There is the perception that drivers brake with too much force at bus-stops as a result of fast driving speed between stops.

> *"it made an emergency stop with no warning, and I went flying down the bus, and er, the lad flew after me and landed on top of me … But the force that he did with it, was so strong that I actually flew down the bus, which was just, absolutely ridiculous" (LU22)*

> *"some drivers rev up to a bus stop and sometimes you think they are not going to stop and then you press the bell and all of a sudden they then put their foot down on the brake to stop" (LU29)*

> *"And I thought, oh, it's not gonna stop, so I'm going to have to get off at the stop after. But then as it was speeding along, I saw him glance at the sign from his cab, and then he slammed the brakes on. And I, obviously I shot forward, but I hung on sort of, screaming, and erm, he pulled up after the stop, because obviously he was going so fast he couldn't stop", (LU08)*

Stationary

Participants were concerned that drivers did not pull into the kerb or routinely lower the bus platform at the bus stop to aid boarding and alighting. There was an expectation that the drivers should do this as standard procedure and not just at random times.

> *"the bus which I hadn't realised was a long way from the kerb, and, they hadn't lowered the er, whatever it is they call the step down, which they do on the buses normally, and I stepped off and er, I just fell straight onto the pavement, smashed my glasses, broke my little finger, did my wrist". (LU11)*

> *"some drivers are very cautious, and you know they do their job correctly and they pull up by the kerb, but this one he pulled up quite a way from the kerb .. didn't lower the platform, he was way – well away – from the kerb, in fact he was too far away from the kerb, so I had to step off of the pavement and into the road, and lift my leg up, and obviously the strength of the leg was weak" (LU16)*

Considering these passengers were mainly elderly it is not difficult to appreciate the need for drivers to pull into the kerb and lower the bus on all occasions.

Whilst the bus was at a stop, one participant had the doors closed on him three times because of an apparent problem with the automatic closing. A second participant described their incident where the doors closed and threw them onto the pavement through an apparent driver error.

> *"I was the last to board, and I thought the driver saw, would have seen me boarding the bus, but I got, oh, one foot on the platform, and I was half on half off, one put on the platform, and the other foot sort of on the pavement, or kerb, and erm, he was preparing to move off, and I think he was looking in his mirror to see that he was, that traffic was clear for him to pull off, instead of seeing that I was getting on the bus, and he, the doors closed, squashing me, well not squashing me, but the doors closed and threw me back" (LU15)*

Moving bus

Two participants attributed their incidents to be a result of the bus turning or cornering and one involved the tipping of a pushchair parked in the wheelchair space.

> *"I do think the bus driver was going a little bit too fast…We went around this corner, the pushchair tilted backwards. And, [child name] kind of backflipped out of the pushchair and ended up face down by the doors. You know by the exit doors of the bus". (LU23)*

Interestingly she described the pushchair as light and the reason she bought it was for ease of lifting on and off buses. However, it tilted easily despite her being aware of not putting shopping on the handles. Furthermore, she admitted to putting the brakes on but not holding onto the handles.

> *"Although I was sitting right next to the pushchair, I wasn't actually holding the pushchair…..I purposely got a lightweight pushchair, so that I could easily get it onto the buses. But the downside of this lightweight pushchair was that it tilted up very easily. It didn't have shopping on it, I don't, I mean I often see people with pushchairs that have shopping on them". (LU23)*

4.1.3 Injuries and recovery

Eighteen of the participants stated they sought medical attention either on the day (from Accident and Emergency Departments) or later from their GP's. Most were minor injuries including bruising or lacerations requiring stitching, soft tissue injury (internal bruising) with only two participants reporting a fracture; one to the upper arm (moderate severity) and one with a finger fracture (minor severity). Most passengers received some general bruising to their body as a result of the fall or through striking objects. However injured body areas included the upper and lower extremities and the head or face.

> *"I had a little bump on my head, and my knees were bruised, and my backside was bruised", (LU22)*

> *"I just tripped over and cracked my er, the ball joint between my arm and my shoulder" (LU28)*

One bus was diverted by a police officer to a hospital as the wait for an ambulance was too long.

> *"they got on the bus to see what was wrong, and one of them bandaged my head up, and said to the driver, because, they said to the driver 'well she can't wait', cause I was bleeding so much, he said 'she can't wait for an hour', he said 'you'll have to take the bus to the hospital'. So he said 'well that's taking it off my route', so the policeman said 'well I'm telling you you've got to take her to the hospital' (LU05).*

Recovery time following the incident varied between 2 days and 1 year with two people stating that it still affects them to the present day. Physically the recovery time was more specific in detail as open wounds were considered healed at 2 weeks and bruises were considered as healed within 1 month.

> *"Well I had the stitches out about 2 weeks afterwards, and then it wasn't much recovery afterwards cause when they stitched were healed, is all I had was waiting for it to heal up, but it's all healed up nicely now" (LU20)*

> *"Well the bruise? Took about a month I think, it was quite bad, it got really quite bad" (LU08)*

Impact of injuries

When the participants were asked about their injuries and recovery the language around their feelings and psychological impact was strong - despite the fact their injuries might be considered 'minor' the incident for them was a 'major' problem.

> *"it was just really painful and frightening", (LU03)*

> *"I was pretty shaken up but, I mean, it all happened so quick, and it's the shock really isn't it. Course I'm elderly as well that doesn't help … You know I was pretty, pretty bad at the time. Never happened before. And I thought, this could happen to somebody worse off than myself, and erm, it's not very nice thing to happen is it" (Lu16)*

"Yes I was shaking like a leaf, to hold on to one of the men's arms, and after I though, I thought if someone had seen us they might have thought we'd been having an affair!" (LU13)

"Yeah, it had a massive impact on me, for the next 6 months really…. I did lose a lot of time having, if you like, like post-traumatic stress from the incident" (LU10)

"I would say I'm not fully recovered. Because erm the side of my ribs is still, it still hurts every now and again, but I can put up with that, I've not got a problem with that" (LU06).

Returning to travel

Returning to travelling on buses following the incidents was one of the other impacts the incident and injury had on the participants.

"Well no, it did shake me up, and basically I haven't been back on the bus since, so it put me off. I now, my condition has got worse and I'm unable to use a wheelchair". (LU22)

"No, and I mean, even now, erm, although I'm ok, I still sort of, if you like, I don't like it if I'm trying to get to my seat and the bus lurches or anything like that .. I get, you know, like whereas before, and to be perfectly honest with you, I'm worse, I hate it, and I won't very often stand on a bus. I don't know". (LU10)

Many participants felt they had 'lost their confidence' when travelling on buses or now felt 'anxious', 'nervous' or 'wary'.

"I am more cautious now, I don't let go of the railing till the bus is stopped" (LU07)

"Well, it was a good 6 to 9 months… also I'm having to be taken everywhere, I'm too scared to get on a bus on my own now" (LU21)

Passenger behaviour change

All participants considered themselves to be more cautious on buses since the incident with some adopting new ways to deal with certain situations. One participant now alights through the front doors and shouts at the bus drivers that he is coming down the aisle so the driver will wait for him to exit and if there is an issue, he tells the driver that the police told him to do it (LU19). Other participants try and sit down before the bus moves off or hold onto the handrails, do not stand up until the bus stops or in some instances wait for the next bus if the first one is full.

"Yes, very cautious when I get on the bus, try to get sat down before it goes off. It just depends on where the seats are though on the bus really, sometimes the drivers pull away before you're actually seated". (LU02)

"I am more cautious now, I don't let go of the railing till the bus is stopped" (LU07)

"if the bus comes along and it's solid, I wait for another one behind it you know, if I can't sit, I won't take that chance again of standing up. I mean I didn't like standing up anyway, but what can you do if no seats are available" (LU20)

Four of the passengers stated that they now stay seated until the bus has stopped before standing as a result of the incident - one now makes sure the drivers lower the platform.

"I say 'can you lower the platform please', cause you have to ask them. Some are very good, they'll pull in, they've seen you, and they lower it automatically. But those that don't, I just speak out, I don't, I'm not going to take any chances". (LU16)

4.1.4 Driver attitude

Negative experiences

Most passengers reported a negative experience with the driver and/or that there was a feeling of them being unconcerned following their incident.

> *"bus driver didn't bother to ask if I was ok, he just carried on" (LU02)*

> *"so I went to the driver and said, and he was driving by then, and I said what are you doing we wanted to get off here, and he said well you should have been quicker …. and he was really grumpy and unsympathetic and nasty, and completely not uncaring" (LU03)*

> *"But after the incidence, he couldn't, he showed no concern as to what had happened to me. Absolutely no concern". (LU24)*

One participant suggested that the driver was unsure of what they should be doing following the incident and felt the driver was more concerned with continuing the route rather than caring for the passenger.

> *"the bus driver got out of his seat, and the bus had just started calling him that he needed to come down, and, he asked me if I could get up, and go wait on the pavement … Some of the other passengers then started getting quite cross with the driver, cause he was kind of acting like I was delaying his journey, and they told him has he called an ambulance yet, and he seemed to not know how he could do that, or what he should do" (LU25)*

Positive experiences

Not all the experiences were negative as some drivers showed concern either immediately or when they were notified that an incident had happened.

> *"The driver did get out, and asked me did I need an ambulance, and I said no, and he said it wasn't his fault, the doors shut automatically, which I don't think that was right" (LU13)*

> *"he was very good the bus driver, he came over and he said he thought I was holding on. I was sort of quite aggressive to him, I said 'you swerved out', and he said 'I wasn't swerving, I pulled out' and he said 'I thought you were holding on', but I hadn't quite held on" (LU14)*

> *"the driver did apologise, he admitted that he was going too fast, and he said it would be like a learning exercise for him. And he apologized. And I don't think he told the police that, it was just me he said that to, off the record" (LU23)*

The participants also expressed their opinions that not all drivers were bad, and some were very good and were also aware of the time pressures placed on them.

> *"well I know they're under pressure to meet their own timetables, but some drivers are very good, and make sure people are sitting down or, before they pull out, but others don't take any notice at all, even if you get on with a stick" (LU14)*

> *"Yes, some are really really helpful, I find it's a lot of the women drivers actually that are better, more considerate, but I shouldn't really say that you know, so some of the drivers, I don't know whether they're bad drivers or not, but they seem, you know, some are fine, but others…. They're not like they used to be" (LU05)*

> *"That's the sad thing unfortunately, for every bad driver you get there's a good driver who get customers shouting abuse at them, and it's got to be a 2-way street really respect" (LU06)*

4.1.5 Nostalgia

There was a distinct sense of nostalgia from the participants about the buses and how they were used to both better attitudes of the drivers and the presence of a conductor. Conductors were believed to be important communicators between passengers regarding what happened on the bus thus were perceived to provide a safer travelling environment. The participants would like to see them returned on buses and felt that their presence would prevent incidents occurring on the bus.

> *"I think it's the only one, you know, I mean bus drivers aren't the same as they used to be if I'm honest with you, they used to be really friendly and now you get on the bus and you say 'oh can you tell me which stop's for something' and they, they're like 'no', really grumpy often" (LU03)*

> *"what they need, what the bus driver needs is something in front of him, just like we did with the old type, with the er, the clippies, you know the conductors, go 'ding ding' to let the driver know he can go off. Yeah just a simple bell, that's all you need" (LU06)*

The change to 'request stops' rather than compulsory stops was also a concern raised by the participants. They believed that making drivers respond to hands signals or a bell possibly causes harsh braking with negative consequences for passenger thereafter.

> *"not all like before like when we had compulsory stops so the drivers knew they had to stop there whether there was anybody, whether the bell had been rung or not". (LU05)*

4.1.6 Bus interior

During the interviews, participants described elements in the bus interiors that were contributory to their injury. One passenger was at the rear of the bus and felt there was no pole for them to hold onto even though there are seats available to use.

> *"There was nothing, nowhere to hold on to, I grabbed the seat, there was a bar, to try and save me, but I couldn't, and that's how I hurt my ribs. So I, I, I was so frightened, well I had to go to hospital in the end with it" (LU06)*

The distance between the front doors on boarding and available seats for some passengers was noted as there is a long gap between poles between the bottom of the stairs and the next pole near the seats by the wheelchair area. This meant that the passenger was at some point not able to hold onto any pole to aid movement.

> *"the bus is designed so that you get in at the front and there's some seats designed for people who are not fully abled, about halfway down the bus.., and that was the one I was aiming for… I use a walking stick in my right hand, and I remember holding on to the pole just by the stairs …and the next pole was just in front of the seat I was aiming for, and, I moved forward and was just about to put my hand out to reach the pole that was there… and the driver pulled out sharply" (LU14)*

> *"I was on a xx, and I was on that small bucket seat opposite the, where you put the trolleys and things, and I shot out the seat, like a cannon actually" (LU19)*

The lowering of the bus step or platform was also perceived to be a problem as it did not always go down low enough to enable access for passengers with shopping trolleys, wheelchairs or those with poor mobility.

> *"I was helped onto the bus, there's a step that goes up and down, err…, and it doesn't go down quite enough to get trolley things on but I was helped up, and I sat in a seat, a convenience seat at the, cause the bus went up tiers, it sort of went up high" (LU22)*

Driver visibility

Whether drivers can see the passengers on the bus and during boarding and alighting was also questioned as it was perceived that they should be able to see what passengers are doing.

> *"And I think what made me cross was I thought well surely he's got mirrors, he must be able to see, the driver must see there's still people on the bus, and that actually he should have waited" (LU03)*
>
> *"He should have looked, and seen if everyone was sitting down" (LU06)*
>
> *"I think he was looking in his mirror to see that … traffic was clear for him to pull off, instead of seeing that I was getting on the bus, and he, the doors closed squashing me, well not squashing me, but the doors closed and threw me back. I fell back onto the pavement", (LU15)*
>
> *"I got a letter from them I believe saying that the bus driver was unable to see, something about there is a blind spot in his mirror. He couldn't see you as you were, and personally I don't think he even looked and just shut the door, and anyway it happened some time ago now" (LU22)*

4.1.7 Bus Operators

Participants also believed that the Bus Operators could be more sympathetic and responsive to the passenger needs following a complaint. The need for communication from the Bus Operators was considered to be important and an expected courtesy. One passenger pointed out that media reports suggest that compensation for poor driving is higher than having to pay fines for late running times.

> *"And I kept stressing, I do not want compensation, I am not after compensation I am after an apology. Because he, the way he was driving, was unacceptable, absolutely unacceptable, and it's not how their drivers normally drive" (LU21)*
>
> *"Well one of the best things they could do is actually contact the people, because if somebody had called me and said 'oh I'm sorry to hear what happened, are you ok', I would have really appreciated it. I did get a bunch of flowers, because I, I phoned the bus garage where the bus came from". (LU25)*
>
> *"I mean, I was reading somewhere, there was an article talking about TfL, that's transport for London, that said they pay out more in compensation for bad driving than they do for getting penalised for running late" (LU28)*
>
> *"I don't know how many incidents go unrecorded. And, cos I think if an incident is properly dealt with, that tends to involve taking the bus out of the service, you know, I think the ambulance service call the police if it is an accident involving an injury. I think they call the police is quite a palaver. So I don't know how many of these incidents actually are never recorded". (LU23)*

4.1.8 Improvements for passengers

All participants were asked during the interviews to suggest what improvements could be made to help prevent incidents in the future. Driving speed and style were the main suggestions that were perceived to help improve the overall journey and prevent the 'speed dash' between bus stops (Table 13). Other suggestions included improving driver training and monitoring as well as changes to the bus interiors.

Table 13: Passenger suggestions for improving safety

Improvements	**Count**	***Examples***
Driving style (harsh braking, /speeding / pulling into kerb / pulling away before seated)	40	*"It's just basically getting the drivers to slow down". (LU02)* *"think they're actually driving a racing car. And so they speed up, and they're always jolting everybody when they're stopping". (LU25)* *"Well I think drivers need, well I know they got air brakes on the buses, but I think drivers approach the stop too fast, and that's why they brake so quickly. I've noticed that women bus drivers are more cautious than men. They don't sort of speed up to the bus stop like men do" (LU07)* *"why can't they pull right into the kerb? Cause when I see elderly people get off, they always struggle. They always used to", (LU06)* *"What a lot of the drivers do, is they park quite a long way away from the pavement" (LU30)*
Driver education	8	*"They could take a bit more time for sure, but that will have to come from the top and not put so much pressure on the drivers to get through their routes so quickly" (Lu06)* *"More training maybe? Maybe perhaps disciplinary, perhaps stricter disciplinary if anything does happen". (LU08)* *"better training. Better bloody training. And better monitoring of those drivers that they pass through that think they're actually driving a racing car". (LU25)* *"They need better monitoring of people's stopping habits, and, training habits on what they do in the event of an accident" (LU25)*
Bus improvements (rails and holds / announcements / stop standing / sensors	23	*"I mean they've either got to make sure that, there's a lot more rails to hang on to or, I mean there's not even anything overhead that you can hang on to anymore, you know, not like you've got on the underground or anything, so you can grab of what have you, I mean, it's you know, if they're gonna leave the whole of it open where people haven't got a lot of places to hold on to, then the driver's gotta wait". (LU10)* *"I think maybe there should be intermittent announcements or something, saying anybody who's, you know who doesn't need to be sitting in a disabled seat, erm get up. I think that might be a good announcement, not necessarily by the driver, but maybe an automated thing" (LU14)* *"Yeah they're really awkward bus stairs actually, they're not well, I don't think they're very well designed" (LU03)* *"I mean perhaps we should be fitted with seatbelts on these buses nowadays "(LU06)* *"buses should have sensors on these doors, and then that kind of thing wouldn't happen" (LU15)* *"also to train the drivers just to look, to check the mirrors and make sure there isn't still someone on the stairs" (LU03)*

4.2 Passenger Interview Insights

The participant interviews provided a broad insight from the perspective of the passengers who were injured following an incident on a bus. The description of incidents and the bus movements at the time reflect the findings from the incident report and CCTV analysis. However, the passengers offered a different viewpoint and interpretation of the events indicated that there were perceived problems with driver behaviour and attitudes; interior of the buses; and definite areas for improvement in services. The psychological impact of the injury was concerning, especially as older passengers tend to rely on bus travel for social and other important activities. Some passengers delayed getting back on a bus post incident due to anxiety or fear and one reported having PTSD. One passenger has not returned to bus travel since his incident due to lack of access for his wheelchair. Lack of bus travel can lead to social isolation and additional psychological conditions including depression and this is probably something that drivers are unaware of.

The passengers need informing of the intended bus movement which was coupled with the nostalgic need for conductors and bells on board the buses. They also believed that the drivers should wait for them to sit down and allow more time for alighting the bus. General better customer service and concern from the drivers was also desired. The changes in passenger behaviour following the incident to always hold on or wait until bus stops or interact with the driver to ensure they wait or lower platforms on entry are all things that informed passengers could do each time they use the bus. The need for driver awareness of how these incidents have an impact on passengers' lives is also necessary, which could also feed into driver training.

4.2.1 Problems

- How might we inform passengers of intended bus movements in advance?
- How might we encourage positive attitudes from the driver?
- How might we improve the outcome of injury for passengers?
- How might we train drivers more effectively to understand passenger effects as a result of their driving?
- How might we reduce the time pressure for drivers?
- How might we prevent drivers from pulling away before passengers are seated?
- How might we improve Bus Operator contact with passengers following an incident?

5 Workshop to Generate Solutions

Objective: Identify key causation factors in bus incidents and identify countermeasures to mitigate injury.

In each phase of the study, insights were generated and converted into problem statements that can be used to ideate solutions. These 'how might we' statements are viewed as positive ways to think about problems; there is a definite question about 'how' something can be done but 'might' or might not work is also a good consideration and 'we' relates to the collaborative effort needed to solve any problems (Tim Brown CEO IDEO). Designers often work in collaboration with other professionals and designers can solve problems through workshops which are an effective method for achieving this.

The aim of the workshop was to generate countermeasures to the problems identified from the both the qualitative analysis and the issues raised by the participants. Th e intention was that this would be achieved through interaction and collaboration (Flick 2009).

5.1 Method

The workshop was open to two Research Groups at Loughborough Design School (Transport Safety Research Centre and the User Centred Design Research Group) providing a diverse background and different experiences and skills to the workshop. The UCD research laboratory was used for the activity as it allowed for large whiteboards to be in situ and space for attendees to move around (Figure 14).

Figure 14: Layout of idea workshop

At the start of the workshop, attendees were shown three different incidents on buses to provide context. Where appropriate, photographic stills were used later to help further illustrate the problems identified. Each whiteboard had different 'how might we' problems pinned to the top and attendees were asked to consider each problem and provide at least one solution to each of the problems (Figure 15). Due to the limited time of the workshop activity not every problem identified in this report was posted. There were rules governing the workshop; the two main rules of significance were 'no idea is a bad idea' and 'respect the ideas of others' (Appendix 4).

Figure 15: How might we statement and post-it ideas

Data was captured on coloured post-it notes with each colour representing the background and expertise of the attendees. They were asked to only write one solution per post-it to enable the data to be sorted and analysed. After 30 minutes the attendees were specifically asked to consider technology as a way of solving the problems if they had not done so already - and to add this type of proposed solution to any of the problems. The researchers then added to the white boards any new ideas they had.

Attendees

There were 11 attendees from Loughborough Design School and 4 researchers present to facilitate the workshop (Table 14).

Table 14: Characteristics of workshop attendees

Research area	Experience / speciality	Number	Post it colour
User Centred Design	Transport innovation technology Usability design and safety	3	Blue
Responsible design	Behaviour change	2	Yellow
Transport safety	Impaired driving Safe and smart mobility Psychology of driving Vehicle safety Road safety	6	Green
Research team	Vehicle safety Human factors Injury	4	Orange

5.2 Results

For each of the ‘how might we’ statements the attendees suggested potential solutions to solve the problem and posted these on the white boards. All the results for each of the statements presented are listed in full in Appendix 4.

5.2.1 Summary of the potential solutions generated

Following the workshop, the researchers categorised the potential solutions into similar idea groups and these were further reviewed to generate the main issues and sub-issues and a combined list of proposed countermeasures (see Table 15 to Table 25).

Overall the workshop generated several ideas some which might not work but the aim of this style of workshop is to ensure that no restrictions were placed on the thought-processes of the attendees. Broadly, the solutions were aimed at changing the design of the bus, changing the behaviour of the driver and passenger and how to achieve such changes. In brief the countermeasures are summarised below.

Technology – using sensors in doors, advance collision warning devices to aid drivers, virtual conductors, warning and awareness devices to aid passenger compliance; having screens on board to allow passengers to see the road ahead; gamification for driver behaviours; communication of passenger needs through Oyster card or smart bus-stops;

Policy change – to enable drivers to wait for all passengers to be seated; not allow standing; pushchair restrictions; kneel at every stop

Bus design – gates on the stairs, better mirror / visual aids for drivers to see all areas of the bus (or remove this need with a conductor); address the problem seats; colour zoned buses for seat choices; softer materials on internal structures.

Conductors were mentioned as a solution numerous times and a further idea emerged that volunteers could act as conductors. This would suit people who liked both travelling on buses and chatting to people thereby reducing loneliness, improving well-being and saving NHS money.

Table 15: Problems with boarding and alighting and suggested countermeasures

Issue: Boarding and Alighting	
Sub-Issue	**Summary of Proposed Countermeasures**
Trapped in doors Hit by doors	Warning sound/alarm Warning voice (stand clear) Motion sensors Double doors like London tube (Jubilee Line) Sliding doors Large cushion-strips on door edge for soft contact Awareness Make departure time clear Countdown timer on outside of bus Doors to open inward at centre to a clear pathway Make departure time clear Inform passengers of waiting-time for next bus Doors to be located near driver only Conductors on rear doors Make doors more visible Light/laser cut-off around door areas Technology matching lift-doors – won't close if someone is in the way Remove doors
Trip prevention	Have lower steps No steps Grippier surfaces Remove the causes of trips More hand-grips and narrower corridors for support

	Remove the perception of pressure to board promptly Lighting Better pavements Raised kerbs and kneeling buses

Table 16: Problems with stairs and suggested countermeasures

Issue: Stairs	
Sub-Issue	**Summary of Proposed Countermeasures**
How to prevent passengers falling on the stairs	Less distractions when climbing stairs Better illumination External view video screens so passengers can anticipate braking Don't move off if anyone is on stairs/prevent access when bus is in motion Camera for driver Perpendicular stairs Bendy-buses – no stairs Make stairs less steep Follow good design to prevent slip/trip Age/mobility restriction to upper deck Stair-bags (like airbags?) Doors/gate at top to prevent access when in motion Chair-lifts/ski-lift

Table 17: Problems with passenger behaviour and suggested countermeasures

Issue: Passenger Behaviour	
Sub-Issue	**Summary of Proposed Countermeasures**
Encouraging safe behaviour to prevent injury, particularly using grab-handles/poles etc.	Better scripting of environment Use nudge techniques to encourage safe behaviour Activating glowing rails when passengers pass Make safe behaviour mandatory for children Passenger announcements Discourage poor behaviour regarding use of poles/rails Restraint features Reward good behaviour Signs painted on poles/rails and on seats Make announcements as bus is about to move Racks on entry for stowage of bags Provide excess of handholds at different heights Enable phone-charging or free wifi through holding onto the rail More poles – make it harder to choose unsafe behaviour

Table 18: Injury prevention countermeasures

Issue: Injury Prevention	
Sub-Issue	**Summary of Proposed Countermeasures**
Design solutions that may prevent injury in the event that a passenger falls over.	Material that turns soft on impact Padding around poles/rails Softer materials/make infrastructure softer overall Rounded fittings – e.g. on request to stop buttons Airbags for contact points Raise 'infrastructures' out of the 'flight-path' of passengers Move infrastructure so it cannot be hit – especially on forward-facing seats Seat-belts and airbags

	Rearward facing seats

Table 19: Driver information and suggested countermeasures

Issue: Driver Information	
Sub-Issue	**Summary of Proposed Countermeasures**
Informing the driver that the bus needs to kneel/ramp required	Remove the need for kneeling/ramp in the first place Greater publicity of the disabled bus service provided by TfL Kneel at every stop Higher pavements at all stops Everyone uses ramps Design buses so they are flush with pavement Ramps/kneeling is the default Passengers to let driver know before bus stops – phone app or another comms device Request button at the bus stop Something lights up at the bus stop Special request sign Embed the needs of passengers into oyster cards and readers to alert the driver Have conductors Performance related pay for drivers 2 buttons for 'stop' and 'stop and help'
Provide driver with information that an incident has occurred	Video and image recognition CCTV Floor sensor detection Better cameras and monitoring technology Smart cameras that can detect falls and alert drivers AI detection of movement of passengers Sound feedback Emergency cords like trains Panic buttons Reward passengers to alert drivers Bus marshals/conductors Let drivers drive and someone else take the community responsibility Intermittent audible reminders to passengers Live alerts in vehicle display

Table 20: Driver behaviour and suggested countermeasures

Issue: Driver Behaviour	
Sub-Issue	**Summary of Proposed Countermeasures**
How to prevent drivers pulling sharply away from bus-stops	Replace timetables with waiting-time apps Ban cyclists from bus-lanes They should be allowed to once passengers are secure on board Legal requirement that other vehicles should give way to buses entering traffic-streams Reward drivers for smooth accel/decel Penalise drivers Train drivers so they understand the consequences of their actions Find out why this happens in the first place Design bus chassis so that it absorbs/dampens sharp movement CAV technology so the driver cannot do it Special clutch arrangement for low-g acceleration Electric buses Change gearbox parameters to limit acceleration

	Legal requirement – CCTV enforced – to allow bus to pull out
Avoiding harsh-braking	Designated bus-only lanes Provide drivers with advanced warning of bus-stops – especially new drivers Improve the brakes Gamification to make drivers slower Telematics Use empathetic design so that drivers can feel what harsh braking feels like Use OA suit (empathy suit) to simulate older people's needs – use this in driver training Semi-automated driving Reduce driver distractions – alerts if eyes off road Technology for better braking systems Proximity detection of vehicles to increase time/distance Drive slower Potential work to be done with suspension Look at other professions where performance = speed/quality and learn from implemented solutions Install traffic-jam assist on buses

Table 21: Driver decision making and suggested countermeasures

Issue: Driver Decision Making	
Sub-Issue	**Summary of Proposed Countermeasures**
Helping drivers make better decisions	Segregate routes and vehicle road-user types Improve visibility and manoeuvrability Screens with forward traffic updates/visual information for drivers (Google maps) Remove tight route schedules/time pressure Autonomous buses/remove the driver Training for driver Advance collision warning devices Simulator training Advanced proactive training Dedicated ADAS Harsh braking warning on the bus especially new drivers/new routes Gamification/'rate my ride' technology Instrumented buses – competition for fewest harsh-braking manoeuvres Cleaner entry into bus-stops for smoother transitions

Table 22: Seating problems and suggested countermeasures

Issue: Seating	
Sub-Issue	**Summary of Proposed Countermeasures**
Stopping passengers from falling from open seats	Remove the risky seats Seat belts/restraints Side arms on forward-facing seats Arm-rests that can be moved up or down Bucket seats Rearward facing seats Review and modify seats Change trajectory of seat base
Suitable seating for	Special buses for older passengers More seats at the front Volunteer helpers on problem routes

older bus passengers	Fines for those who sit in wrong seats Make seat unappealing to the young Signs for specially designated seats Elderly-only bus service Riser seats Colour-coded seats Use colour coded flooring to hep define seat choice and match to oyster-card Encourage positive driver interactions with elderly passengers

Table 23: Standing and seating issues for passengers and suggested countermeasures

Issue: Seating and Standing	
Sub-Issue	**Summary of Proposed Countermeasures**
Keeping passengers seated until bus stops	Seat-belts that do not unfasten until bus stops Seat-belts like airplanes Have more exit points so there isn't a long walk to get off Improve layout to make exiting quicker Prohibit standing on buses Embed info on oyster card which lets the driver know that certain stops are required – passenger swipes off, so driver knows they have alighted Remove symbolism that standing = I want to get off Information by way of posters about the dangers of falling Have internal lighting that passengers learn not to stand up until internal lights change Have conductors Reduce the worry – provide reassurances Have information device on seat back so passenger is reassured More warnings of stop approaching Make bus stop at all stops Make it the norm that you sit until the bus stops Don't be made to feel that you are holding the bus up Change driver behaviour
Making sure boarding passengers sit down when bus is stationary	Audible/visual countdown before setting off Better warning to passengers Drivers all access video/mirrors Bus doesn't move if anyone still standing Don't allow standing Allocated seats for various passengers Brightly coloured seats – more visible Layout more like a tube/tram Passengers made aware that bus won't move until they are seated Shorter distances to walk to seats Reduce time-pressure and performance measurement of drivers Training for drivers Increase running times Social enterprise not profit-driven Encourage seating as quickly as possible

Table 24: Pushchairs and wheelchair problems and suggested countermeasures

Issue: Pushchairs and Wheelchairs	
Sub-Issue	**Summary of Proposed Countermeasures**
Prevent push-chairs falling over and hitting/tripping other passengers Prevent wheelchairs hitting other passengers	Place to hook handles Required pushchairs to be stowed fore/aft Bus-isofix Chocks in floor for wheelchairs Locking mechanisms for wheelchair wheels Improve the space/more space Lower handrails for wheelchair users Restraints/barriers Insist they are folded Take wheels off Grippy floors Magnets in floors to hold wheels in place Prohibit pushchairs Baby/no-baby zones/buses Special seats for toddlers Monitor the types of occupants over time. Adapt the bus for occupants according to the data. Have a facility to take a child out of push-chair and sit with child on seat

Table 25: Passenger information needs and suggested countermeasures

Issue: Passenger Information	
Sub-Issue	**Summary of Proposed Countermeasures**
Inform the passenger of the intended motion of the bus	Have a conductor Tactile (proprioceptive) feedback prior to movement PA interactive display Display a message on the screens TV Screens with information displayed TV screens showing the road in front Use windows as screens Red braking light Internal lights on the bus which change colour or dim to identify when bus is moving/stationary/braking/accelerating Screen at front visually showing direction of travel Sound

6 Stakeholder Workshop

Objective: Dissemination of the results of the study to stakeholders of the transport system through seminars/workshops and a bilateral one to one meeting with industry and TfL.

The aim of the stakeholder workshop was twofold; firstly, to present the results from the analysis and secondly, to assess the feasibility of implementing any of the design solutions offered from the project. London TravelWatch organised the stakeholder meeting at the TfL headquarters in London so that Loughborough University could disseminate the project findings and facilitate a feasibility workshop to complete the final data collection phase.

6.1 Format

London TravelWatch invited stakeholder organisations to attend the half day workshop in London; invitations were sent to TfL, companies that operate bus services on behalf of TfL, and bus manufacturers. Members from the London TravelWatch and the Road Safety Trust also attended.

The workshop was split into two halves; in the first half the results of the quantitative and qualitative phases of the work were presented, and in the second half the feasibility workshop with the stakeholders was carried out.

Attendees

There were 32 attendees from stakeholder organisations, and 4 members of the research team from Loughborough University attended to present the results and facilitate the workshop (Table 26). The attendees represented a range of backgrounds and roles within their organisation, including; Transport Safety Manager(s), Risk Manager(s), Policy Officer(s), Development Manager(s), Health and Safety Officer(s), etc.

Table 26: Stakeholder workshop attendees

Organisation / Type	Number
Loughborough University	4
London TravelWatch	4
Road Safety Trust	1
Transport for London	3
London bus operators	18
Bus manufacturers	5
Academic	1

6.1.1 Presentation of Results

The aim of the presentations was to give an overview of the study purpose, the methods used, and the insights gained from the analyses. The full slide pack is included in Appendix 5, broadly the presentations covered four areas;

1) Introduction to the study - purpose and aims;
2) Quantitative analysis phase – objective, data sources, methods and results;
3) Qualitative analysis phase – objective, data sources, methods and insights (themes);
4) Countermeasure generation – objective, methods, results;

During the presentations, the research team also stressed to the attendees that this research has been carried out independently from TfL, the bus operators and the manufacturers. It was important to highlight that the research was carried out to look objectively at how passengers were getting injured, it was not the purpose of the study to assign blame or compare injury levels between organisations. It was also mentioned that because this research had been undertaken independently, it had identified problems purely based on observations from the data analysis. The project team explained that some of the proposed solutions might already be operational which would be a good outcome and useful for the research team to know.

6.1.2 Feasibility Workshop

After the presentations, attendees were given a short break for refreshments and to digest the results and ask any questions, before being asked to participate in the feasibility workshop. The aim of this workshop was to give the stakeholders an opportunity to comment on the feasibility of the proposed countermeasures that were identified through the previous analysis phases. The research team aimed to learn from the stakeholders which proposals would be feasible in either the short or long term, and what would be the barriers or enablers for implementing the proposed solutions.

Furthermore, it was also important to identify which solutions were deemed as not feasible, and particularly whether there was any disagreement in feasibility between policy makers / operators / manufacturers. A determination of ‘not feasible’ in response to a countermeasure would not prevent the current study from recommending a solution if it was still thought to be effective in reducing casualties; however it would inform the policymakers that further research and discussion would be needed in order to determine *why* a solution was deemed as unfeasible, and *how* that barrier might be overcome.

The attendees were spread across 5 tables and were asked to complete the activities in groups, with each group having a mixture of people from different organisations. This enabled all the solutions to be considered, facilitated easier discussion between people and captured the results for analysis. Each table was given some flip chart paper, a range of coloured pens, post-its and stickers, and an envelope containing 51 design solutions on individual cards. Each table was asked to write on their paper which types of organisation were represented within their group, to allow the researchers to see which results came from the different mixes of organisation type.

The selection of 51 countermeasures resulted from a review of the full 170 design solution offered in the internal workshop. Many of the solutions were similar and categorised together as a feasible solution to take forward to the stakeholder workshop, others were excluded since they were considered inappropriate. The time available to hold the stakeholder workshop was also limited and the aim was to offer potential solutions with a real possibility of their implementation so pre-selection of design solutions was necessary. The design solutions selected covered the following categories;

- Passenger behaviour;
- Driver behaviour;
- Bus design;
- Policy and legislation (bus operator; TfL).

The activities were split into 4 stages outlined below and these were followed by a general discussion session involving all workshop participants in which groups could discuss their results and the research team could ask for clarifications or further input on why some decisions were made.

Stage 1: Feasibility

Each table was first asked to draw a timeline on their flipchart paper, with the labels ‘Within 1 year’, ‘Within 5 years’, ‘Within 10 years’, and ‘Not feasible’ (Figure 16). They were then asked to go through each of the 51 design solutions as a group and place them under one the categories based on their expertise and wider knowledge of the industry.

The design solutions were then labelled with sticky dots to indicate the time period the groups assigned to each solution as to when they could be feasibly implemented; this was to assist with data analysis (Figure 17).

Figure 16: Workshop tables

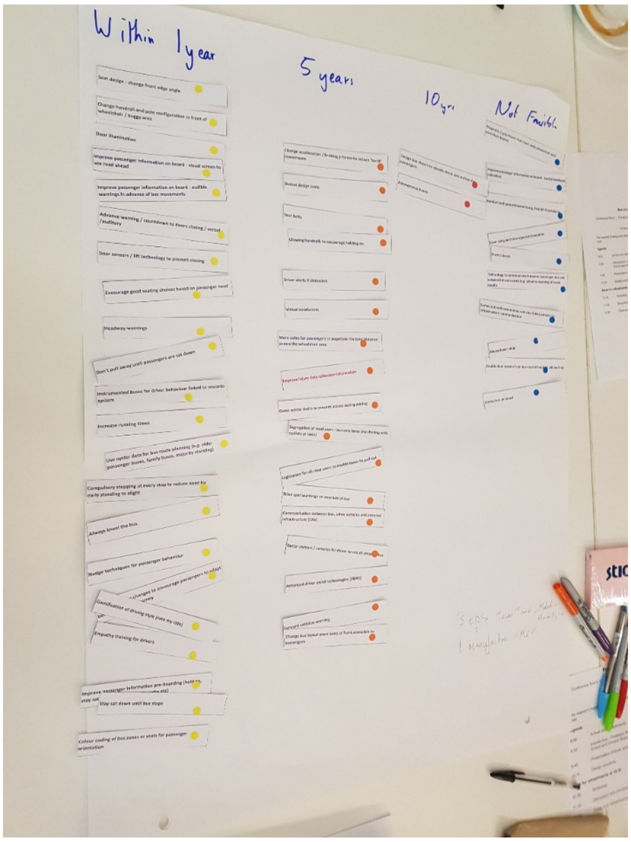

Figure 17: Assessing the feasibility of the design solutions

Stage 2: Prioritising

In the second stage the 'Not feasible' solutions were taken out, and for each of the timescales the groups were asked to look through the solutions they had assigned to that category and select the top 5 that they felt would have the biggest impact on reducing injuries (Figure 18).

Some flexibility was allowed if groups thought that solutions could be grouped, or if the category did not contain more than 5 solutions (usually the 'Within 10 years' category).

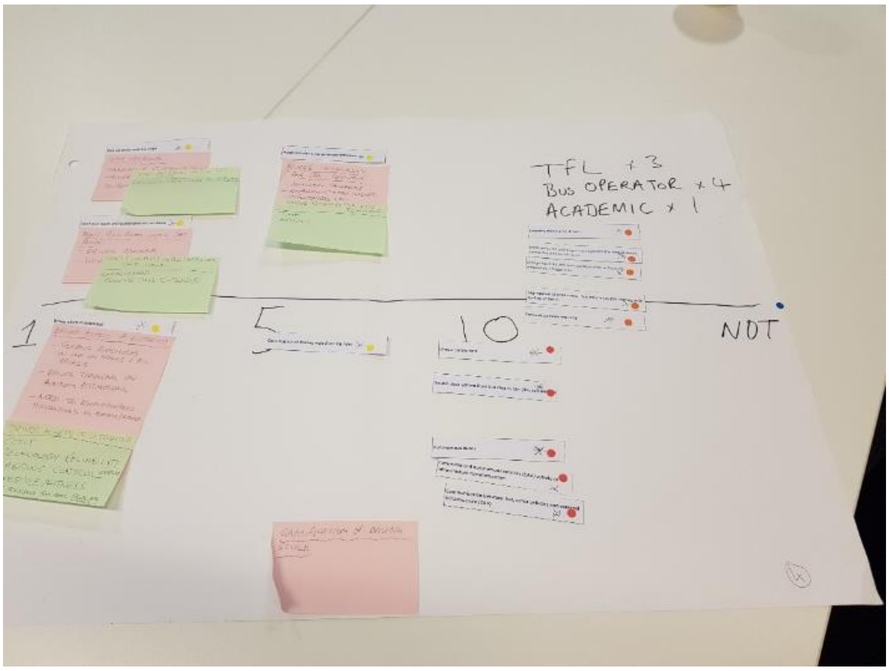

Figure 18: Prioritising design solutions and identifying enablers and barriers

Stage 3: Enablers

Next, the groups were asked to remove the non-prioritised solutions, and for the remaining solutions use post-it's to write enablers for these solutions, i.e. what would need to happen for them to implemented.

Stage 4: Barriers

Finally, the groups were asked to use a different coloured pad of post-its, and for the prioritised solutions write what they felt were the barriers to implementation.

Discussion

Once all tables had completed the exercise, the research team facilitated a discussion amongst everyone to discuss what the groups had found. This enabled the groups to compare their results, and if there were differences in opinion, to discuss why this was so. It also allowed the research team to ask further questions as the discussion developed; for example, why a solution was found to be unfeasible, or what organisations were already doing in terms of these solutions. Finally, the attendees were asked if they had ideas for any other solutions that weren't included in the cards. Ultimately the feasibility of the proposed solutions were for the stakeholders to determine and overall their input in the workshop was valuable to identify potential 'real' solutions that could be taken forward into practice.

6.2 Results

The results were collated from the workshop to identify the feasibility by group for all the presented design solutions (Table 27). The text in bold identifies the 'priority' **(P)** solutions for each time period identified in stage 2 of the workshop. Group 5 grouped some of the solutions into one priority area **(Pa, Pb)** e.g. passenger information. A more detailed comparison of those selected as 'top priority' within each time phase are presented separately below. All results are included in Appendix 5.

Table 27:Stakeholder group results from the feasibility and prioritising of design solutions workshop

Solution	Group 1	Group 2	Group 3	Group 4	Group 5
Increase running times	1 year	Not feasible	**1 year (P)**	1 year	1 year
Advance warning / countdown to doors closing / verbal /auditory	1 year	**1 year (P)**	1 year	1 year	**1 year (Pa)**
Always kneel the bus	**1 year (P)**	Not feasible	**1 year (P)**	1 year	**1 year (P)**
Change handrail and pole configuration in front of wheelchair / buggy area	**1 year (P)**	1 year	**10 years (P)**	**5 years (P)**	**5 years (P)**
Colour coding of bus zones or seats for passenger orientation	1 year	1 year	Not feasible	Not feasible	1 year
Compulsory stopping at every stop to reduce need for early standing to alight	**1 year (P)**	1 year	1 year	1 year	1 year
Don't pull away until passengers are sat down	**1 year (P)**	1 year	**1 year (P)**	**1 year (P)**	Not feasible
Door illumination	1 year	1 year	**5 years (P)**	1 year	5 years
Door sensors / lift technology to prevent closing	1 year	1 year	**5 years (P)**	1 year	1 year
Empathy training for drivers	1 year	1 year	**1 year (P)**	**5 years (P)**	**1 year (P)**
Encourage good seating choices based on passenger need	1 year	1 year	1 year	1 year	1 year
Gamification of driving style (rate my ride)	1 year	**5 years (P)**	5 years	**1 year (P)**	1 year
Headway warnings	1 year	Not feasible	5 years	1 year	**1 year (Pb)**
Improve passenger information on board - audible warnings in advance of bus movements	1 year	1 year	1 year	1 year	**1 year (Pa)**
Improve passenger information on board - visual screen to see road ahead	1 year	**1 year (P)**	1 year	5 years	**5 years (P)**
Improve passenger information pre-boarding (hold on, stay sat down, p/chair etiquette etc)	1 year	1 year	1 year	1 year	**1 year (Pa)**
Instrumented buses for driver behaviour linked to rewards system	1 year	1 year	1 year	1 year	1 year
Internal lighting changes to encourage passengers to adapt behaviour on the journey	1 year	1 year	5 years	Not feasible	5 years
Nudge techniques for passenger behaviour	1 year	1 year	1 year	**1 year (P)**	5 years
Seat design - change front edge angle	1 year	1 year	10 years	5 years	**5 years (P)**
Stay sat down until bus stops	**1 year (P)**	1 year (P)	**1 year (P)**	**1 year (P)**	**1 year (Pa)**
Use oyster data for bus route planning (e.g. older passenger buses, family buses, majority standing)	1 year	**5 years (P)**	10 years	5 years	5 years
Better mirrors / cameras for driver to see all areas of bus	**5 years (P)**	**1 year (P)**	1 year	1 year	**1 year (P)**
Blind spot warnings on nearside of bus	5 years	**1 year (P)**	1 year	5 years	1 year
Change bus layout more seats at front accessible to passengers	5 years	1 year	**10 years (P)**	5 years	**10 years (P)**
Design bus chassis to absorb shock and motion for passengers	**10 years (P)**	**1 year (P)**	10 years	1 year	5 years
Improve passenger information on board - tactile feedback (vibration)	Not feasible	1 year	5 years	Not feasible	**1 year (Pa)**
Legislation for all road users to enable buses to pull out	5 years	1 year	5 years	1 to 5 years	1 year
More poles for passengers to negotiate the long distance across the wheelchair area	5 years	1 year	**10 years (P)**	**5 years (P)**	Not feasible

Solution	Group 1	Group 2	Group 3	Group 4	Group 5
Technology to communicate between passenger, bus and external infrastructure (e.g. advance warning of travel needs)	Not feasible	1 year	10 years	1 year	**10 years (P)**
Virtual conductors	5 years	1 year	Not feasible	**10 years (P)**	5 years
Improve injury data collection information	5 years	**5 years (P)**	1 year	1 year	5 years
Always lower ramp	Not feasible	Not feasible	**1 year**	Not feasible	Not feasible
Electric buses	Not feasible	Not feasible	1 year	1 year	1 year
Driver alerts if distracted	5 years	**5 years (P)**	**5 years (P)**	**1 year (P)**	**1 year (Pb)**
Conductors on board	Not feasible	Not feasible	Not feasible	1 year	1 year
Drive using wait time apps not timetables	Not feasible	Not feasible	5 years	1 year	1 year
Glowing handrails to encourage holding on	5 years	5 years	Not feasible	1 year	5 years
Advanced driver assist technologies (ADAS)	**5 years (P)**	5 years	**5 years (P)**	5 years	**1 year (Pb)**
Forward collision warning	**5 years (P)**	Not feasible	**5 years (P)**	**5 years (P)**	**1 year (Pb)**
Gates across stairs to prevent access during driving	5 years	Not feasible	**10 years (P)**	Not feasible	**5 years (P)**
Bucket design seats	**5 years (P)**	Not feasible	Not feasible	5 years	**5 years (P)**
Change acceleration / braking g-forces to reduce 'harsh' movements	**5 years (P)**	Not feasible	**5 years (P)**	5 years	5 years
Communication between bus, other vehicles and external infrastructure (CAV)	5 years	**5 years (P)**	5 years	**10 years (P)**	**10 years (P)**
Seat belts	**5 years (P)**	Not feasible	Not feasible	Not feasible	5 - 10 years
Segregation of road users - bus only lanes (no sharing with cyclists or taxis)	5 years	**10 years (P)**	**5 years (P)**	**5 years (P)**	**5 years (P)**
Autonomous buses	**10 years (P)**	Not feasible	**10 years (P)**	**10 years (P)**	10 years
Connected and autonomous vehicles (CAV) vehicle to infrastructure communication	Not feasible	**5 years (P)**	10 years	**10 years (P)**	**10 years (P)**
Double door system from bus stop to bus (like Jubilee line)	Not feasible	**10 years (P)**	Not feasible	**10 years (P)**	10 years
Handrail and pole enticements e.g. free Wi-fi to hold on	Not feasible	Not feasible	Not feasible	Not feasible	Not feasible
Magnetic / grip floors that react with wheelchair and pushchair brakes	Not feasible	Not feasible	Not feasible	Not feasible	**10 years**

When selecting only the solutions that all groups agreed were feasible, it is possible to put them in a timeline of when they could be implemented (Table 28). The solutions have been colour-coded according to the categories previously described; passenger behaviour (blue), driver behaviour (grey), bus design (green) and policy / legislation (purple).

There were 26 solutions that were said to be feasible by all groups; generally the short-term solutions were related to passenger or driver behaviour, whereas bus design or policy related solutions would take longer to implement.

Table 28: Solutions agreed as feasible by all groups, grouped by time frame

Timeframe	Solution
Within 1 year	Advance warning / countdown to doors closing / verbal /auditory
	Compulsory stopping at every stop to reduce need for early standing to alight
	Encourage good seating choices based on passenger need
	Improve passenger information on board - audible warnings in advance of bus movements
	Improve passenger information pre-boarding (hold on, stay sat down, pushchair etiquette etc)
	Instrumented buses for driver behaviour linked to rewards system
	Stay sat down until bus stops
Within 1 to 5 years	Advanced driver assist technologies (ADAS)
	Better mirrors / cameras for driver to see all areas of bus
	Blind spot warnings on nearside of bus
	Door illumination
	Door sensors / lift technology to prevent closing
	Driver alerts if distracted
	Empathy training for drivers
	Gamification of driving style (rate my ride)
	Improve injury data collection information
	Improve passenger information on board - visual screen to see road ahead
	Legislation for all road users to enable buses to pull out
	Nudge techniques for passenger behaviour
Within 1 – 10 years	Change bus layout more seats at front accessible to passengers
	Change handrail and pole configuration in front of wheelchair / buggy area
	Design bus chassis to absorb shock and motion for passengers
	Seat design - change front edge angle
	Use oyster data for bus route planning (e.g. older passenger buses, family buses, majority standing)
Within 5 – 10 years	Communication between bus, other vehicles and external infrastructure (CAV)
	Segregation of road users - bus only lanes (no sharing with cyclists or taxis)

The remaining 25 solutions showed variation between groups as to whether they were feasible. These have also been grouped in a timeline of when they could be implemented, according to the groups who said they were feasible (Table 29). The table also states how many groups said 'Feasible' **(F)** or 'Not feasible' **(NF)** so the solutions can be further prioritised; i.e. a solution that 4 out of 5 groups said was Feasible could be considered more of a priority to a solution that only 1 group thought was Feasible.

Table 29: Solutions where the feasibility response was mixed, grouped by time frame

Timeframe	F	NF	Solution
Within 1 year	4	1	Always kneel the bus
	1	4	Always lower ramp
	3	2	Colour coding of bus zones or seats for passenger orientation
	2	3	Conductors on board
	4	1	Don't pull away until passengers are sat down
	3	2	Electric buses
	4	1	Increase running times
Within 1 to 5 years	3	2	Drive using wait time apps not timetables
	4	1	Forward collision warning
	4	1	Glowing handrails to encourage holding on
	4	1	Headway warnings
	3	2	Improve passenger information on board - tactile feedback (vibration)
	4	1	Internal lighting changes to encourage passengers to adapt behaviour on the journey
Within 1 to 10 years	4	1	More poles for passengers to negotiate the long distance across the wheelchair area
	4	1	Technology to communicate between passenger, bus and external infrastructure (e.g. advance warning of travel needs)
	4	1	Virtual conductors
Within 5 years	3	2	Bucket design seats
	4	1	Change acceleration / braking g-forces to reduce ‘harsh’ movements
Within 5 to 10 years	4	1	Connected and autonomous vehicles (CAV) vehicle to infrastructure communication
	3	2	Gates across stairs to prevent access during driving
	2	3	Seat belts
Within 10 years	4	1	Autonomous buses
	3	2	Double door system from bus stop to bus (like Jubilee line)
	1	4	Magnetic / grip floors that react with wheelchair and pushchair brakes
Not feasible	0	5	Handrail and pole enticements e.g. free Wi-fi to hold on

The tables below show the enablers and barriers for the **prioritised** solutions, separated into priorities within 1 year (Table 30), within 5 years (Table 31) and within 10 years (Table 32).

The group number(s) that selected the solution as a priority are indicated in brackets next to the solution.

Table 30: Enablers and barriers for 1-year priority solutions

Prioritised Solutions (1 year)	Enablers	Barriers
Advance warning / countdown to doors closing / verbal /auditory (2)(5)	- Rollout of iBus 2 - Engagement with targeted user groups and influencers (e.g. mumsnet, age concern, buggy stores) - The will to do it - Driver education and monitoring - Money - Innovative campaigns - Extend journey times - Stop at every stop	- Cost - Time - Apathy - Lack of space on board - Potential loss of revenue - Getting target users attention - Driver behaviour - Passenger behaviour - Knowing what will/won't work
Improve passenger information on board - audible warnings in advance of bus movements (5)		
Improve passenger information on board - tactile feedback (vibration) (5)		
Improve passenger information on board - visual screen to see road ahead (2)		
Improve passenger information pre-boarding (hold on, stay sat down, pushchair etiquette etc) (5)		
Nudge techniques for passenger behaviour (4)		
Stay sat down until bus stops (1)(3)(4)(5)		
Advanced driver assist technologies (ADAS) (5) *Including: Forward Collision Warning, Headway Warnings*	- TfL to mandate fitment - Funding from TfL - Driver education / training - Driver monitoring and disciplining - Passenger education - Extend journey times - Increasing automation - The will to do it - Put it in the 'big red book' - Bus safety standard - Some of these already in progress / about to start implementation - Minimise distractions for drivers - Money - Wider cultural change	- Cost - Time - Risk of education not embedding - Remembering training over time - Driver behaviour - Passenger behaviour - Political will - Technology development / choices - Technology reliability - Driver overload - Space in cab - Enforcement - Extended running times - Not solving the real problem
Always kneel the bus (1)(3)(5)		
Always lower the ramp (3)		
Better mirrors / cameras for driver to see all areas of bus (2)(5)		
Blind spot warnings on nearside of bus (2)		
Compulsory stopping at every stop to reduce need for early standing to alight (1)		
Don't pull away until passengers are sat down (1)(3)(4)		
Driver alerts if distracted (4)(5)		
Empathy training for drivers (3)(5)		
Gamification of driving style (rate my ride) (4)		
Increase running times (3)		
Change handrail and pole configuration in front of wheelchair / buggy area (1)	- Legislation changes - Clear specifications - Driver training / research - Improved road condition	- Legislation - Cost
Design bus chassis to absorb shock and motion for passengers (2)		

Table 31: Enablers and barriers for 5-year priority solutions

<table>
<tr><th>Prioritised Solutions (5 years)</th><th>Enablers</th><th>Barriers</th></tr>
<tr><td>Door illumination (3)</td><td rowspan="3">- Money
- Make part of the tender process (level playing field)</td><td rowspan="3">- Cost
- Change in law – political, enforcing change will affect other road users</td></tr>
<tr><td>Door sensors / lift technology to prevent closing (3)</td></tr>
<tr><td>Improve passenger information on board - visual screen to see road ahead (5)</td></tr>
<tr><td>Advanced driver assist technologies (ADAS) (1)(3)</td><td rowspan="9">- Money
- Make part of the tender process (level playing field)
- Technology, automation, iBus2
- Road safety standards
- Ticket machine button
- Speak to driver button
- Political will
- Physical infrastructure
- Road space reallocation</td><td rowspan="9">- Cost / funding
- Change in law – political, enforcing change will affect other road users
- Confusion for driver / overload
- Extend journey times
- Increased conflicts with other road users - Passenger engagement
- Healthy streets agenda
- Road space / restrictions
- Fall out</td></tr>
<tr><td>Better mirrors / cameras for driver to see all areas of bus (1)</td></tr>
<tr><td>Communication between bus, other vehicles and external infrastructure (CAV) (2)</td></tr>
<tr><td>Connected and autonomous vehicles (CAV) vehicle to infrastructure communication (2)</td></tr>
<tr><td>Driver alerts if distracted (2)(3)</td></tr>
<tr><td>Empathy training for drivers (4)</td></tr>
<tr><td>Forward collision warning (1)(3)(4)</td></tr>
<tr><td>Gamification of driving style (rate my ride) (2)</td></tr>
<tr><td>Segregation of road users - bus only lanes (no sharing with cyclists or taxis) (3)(4)(5)</td></tr>
<tr><td>Bucket design seats (1)(5)</td><td rowspan="5">- Money
- Make part of the tender process (level playing field)
- Legislation
- Extend journey times</td><td rowspan="5">- Cost
- Change in law – political, enforcing change will affect other road users
- Legislation
- Reduced capacity if not allowed standing passengers</td></tr>
<tr><td>Change acceleration / braking g-forces to reduce ‘harsh’ movements (1)(3)</td></tr>
<tr><td>Change handrail and pole configuration in front of wheelchair / buggy area (4)(5)</td></tr>
<tr><td>Seat belts (1)</td></tr>
<tr><td>Seat design - change front edge angle (5)</td></tr>
<tr><td>Gates across stairs to prevent access during driving (5)</td><td rowspan="3">- Money
- Manufacturer development
- Put into bus safety standard 2
- Technology, automation, iBus2
- Road safety standards
- Ticket machine button</td><td rowspan="3">- Ensuring it’s safe
- Not trapping people / don’t have something able to jumpy over
- Driver overload
- Increased conflicts with other road users</td></tr>
<tr><td>More poles for passengers to negotiate the long distance across the wheelchair area (4)</td></tr>
<tr><td>Use oyster data for bus route planning (e.g. older passenger buses, family buses, majority standing) (2)</td></tr>
<tr><td>Improve injury data collection information (2)</td><td>-</td><td>-</td></tr>
</table>

Table 32: Enablers and barriers for 10-year priority solutions

<table>
<tr><th>Prioritised Solutions (10 years)</th><th>Enablers</th><th>Barriers</th></tr>
<tr><td>Autonomous buses (1)(3)(4)</td><td rowspan="5">- Money
- Legislation
- Insurance industry (reduce premiums and claims)
- Technology</td><td rowspan="5">- Cost
- Legislation
- Culture change
- Technology
- Passenger consideration
- Opposition from other road users
- Disruption to others</td></tr>
<tr><td>Connected and autonomous vehicles (CAV) vehicle to infrastructure communication (4)(5)</td></tr>
<tr><td>Communication between bus, other vehicles and external infrastructure (CAV) (4)(5)</td></tr>
<tr><td>Segregation of road users - bus only lanes (no sharing with cyclists or taxis) (2)</td></tr>
<tr><td>Virtual conductors (4)</td></tr>
<tr><td>Change handrail and pole configuration in front of wheelchair / buggy area (3)</td><td rowspan="3">- Money
- Legislation
- Insurance industry (reduce premiums and claims)
- Design and feasibility</td><td rowspan="3">- Technology
- Passenger consideration</td></tr>
<tr><td>Design bus chassis to absorb shock and motion for passengers (1)</td></tr>
<tr><td>Magnetic / grip floors that react with wheelchair and pushchair brakes (5)</td></tr>
<tr><td>Change bus layout more seats at front accessible to passengers (3)(5)</td><td rowspan="5">- Money
- Legislation
- Insurance industry (reduce premiums and claims)</td><td rowspan="5">- Cost
- Technology
- Passenger consideration
- Disruption to infrastructure and neighbours
- Maintenance</td></tr>
<tr><td>Double door system from bus stop to bus (like Jubilee line) (2)(4)</td></tr>
<tr><td>Gates across stairs to prevent access during driving (3)</td></tr>
<tr><td>More poles for passengers to negotiate the long distance across the wheelchair area (3)</td></tr>
<tr><td>Technology to communicate between passenger, bus and external infrastructure (e.g. advance warning of travel needs) (5)</td></tr>
</table>

Main identified short term solutions

The main short-term feasible design solutions related to passenger or driver behaviours to help prevent injuries occurring on buses. The top solution was to encourage passengers to stay seated until the bus stops which requires educating passengers and bus drivers to prepare to stop or make stopping at all bus stops compulsory which would increase the journey time.

Improving passenger information on board and pre-boarding appeared to be another feasible solution to encourage passengers to behave in an expected way; for example, audible warnings on buses to inform of door closing times (2 groups) or intended bus movements to allow passengers to 'hold on' or not board in a dangerous situation. Only 1 group considered nudge techniques as a feasible solution in the short term to change passenger behaviour; however one group indicated that the messages on the London underground seem to work i.e. stand on the right, audible warnings to stand clear of doors or move down the train - but there is a lack of presence of such information on London buses.

The other aspect that was considered feasible in the short term were changes to driver behaviour; particularly for three of the groups "not pulling away until passengers are sat down" was an achievable priority as was to "always kneel the bus". Both changes would require improvements to driver education and would potentially increase journey times. Two groups prioritised "empathy training" for drivers and TfL were provided with 5 of the presentation slides to be incorporated into driver training to show the impact their driving has on passengers. One group liked the potential of gamification of driving style ("rate my ride" etc.) which could change driver behaviour and a second group thought this was feasible within the 5-year time range.

Advanced Driver Assistance Systems (ADAS) was considered to be feasible within one year by one of the groups to assist with forward collision warning, headway warning and driver alerts if distracted, two other groups thought this was feasible in 5-years. A second group prioritised driver alerts if distracted but not the other potential uses of ADAS.

Other priorities and potentially feasible bus design solutions within a year were changing handrail and pole configuration in front of wheelchair / buggy area, installing better mirrors / cameras for driver to see all areas of bus (2 groups), blind spot warnings on nearside of bus (1 group) and design of bus chassis to absorb shock and motion for passengers (1 group). These would require legislation changes and funding to allow implementation.

Interestingly, only one group suggested increased running times as a feasible solution within 1 year; however, some of the other suggestions above would require this to happen to enable passenger and driver behaviours to occur routinely.

Main identified mid-term solutions

Interestingly, many groups considered the fitting of advanced driver assistance systems (ADAS) to be feasible in the mid-term and particularly the use of forward collision warning (3 groups) and distracted driver alerts (2 groups). The other type of technology that was deemed as feasible in this time period is the connected and autonomous vehicles (CAV) communication between buses, other vehicles and external infrastructure (2 groups).

Three groups identified the need for segregation of road users (bus only lanes) to help in preventing harsh braking. However, this would require the political will, physical infrastructure and ultimately funding for implementation across London.

There were more internal bus design solutions considered in the mid-term period which included changing the handrail and pole configuration in front of wheelchair / buggy area (2 groups) and more poles for passengers to negotiate the (relative) long distance across the wheelchair area (1 group) but both would require clear specifications, legislation changes and funds to support this. Changes to seat design was a possibility in this time period and could include bucket seat designs (2 groups) or changing the front edge angle (1 group).

Other design solutions chosen were fitting of better mirrors / cameras for driver to see all areas of bus, which were considered feasible within 1 year; fitting door sensors / lift technology to prevent doors closing as well as illuminating the doors to help prevent passengers boarding late. The fitment of seatbelts by one group and the fitting of stair gates by another group were determined to be feasible and a priority in the mid-term.

Some of the priority solutions for the mid-term period had already been considered within the 1 year- short term period and included gamification of driving style ("rate my ride"), empathy training for drivers and improved passenger information on board buses using a visual screen to see the road ahead.

There was also the identification of changing acceleration / braking g-forces to reduce 'harsh' movements by two of the groups. The other 5-year design solutions included using Oyster card data for bus route planning (e.g. older passenger buses, family buses, majority standing) and only one group identified the need to improve injury data collection information.

Main identified long-term solutions

The long-term solutions considered to be feasible and a priority at that time point mainly centred on technology advancements and internal bus layout.

Three groups identified autonomous buses and three groups considered connected and autonomous vehicles (CAV) to be important for communication between passenger, bus and external infrastructure (e.g. advance warning of travel needs) that would assist the driver of passenger needs.

Internal infrastructure solutions comprised the fitting of gates across stairs to prevent access during driving (2 groups), changes to handrail and pole configuration in front of wheelchair / buggy area (2 groups), changes to the bus layout to have more seats at the front of the bus and accessible to passengers (3 groups) and the addition of more poles for passengers to negotiate the long distance across the wheelchair area (2 groups).

Other potential solutions feasible were fitting a magnetic / grip floor that reacts with wheelchair and pushchair brakes to fix them in place; and changes in chassis design to absorb shock and motion for passengers. Larger external infrastructure considerations were the segregation of road users - bus only lanes (no sharing with cyclists or taxis) and having a double door system from bus-stop to bus (like Jubilee line) to enable safer alighting and boarding.

Main identified not feasible solutions

All the groups identified that having enticements to hold the handrail or pole (e.g. free Wi-fi to hold on) was not feasible and all bar one group believed that having a magnetic / grip floor that reacts with wheelchair and pushchair brakes was unfeasible.

Interestingly having a conductor on board was not feasible for three groups but was feasible within 1-year for the other two groups. Also, always lowering the ramp on the bus was feasible for one group but was considered unfeasible by the other four.

Increasing running times was only considered to be unfeasible by one group; all the others thought it feasible within 1-year.

Summary of Enablers

There were several factors considered to be enablers to introduce design solutions to current practice. One of the main factors was increasing journey running times as this was perceived to enable the drivers to stop at every bus stop on the route, wait for passengers to sit down after boarding and allow passengers to remain seated until the bus stops for alighting. In addition to this driver education / training was necessary to enable this behaviour to be routine and would also need to be alongside passenger education to promote the required behaviour to minimise injuries on buses. Furthermore, this would also require the support of TfL and there was mention of the 'big red book' which accompanies driver training - additions could be made to this to support any of these moves by the bus operators.

Passenger education was a considered enabler and to achieve this, mass campaigns were suggested as well as innovative communication on board buses, with passenger groups and community influencers for example 'mumsnet'. It was apparent there are some technologies in existence to inform passengers and the mention of programming and rolling out iBus2 would support onboard communications for passengers providing warnings and other information.

Other enablers were to use the bus safety standard to promote any design solutions and fit certain equipment, for example better mirrors on board the bus for the drivers as well as the recommended external mirrors to enhance visibility in previous blind spots. Other aspects suggested that legislation is necessary to enforce changes either through policy change or bus design, all of which assume that there would be a willingness to change bus design. Where ADAS and other potential technology was considered (for example having lift door type sensors or forward collision warning) the need to have these as standard should be written into any bus tender processes to have a standard and level base for all bus manufactures and operators.

The larger scale changes, for example road user segregation, requires political will and funding to change the road use and layout. Funding was one of the main enablers to introduce many of the design solutions in addition to TfL support.

Summary of Barriers

Not surprisingly cost and legislation were the main barriers mentioned by all the groups for one or more of the design solutions. Other interesting factors mentioned were the need not to overload the driver with information if (for example) CAV technology was implemented. Driver education was an enabler but also a barrier as there are 14,000 drivers to inform regarding 'always kneeling the bus' and 'allowing passengers to sit down'. Each would also have a cost implication. These are not currently in the 'big red book' which would be one way to inform drivers; there is a new edition due for release, but this new information cannot be added at this late stage. Driver training is also being updated but the inclusion of empathy training is again perhaps too late to be included. However, TfL have been supplied with a few pertinent slides from the workshop to help drivers understand the impact their driving has on passengers if they drive poorly.

Reaching passengers innovatively, having the time and apathy were all considered barriers to passenger behaviour change education and there is always the general will for change that needs to be addressed for passengers and drivers alike.

Summary of Discussion

During the discussion at the end of the workshop all the groups informed the room about their selected priority design solutions and the barriers and enablers that were also required. It further provided a forum to inform the researchers and other stakeholders of any solutions currently in practice or likely to be in the future.

Overall improved passenger information seemed to be the most popular theme; how to persuade the passengers to behave as the operators and drivers expect them to. Broadly this requires TfL to promote this on a service-wide basis and it could be promoted using a similar approach to tourist information provision. Information was needed on buses and then for targeting user groups in appropriate places for example, GP surgeries and schools. Training people while they are young (in primary school) to sit whilst the bus is in motion and hold on might be effective as these lessons often stick with them into adulthood. It was recognised that the push to change behaviour has been hard in the past and there needs to be a will to do it in an effective way.

There were some interesting points raised by the operators when discussing the need for more mirrors or display screens for drivers to see throughout the bus. It was identified that when a double decker bus is in motion, the monitor the driver can see shows the upstairs deck, but when the bus stops, it switches and shows the driver the doors. Therefore, when the bus is stopped, the drivers cannot see the upstairs or stairs area and therefore miss people descending the stairs if they are alighting the bus. Furthermore, if the bus is noisy the driver cannot hear anyone on the stairs and might assume that no-one is coming downstairs and consequently will not wait for them. One of the operators mentioned that they are thinking of fitting a ‘dual switch’ option for drivers, so they can flick between feeds and check all angles.

One of the operators have trialled Mobileye and this was shown to be effective particularly for the forward collision warning system resulting in a reduction of harsh braking incidents. In principle this is a good system and the technology is not expensive when fitting a small number of buses but when fitting 9000 buses it becomes prohibitive. The fitting of Mobileye can be done as a retrofit and if funding was not a problem it could in theory have quick fleet penetration. Any of the design solutions that can be a retrofitted at the refurbishment stage, if not immediately are likely to happen otherwise there is a 15-year cycle of new vehicles in the fleet and other technology and advances would be available by then.

It is important to note that design changes generally apply to new vehicles only, so the existing fleet would not benefit from changes. Realistically, any interior design solutions were in the 5-year bracket as bus re-design takes time to implement. Interior design changes are in the bus safety standard that is coming up but are only discussed as part of the second rather than first-phase due to timescales. The safety standard offers broad consideration of the bus interiors rather than addressing specific problem areas identified here.

‘Always kneeling the bus at stops’ was one of the top 5, priorities and in theory is a very simple policy change that needs to be disseminated to drivers. However, this would need to come from TfL to give legislative weight behind the changes and to ensure they are service-wide. TfL regularly publish and update the ‘big red book’ of best practice / rules; if it were to be included in this, it would be enforced in the driver training. Unfortunately, with revisions now imminent, it is unlikely that it can include nay of the findings / recommendations from this study. Some of the proposed changes such as always kneeling the bus would increase running times and need support from TfL to enable this to happen. There are potential opportunities to have extended running times at off peak periods in the initial phase and evaluate any passenger benefits from implementing the measure.

A discussion on seat design and the fitting of seatbelts was interesting and having manufacturers in the room added significant insight to this conversation. Seatbelts are considered a possibility, but they would come with many other considerations and the issue is not simply a matter of retrofitting. If they were to be fitted on buses, they would need to be of a specific design different to passenger car seat belt and they would need to be 'intelligent' to prevent misuse. More importantly if they were fitted, then legally the onus would be on the driver to make sure that every passenger was wearing them which would involve the impractical requirement to check usage at every bus stop. A further counterargument is that if seatbelts were mandatory while sitting, then there should not be any standing passengers which would significantly reduce bus capacity.

Seat design appeared to be a 5-year design solution and it was also identified that seat re-design needs to consider other factors beyond having a 'bucket shaped' design or increasing the front edge angle. These factors included the weight and size of the seats which would affect the bus capacity. It was also suggested that innovation is needed to make a seat redesign work and requires some sort of call for someone to re-design the seats in order to address some of the issues without compromising on weight or capacity. The new bus safety standard is also considering seat design in the longer term and recommends high back seats for prevention of whiplash in rearward facing seats (which interestingly was not found to be a major injury category in the quantitative analysis). These high back seats are an example of seat re-design but involve weight and capacity issues. It was also discussed that more high back seats would prevent people flying out of seats, and a seat is a softer thing to collide with compared to a metal bar when thrown forward. Buses could also all have rear-facing seats only, but this would then affect capacity and additionally it is unlikely the passengers would like this approach (with motion-sickness being a factor) even with a big screen at the back showing the forward view.

Operators did agree that the two forward facing seats just by the buggy area are a big problem. This has already been highlighted to TfL, but there are no solutions yet. Fitting a stiff structure in front of them to prevent people flying out could be a countermeasure but then this becomes a contact point by itself. One idea was to fit arm-rests on seats as they are softer than stiff bars to hold on to and more natural to use as a handhold for stability. These are already present on most of the priority seats but not on the 'problem' seats, but again capacity issues are evident if they are fitted to every seat.

Stairs are known to be a big problem for the bus operators and require 'something' to be done but no suggestion of what was mentioned. This is also being considered during phase 2 of the bus safety standard. A discussion about having stair-gates at the top and bottom to stop people using the stairs when the bus is in motion found that they were not completely unfeasible. The gates would require careful programming so as not to prevent people using the stairs when needed and provide an override option in case of emergencies.

It was noted that not all the solutions were due to the bus design or users but other external factors, e.g. people parking too close to the bus stops, particularly blue badge holders whereby the bus cannot gain access to the bus-stop and therefore cannot kneel the bus or lower the ramp. This then creates a problem for passengers who are forced into the road and must negotiate the kerb heights too. It was also recognised that often other road users were the cause of the bus driver needing to brake harshly. Having segregated bus lanes or dedicated longer areas to the side of the road that were only for buses where they could pull in when stopping, could be solutions but most people believed that other road users would still abuse the system and park in these areas. This would require legislation and enforcement to resolve any such issues.

An additional discussion was held about wheelchair users and the allocated space on buses. Interestingly how the wheelchair users use the bus dictates much of the current bus design. For example, they are supposed to go up the ramp then perform a 'backing in' manoeuvre into the wheelchair space and position themselves against the wall. This means a lot of space is needed for the wheelchair area to allow them to manoeuvre and it was proposed that moving the wheelchair area right to the back might help alleviate the long-distance that other passengers must negotiate to reach their seats. However, this is probably impractical requiring widening of the aisle so wheelchairs could fit all the way along the bus reducing seat capacity. It was also noted that the markings / guidance for wheelchair users was not clear. There is a blue area on the floor with a picture of the wheelchair, and a sign on the wall shows how they are meant to position themselves in the area. It is not immediately apparent that it is showing wheelchair orientation and it appears like a normal sign to indicate that this is a wheelchair area. Apparently, this is currently being clarified in the big red book for the new version. A confounding factor in this is that there is a presumed 'one wheelchair orientation' fits all wheelchair user-needs but capabilities vary considerably dependent on the users' condition.

One idea suggested was the use of floor and seat colouring particularly for elderly people, or those with dementia who could find it easier to find a seat if there is a clear separation of colours. This is one way to 'nudge' behaviour making coloured seats available and clarifying that they are for elderly or schoolchildren which could encourage them to a use those seats rather than less appropriate seats.

The researchers raised the point regarding unreliable injury data, and it was identified that operators find this difficult to collate as some injuries (e.g. whiplash) don't become apparent until later. Therefore, this is not captured on their original incident report and is not a full reflection of their injuries.

7 Discussion

The mixed method approach identified various aspects of injury causation on London buses. What was immediately evident was the disparity between the numbers of casualties officially reported in STATS19 data involving a bus in London and the threefold increase in casualty figures for the TfL reported IRIS data. Although the types of incidents vary between the reporting in IRIS and STATS19, there still is an apparent higher number of incidents and injured casualties in London which has steadily increased during the analysis period. Predominantly, the casualties are a result of non-collision incidents and would account for the lower STATS19 numbers. Furthermore, there is an over representation of females and the age distribution of casualties is skewed towards older occupants. This is expected, and reflects the general demographics seen amongst bus passengers. However, it does raise the question whether there are underlying physiological differences that render females to be more at risk than males of sustaining an injury.

One of the problems in the data is the limitations in describing the actions of the bus and what the passenger intent is resulting in a reliance on assumptions to be formed about the data. This makes it difficult to define countermeasures when broad categories of standing and seated are used in addition to alighting and boarding. There is no allowance for the detail about the actual problem with seated passengers; for example, sudden deceleration can be assumed if the bus is slowing but is not captured in detail in STATS19. One of the other differences in the reporting is the injury descriptions used which again do not lend themselves easily to assist in countermeasure design. STATS19 reported nearly all the casualty incidents as minor and no further detail whereas IRIS can report the ‘type’ of injury sustained within the ‘minor’ category. Unfortunately, the reporting of injury in IRIS data is not consistent and is even unhelpful when looking at injury trends as many of the descriptors used are mechanisms of injury; for example, ‘bump’, ‘crush’ and ‘knock’ rather than an injury for example bruise or abrasion. In injury terms ‘crush’ is a specific kind of injury that would align with sustaining serious injury but is often mis-used in cases where the injuries are ‘minor’ and not what would be expected from such a description. Additionally, the use of ‘slip / trip/ fall’ category is overused and appears as a ‘catch-all’ category. There have been amendments to the IRIS data collection system to enable sub-categorisation below this to describe falls on the same level etc; however, it is incomplete. Where it was possible to consider the body-area injured, the head and face in children and face and lower/ upper extremity for elderly passengers were commonly reported. Most of the lower extremity injuries in the subcategory of data were caused in alighting and boarding incidents. The interpretation of this data again relies on assumptions to understand the data as the detail is not present. Intuitively, head and face injuries in children could be buggy-related or, following the CCTV review, could be attributed to hitting the seat in front as children tend to be thrown forwards during braking, usually head/ face first due their physiology and possibly since they are lighter in weight than adults thus affecting their kinematics.

From the quantitative analysis it is evident there are many discrepancies that make it difficult to develop a broad and full understanding of injuries on London buses in any specific detail. Even with perceived improvements and adding sub-categories to the IRIS data, it is argued that the data is not adequate to obtain a full representation of injury on buses. The qualitative data analysis added value to the quantitative data as it attempted to add meaning to the data such as the example of child head / face injuries noted above.

What is limiting in the datasets was the passenger and bus movement which helps inform assumptions about injury causation, but the detail is not present compared to the qualitative data whereby it was noted that certain seats were deemed to be ‘problem seats’ on the bus. These problem seats cannot be isolated in the datasets to identify if passengers who sit in them are more prone to injury compared to other seated passengers. Adding the interpretation of the qualitative data to the dataset analysis accounted for certain passenger and driver behaviours which could contribute to the injury outcome of the passengers. For 'boarding' incidents it is evident that this could be at any stage, from the passenger physically stepping onto the bus, to the point where they are sat down. Ultimately during this period, the bus is' stationary', 'moving off 'or could 'brake sharply' for whatever reason. This now expands the notion of boarding incidents and the causative factors up to the point the passenger is seated; attempting to board when doors are closing or tripping on the platform or falling over because the bus has not been knelt at the stop, all of which one would assume the bus is 'stationary' at the time. The additional factors here are the passenger and driver behaviours which could exacerbate these incidents including the driver closing the doors too early or by mistake, the passenger not being cautious of the doors or being impaired due to the height of the step; and bus factors if the driver has a blind spot and cannot see an approaching passenger on the nearside of the bus. These surmises can be extrapolated for the passengers' next phase of boarding which is the progression through/down the bus to find a seat. The problems here have been highlighted above and the 'moving off' from the stop and not waiting for passengers to be seated before this happens was a major problem but was also considered to be a priority and a feasible problem to fix by the stakeholder workshop. The nearside blind-spot should in theory be helped by the new proposed EU regulations for HGV mirrors which have been proposed for inclusion in the new bus safety standard following the work of Summerskill et al (2019).

Slowing down was another category identified in the datasets and was found to contribute to many of the incidents in the qualitative data. This was often described as 'harsh braking' but few of such incidents were for emergency-stop purposes although a higher proportion were needed to avoid collisions. Whatever reason for braking, the actual 'sharpness' of the bus movement is a major concern for passenger injury causation whether seated or standing. The findings suggest that a lot of 'minor passenger injuries' due to harsh braking could easily be avoided if slight changes in passenger and driver behaviour occurred, or there was assistive technology to help drivers avoid braking harshly. The use of ADAS, specifically forward collision warning devices (e.g. Mobileye) on bus fleets would have a preventative effect on passenger injury as harsh braking would then be avoided and injury risks subsequently reduced. As an injury prevention strategy, this was considered feasible within the short to mid-term time period but relies on investment to enable the retrofit on a large fleet of buses. There is a confounding factor to this which is the proposed fitment of AEBS brakes to the bus fleet as part of TfL's new Bbus Safety Standard[9]. The benefit to vulnerable road users is the driving force behind this recommendation; however, the impact on bus occupants needs to be reviewed in detail to understand passenger kinematics and the potential risk of injury if they were to be fitted as standard.

What was evident from this study was the multifaceted nature of injury causation to bus occupants whereby some design solutions are possible to help prevent them but might incur large costs. In the immediate period there needs to be a general shift-change in passenger and driver behaviour to understand needs and expectations from both perspectives. This was evident when the drivers do not wait for passengers to sit down after boarding and the passenger believing the driver must wait for them - but this is not actual bus operator policy. Thus, innovative and targeted information campaigns would help change long-term passenger behaviours and embedding policy in the big red book and including empathy training elements in driver training would further help to enable drivers to make informed decisions.

[9] Bus Safety Standard: Executive Summary; TfL October 2018; ISBN: 978-1-912433-62-9

7.1 Limitations

The aim of the study was to look at injury causation on buses which we did but the information and data collection systems to establish injury severity is woefully lacking in detail and is therefore difficult to establish the true picture. It is further assumed that many incidents go under-reported as it was obvious that some passengers alight the bus without speaking to the drivers and might only complain or contact the bus operators later presuming that their injury is more serious than first thought or that they can claim compensation. Therefore, establishing the prevalence of injuries on buses is difficult without using statistical modelling with exposure data.

Following the initial meeting with bus operators no attempt was made to identify the type and design of buses that resulted in an occupant casualty which might, over the data analysis period, have had an influence on injury outcomes. Further to this there was reliance on the co-operation and support of bus operators to provide the agreed data. The support varied between bus operators and in some cases, was possibly not seen as a priority by them. Also, there was variation within the data received and what was originally agreed, particularly regarding the incident reports which was partly compensated and offset through additional CCTV footage from one bus operator. No additional incident reports were requested from the two operators due to the time restrictions and the incident reports were not as detailed as expected. The additional CCTV was offered by one operator which was the reason that further footage was requested. Data sharing agreements were put in place between the two co-operating operators and data was shared and stored in accordance with these agreements (and will be deleted from the University system at the end of the project). The type of incident data received for the study in some cases was not at the level of detail required as it involved only slightly more detail than that contained within the IRIS dataset. It is difficult to establish whether there is more detailed investigation data available, but it is suspected that this may be the case.

A further limitation of the project was the follow up of bus passenger invitation letters; the original letter stated that no follow up would be posted to the passengers and this was initially to prevent burden on the bus operators and the cost implications of a second mail-out. Based on experiences from previous crash studies it was proposed that a 10-15% response rate would be normal for this kind of survey and it was expected that a large mail out would achieve such returns to obtain a sample of 60. To compensate for the low return rate, additional CCTV clips were requested and were provided. The low return might have been affected by the bus operator letter in the invitation. There was also a bias in the participants towards older females which might have affected the results although on the other hand, these are the predominant user group on buses.

One operator did not provide any incident data and only mailed out to 40 passengers as this was the amount of people who were on their claim database. This may have affected the results of the study, however operator presence and contribution to the stakeholder workshop indicated that the results and proffered solutions were valuable knowledge to them. TfL can probably influence the level of bus operator co-operation and support on subsequent similar studies.

7.2 Recommendations

The study was disadvantaged by the provision of bus operator data and the variance in databases and processes between them and ease of providing data. To enhance future studies of this type a memorandum of understanding could be signed between the bus operators and the research institution regards the provision of data and instil processes to ensure the current General Data Protection Regulation (GDPR) is adhered to and enable data sharing. Future studies of this type and nature would benefit from the following;

- Better reporting systems including more accurate injury data and injury causation information;
- Standardisation of language and parameters across incident reporting systems;

- Consistency with the IRIS database;
- In-depth case reviews of existing/historical cases involving major incidents and collisions on buses in which major injuries have been sustained by bus passengers/drivers;
- Development of a process for independent in-depth investigations of future major incidents and collisions on buses in which major injuries have been sustained by bus passengers/drivers.

8 Conclusions

This study aimed to explore injury causation on London buses independently of TfL and bus operators. To achieve this, a mixed method approach was used which combined quantitative and qualitative data analysis methods including a review of CCTV data and interviews of bus passengers. This has provided a rich source of data to enhance and understand the available STATS19 data to thereby providing a deeper understanding and explanation of injury causation to London bus passengers.

The strength of this study was the approach taken by the researchers and despite the difficulties accessing data, an interpretation of the problem of injuries on London buses has been provided. Using a design research methodology approach to generate ‘expert’ solutions from ‘how might we’ statements proved to be an innovative approach to injury countermeasures. This approach identified a range of potential solutions, some of which were traditional and others unconventional, which were taken to stakeholders. This enabled stakeholder input into identifying the feasibility and priorities for implementing solutions to the problems identified. A stakeholder workshop approach was very successful in providing an immediate evaluation of the feasibility of the identified solutions.

It was evident from the data analysis and the workshop that the problems and solutions are not confined to one area but require a systems approach to achieving a reduction in bus passenger injuries. This would involve passenger and driver behaviour change, vehicle design improvements, road infrastructure changes, legislative and policy updates and changes to the behaviour of other road users. To implement any of the findings of this study may require support from TfL in conjunction with the London bus operators.

9 References

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List of Appendices