Identifying Solutions to Pedal Confusion in Buses

For **Transport for London**

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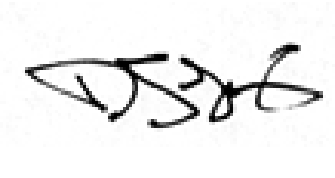
***Signature**		***Signature**	
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ACRONYM LIST

HE	Human Engineering
SME	Subject Matter Expert
TfL	Transport for London
UA	Unintended Acceleration

EXECUTIVE SUMMARY

Background
Human Engineering, on behalf of Transport for London (TfL), conducted an investigation into potential solutions for addressing unintended acceleration (UA) incidents in London Buses. A review of previously published literature and analyses of cognitive models of the driving task identified the main factors considered to cause, or contribute to UA as pedal confusion. The aim of this project was to identify potential solutions to the problem of pedal confusion, and to consider their feasibility.

Methodology
An analysis of available literature was undertaken, however, it was not possible to determine the extent of UA incidents due to a lack of quantifiable information and conflicting personal reports. The review provided information on the factors causing/ contributing to UA incidents which may be categorised as:

- Poor proprioception (sense of position of limbs)
- High workload while driving
- Inability to recover from error
- Severity of consequences

Corresponding solutions were then generated and subject to an iterative review/development process comprising:

- Building psychological model of UA incidents
- Interviews with bus drivers and engineers (Appendix A & B)
- Bus orientation exercise
- Develop criteria for assessment
- Workshops with subject matter experts
- Analysis and selection of solutions
- Use experimental design expertise to decide how to trial selected solutions

The process identified a diverse set of potential solutions involving physical changes to the pedal layout, visual or audio indicators, mechanical interventions, improvements to driver processes affecting workstation set-up, additional controls, and UA specific training.

Solutions
Of the initial set of solutions, eight were considered suitable for further investigation.

Table 1 – Summary of potential solutions

Cause	Goal	Solutions
Poor proprioception	Increase awareness of foot location	Changing the size of pedals
		Increasing the distance between pedals
		Change pivot point of pedal
		Use different pedal types for brake and accelerator (suspended vs. organ pedal)
	Make it more difficult to place foot in wrong place	Installation of a barrier between pedals
		Bus drivers to use left-foot braking
		Redesign throttle so drivers must accelerate using hand controls
High workload while driving	Ensure cab layout is aligned to mental model	Standardisation of pedal layout
	Ensure drivers are suitably settled and prepared before setting off	Have engine cut-out when driver door is opened (i.e. during hand-over)
		Improvement of seat adjustment controls
Unable to recover from error	Increase ability of drivers to recognise UA event is occurring	Provide training on UA
	Support drivers in achieving recognition of a UA incident	Provide audible indication of accelerator status
		Provide visual indication of accelerator status
		Provide integrated tactile indication of accelerator operation[1]
	Support drivers in responding to an UA incident	Provide hand-operated emergency stop pushbutton
Severity of consequences (collision)	Reduce severity of UA incident	Automatically cut-off engine/accelerator under certain circumstances
		Limit rate of acceleration (or time-out)

	Suitable for further investigation
	Suitable for further investigation in conjunction with other design elements
	Not suitable for further investigation

Identified solutions require further consideration from TfL and associated parties to ensure feasibility and suitability of options. It is recommended that trials are developed and conducted systematically.

[1] May also help with poor proprioception.

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1. INTRODUCTION

1.1 Requirement

1.1.1 Transport for London (TfL) has asked Human Engineering Limited (HE) to use their human factors expertise to generate potential solutions to the problem of unintended acceleration incidents on London's bus network.

1.1.2 This document describes the outputs of a process which identified, analysed and selected solutions for further investigation.

1.2 Background

1.2.1 TfL has noticed that a number of traffic incidents involving London buses have been attributed by drivers to "brake failure" or "a power surge". However, when the buses involved in these unintended acceleration (UA) incidents were inspected, they were found to be mechanically sound.

1.2.2 Pedal confusion is believed to be the main contributor to UA incidents. These incidents occur when drivers press the accelerator rather than the footbrake. This causes the bus to accelerate rapidly until either the driver corrects their error or the bus strikes a stationary object. Many drivers that are involved in these incidents remain convinced that their foot was on the brake pedal.

1.2.3 UA is an issue that has been known about for some time and the psychological underpinnings have been well explored in the past, e.g. the assessment of bus cab foot pedals performed by Human Engineering for London Buses in 2000 (Ref: HEL/LB/00424).

1.2.4 On the other hand, a limited amount of work has been done exploring potential solutions to the pedal confusion issue and TfL have reached a point where there is sufficient support amongst London bus operators for work to be done to redress this.

1.2.5 TfL has now contracted Human Engineering to begin an investigation into potential solutions.

1.3 Scope

1.3.1 The aims of this study were to:

- Determine the true extent to which pedal confusion is an issue
- Identify potential solutions or mitigations to the problem
- Conduct an initial analysis of the solutions from a human factors perspective
- Select some of the most promising solutions for trials.

1.3.2 It is not within the scope of the current project to trial any of the solutions or to provide experimental evidence relating to their suitability.

1.3.3 In addition, a number of the solutions refer to design changes or modifications. These are just conceptual changes at this stage and design specifics are not provided.

2. METHODOLOGY

2.1 Overview

2.1.1 The aims of the study were supported by the following activities:

- Build psychological model of UA incidents
- Interviews with bus drivers and engineers
- Bus orientation exercise
- Develop criteria for assessment
- Workshops with subject matter experts
- Analysis and selection of solutions
- Use experimental design expertise to decide how to trial selected solutions.

2.1.2 Brief descriptions of these activities are contained in this section of the report.

Analysis of Incident Data and Reports

2.1.3 It was originally planned for the set of initial solutions to be informed by analysis of incident data and reports. Unfortunately, data had not been categorised in a way which allowed identification of UA attributed incidents and detailed incident reports were unavailable from TfL.

2.1.4 This made it difficult for the project team to determine the true extent of UA incidents. The workshops and interviews generated conflicting views as to the true extent of UA incidents with some participants believing that they were infrequent or unlikely and others recognising it as a serious problem and even having some personal involvement of investigating such incidents. It is likely that the true extent is higher than was reported as there may be social barriers to reporting UAs (fallibility) or, if recovered, they may simply be forgotten.

2.2 Description of Activities

Build Model of UA Incidents

2.2.1 A psychological model of UA incidents was developed and used as a framework to generate and analyse solutions. A full description of the outputs of this activity is given in the next section of the report (Section 3).

Interviews with Bus Drivers and Engineers

2.2.2 A series of depot visits were undertaken in order to discuss UA incidents and potential solutions with drivers. The approach used was semi-structured interviews whereby a set of questions was used to guide discussion (see Appendix A) while allowing time for participants to comment on any other relevant areas of interest and some potential solutions. A table containing the driver feedback on potential solutions can be found in Appendix B.

2.2.3 Interviews were conducted with various bus operating companies at various London garages.

2.2.4 In addition, an interview was conducted with the TfL Fleet Development Manager and a telephone interview was held with a Depot Manager.

2.2.5 Information gained from these interviews was used to develop existing designs and identify which potential solutions warranted more emphasis moving forward to the stakeholder workshops.

Bus Orientation Exercise

2.2.6 As part of the depot visits, a series of bus orientation exercises were also carried out. This provided practical experience of different pedal arrangements, pedal resistance, seat controls and other workstation components.

2.2.7 These included examples from the manufacturers:

- Alexander, Dennis
- Transbus, Trident
- Mercedes-Benz, Envirobus
- Optare, X1060
- Scania
- AEC, Routemaster.

Figure 1 – Examples of the buses experienced during the orientation exercise

Development of Criteria for Assessment

2.2.8 The criteria used to assess solutions were based upon suggestions made during the interviews and also on human factors best practice principles. A full description of the selected criteria and their rationale is given in Section 5.

Workshops with Subject Matter Experts (SMEs)

2.2.9 Three workshops were held at TfL offices in the Palestra building on 15th, 17th and 19th November 2010. Human Engineering presented details of the potential design solutions for the representatives to discuss. This helped to confirm which solutions were considered viable given the assessment criteria and to develop or modify some of the solutions.

2.2.10 Workshops were attended by representatives from the following areas:

- Incident Investigation
- Risk and Securities
- Operations Health & Safety
- Training and Recruitment
- Claims and Motor Risk
- Driver/Trainer
- Accident Prevention

- Safety and Facilities.

Analysis of Solutions

2.2.11 Initial solutions and solutions suggested or developed during the interviews and workshops were classified using the psychological model of UA in order to show the mechanism by which they might work. They were then analysed against the assessment criteria to establish whether it was worth taking them forward for further investigation. A full analysis of each solution is given in Section 6.

Next steps for Trialling Solutions

2.2.12 Human Engineering has considerable expertise designing and running various kinds of trials in order to investigate user fit and preference, usability, safety, potential error outcomes and so on. This expertise was used to produce a brief overview of a preferred trial approach for each of the selected solutions. These approaches are described in Section 7.

2.3 About the Iterative Process

2.3.1 This process was less linear than it may appear in this section. It was not thought to be beneficial to prevent drivers from discussing how solutions might be assessed or to stop workshop participants from suggesting new solutions. So the process has remained iterative throughout – ideas for solutions, criteria and criticisms were captured at all stages of the process.

2.3.2 Drivers and Workshop attendees were actively encouraged to provide their own ideas which were then evaluated in following interviews and workshops or with the assessment criteria developed by Human Engineering.

2.3.3 The rest of this report contains the main outputs of the activities described in this section.

3. MODEL OF UA INCIDENTS

3.1 Cognitive Model

3.1.1 Cognitive psychology uses a model of human information processing that helps us to understand the way in which people perceive and interpret information. The diagram in Figure 2 is a simplified model of human cognition showing the different brain functions that people use when carrying out a task and how they are interlinked.

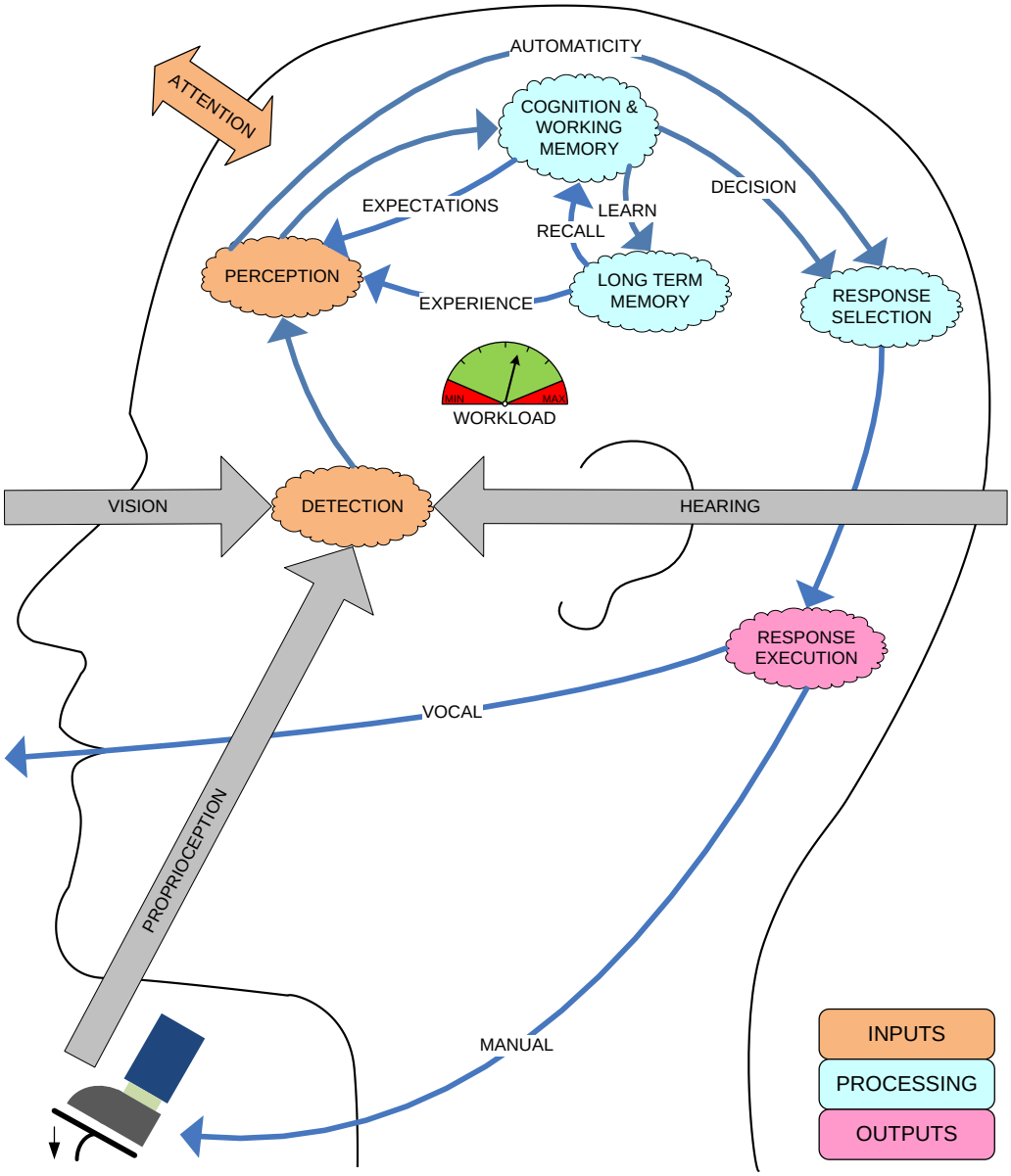

Figure 2 – Simplified Model of Human Cognition

3.1.2 Within the information processing literature, the relationship between the environment, human information processing and behaviour is usually broken down into a series of steps which accommodate the key processing stages and capacities of human performance (Figure 2). Most modelling approaches adopt an [Input] → [Process] → [Output] approach which allows a step-by-step analysis of how information from the outside world is analysed and utilised to enable the human to make decisions on how to operate in their environment.

3.1.3 Our model of driving behaviour breaks the task into six stages:

1. An **anticipation** stage, where the driver draws on their experience and expectations to attend intelligently to the environment around them
2. A **perceptual** stage, where an item of potential interest is detected and perceived (e.g. a bus stop)
3. A **processing** (cognition) stage, where the driver draws on their experience and expectations to come to a decision on how to respond to the item (e.g. this stop is on my route, I need to stop here)
    - This stage may be skipped for automatic, highly-learned responses.
4. A **response** stage, where the desired response is translated into physical movement (e.g. an action plan is formed to move arms to steer and foot to the pedal)
5. An **action** stage where the action plan is carried out (e.g. driver presses brake and steers)
6. A **feedback loop**, where close attention is paid to the outcome of the actions to determine if the desired effect was consistent with their overall goal (e.g. driver attends to road markings, sound of engine, vibrations and so on in order to check whether the bus is slowing down).

3.1.4 Errors may occur at any of these stages. In UA incidents drivers have perceived the situation correctly, recognised what needs to be done and decided on an appropriate course of action but they have made the error of pressing the wrong pedal (action stage). This kind of error is called a “slip”. The most relevant parts of the cognitive model to UA incidents are proprioception and workload.

3.1.5 *Proprioception* is the sense of where the different parts of the body are located. Pedal confusion errors occur, in part, because the driver does not have an accurate perception of the location of his foot.

3.1.6 *Workload* refers to the level of arousal that a person needs in order to attend to all the relevant information sources needed to complete a task. Very low arousal states can lead to boredom and reduced reaction to stimuli. Very high arousal states can lead to overload and inhibit a person’s ability to react to stimuli, make decisions and schedule tasks.

3.1.7 A person with a great deal of experience will have developed strategies to cope with demanding situations and recognise patterns of information (thus reducing the time and effort needed to make a decision and take action). Experience can be boosted by training.

3.1.8 Similarly, if a person is distracted their attention will be divided amongst multiple inputs and they will be operating in a state of higher workload. This will make it more difficult for them to react to stimuli, make decisions and schedule tasks and they will be more likely to make mistakes and slips. Sources of distraction may include any change to the usual or expected environment in which people operate.

3.1.9 In a totally novel or unexpected and threatening situation, people may panic and the fight-or-flight response will take over. This can be thought of as a state of extremely high arousal in which rational thought is almost impossible. In this state it is difficult for people to react with anything other than an automatic, highly learned behaviour.

3.1.10 An understanding of these factors is helpful for determining what kinds of solutions to the UA incidents are likely to be successful.

3.2 Typical UA Scenario

3.2.1 Through discussions in the interviews and at the workshops, a typical scenario for a UA incident was created. Figure 3 shows how driver actions may deviate from the preferred course of action to cause a UA incident.

3.2.2 The antecedents of the incident will include latent errors (Reason, 1990). These are errors made prior to the incident at managerial levels within the organisations which influence and oversee the driver's activities (e.g. employer, TfL, local council etc.).

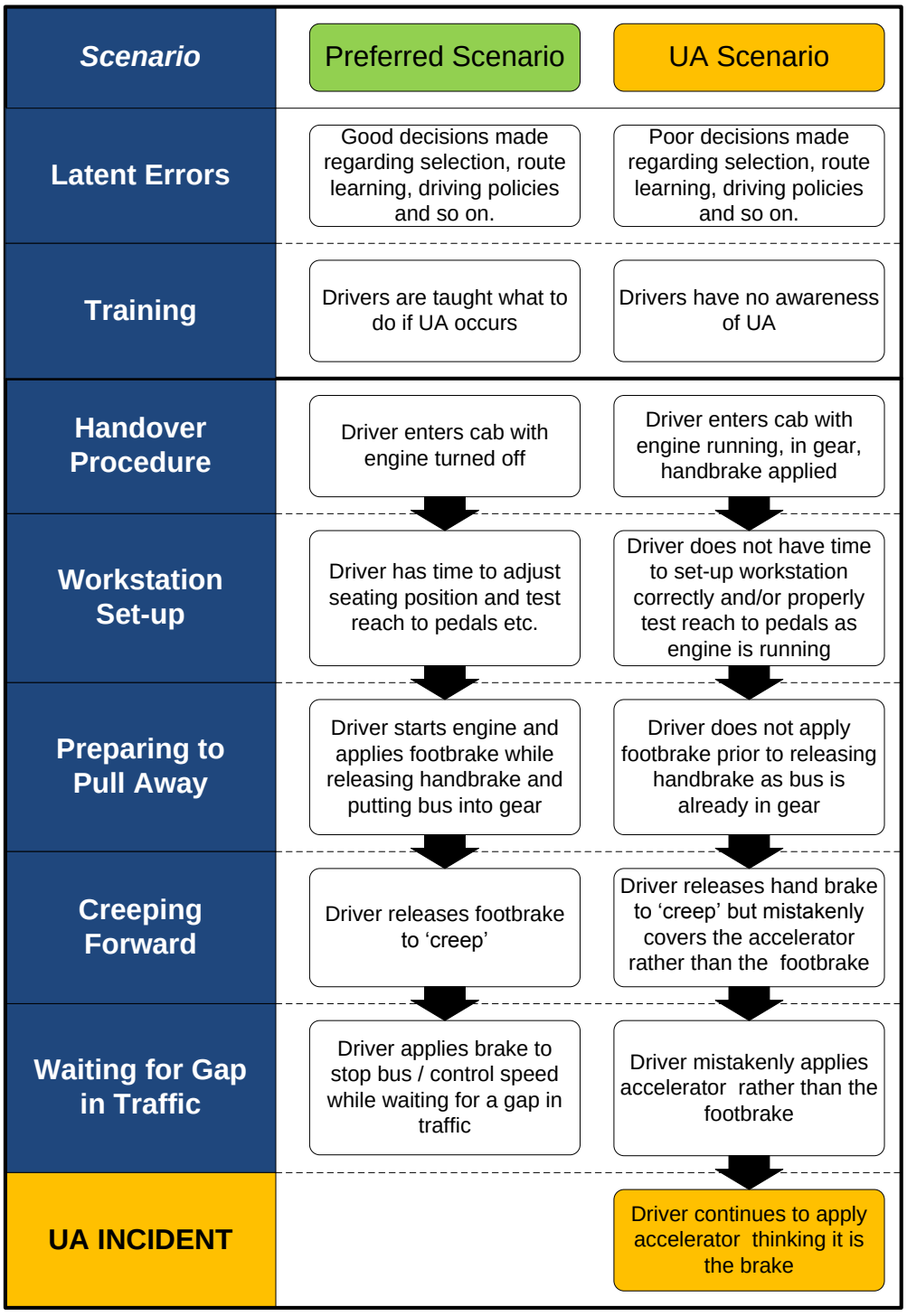

Figure 3 – Typical UA Scenario

3.3 Targets for Solutions

3.3.1 As the model and scenario show, UA incidents have multiple causes. Table 2 shows a summary of the high-level causes and one additional factor relating to UA incidents and describes the consequent aims that any solutions will need to achieve in order to mitigate them.

Table 2 – Causes of UA incidents

Cause	Goal
Poor proprioception	Increase awareness of foot location
	Make it more difficult to place foot in wrong place
High workload while driving	Ensure cab layout aligned to mental model
	Ensure drivers are suitably settled and prepared before setting off
Unable to recover from error	Increase ability of drivers to recognise UA event is occurring
	Support drivers in achieving recognition of a UA incident
Severity of consequences (collision)[2]	Reduce severity of UA incident

3.3.2 The following section shows how the initial set of solutions that was generated maps onto the goals identified in the table above.

[2] This is not a cause but it is an important factor relating to UA incidents that should be addressed by some of the solutions.

4. PROPOSED SOLUTIONS

4.1.1 In order to identify potential solutions, Human Engineering had early discussions with the TfL Safety Manager on the issue, reviewed relevant scientific reports and previous projects undertaken by Human Engineering (Reference 1).

4.1.2 The solutions listed in Table 3 were those identified as possibly addressing the causes shown in Table 2.

Table 3 – Solutions Mapped Against Goals

Cause	Goal	Solutions
Poor proprioception	Increase awareness of foot location	Changing the size of pedals
		Increasing the distance between pedals
		Change pivot point of pedal
		Use different pedal types for brake and accelerator (suspended vs. organ pedal)
	Make it more difficult to place foot in wrong place	Installation of a barrier between pedals
		Bus drivers to use left-foot braking
		Redesign throttle so drivers must accelerate using hand controls
High workload while driving	Ensure cab layout is aligned to mental model	Standardisation of pedal layout
	Ensure drivers are suitably settled and prepared before setting off	Have engine cut-out when driver door is opened (i.e. during hand-over)
		Improvement of seat adjustment controls
Unable to recover from error	Increase ability of drivers to recognise UA event is occurring	Provide training on UA
	Support drivers in achieving recognition of a UA incident	Provide audible indication of accelerator status
		Provide visual indication of accelerator status
		Provide integrated tactile indication of accelerator operation[3]
	Support drivers in responding to an UA incident	Provide hand-operated emergency stop pushbutton
Severity of consequences (collision)	Reduce severity of UA incident	Automatically cut-off engine/accelerator under certain circumstances
		Limit rate of acceleration (or time-out)

[3] May also help with poor proprioception.

5. ASSESSMENT CRITERIA

Assessment Criteria

5.1.1 The solutions were evaluated against the principle of usability; usability is the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (ISO 13407 – Reference 4).

5.1.2 In this context these criteria equate to:

- **Effectiveness**
  - Will the solution be effective in preventing/reducing UA incidents?
    - Will it actually work?
    - Will it address all types of UA incidents or just a small set?
    - Will the design impact on driver workload and thus make errors more likely?
    - Will the design encourage other unsafe behaviours or workarounds?
- **Efficiency**
  - Will the solution be efficient enough for stakeholders to benefit from it with minimum effort on their part?
    - Will the solution require additional training?
    - Can solution be retro-fitted?
    - Might the co-ordination between operating companies, manufacturers, TfL and legislative bodies become too complicated?
    - How much will the solution cost, accounting for additional training, materials, design work etc.
- **Satisfaction**
  - Will the solution impact on the job satisfaction of drivers using the buses that it has been applied to?
    - Will the solution cause a distraction to the driver?
    - Will the solution reduce the capabilities of the bus?
    - Might the solution have unintended other outcomes?

5.1.3 The solutions were assessed at a fairly high level. It was not considered worthwhile to attempt to establish the precise costs associated with each solution at this early stage.

6. ANALYSIS OF PROPOSED SOLUTIONS

6.1 Increase Awareness of Foot Location

Changing the Size of Pedals

Rationale

6.1.1 The pedals in both the organ and the pendulum layout are similarly sized, and do not enable the driver to differentiate between the brake and the accelerator through tactile feedback in either set-up. A driver must therefore be reliant on their mental model of pedal positions and proprioception; an awareness of their own body alignment. Changing the size of one or more of the pedals may improve the driver's ability to differentiate between the (e.g. larger) brake and (e.g. smaller) accelerator, therefore reducing the risk of pedal confusion.

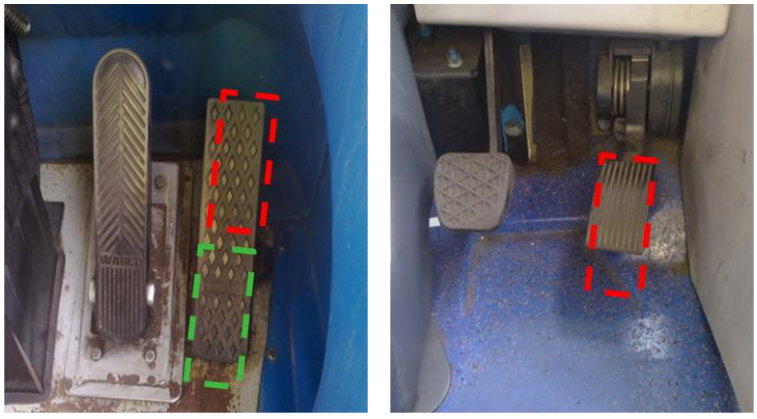

Figure 4 – Examples of Differentiation through Changing the Size of the Pedals (coloured boxes indicate different size/positioning options)

Additional Benefits

- No additional training or adjustment to driver behaviour required
- Depending on the specific nature of the change, retro-fitting may be possible and relatively inexpensive.

Critique

- Feedback from the pedal may be inhibited by thick soled shoes
- The pedal information must be re-learned and old pedal information may be latent.

Barriers

- Would require consensus to be reached by industry, this may be difficult even after a study to identify optimum pedal arrangement and method of operation has been performed
- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.1.2 Specific benefits of change in pedal size need to be established, but would be a comparatively simple design change. Learning of pedal arrangement does not present long-term issues.

6.1.3 **Suitable for further investigation as part of overall pedal arrangement review** ✓

Increase Distance between Pedals

Rationale

6.1.4 Increasing distance between brake and accelerator pedals will reduce the likelihood of error of incorrect orientation with the pedals. There will be a much more distinct difference between the foot positions required to operate each pedal which will be noticed by the driver.

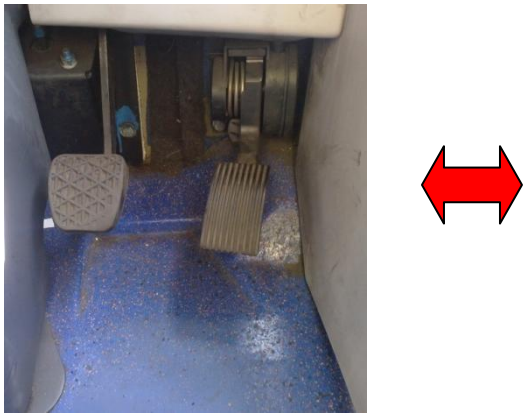

Figure 5 – Increase Distance between Pedals

Additional Benefits

- No additional systems, procedures or practices
- Depending on the specific nature of the change, retro-fitting may be possible and relatively inexpensive.

Critique

- The pedal information must be re-learned and old pedal information will be latent, this may be marked in this case due the movement of pedal required
- Increased distance between pedals may increase time to transfer from one to the other, particularly in a emergency
- While increasing distance improves differentiation it may reduce ability to quickly locate a pedal when transferring.

Barriers

- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.1.5 Specific benefits of change in distance between pedals need to be established, but would be a comparatively simple design change. Learning of pedal arrangement does not present long-term issues.

6.1.6 **Suitable for further investigation as part of overall pedal arrangement review**

Change Pivot Point of Pedal

Rationale

6.1.7 Floor pedals are hinged at the front of the pedal, nearest to the driver. This is identical in both brake and accelerator so does not provide any differentiation through body position or tactile feedback. If the pivot point were moved to the mid-point for the accelerator so that a rocking action was used rather than a pressing action, this could increase the feedback to the drivers as to which pedal is being operated and therefore reduce the risk of pedal confusion and an UA incident.

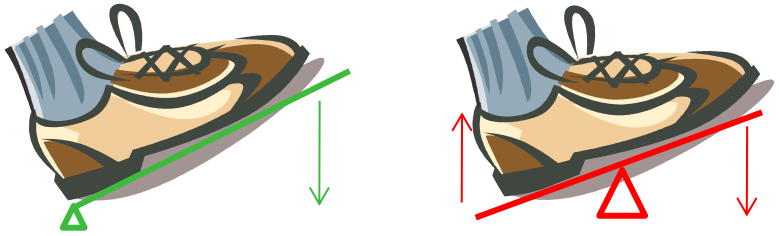

Figure 6 – Examples of different pivot points of pedals

Additional Benefits

- No additional systems, procedures or practices required
- If the driver was confused between the brake and accelerator and used a pressing action on the rocking pedal then the bus would not accelerate thus reducing the severity of the UA incident.

Critique

- Likelihood of increased stress/fatigue in leg as different muscles will be used to operate pedals with a different pivot point
- Pedal operation technique must be re-learned and old pedal information may be latent
- More difficult to slide foot from one pedal to another
- Operation of the rocking pedal design would require greater precision of movement which may be difficult to achieve
- Retro-fit may not be possible.

Barriers

- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.1.8 Solution is likely to cause stress and fatigue in the leg muscles and/or require significant movement of the accelerator towards the driver which may impact comfort and use of the pedals in normal driving.

6.1.9 **Not suitable for further investigation** ✘

Use of Different Pedal Types for Brake and Accelerator (Suspended vs. Organ Pedal)

Rationale

6.1.10 Currently two different types of pedal are used: organ (attached to the floor) and suspended (attached at the top). In most current designs both pedals are suspended/pivoted at the same point.

6.1.11 Changing the type of one of the pedals would introduce differentiation between the pedals due to the different foot movements and positioning of the foot during operation. This will provide better feedback to the driver as to which pedal is being covered/pressed which will reduce the likelihood of pedal confusion. The preferred arrangement with SMEs was to have the brake as the in-floor, organ style pedal with the accelerator as the suspended pedal.

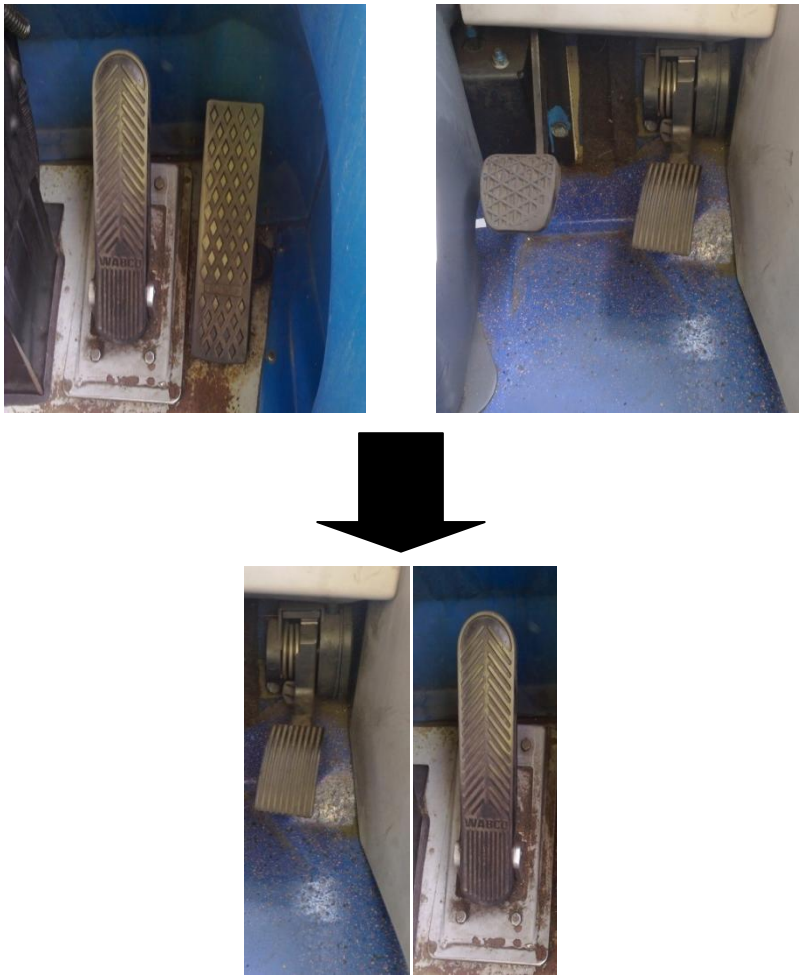

Figure 7 – Example of Differentiation through Pedal Design

Additional Benefits

- No additional training or adjustment to driver behaviour required.

Critique

- Would be expensive to retro-fit so may only be applicable to new build buses
- Change in pedal arrangement may impact existing designs and require costly re-design for some companies.
- Lack of data comparing rate of UA incidents in buses with two different pedal types with buses with two identical pedals – cannot be sure of the effectiveness of this solution.

Barriers

- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.1.12 Despite the solution having a long lead time it is considered to provide a long-term benefit once implemented. However, it must be recognised that this arrangement is used in some vehicles.

6.1.13 **Suitable for further investigation as part of overall pedal arrangement review**

6.2 Make it more difficult to place foot in wrong place

Installation of a Barrier between Pedals

Rationale

6.2.1 Installing a barrier between pedals would act as a guide when locating the pedals i.e. if their foot is slightly misaligned it is likely that they will hit the barrier which will remind them which pedal they are covering. Drivers will also be able to tap the barrier with their foot as a reminder of which side they are on.

6.2.2 A barrier could also be positioned such that the driver's foot is in contact with the barrier when operating the pedal. This will give the driver feedback on which pedal is being covered/pressed (they will be able to feel which side of the foot is in contact with the barrier).

Figure 8 – Example of a barrier between pedals

Additional Benefits

- No additional systems, procedures or practices
- Retrofit would be relatively cheap and simple.

Critique

- Drivers will have to adjust how they move their foot between pedals to avoid hitting the barrier – this may result in initial confusion during re-learning

- It will be more difficult to slide the foot from one pedal to the other thus increasing reaction time. This could be a potential safety issue.

Barriers

- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.2.3 This solution may provide a suitable guide and reference point for pedal position, but in emergency scenarios this type of barrier has the potential to cause an obstruction to accessing the required pedal quickly. This would be unsafe and more incidents could occur than UA incidents that are prevented.

6.2.4 **Not suitable for further investigation** 

Left-foot Braking

Rationale

6.2.5 Training drivers to brake using their left foot (possibly in conjunction with moving the pedal further to the left of the steering column) will remove orientation issues with the pedals. It should eliminate UA incidents completely.

Additional benefits

- No identified additional benefits.

Critique

- Left foot braking is a skill which would need to be learned by drivers which is likely to cost money and take time
- Driving standards and safety may be reduced during initial introduction
- If pedals are moved, significant design changes to the cab may be required. Retro-fit may not be possible
- Drivers may struggle to switch between left-foot braking and normal braking when driving a personal car or a bus which isn't suitable for left foot braking.

Barriers

- Plan for integration including providing training/practice and consideration of using mixing new (left foot braking) design with buses operated in the standard manner.
- Likely to meet resistance from bus drivers. Will be hard to monitor and enforce if drivers prefer to use normal driving style
- Would require some co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.2.6 While this solution directly addresses and is likely to resolve the pedal confusion and unintended acceleration issue. It will be costly from a design, training and implementation perspective and is also likely to present additional driving standard/safety issues, especially during initial use.

6.2.7 **Not suitable for further investigation** 

Redesign Throttle so that Drivers Must Accelerate Using Hand Controls

Rationale

6.2.8 Introducing a hand control for acceleration would remove the pedal confusion issue, ensuring no drivers mistakenly push the accelerator pedal rather than the brake.

Additional benefits

- No identified additional benefits.

Critique

- Driver's already have a lot of controls to manage with their hands, introduction of a hand controlled accelerator will remove one hand from use when driving
- Driving using a hand control will need to be learned by drivers which is likely to cost money
- Driving standards and safety likely to be reduced during initial introduction
- Significant design change to cab layout will mean retro-fit is unlikely to be possible
- Drivers may struggle to switch between hand-operated throttle and normal driving when driving a personal car or a bus which isn't set up for hand-operated throttle.

Barriers

- A plan for integration will be required including provision of training/practice and consideration of how to deal with buses still operated in the standard manner (at least initially)
- Cost-benefit is unlikely to add up
- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.2.9 While this solution directly addresses and is likely to resolve the pedal confusion and unintended acceleration issue, it will be costly from a design, training and implementation perspective and is also likely to present additional driving standard/safety issues especially during initial use.

6.2.10 **Not suitable for further investigation** 

6.3 Ensure Cab Layout is Aligned to Mental Model

Standardisation of Pedal Layout

Rationale

6.3.1 There are a variety of pedal configurations due to the different makes and models of buses used to support London Bus services. Because they are not directly in his or her line of vision, a driver must depend on physical feedback and his mental model (experience and expectations) of pedal position, height, angle and operation (floor attached or suspended) before setting off. A driver could potentially need to change buses up to 5 times a day and will be required to adjust to each buses differing pedal layout.

6.3.2 UA incidents often occur in situations of high workload and stress, in these instances drivers may fail to accurately update their mental model of pedal layout for the specific bus in use. Standardisation of pedals would help to reduce the risk of unintended acceleration due to incorrectly applied mental models of pedal layout and operation and/or high workload.

Figure 9 – Different pedal layouts found in London buses

Additional Benefits

- Likely to result in quicker adjustment when switching between different types of bus
- No additional training or adjustment to driver behaviour needed.

Critique

- Would be expensive to retro-fit so may only be applicable to new build buses
- Change in pedal arrangement may impact existing designs and require costly re-design for some companies.

Barriers

- Would require consensus to be reached by industry, this may be difficult even after a study to identify optimum pedal arrangement and method of operation has been performed
- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement.

Summary

6.3.3 Despite the solution having a long lead time it is considered to provide a long-term benefit once implemented. Possible alterations to the current pedal layouts that may optimise the standardised layout are discussed in section 6.1.

6.3.4 **Suitable for further investigation** ✓

6.4 Ensure Drivers are Suitably Settled and Prepared before Setting Off

Engine Cut-Out when Driver Door is Opened

Rationale

6.4.1 During “hot handovers” where the drivers must change with passengers already on-board, drivers feel pressurised to begin the service quickly and so do not always take time to set up their seat/driver area correctly. They may also neglect to fully orientate their feet to the pedals by depressing them fully and testing reach. This occurs especially when the exiting driver leaves the engine on and the bus in-gear (ostensibly to accelerate the change-over process) as the incoming driver may not want to test both the pedals while the bus is running and in gear.

6.4.2 If there was a way to reset the bus when a driver leaves the cab, such as having the engine cut-out, this may encourage drivers to conduct a proper seat and workstation set up during handover.

Additional Benefits

- May be relatively cheap to retrofit
- Does not require significant change to workstation design
- May address other non-UA incidents relating to door interlock preventing bus from moving but not cutting out engine.
- In general, improved workstation set-up and working posture is likely to reduce musculo-skeletal complaints among drivers and associated absence.

Critique

- In isolation, this step may not address all UA incidents
- Potentially slower changeover may have to be accounted for in timetabling
- Engine cut-off may have the opposite effect to what is intended and make the operator feel more rushed and allocate less time to workstation set-up (although at least the bus would not allow the driver to start in-gear).

Barriers

- Must be accounted for in timetabling
- Drivers will always feel under pressure from passengers to changeover quickly especially if already late, measures will be required to reduce this
- May impact maintenance activities, although override function for maintainers could be integrated.

Summary

6.4.3 This option was well received by the SMEs and acts as a prompt to correct driver area set-up, therefore promoting the correct response. However, it is dependent on the driver feeling they have enough time to set up their area correctly. This measure will only prevent some UA incidents.

6.4.4 There were concerns that it would impede the engineers when making adjustments to the vehicles.

6.4.5 **Suitable for further investigation** 

Improvement of Seat Adjustment Controls

Rationale

6.4.6 As with the previous solution, this relates to UA incidents caused by high workload and poor pedal orientation following a “hot handover”.

6.4.7 General improvement and standardisation of seat adjustment controls to ease and or speed up the workstation set-up process will encourage correct workstation set-up, particularly in handover situations. Solutions could range from simplification of controls, to fully automated programmable seat positions.

Additional benefits

- No additional systems, procedures or practices required
- Changes to seat only would be relatively simple and cheap to retro-fit
- In general, improved workstation set-up and working posture is likely to reduce musculo-skeletal complaints among drivers and associated absence.

Critique

- Alone may not address all UA causes.

Barriers

- Cooperation from the seat manufacturing industry
- Only effective if drivers are willing to set-up their seats

Summary

6.4.8 Improvement of seat adjustability is a general benefit and failure to set-up workstations correctly is considered by SMEs to be a contributing factor to UA incidents.

6.4.9 **Suitable for further investigation** 

6.5 Increase Ability of Drivers to Recognise UA Event is Occurring

Provide UA Specific Training to Drivers

Rationale

6.5.1 UA specific training for all drivers will make the issue much more explicit and drivers will have learnt to recognise and react to an UA incident which should enable them to recover more reliably.

6.5.2 General improvements to training and more frequent refresher training may also make drivers generally more competent and able to avoid or deal with UAs. Training may also be used to improve adherence to workstation set-up requirements which may be related to UA incidents.

Additional benefits

- Does not require design/build/retro-fit activities
- Could generally improve driving standards and driver behaviour in other areas.

Critique

- Success is dependent on quality of training and motivation of recipient
- UA is not categorically linked to quality or experience of driver and some incidents are likely to occur regardless.

Barriers

- It must be ensured that trainers are at the required standard to give the improved training, training of trainers may be required
- Drivers must be suitably motivated to take new/improved training on board.

Summary

6.5.3 Generic overhaul of training is not seen as directly beneficial to preventing or reducing UA incidents. However, directly addressing UA as an issue and identifying ways to recognise, prevent and recover from them would be a useful addition to current training programmes.

6.5.4 **Suitable for further investigation** 

6.6 Support Drivers in Achieving Recognition of a UA Incident

Audible and/or Visual Indication of Accelerator Status

Rationale

6.6.1 When pedal confusion occurs drivers may not receive sufficient feedback to inform them that they have made an error that requires correction as opposed to the bus being faulty.

6.6.2 An audible or visual indication upon activation of the accelerator would indicate to the driver that the accelerator, rather than the brake, was being pressed. This could aid decision making and allow a quicker recovery from the UA incident.

6.6.3 One of the keys to this is that the indication should be linked to the physical accelerator pedal itself rather than the acceleration of the vehicle. This would indicate that any acceleration is due to activation of the pedal, not through a fault.

6.6.4 The solution could involve an indication whenever the accelerator is operated or only when the accelerator is fully depressed (relatively rare under normal driving). A time delay of a few seconds may prevent false alarm indications from being displayed/sounded too frequently (the exact time of the delay will need to be determined).

Figure 10 – Example of Visual Indicator in Driver Area

Additional Benefits

- No additional procedures or practices required
- Provides indication of accelerator deployment / potential UA event
- Retro-fit may be relatively inexpensive.

Critique

- Additional alarm increases driver workload/distraction
- Habituation to noise/light may mean driver is does not notice it when required
- Indication may not be perceived or understood when panicking
- Drivers often perceive UA as mechanical failure and may assume this to be the case here (believe that indication has failed also)
- Low speed UA incidents may lead to an impact within a few seconds, indication of this sort is not likely to prevent this type of incident.

Barriers

- Requires integration with current alarms/indications, particularly RIBAS (or similar), which provide indication relating to rate of acceleration as an environmental measure
- Some co-ordination with manufacturing and industry legislation to ensure design is implemented correctly into newly designed vehicles.

Summary

6.6.5 This solution was unpopular with the SMEs who feared that it would be irritating during normal driving and ignored during emergency situations. For the audio alarm a speech module was preferred over other sounds – this could feature a clear worded message, e.g. "Remove your foot from the accelerator".

6.6.6 From a psychological perspective, it is scientifically proven that people become habituated to visual and audible stimuli; habituation is a decrease in response to a stimulus after repeated presentations. In a panic situation, people's ability to reason rationally is reduced and they are less likely to be able to detect and correctly interpret an audible or visual indication. This would reduce the value of an indication.

6.6.7 A delayed indication will be less obtrusive in normal use, but it will allow significant acceleration prior to the indication and will therefore only address the more severe UA incidents where drivers continue to accelerate over a distance.

6.6.8 **Not suitable for further investigation**

Integrated Tactile Indication of Accelerator Operation

Rationale

6.6.9 When pedal confusion occurs drivers do not receive sufficient feedback to inform them that they have made an error that requires correction as opposed to the bus being faulty.

6.6.10 In this solution, when the accelerator is pressed down a certain amount, an integrated protrusion from beneath the pedal passes through a cut-out section of the accelerator pedal and can be felt by the driver. This could prevent constant 'slamming' of the accelerator when it is assumed to be the brake.

Figure 11 – Tactile protrusion giving feedback to driver's foot when fully accelerating

Additional Benefits

- No additional procedures or practices required
- Retro-fit may be relatively inexpensive (although it could be complex)
- No electrical or mechanical element which can be assumed to have failed
- May improve fuel economy by reducing use of the accelerator.

Critique

- Many minor UA incidents become crashes as the bus immediately accelerates only travelling a few metres; this solution is not likely to prevent this type of incident.
- If drivers are wearing thick soled shoes such as boots, they may not feel the tactile protrusion.

Barriers

- Would require study to ensure arrangement would work with a variety of different pedal designs, foot-sizes and positions
- Would require co-ordination with the manufacturing industry

- Would require agreement from appropriate legislative body and TfL to ensure enforcement and uniformity
- Footwear may need to be standardised to ensure protrusion can be felt through the driver's sole.

Summary

6.6.11 This design removes alarm issues and electrical/mechanical connections but still allows significant acceleration prior to the indication and will therefore only address the more severe UA incidents where drivers continue to accelerate over a distance.

6.6.12 **Suitable for further investigation as part of overall pedal arrangement review**

6.7 Support Drivers in Responding to an UA Incident

Hand operated Emergency Stop Button

Rationale

6.7.1 In a situation where there is confusion between the believed and actual foot position an alternative hand control that overrides the foot controls (e.g. emergency stop push button) could avert an incident. A fist/palm operated emergency push button that automatically applies brakes when activated would provide an alternative action when the driver believes the brakes have failed.

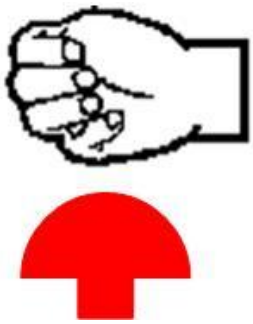

Figure 12 – Example of hand operated emergency stop 'Mushroom Button'

Additional benefits

- Solution presents no change to general driving task, handover, workstation set-up etc.

Critique

- Many minor UA incidents become crashes as the bus immediately accelerates only travelling a few metres; this solution is not likely to prevent this type of incident.
- Drivers may not have time to deploy, or think to use it
- Concerns over sudden braking and potential injury to passengers
- Accidental or intentional activation (i.e. sudden braking) could have dangerous consequences for passengers.

Barriers

- Requires additional training on emergency driving behaviour
- Requires integration with current workstation layouts and braking systems

- Would require co-ordination with the manufacturing industry
- Would require agreement from appropriate legislative body and TfL to ensure enforcement and uniformity.

Summary

6.7.2 This design provides an alternative response for drivers who believe that the brakes have failed during a UA incident, as long as drivers think to use it. The lack of certainty that it will be used when needed, and the potential consequences of misuse suggest that the negatives may outweigh the potential benefits.

6.7.3 **Not suitable for further investigation** 

6.8 Reduce Severity of UA Incident

Intervention when accelerator 'floored'

Rationale

6.8.1 Under normal driving, there is no real need for drivers to floor the accelerator for a lengthy period of time. Some drivers in the workshops said that one should never floor the accelerator although others said that when pulling away from roundabouts or going up a steep slope it may be necessary, depending on the power of the bus. During an UA incident drivers floor the accelerator as if it were a brake.

6.8.2 An automatic accelerator isolation that shifts the bus into neutral when the accelerator had been fully depressed for a period of time would prevent further unintended acceleration, reduce the momentum of the bus and the likelihood of serious damage. This removes some of the need for user-initiated recovery described in other solutions.

6.8.3 Accelerator cut-out as opposed to automatic brake application was preferred by SMEs due to concerns over harsh braking and injury to passengers upon spurious activation.

Additional benefits

- Automatic response to unintended acceleration
- May be retrofitted fairly easily to "fly-by-wire" buses
- Adds no additional design element to the cab.

Critique

- Many minor UA incidents become crashes as the bus immediately accelerates only travelling a few metres; this solution may not prevent this type of incident
- Would depend on bus having sufficient power when not fully depressed (to avoid spurious activation)
- May only work on modern "fly-by-wire" buses
- Requires amendment to normal driving behaviour and may result in engine cut-out when not necessary
- Timing-based cut-out may not work if drivers pump the "brake" during an incident
- This kind of intervention would not prevent collisions from occurring, even at low speed a UA incident could have serious consequences.

Barriers

- Would require agreement from appropriate legislative body and TfL to ensure enforcement and uniformity
- Would require integration with manufacturing industry to ensure required levels of acceleration without 'flooring' the accelerator
- Requires integration with current systems.

Summary

6.8.4 Whilst this solution proved popular with some SMEs it could create problems for drivers and maintenance staff. It may affect the drivers in their day-to-day routes by causing "unintended power failure" at a critical point e.g. accelerating to get up a hill or out at a roundabout. This solution may generate more work for the maintenance crew who would have to ensure that the bus had sufficient power to be able to operate without the need for full deployment of the accelerator which could be an issue for older buses.

6.8.5 **Not suitable for further investigation** 

Limit rate of Acceleration

Rationale

6.8.6 Limiting the rate of acceleration would, in UA incidents, reduce the bus speed at point of impact. This would also provide greater time to recover from the incident and may reduce subsequent damage/injury.

Additional benefits

- Automatic response to unintended acceleration
- May be retrofitted fairly easily to "fly-by-wire" buses
- Adds no additional design element to the cab.
- May encourage smoother acceleration and less harsh braking (better fuel economy).

Critique

- Does not directly resolve or provide indication of UA
- Drivers may encounter situations where a better rate of acceleration is required but is not available – this could be dangerous.
- Would not address all UA incidents
- Requires amendment to normal driving behaviour
- Would depend on bus having sufficient power to perform manoeuvres at lower rates of acceleration
- This kind of intervention would not prevent collisions from occurring, even at low speed a UA incident could have serious consequences.

Barriers

- Would require agreement from appropriate legislative body and TfL to ensure enforcement and uniformity
- Requires integration with current system
- Agreement from industry on rate of acceleration deemed excessive/indicative of UA.

Summary

6.8.7 Solution may help reduce impact of UA incidents and allow more time for recovery in some cases but the potential benefits are not great enough to account for the negative aspects that it could introduce.

6.8.8 **Not suitable for further investigation** 

7. CONCLUSION & NEXT STEPS

7.1 Overview

7.1.1 Human Engineering has conducted a study to identify potential solutions for addressing unintended acceleration caused by pedal confusion amongst drivers of London buses. The process of reviewing past literature, interviewing drivers and running SME workshops identified a number of solutions in an iterative manner.

7.1.2 Ultimately, Human Engineering has identified solutions which are deemed suitable for further investigation by TfL having conducted a final review of each solution against the criteria identified in section 5.

7.2 Overall Findings

7.2.1 As Table 4 shows, eight solutions were selected for further investigation. These are shown in green and amber (where there are still some reservations). Solutions shown in red were not thought suitable for further investigation.

Table 4 – Final Solution Status

Cause	Goal	Solutions
Poor proprioception	Increase awareness of foot location	Changing the size of pedals
		Increasing the distance between pedals
		Change pivot point of pedal
		Use different pedal types for brake and accelerator (suspended vs. organ pedal)
	Make it more difficult to place foot in wrong place	Installation of a barrier between pedals
		Bus drivers to use left-foot braking
		Redesign throttle so drivers must accelerate using hand controls
High workload while driving	Ensure cab layout is aligned to mental model	Standardisation of pedal layout
	Ensure drivers are suitably settled and prepared before setting off	Have engine cut-out when driver door is opened (i.e. during hand-over)
		Improvement of seat adjustment controls
Unable to recover from error	Increase ability of drivers to recognise UA event is occurring	Provide training on UA
	Support drivers in achieving recognition of a UA incident	Provide audible indication of accelerator status
		Provide visual indication of accelerator status
		Provide integrated tactile indication of accelerator operation[4]
	Support drivers in responding to an UA incident	Provide hand-operated emergency stop pushbutton
Severity of consequences (collision)	Reduce severity of UA incident	Automatically cut-off engine/accelerator under certain circumstances
		Limit rate of acceleration (or time-out)

[4] May also help with poor proprioception.

7.2.2 In general, preferred solutions were those which directly addressed the cause of pedal confusion without causing significant deviation from current practices. This included pedal design and arrangement, and subsequent standardisation of a preferred design. Also preferred were the methods for facilitating and encouraging correct workstation layout.

7.2.3 Rejected solutions tended to be those which caused significant alteration to driver practices, such as left-foot braking, or those which were perhaps to the detriment of normal driving activities.

7.3 Suitable solutions and further work required

Pedal design modifications

7.3.1 The following five solutions can be grouped into a single “pedal design” solution.

- Standardisation of Pedal Layout
- Changing the Size of Pedals
- Increasing the Distance between Pedals
- Providing Differentiation in Accelerator and Brake Operation
- Integrated Tactile Indication of Accelerator Operation.

7.3.2 A suggested approach is outlined below:

Fitting trials

7.3.3 Fitting trials using a selection of mock-ups to investigate how the various set-up options might work in practice would be performed. Fitting trials with a selection of bus drivers and other stakeholders would enable an initial judgement to be made on which solutions are worth progressing further and to generate some specific information regarding design preferences and how they might be designed.

Proof of concept

7.3.4 A basic proof of concept trial using a driving simulator will be required to support the theory that change of this nature will indeed aid pedal identification and reduce incidents of unintended acceleration.

Establishment of working group

7.3.5 The next step would be for TfL to initiate and head a working group for “Pedal optimisation and standardisation”. This would include key stakeholders such as TfL, bus operators, unions, human factors specialists, vehicle and equipment manufacturers driver/trainers and engineers.

7.3.6 The group would discuss the initial ideas and seek to agree on a way forward. The ultimate aim would be to get working prototypes built for more detailed user trials to be performed.

In depth trials and selection

7.3.7 Finally, some in depth user trials would be required to agree the specifics of the prototype and to develop the concepts further. Further meetings of the working group would refine the designs and make a final decision regarding how to take forward the ideas and implement them.

Engine Cut-Out when Driver Door is Opened

7.3.8 This requires little further design input, other than ensuring the manufacturers can implement it. Technical discussions will need to be held and trials run with real buses to ensure that the technology is effective and does not have any unintended consequences.

7.3.9 As discussed, this solution requires significant organisational input to endorse the time taken to arrange the workstation, including allowances in timetabling, means of indicating the delay (and the fact it is allowed for) to passengers and making a specific link between workstation set up and UA incidents in training.

7.3.10 TfL and bus operating companies must consider whether these measures can be introduced to support the design change. This would also be supported by improvements to seat adjustment controls.

Improvement of Seat Adjustment Controls

7.3.11 As with pedal arrangement, it would be beneficial to standardise seat adjustment controls. In order to identify a suitable design arrangement a design working group will be required to be set-up to develop the designs with input from manufacturers, human factors, unions and legislative bodies.

7.3.12 Prototyping and trialling of preferred solutions will be required to refine designs. Any preferred design would need to be subject to a process like the one described for pedals. Although this solution should reduce time required for workstation set-up, organisational elements described in section 7.3.9 must also be considered to get the most from any design change.

Training (UA Specific)

7.3.13 In order to introduce UA specific training, agreement will need to be reached on the key points associated with UA so that useful training material can be written. This will require the establishment of an expert panel to include incident investigators, highly experienced driver/trainers, human factors experts and TfL representatives. A ‘train the trainer’ process would then be rolled out to filter down the training to the drivers.

7.3.14 Commitment from operating companies and unions will be needed to ensure that the training will be fully adopted and endorsed.

7.4 Conclusion

7.4.1 The aim of this investigation was to determine the true extent to which pedal confusion is an issue, identify potential solutions or mitigations to the problem, conduct an initial analysis of the solutions from a human factors perspective and select some of the most promising solutions for trials.

7.4.2 Human Engineering were unable to identify the full extent of the issue as incident data did not specify pedal confusion or unintended acceleration as a cause, nor were detailed incident reports available for review.

7.4.3 Through a review of the cognitive driving process, interviewing drivers and conducting workshops with relevant stakeholders, a series of potential solutions were identified and reviewed in an iterative process.

7.4.4 This document presents a final review of the solutions against the identified criteria, identifying the most promising solutions which can be taken forward for trial. Overview of the future task required to develop and implement designs has also been provided.

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APPENDIX A:
SEMI-STRUCTURED INTERVIEW QUESTIONS

Script for Semi-structured Interviews (Driver)

Hello

My name is XXXXX and I'm a usability and ergonomics specialist. Ergonomics looks at how we can design things so that they best suit the capabilities of human beings. We are interested in making things easier and safer to use.

We've been asked by TfL to find out about unintended acceleration incidents. Do you understand what we mean by this?

Basically we are interested in those occasions where drivers have reported experiencing a sudden power surge or uncontrollable acceleration. In these circumstances people often report that they are pressing the brake pedals but they don't work. Experience shows that in reality these incidents are due to pedal confusion. Our project is about exploring the ways in which we can reduce or prevent these incidents from occurring. That is why we are going to a number of bus depots to speak to experienced drivers and get their views on this issue.
Does that make sense to you?

So I'd like to start by asking you a few questions. I'll be taking notes so please bear with me as I write your answers. All the information you tell me will be confidential, I won't record your name together with your answers. I won't be reporting what you say to your boss. So please be as open and honest as possible. I'll need about 20 minutes of your time.

1. What is your experience of unintended acceleration incidents? (has it happened to you, your colleagues/friends)?
2. How frequently do you think they occur?
3. What's the typical impact of these incidents?
4. How do people usually recover from these incidents?
5. Why do you suppose the incidents occur?
6. Can you think of any ways to prevent them from occurring?
    a. Any technical/engineering solutions? Physical or electronic?
    b. Any training/procedural solutions?
    c. Do you think some people more prone to this error than others? Any ideas why?
7. Do you have anything else to say about this issue?

Thanks for your time!

If you are interested in this topic, would you like to participate in further activities?

If YES, record on separate page:

Company:
Name:
Contact information:

If you think of anything else to say please feel free to contact me by email:

Script for Semi-structured Interviews (Engineer)

Hello

My name is XXXXX and I'm a usability and ergonomics specialist. Ergonomics looks at how we can design things so that they best suit the capabilities of human beings. We are interested in making things easier and safer to use.

We've been asked by TfL to find out about unintended acceleration incidents. Do you understand what we mean by this?

Basically we are interested in those occasions where drivers have reported experiencing a sudden power surge or uncontrollable acceleration. In these circumstances people often report that they are pressing the brake pedals but they don't work. Experience shows that in reality these incidents are due to pedal confusion. Our project is about exploring the ways in which we can reduce or prevent these incidents from occurring. That is why we are going to a number of bus depots to speak to experienced drivers and get their views on this issue.
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1. What is your experience of unintended acceleration incidents? (has it happened to you, your colleagues/friends)?
2. How frequently do you think they occur?
3. What's the typical impact of these incidents?
4. How do people usually recover from these incidents?
5. Why do you suppose the incidents occur?
6. Can you think of any ways to prevent them from occurring?
    a. Any technical/engineering solutions? Physical or electronic?
    b. Any training/procedural solutions?
    c. Do you think some people more prone to this error than others? Any ideas why?
7. Do you have anything else to say about this issue?

Thanks for your time!

If you are interested in this topic, would you like to participate in further activities?

If YES, record on separate page:

Company:
Name:
Contact information:

If you think of anything else to say please feel free to contact me by email:

APPENDIX B:
INTERVIEW FEEDBACK

Table 5 – Notes from Semi-Structured Interviews with Bus Drivers (Excluding Question 6)

No.	Q1 What is your exp of UA?	Q2. Est. freq?	Q3. Typical Impact?	Q4. How do people recover?	Q5. Reason for UA?	Q7. Some people more prone?	Q8. Further insight
1	n/a Engineer not Driver	6 per year	Driver suspension		Driver error		It may be worth looking at the number of instances of pedal confusion reported if/when the acceleration control is implemented
2	Not heard of it happening	n/a	n/a	n/a	Driver error		
3	It is down to driver error; you do hear of it but hasn't happened to him.	1 or 2 per year	In 3yrs experience has only heard of 2 crashes	If have low enough speed then will have enough time to process error	Speed and inexperience (believes some of it is iBus controllers setting unrealistic demands)	Older drivers have slower reactions but younger drivers don't have the necessary experience	Handbrake must be on for back door to open
4	Never happened to him but has heard of it		In 3yrs experience has only heard of 3-4 crashes	Doesn't normally lead to an incident. It is dependent on mental state (panic) and time available to react	When people get distracted or have too much information to process. Buses take a long time to brake so initially could not notice speed increase?	Can happen to anyone but experienced drivers have better judgement	25-30% Drive Hybrid (with start-stop pedals) but don't like it
5-6	New girl went through the front of McDonalds on 3rd day of driving		Results in an accident	If have low enough speed then will have enough time to process error	Think it is due to distraction where you switch off and then panic		
7-8	Can get foot slip but doesn't believe people confuse the pedals	n/a	n/a	n/a	People panic People change buses a lot		Braking is proportional to the gear you're in so very difficult to emergency brake.
9-11	Down to human error, when people do not follow good driving techniques (should only have the foot in 3 positions: ACC, BRK, covering BRK) NB Surges could be confusion of spring breaks	A lot but have no idea of how much as it is not reported	Doesn't result in an accident	If have slow enough speed or enough time for thought process	People are not paying attention. Probably stems from position of foot; if take foot completely off pedal then have to put it back and it may be in the wrong place	Can happen to anyone whose mind is somewhere else.	Bendy buses have less braking power so could look at regularity of incidents. Does it occur on coaches where they have the same layout as car pedals?
12-13	Never happened to either on bus	Once a month	Doesn't result in an accident	Depends on situation but probably how concentrated your mind is, e.g. over familiar with route or roads quiet	Buses don't accelerate quickly enough so don't notice change in velocity! People not concentrating or bored	When fatigued or if don't set seat properly	Some buses pedals are very different and have different rates of acceleration etc. Need to get used to it each time you change buses
14	Never heard of it/done it	Once a week	Doesn't know as have no internal communications to provide data on accidents	Depends on speed and reaction time in relation to distance	People drive too close and too fast	When get into a new vehicle - variation is a problem	Pedals should be like Scania.
15	Get pedal surge when retarder doesn't work properly - power surges DO occur - has had 50 of them	n/a	Most are recovered	Experienced drivers will recover	People going too fast and inexperienced drivers	Young drivers as have too little experience	
16	Don't hear of it because drivers go to office with incidents, the culture is that you don't talk about accidents in the cafeteria and nobody from the office informs you either	n/a	n/a	Drivers need to be more observant of the traffic in front and give themselves space to react	Fatigue, footwear, people driving too close. Some people cannot adjust the seat properly and (esp. amongst foreign drivers) are too timid to refuse to drive the bus	n/a	Have heard people blame the brakes but never get to hear the results of the investigation
17	Hasn't experienced it but have had feeling of power surge when kicked the throttle but knew to knock it back into neutral (not something taught during training)	n/a	Can lead to an accident with a less experienced driver	People normally recover	Distraction, turn around and the driver's foot moves without realising it. Too much repetition and become complacent		Only answer is to put into neutral. Drive 5 different types of buses at this depot, all have a very simple pedal layout

No.	Q1 What is your exp of UA?	Q2. Est. freq?	Q3. Typical Impact?	Q4. How do people recover?	Q5. Reason for UA?	Q7. Some people more prone?	Q8. Further insight
18	Not heard of it and hasn't experienced it	n/a	n/a	n/a	Driver error - if driving erratically will panic if something different happens		People are just using brake failure as an excuse for them mucking up
19	Has happened once in 7 yrs	?	Most people recover especially if it has happened to them before as then they are aware of it	Realise in time and have nothing in front	When people are distracted or have a lot on their mind	Can happen to anyone	
20-21	Not heard of it and has experienced it only when retarder isn't working properly - can feel like it	n/a	Think people recover	If people realise quickly enough	Switch off for a second	Could be down to character, could just be unlucky	People are just using brake failure as an excuse for them mucking up
22-23	Not happened in 32 yrs but agree it could happen	n/a	n/a	n/a	if people aren't paying attention	People who don't pay attention	Training isn't good enough for new drivers and people are thrown in at the deep end
24	Not happened to her but heard of "brake failure incident" amount of damage incurred after the accident meant he must have been accelerating	n/a	Dependent on experience of the driver	Don't panic	When panic and inexperience are combined		
25	Happened twice in 20 years, first time took 2-3 seconds to realise but second time was much quicker - initially thought there were physical problems with him	Twice in 20 years	If lucky can catch it in time	Quick reaction times	Panic reaction, don't have the correct feedback, repetitive actions and go into auto pilot, lack of concentration	Can happen to anyone, however not in a manual car	
26	None as a driver but he finished driving before vehicle design changed to have brake and accelerator pedals very similar size look and feel.	Has had approximately 6 reported in 20 years as a depot manager. More probably go unreported.	Minor crashes - he has only known of these incidents to occur in the depot or bus stand.	Unknown - the only ones he knows about have not recovered.	Theory that lack of differentiation between the pedals causes confusion. Also he thinks it might happen more when a driver gets in a bus with the engine running - normally drivers will go through a seat adjustment routine which will include pressing pedals to confirm they are in a suitable position. If the engine is running they won't do this and may be liable to confuse the foot position in relation to pedals. Modern airbrake systems make brakes and accelerators feel the same.	No. In his experience a mix of male, female, old and young.	Happy to be invited to workshop.
27-28	Heard of one of in 1998. Happened to one of the drivers once.	Very rare but acknowledges that it can happen	n/a	Stay calm	Panic - when reacting you are already on the accelerator and react too quickly and are not in the correct position. When you're learning. When you're under time pressure. The job is repetitive and some don't pay attention to the road. Same routes everyday and regular drivers may relax too much. Technology is helping you too much (allows attention to wander).	Some people act faster to recover	Have to be considerate of the passengers as well, not just the driver performance.

No.	Q1 What is your exp of UA?	Q2. Est. freq?	Q3. Typical Impact?	Q4. How do people recover?	Q5. Reason for UA?	Q7. Some people more prone?	Q8. Further insight
29	n/a	n/a	50:50 whether accident or not	Person reacts in time or not	Some people react more slowly	No, it's just a mistake and all people are liable to mistakes	n/a
30	Never experienced it but heard about it when it has lead to an accident	Not often	Don't know	Hasn't happened to him so doesn't know	Not concentrating, under time pressure	n/a	n/a
31	Never experienced it but heard about it when it has lead to an accident	Not often	Normally recover	Experience	Could be anything, really depends on the day	More experienced people could be overconfident and that could lead to mistakes	Mistakes just happen and can't do anything about it. A driver had a UA because he saw another accident and was looking at the ambulance
32	Heard of it happening , probably happened a handful of times but forget, perhaps when put on both pedals but slightly more on accelerator	n/a	Normally recover	Have time to reason	Put foot between pedals	Don't know	n/a
33	Never happened to him but have read in newspapers that it happens	n/a	Don't know	Sharp reflexes	Foot slipped or genuine mistake	People who can't adapt quickly enough (to buses and situation)	Has stepped on both pedals in the car
34	Never happened to him as he is a very careful driver and doesn't rush. Doesn't ever ask about cause when hear of someone in an accident	n/a	Don't know	Should realise but if in a hurry may not	If a person drives too fast, some people always use the maximum acceleration	People who drive too quickly	Need sticky/rubber grips on shoes
35	Never experienced it but heard about it when it has lead to an accident	Rarely	Have only heard of it when it turns into an accident	Have enough space between bus and hazard - this gives you time to react	Have to react quickly but for whatever reason don't get it right Not about acceleration rate but about velocity of the bus	n/a	Have 3 main vehicles here, Alexander Dennis, Trident and Environ
36	n/a	n/a	n/a	n/a	Loss of concentration	Never hears about it so don't know	Bus drivers must be considerate of passengers
37	Never happened to him. Believes it is due to driver error	Not often	People should realise because should feel different	n/a	Driver isn't concentrating or is distracted by something	Inexperienced people	n/a
38 - 39	People don't talk about faults with their own driving – only hear if have an incident. It may have happened but probably forgotten	More than you get to hear about	Probably just correct the fault & don't register it so it isn't known as a problem	Realisation time is dependent on Many things (fatigue, wiggle room, av. reaction rate vs. experience)	Over familiarity with the driving task; it is repetitive so people have low levels of attention. Also affects rates of reaction and the point at which you notice you are coming into a problem – don't notice it until late	Dependent on circumstances	n/a
40 - 41	After an incident will fill out vehicle incident report, request CCTV and have a fact finding interview – this data is entered into IRIS. Drivers are unwilling to admit errors. Had a 10 car incident at the depot in June	n/a	n/a	n/a	Delayed reactions, people react in panic and choose the wrong action – perhaps it's a lapse in concentration	If driver has UA incident it is likely that they will be dismissed so have got very little history on them	Drivers have a 1:1 appraisal every year. Research findings are fed back via route/union rep and put on notice board. For frequent errors they put a memo into the wages that have to sign for

Table 6 – Notes from Semi-Structured Interviews with Bus Drivers (Question 6 Only)

No.	Vertical panel between accelerator and brake	Standardise pedals	Reduce acceleration of bus	Provide better feedback from pedal depression	Accelerate/brake with hand	Alarm/cut out if accelerator is floored	Emergency Stop button	Better initial driver training	Refresher training	Better familiarisation procedures	Other comments
1*	*Participant 1 did not comment on individual solutions; prompts for these solutions were subsequently included in bus driver interviews.										
2	Would be OK	Doesn't believe there is much of a difference currently	Wouldn't work because need full acceleration when fully loaded	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	Thinks it would be awkward	Would be good - use Scalia (smaller pedals) as guide	Need acceleration for good performance on route	Already have got enough feedback	Wouldn't be practical	n/a	n/a	Is already OK	Is already OK	Is already OK	n/a
4	Good idea	Would be good idea	Need acceleration for good performance on route	There is different feedback/ resistance from different buses	Would be uncomfortable to use	OK	Would be OK	Is already OK	Good idea	Good idea - only get used to new bus after first 3-4 stops	25-30% of time drive Hybrid buses which have stop-start accelerator
5-6	Wouldn't work	Brake pedals are fairly standard and don't present a problem as they are	There is a lot of variety in the buses that they drive & some already have poor acceleration due to age	n/a	Not good idea	This would not help as there are too many alarm as it is, there is a bell every time someone calls, bell for disabled etc	The driver probably wouldn't have time to think/reason to use that	Is already OK	Is already OK	It feels different but still fairly similar/simple	n/a
7-8	Wouldn't work with variety of foot positions, e.g. having the heel central	Standardisation of pedals and pedal response would be good - normally have to adapt at the start of route as each bus is different	Would cause problems on roundabouts - would be unable to accelerate into gaps	Brake pedal should be angled so that it is easier to hit and not slip off onto accelerator. Should be conscious decision to hit accelerator. Bigger brake than accelerator	Already have too many hand requirements	Extra alarms would be irritating and fatiguing	A cut-out wouldn't work because you need power for steering. Also if just put into neutral would freefall down hills	Good idea	Good idea	Typical journeys are 4hrs and it can take that long to adjust to a bus layout	Could make an area for foot to operate that was similar to guide idea but would just be like a box. Could teach drivers to use toe and heel procedure as in rally driving. Adjustable pedals? Use heel guide? Have smooth point as pivot aid?
9-11	Would be OK but would have to be trained to use it	Good idea, need to stay similar to layout of car - perhaps have pedals with height difference	Need full acceleration to get out of dangerous situations	Differentiation is good idea - could be size, further apart (but would increase thinking /reaction time) heel pivot, height would be OK. Newer buses have shorter brake	n/a	Don't need much acceleration to still have a UA and a problem! People would still disregard alarm in panic (trainees have tunnel vision)	Too many alarms already - wouldn't think to use it	n/a	Posters could also provide refresher training	n/a	Also require standardisation of response amongst different fleet vehicles. Stop go system wouldn't affect this issue? Some buses have such powerful tick over that drivers get used to using that
12-13	Wouldn't work	Would be good	n/a	Could make the acc. higher and brake lower, make them further apart & diff. shapes	n/a	n/a	n/a	n/a	Already have mystery shoppers - if know then makes nervous	Can take up to an hour to familiarise yourself to a new bus	n/a

No.	Vertical panel between accelerator and brake	Standardise pedals	Reduce acceleration of bus	Provide better feedback from pedal depression	Accelerate/brake with hand	Alarm/cut out if accelerator is floored	Emergency Stop button	Better initial driver training	Refresher training	Better familiarisation procedures	Other comments
14	Could press instead of brake, besides already have steering column for guidance	Would help problem	Need acceleration for good performance on route	Good idea, further apart but bigger please! Diff size shape same level, resistance is OK	Already have too many hand requirements - plus not allowed to drive with one hand!	Annoying if ringing all the time - already have too many alarms	Could work but difficult to factor in	Wouldn't help this problem	Wouldn't help this problem	Perhaps training could introduce a check to get familiar with new buses at the start of a trip. Is difficult to familiarise as all so different	n/a
15	Wouldn't work	Could help, plus have heel rest to guide placement of heel/foot	Need acceleration for good performance on route	Different size and height would be good	Not good	Some already have electronic alarm for when going too fast - have too many alarms already	Could be dangerous if truly an emergency stop - could injure passengers. If stop power then will lose steering.	Wouldn't help this problem	Wouldn't help this problem	Not a problem - just down to level of experience.	n/a
16	The vertical panel wouldn't work; it would get in the way	Would be good to standardise, some have different pivot points too	Need acceleration for good performance on route	There is already differentiation - the acc goes to the floor but the brake only goes so far	Pedals are fine	Already have enough alarms	Already have passenger alarm	Good enough	Don't need it	Not a problem	n/a
17	Not helpful	Very helpful	Delayed or reduced acceleration would result in delays in the service - some buses aren't fast enough as it is and could cause problems on roundabouts	it is OK as is but acc pedal could be made smaller	No, already have enough to do with hands and are supposed to keep 2 hands on the wheel at all times	These are being fitted now in the form of RIBAS - economical driving	Currently have assault alarms and these could be incorporated	Yes	Currently only get training on new vehicles, however, doesn't need it	Professional drivers should be able to do this	The pivot is sometimes in the middle and not at the end of the pedal which makes it difficult to operate
18	Could put foot on top of it & mistake for pedal	Doesn't notice a difference between buses anyway	Need acceleration, it would be helpful to make acceleration rates all the same	Are familiar with it as they are so should stay same	Too many hand tasks as it is	Too many alarms already	People wouldn't use it	No	Don't need it	Professional drivers should be able to do this	n/a
19	Wouldn't work	Already have consistency of buses/ pedal layout at this depot	Already different in different models and much reduced in some older buses	Better differentiation would be good - bigger brake? Position is fine, height is fine, angle could help but more research into comfort needed. Different pivot?	Need both hands on the wheel	RIBAS coming in so will provide visual display	Too much potential for malfunction	Initial training is fine	Have 7hrs CPC per year already but that is classroom based	Have 16pt check on 1st use. Don't allocate enough time for mid-route change	n/a
20-21	Layout is OK as it is	Not a problem if working correctly but in an ideal world they would all be like it is in the Environ	This would be dangerous	Don't want pedals to change, they are OK on newer buses	Need both hands on the wheel	Annoying, there are too many alarms as it is and drivers wouldn't register if panicked	Wouldn't use it	Initial training is fine	Get PCV training	It is difficult but not dangerous, standardisation of buses would help	n/a
22-23	Doesn't know if it would work - regulation boots are thick and cumbersome so creating more obstacles might be hazardous	Pedals are fine	n/a	Pedals are different enough as it is	Couldn't do it	Not useful as wouldn't have time to register if panicked	Could only work with proper sensors	Proper training would improve standards (people currently pass and get into service within 3 weeks)	This would be helpful	Most buses are very similar in this depot	n/a

No.	Vertical panel between accelerator and brake	Standardise pedals	Reduce acceleration of bus	Provide better feedback from pedal depression	Accelerate/brake with hand	Alarm/cut out if accelerator is floored	Emergency Stop button	Better initial driver training	Refresher training	Better familiarisation procedures	Other comments
24	Could work	Very standard already, prefer that they're different to a car because you are in a bus!	Need acceleration for good performance on route	Staggered pedals aren't good for shorter people who have to have leg right forward as it is. Angled pedals might be uncomfortable to drive with	Wouldn't work	Could work	Wouldn't work in panic situation	Yes	Yes, very good idea	All very similar already	n/a
25	Could work	Not necessary - have standard layout already	Buses are slow enough already	if pedals were at a slightly different angle/tilt	Wouldn't work	Incoming (RIBAS)	Wouldn't react quickly enough, on both occasions didn't even think about handbrake - already have the neutral button	Yes, could include warning in training and actions	training is very bad at this garage and refresher non existent	get type training but that is it, any type of training is a bonus	n/a
26	n/a	Not really	Need acceleration for good performance on route	Yes - he was of the opinion that similarity in pedals is a big issue and difference in size, feel, operation etc. would be useful.	No - too much going on with hand.	n/a	No - drivers have never reported pulling up handbrake in UA incident. They do not think clearly.	Would not solve problem	Would not solve problem	N/A	Procedures for ensuring bus engines were turned off would encourage more complete seat adjustment.
27-28	New buses already have the steering column very close, could be used for guidance	Good idea	Would help UA problem but would probably irritate drivers	Size, height, angle, yes but already have angle. Tilt no	Don't like the sound of it as it wouldn't feel right	Alarm would help	This would have to be backed up with training for it to work	Good idea	Good idea	Not a problem	**Said there is an interlock to ensure brake pedal deployment when shifting from Park to Drive but has little effect as most drivers just use the handbrake and leave it in Drive. Could be a factor in UA when pulling away from stops.**
29	Vertical panel wouldn't make a difference when the person makes a mistake it's an accident	Pedals are all very similar at this garage	No - is not an acceptable solution	Could move them further apart but not change size height, or angle	This could work but might not be comfortable	No, wouldn't work	Good idea	Yes, there isn't enough driver training	Good idea to reduce bad habits, refresher training every 3yrs?	Could be improved, don't get enough type training	n/a
30	Might cause confusion if foot is on accelerator and you think something is touching your foot	Pedals are all very similar at this garage	Buses are slow enough already	Already have different height, not sure about size	Have too many things to do with hands	No, wouldn't work	Have already got an isolator	This is variable and depends on who trains you	Not necessary as becomes 2nd nature after a time	Not a problem	n/a
31	Wouldn't work; people would get used to it and become desensitised to the barrier as a reference point	Pedals are all very similar at this garage	Buses are slow enough already	Further apart makes it more difficult for driver, angled pedals could hurt	n/a	n/a	n/a	Good idea	Good idea	Professional drivers just get used to the changing	n/a

No.	Vertical panel between accelerator and brake	Standardise pedals	Reduce acceleration of bus	Provide better feedback from pedal depression	Accelerate/brake with hand	Alarm/cut out if accelerator is floored	Emergency Stop button	Better initial driver training	Refresher training	Better familiarisation procedures	Other comments
32	Could work	Pedals are all very similar at this garage	Buses are slow enough already	Further apart would help but need to find pedals quickly, acc higher and brake lower good, difficult to imagine angle	No	Could just have panels that read acc or brake (NB do not have rev counters on buses)	Have already got an isolator	No	Good idea	n/a	n/a
33	Could work	Pedals are all very similar at this garage	Need acceleration for good performance on route	Pedals are OK as it is	Would have to try first	Good idea, someone could be going too fast but not know it	Button would help as only have hand brake and this is violent	Got it already	Got it already	Don't get adequate type training here	Should always have shoes with rubber grips. Many drivers just use handbrake when at stops (don't shift into Park).
34	Yes could work but would need special shoes	Get used to the type of bus OK	Could work	Already used to pedals as they are and if they change it will take time to get used to them	No, pedals are fine	Very good idea	Good idea	Good idea	Good idea	Professional drivers just get used to the changing	n/a
35	Fatiguing for foot	Pedals are all very similar at this garage	This is already limited to 30	Accelerator is already generally bigger than brake, moving further apart would be OK but don't want to lodge in middle, acc is already higher than brake	Too many controls for the hands already	Good, will work BUT problem as have no control over rate of acceleration	Currently have problems because driver doesn't want to brake suddenly	RIBAS is very good for training and is being installed here	Good idea	Not a problem	n/a
36	No, wouldn't work	Pedals are all very similar at this garage	Professional drivers need to be able to control speed	Not enough space in cabin to move pedals further apart	No	No, it wouldn't work	No, it's too easy to make a mistake in a panic	Fine as it is	Not necessary as have enough practice	Not a problem	n/a
37	Maybe, but not convinced it would work/fit	Pedals are all very similar at this garage	Could work, or just adjust so all buses are the same	Change position, not height as uncomfortable to lift foot for 10hrs	No	Might work to warn driver	Could work	Fine as it is	Already in place	Not a problem	Some new drivers are too inexperienced in a car, let alone a bus. There should be 2-3yr gap between getting your driving license and your bus license.
38 - 39	Wouldn't notice it after a while - would become desensitised	Pedals are all very similar at this garage, however, response rates of buses are different	Need acceleration for good performance on route	Yes, very good idea	No	No	Wouldn't use or notice in an emergency	Should be as a drill in part of the training - "Bus is not responding so check pedals, hit neutral, apply handbrake"	Good idea	Not a problem	n/a
40 - 41	Would be a problem for drivers with big feet	Pedals are very similar at this garage but due to preference of Engineering Director - if got a new one may introduce different types of buses - same with gear selection and handbrake	Need the kick down on the accelerator to get up some hills	Can change size, height but position and angle will introduce different problems like more strain on foot - pivot difference could work	No	By the time an alarm comes on the damage is probably done	Danger of knocking it accidentally	Training is currently on hold	Got it already every 2 years - adv driver training is very good. Already have mystery driver to monitor driving quality. Also fleet is soon to be fitted with genius drive smart system	n/a	n/a

Table 7 – Summary of comments on potential solutions

Vertical panel between accelerator and brake	Standardise pedals	Reduce acceleration of bus	Provide better feedback from pedal depression	Accelerate/brake with hand	Alarm/cut out if accelerator is floored	Emergency Stop button	Better initial driver training	Refresher training	Better familiarisation procedures
The drivers considered that a vertical panel to the left of the brake would not aid differentiation between the two pedals and could inhibit driving, causing muscle fatigue from the lifting (as opposed to sliding) action.	Standardisation of the pedals was approved of by drivers who frequently drove different types of vehicles with different layouts. This was not considered to be an issue at depots which had ensured standard pedal layouts through continuity of bus makes and models.	Reduction in the acceleration of the bus was considered to increase the danger of day-to-day operations. Some buses already had low rates of acceleration due to age or mechanical limitation, this variability was introduced as a potential hazard.	Most drivers agreed with the principle of increasing differentiation of pedals through tactile feedback, however there was a great deal of difference in the preferred method. Tilt of pedal was discounted by all due to its potential for discomfort. Size, height, pivot and angle changes were considered but it was agreed any changes would have to be subject to considerable evaluation to meet the approval of the driving population.	The use of hand controls was discounted due to the requirement for two hands to be on the wheel at all times.	An alarm or cut out in the event of flooring the accelerator was not considered to provide sufficient benefits by most drivers. Alarms would not be registered in cases of driver panic and a cut-out could increase problems in day-to-day driving including inappropriate/dangerous reduction of power during manoeuvring. The monitoring aspect of the solution is also already present in buses fitted with RIBAS systems, although it doesn't indicate the strength of the application of brake/ accelerator.	The principle of an emergency stop button was applauded; bringing the bus to a controlled stop. However, there were reservations regarding the potential method of activation, and the mechanics of controlling the stop without harming the passengers.	The driver interviews identified a potential gap in the driver training. Initial training had been reduced in scope in recent years, some depots did not manage their type training adequately and refresher training was not provided by all organisations.		This was dependent on the depots adherence to the provision of type training, and was subsequently identified as a potential pitfall by some. Most drivers agreed that professional drivers should be able to drive multiple vehicles on multiple routes, however, the lack of formalisation of familiarisation procedures could be an area for improvement during training.