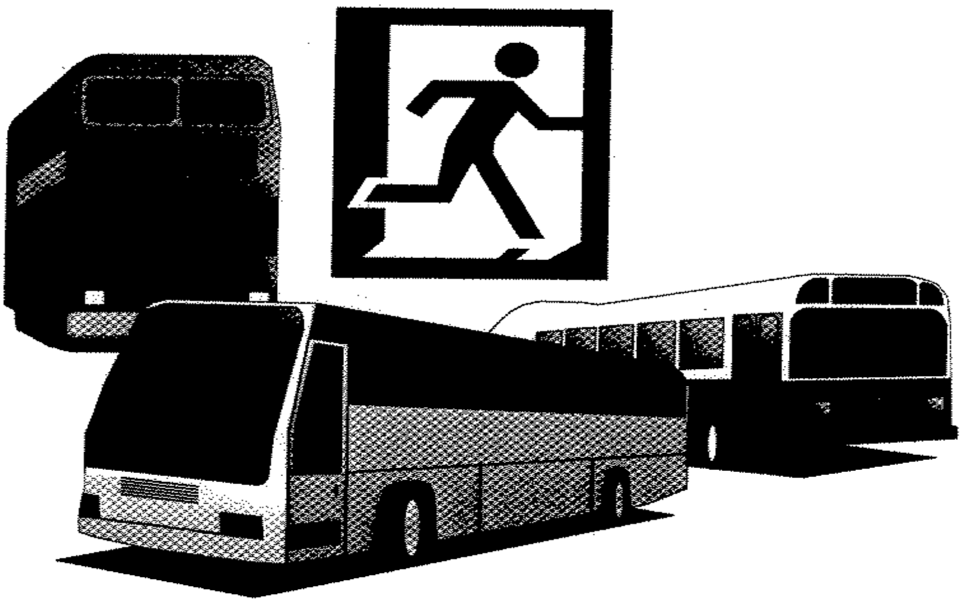
PSV EMERGENCY EXITS:

PASSENGER BEHAVIOUR AND EXIT DESIGN



Summary

This study tested the speed and ease with which individual passengers could open and use the emergency exits currently provided on buses and coaches. The survey found that passengers believed that certain emergency exits, such as doors and hinged windows, would be easy to use in an emergency, that they knew how to use them and that instructions would help if they were uncertain. Twenty exit types were then tested with passengers, including emergency doors, 'continental' doors, roof hatches, hinged windows, break-glass windows and the emergency operation of service doors. It was found that passengers' expectations were generally not being met. Poor handle design, location, feedback, anti-tamper cover guards and unclear instructions were found to result in significant delays in evacuation. The study recommends design improvements in these areas together with a consistent approach to the design and provision of emergency exit signage, conspicuity and instructions. It also recommends that high level doors are equipped with steps and that if window exits are to be retained these should be hinged rather than break-glass as the latter have severe disadvantages .

Introduction

The UK Department of Transport commissioned this work in view of proposed new European regulations covering the provision of emergency exits on public service vehicles. The objectives of this study were to examine the ease, speed and safety with which passengers can use current types of emergency exit (dedicated emergency doors, roof hatches, window exits and the emergency operation of service doors), and to make design recommendations.
ICE Ergonomics designed and conducted an extensive suite of research and testing to establish both the performance of current emergency exit systems and to validate the recommendations made as a result of the research.

The research

Part 1: Review of existing knowledge

Review of accident data. An investigation of PSV accident data was made to identify if any information could be obtained on how easily passengers have found exits to use in real-world accidents. Three approaches to this review were made:

1. Previous international studies were reviewed and these identified a number of critical issues affecting the injury outcomes of PSV accidents: one study suggested that problems in locating and reaching exits were implicated in around a third of studied fatalities. A number of studies identified the increased severity of injuries where ejection from the vehicle had taken place. Ease of egress by passengers and access by emergency services were also highlighted as being problematic.

2. Information from over 300 PSV accidents reported to the Vehicle Inspectorate during 1995 was reviewed. Of these accidents, only 16 provided information relevant to the performance of emergency exits in real world accidents. None of the reported accidents that met the selection criteria were identified as having problems with passenger evacuation that led to injury. Anecdotal evidence from members of the emergency services identified a number of behavioural problems both by passengers using exits and by persons assisting the evacuation.

3. Responses from passengers involved in emergency evacuations were obtained. Their responses suggested that they were concerned with the signage and positioning of exits.

Operators' and manufacturers' opinions. Information on operational and manufacturing issues was obtained from operators and manufacturers and their respective professional organisations, the Confederation of Passenger Transport and the Society of Motor Manufacturers and Traders. This information was used within the context of the expert audit of current exit systems described below.

Audit of current exits. Ergonomists reviewed a number of current vehicles representing the range of vehicles and types of exit currently in service. Expert appraisal of existing systems included consideration of exit types, numbers, activation methods, access and predicted ease of use. The location and appropriateness of exit signage was also reviewed, along with a consideration of the conflict between use and abuse/misuse deterrents, such as handle and hammer guards.

Alternative emergency exit designs. The results of the initial research and the experimental trials provided both statistically and anecdotally valuable evidence to use when recommending design and operational changes to PSVs. As a further source of information, other types of passenger carrying vehicles were studied, in an attempt to identify complementary technologies and procedures that could be used in PSVs. Underground and surface rail, helicopters and fixed wing aircraft, and ambulances were studied and a number of potential solutions with applicability to PSVs were identified.

Part 2: Testing emergency exits with typical passengers

Usability trials. Seventy-four members of the public ranging in age from 18 to over 70 years participated in the trials. The range of exits tested was based on the vehicle audit and included single and double service doors, 'continental' doors, emergency doors, hinged and push-out roof hatches and hinged and break-glass windows. Different types of operating mechanism were also represented to give a total of 20 test exits. The trials were undertaken on actual vehicles or, where this was inappropriate, on specialised rigs built to simulate vehicle interiors. The subjects undertook the trials individually and were given no instruction on the use of the exits, nor were they forewarned as to the purpose of the trials. They were timed as they left the vehicle as quickly as possible via a specified exit and were then interviewed about their experience and opinions of its use.

	
Break-glass window trial on a test rig	Passengers tested other exits on actual vehicles

The results show that the design of the opening mechanism has a far greater effect on exit times than, for example, whether the door is a service, emergency or 'continental' door. With good operating mechanisms doors can be the quickest exits to use. While hinged windows are only marginally slower than doors, break-glass windows can take up to 6 times longer due to the time taken to clear the glass from the frame.

The theft of hammers provided for use with break-glass windows is a serious problem according to operators. There are not only financial and wider crime implications associated with hammer theft but, additionally, their absence reduces the number of available exits. We have found that the current methods for securing hammers against theft can seriously impede their legitimate use in an emergency.

Simple pull handles, push buttons or rotary handles can be equally quick to use but have been found to be severely impaired by:-

- locations which are at the limits of reach,
- locations which are not where expected or not conspicuous;
- inappropriate, misleading or poorly located instructions;
- poorly designed 'safety' devices aimed at avoiding misuse.

The following table gives the average exit times for all of the exit systems tested in the study.

Average exit times

Type, number and method of exit				Timing (seconds)	Rank (1=fastest)
Doors	Single Service	1	Pull handle	22.1	16
		2	Push Button	6.4	5
		3	Lift/Turn Handle	6.2	4
		4	Rotate	8.5	7
	Double Service	5	Pull Handle	21.2	15
		6	Push Button	15.9	12
	Continental	7	Pull Handle	5.0	2
		8	Pull Handle(small)	10.6	10
		9	Push Button	14.5	11
		10	Lift/Turn Handle	24.0	17
	Emergency Rear	11	Pull Handle	7.7	6
		12	Pull Handle (bus)	4.5	1
		13	Push Button	5.2	3
Windows	Hinged	14	Turn Handle	8.7	9
	Break Glass	15	Small	27.9	18
		16	Large	17.9	13
		17	Rear	19.2	14
		18	Small Double	34.7	19
Roof Hatches	Push Out	19	Pull Handle	59.1	20
		20	Turn Handle	8.6	8

The results demonstrate the critical effect that design features can have on ease and speed of PSV evacuation.

It can be seen that the evacuation times of the emergency rear and ‘continental’ doors fitted with pull handles took around 10 seconds or less to operate compared with 22 seconds for the same type of handle on the single service door. The reason for this much slower time is that the handle on the single service door was located at the top of the door out of the passenger’s field of view and indeed beyond the reach of smaller passengers.

The pull handle on the double service (bus) doors also took a long time to operate and this is because it is the large grab handle which must be used to physically overcome the pressure within the air operated doors. It might be thought that in real life, if there is air in the system, then the passenger can use the push buttons to operate the doors automatically. However, the location of these buttons was on the front bulkhead of the vehicle and whilst within easy reach they were not within the field of view of the passenger when standing in front of the door; and consequently were not seen. What could be seen was a grab handle with a sign indicating that it should be pulled to open the door in an emergency and therefore passengers attempted to use it. Hence, again, the importance of the appropriate location of operating mechanisms and unambiguous signage is demonstrated.

Two of the doors tested had similar lift/turn handles yet the handle on the single service door took only 6.2 seconds to operate whereas the handle on the ‘continental’ door took four times as long at 24 seconds. The delay in using this handle was caused by a plastic cover which was placed over it to prevent inappropriate use. Another type of safety cover located over the ‘continental’ door push button explains why this took 14.5 seconds to operate compared to the 5.2 seconds to use the same handle, but without the cover, on the emergency door. For these reasons we recommend that alternatives to covers are developed to prevent inappropriate use of the doors. An example may be the use of speed related interlocks as currently found on some taxis. Similar problems were found with the various devices used to prevent the theft of break-glass hammers: break glass covers were very difficult to break without injury and plastic covers increased the average time to obtain the hammer from 1.3 seconds to 16 seconds. This was another factor leading to the conclusion that break glass windows are not an acceptable emergency exit.

It will be noted from the table above that the pull handle roof hatch was the slowest exit, despite the fact that the principle of operation is quite simple. The problem that arose with this exit serves to highlight the importance of ensuring that the operating mechanism provides appropriate feedback, especially to inexperienced users. This pull handle came against a false stop part way along its travel. As passengers thought they had therefore reached the end of the handle’s travel, they were uncertain what to do when the hatch would not open and so spent time searching for other handles or instructions.

Passenger attitude and knowledge survey. Interviews were conducted with 112 bus and coach passengers to assess their knowledge and expectations of emergency exits. Doors were the most frequently recalled form of emergency exit (75% for buses, 59% for coaches), followed by windows (25% buses, 38% coaches) then roof hatches (0% buses, 3% coaches). Respondents exhibited greatest knowledge about doors with only 11% of respondents saying that they wouldn’t know how to open the door compared to 30% for windows and 28% for roof hatches.

Passenger knowledge seems to be acquired passively over time, rather than by passengers actively seeking out the means of emergency egress each time that they travel. Certain stereotypes regarding the position and use of exits may be exploited by ensuring a consistency of exit type and placement across vehicles. Where this is not possible, it may be necessary to provide an increased level of information about the alternative designs used.

The low level of passenger knowledge and awareness concerning the use of certain types of exit (notably roof-hatches and break-glass windows) should be countered within the constraint that passengers will typically attempt to use any exit before they resort to reading the instructions associated with it.

Passenger behaviour was also studied, and existing research used to identify likely behaviour patterns for passengers in emergency situations. Such research shows that passengers, under the stress of an evacuation, will not necessarily use the most appropriate exit. When under stress people are less able to cope with new equipment and information. Their natural inclination will be to leave by the exits they know of: the door by which they entered or the emergency off-side rear door. In the confusion they may follow the actions of other people who appear confident in what they are doing even if this is inappropriate. The stress means that when they reach an exit they may have difficulties working out the method of operating it if this is not intuitive or matches their immediate expectations.

Hence the need to design exit systems that match the expectations of passengers, are conspicuous and to 'train' passengers in their location and use.

Development and validation of recommendations

By comparing the performance of the wide range of exits tested, and drawing upon good ergonomics practice it was possible to develop a series of recommendations. The benefits of a number of these are shown by comparing the results from the different exit designs tested in the main trials. To confirm the benefits of other recommendations a series of validation trials were undertaken with typical passengers following the procedures used in the main trials to directly compare the recommended design with existing practice:

1. Doors with interior steps were tested against high doors without steps (i.e. the more common type of off-side rear emergency door).
2. Top-hinging windows with a system to keep them open without passenger effort were tested against top hinged and bottom hinged windows without such systems.
3. Exit signage and conspicuous markings as proposed within the study were tested against standard current markings.
4. The location of break glass hammers was tested for their placement in relation to the windows and the means of retention.

Recommendations

1. General

1.1 Ensure consistency within and across vehicles in the type, location, signing and operation of exits.

1.2 Ensure exits are clearly identifiable as such, both for passengers inside the vehicle and rescuers outside, under conditions of normal and low visibility.

1.3 Operation of the opening mechanism, from inside and outside, should be 'self evident' as there is little opportunity for instruction.

1.4 Doors with interior steps are recommended as the primary exit as they optimise speed and ease of use. (For floor to ground heights in the order of 1.5m, emergency evacuation times could be reduced by 28% if the high step emergency rear offside exit was replaced with a door with internal steps). Doors without steps are suitable only where the provision of steps is not possible.

1.5 Windows (hinged and break glass) and roof hatches are not recommended as a primary evacuation route as they are slow and difficult to use and passengers will avoid using them.

1.6 Where windows are provided as a secondary route these should be hinged rather than break glass. They should be hinged at the top since top hinging windows are two thirds quicker to use than bottom hinging windows. They should also be self supporting e.g. by gas struts since this reduces evacuation time by a half.

2. Signs and instructions

2.1. Standardised signage should be used consistently for all exits in all PSVs.

2.2. These should be printed in red and white, to be consistent with other emergency equipment, and use commonly understood words. (Symbols should only be used where their effectiveness has been proven). This format should be reserved solely for emergency information.

2.3. Signs should be located immediately adjacent to all exits and be visible from all areas of the passenger compartment and not obscured by trim or other items of equipment.

2.4. Signs should be visible even under low light levels and ideally be self-illuminated. The immediate surround of any exit should be highly conspicuous.

2.5. Signs should be of sufficient size that they can be identified on approach and not just when the passenger is at the exit.

2.6. Exits should be outlined in a high visibility finish to increase their conspicuity.

2.7. Instructions located at the exit should be placed immediately adjacent to the mechanism to which they refer and positioned face-on to the user.

2.8. Good signage, based on the recommendations of this study, enabled passengers to identify more emergency exits in 30% less time than conventional signage.

3. Training

3.1. Drivers and other key crew should be trained in emergency procedures, the use of exits and the supervision of passengers in an emergency situation.

3.2. Training should also be given to potential high risk groups such as children and to staff who accompany them on journeys.

4. Doors

4.1. Manually operated doors should be operated by a simple red pull handle. A turn handle is acceptable for vehicles where a pull handle is impractical (such as van-based mini-buses).

4.2. Power operated doors should be operated either by a simple push-button or a handle similar to that used for manually operated doors.

4.3. The operating mechanism should be located so that it is within the direct field of view of a person standing at the exit, either on the exit or immediately adjacent to it.

4.4. The operating mechanism should be within the grasp reach of the smallest passenger likely to use it.

5. Hinged windows

5.1. Windows should be hinged at the top to provide an unobstructed aperture. They should be operated by a single red turn handle and remain in the open position once opened.

6. Break-glass windows

6.1. The larger of the current hammers available is recommended in order to assist glass clearing.

6.2. Hammers should be red and located immediately adjacent to the break-glass window, in a vertical plane on the body wall so they are clearly visible to passengers. Hammers located on window pillars were found in a third of the time taken to find those located on the underside of luggage racks.

6.3. They should not be obscured by trim, curtains or other items of equipment. Where such items may restrict visibility a label should indicate the hammer position.

6.4. The use of physical barriers designed to prevent hammer theft must be carefully considered since devices such as security wire and plastic or glass covers can increase the time taken for passengers to access the hammer twelvefold.

7. Roof hatches

7.1. The number of operations required to open the hatch should be no more than two. One to release the latch and one to open the hatch.

7.2. The latching mechanism should be operated by a single, red pull or turn handle large enough to be gripped by the whole hand and provide good leverage.

7.3. If the hatch is also used as a roof vent then the emergency exit handle should be more distinct than the vent controls and their relative location should be such as to avoid confusion between them.

Conclusions

A significant conclusion is that the operating times and passengers' likelihood of using break-glass windows are such that they should not count toward the emergency exit provision on buses, coaches and minibuses. This is not to debar their inclusion so long as adequate provision for exits is made by other means. However, recognising that a large proportion of the current fleet contains such exits, the report makes recommendations for their improvement, although these cannot overcome the inherent problems with this type of exit.

The study identifies actions which can be taken to improve passenger safety in the immediate, medium and long term.

Immediate actions can be applied to all current vehicles at low cost and include, for example, improved signage and instructions, driver training and passenger information.

Medium term actions require some modifications to current vehicles at medium cost and include, for example, the improvement in the operating handles/door latching mechanism, the fitting of speed interlocks to prevent occupant ejection.

Longer term actions should be implemented at the design/build stage of new vehicles and include, for example, the fitting of opening, rather than break-glass, windows and the provision of steps to doors in high floor vehicles.

Many of the recommendations set out above may seem self evident, yet we have found during our audit that each one has been violated on at least one make of PSV currently in use. Clearly then there is practical scope for actions to improve passenger safety during the evacuation of buses and coaches in an emergency.

Additional copies of this paper can be provided by applying in writing to:

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