A common system of passenger safety signage

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Abstract

This paper describes a 12-month research study commissioned by the Rail Safety and Standards Board on behalf of the Association of Train Operating Companies. The work responded to recommendations concerning passenger safety signage in the Cullen Report arising from the Ladbroke Grove rail accident. The study involved smoke chamber tests to develop graphics guidelines to ensure the legibility of luminous signs, design development and comprehension testing of over 130 graphical symbols, the development of graphics guidelines and the development of over 100 new safety signs as the initial part of a new common system of signage across the UK rail industry.

1 Background

In May of 2002, Davis Associates Ltd and Interfleet Technology Ltd commenced a 12-month safety signage research project for the Rail Safety and Standards Board (RSSB). The work had been commissioned on behalf of the Association of Train Operating Companies (ATOC) and was one of several projects commissioned in response to the recommendations of the Cullen Report into the Ladbroke Grove rail accident.

The Cullen recommendations most directly addressed by this project are:

	Cullen recommendation	Key objectives
71	The requirement for emergency signs to be luminous should be made retrospective.	Luminous signs
72	So far as is feasible, emergency signs on all trains should be capable of being understood by passengers without the need to read text.	Graphical symbols
73	There should be research with the aim of arriving at a system of signage which is common to all trains in Great Britain.	Common signage system

The key challenges for the project were therefore:

(i) Luminous materials: What graphical rules are appropriate to ensure symbol and text legibility in darkness, low light and smoke-filled conditions?

(ii) Graphical symbols: What graphical symbols are required?
What methods would ensure comprehension of the symbols?

(iii) Common system: What graphics rules should be applied to ensure a consistent style and quality of signs?
What process should be followed to develop new symbols?

The scope for the project covered the following safety sign categories:

- Safe condition
- Fire equipment
- Passenger alarm / communication devices

The following sign categories were excluded from the scope by RSSB: hazard warnings, prohibition signs, mandatory signs and all non-safety signs.

2 Research programme

Davis Associates proposed an outline research programme but it was clear that some initial research would be necessary in order to determine what relevant information and research material was already available before the programme could be refined and finalised. Therefore, Stage 1 of the programme was commissioned to define current best practice.

Stage 1 - Defining best practice

The research programme commenced with a literature review covering: graphics and typographics guidelines, the characteristics of luminous materials and their application to signs, the psychological and physiological aspects of legibility and comprehension particularly in low light and smoke-filled conditions, relevant standards, guidance and best practice in the railway industry and other industries. The review included a search for the most appropriate and practical testing methods to evaluate the relevant factors.

As a result of the information obtained during Stage 1, the outline research programme was reviewed and the following programme stages were scoped and agreed:

Stage 1 Defining best practice (previously completed)

Stage 2 Information needs analysis

Stage 3 Benchmark legibility tests

Stage 4 Symbol development and comprehension testing

Stage 5 Instructional comprehension tests in context

Stage 6 Legibility and discriminability verification testing

Stage 7 Standardisation (defining guidelines and procedures)

The scope was confirmed, including the development of graphical symbols for at least forty referents and an initial batch of one hundred safety signs. Through a parallel project, all of the deliverables would be made available via the ATOC website.

Stage 2 - Information needs analysis

The primary objective of this stage was to define the list of referents for which graphical symbols were required. A referent is a written description of a single element of information such as an object (e.g. Fire extinguisher) or action (e.g. Pull handle).

An industry stakeholder workshop was facilitated to discuss:

- All possible safety information that might need to be communicated via fixed signage in trains.
- The characteristics of the user group (including staff and emergency services as well as passengers).
- The scenarios and circumstances under which the information might be needed.
- The associated emergency equipment and the actions required to operate it.

An existing "catalogue" of UK safety signs was reviewed, although it was not an exhaustive collection and featured many examples of poor practice. In addition, Interfleet had previously conducted a signage survey on a wide sample of UK and overseas trains and had engineering knowledge of the associated emergency equipment and how it should be operated. Each existing sign was broken down into its constituent information elements and referents were defined for each. Certain elements had to remain text only (e.g. "Penalty for improper use"), and others were so specific to a particular device and vehicle that those too had to remain text only.

Stage 2 culminated in a list of 48 referents. Of these, eight were to be based on existing British Standard symbols (e.g. fire extinguisher) and a further five did not require comprehension testing (e.g. direction arrows). There remained a list of 35 referents requiring comprehension testing.

Stage 3 - Benchmark legibility tests

Before any symbols or signs could be developed it was first necessary to define the graphics guidelines that would ensure their legibility when printed on luminous material and when viewed under low-light and smoke-filled conditions. This was necessary because the literature review had revealed that no such guidelines existed.

A custom-designed viewing chamber was constructed to allow the controlled introduction of smoke and the representation of various lighting conditions (see Figure 1). The chamber was 3-metres long with a shielded viewing port at one end facing the visual target area at the other. The chamber was sealed to contain the smoke and to enable the smoke density to be maintained at a consistent level throughout each trial session. The smoke was a non-toxic, oil-based aerosol with small droplet size providing a longer persistence time.

Test graphics were inserted into the viewing area on boards, through a sealed slot in the side of the chamber. There was a separate compartment within the chamber containing ultraviolet lamps in order to rapidly energise the luminous material. All tests were conducted with the material at or near maximum saturation.

Figure 1: The purpose-built viewing chamber (access panels shown open)

The following smoke/light conditions were set in the viewing chamber:

Condition	Representing	Illumination level	Colour temperature
"Daylight"	Carriage illumination during daylight hours.	1700 lux	4,750K
Carriage lighting	Carriage lighting at night or in tunnels	410 lux	3,450K
Emergency lighting	Conditions under the emergency lighting system	20 lux	2,650K
Total darkness	Failure of the emergency lighting system at night or in a tunnel	0 lux	Not applicable
Snap wands	The glow from yellow snap-wands (in otherwise dark conditions)	1.5 lux	Not measured

Test graphics were designed and printed onto the luminous material. The graphics were of two types:

(i) Snellen charts - to test different text sizes and stroke widths, in red/green and positive/negative permutations.

(ii) Landolt Rings - of different sizes to determine the minimum legible graphical elements, also in red/green and positive/negative permutations.

The series of legibility tests were performed with thirty-three people representing a range of visual acuity levels.

The following key findings of the legibility tests enabled the graphics design of the symbols and signs to commence.

- Helvetica medium font (as specified in BS5499-1) proved adequate for use on luminous signs.
- Signs were more legible if printed in positive format (i.e. light text on dark background).

- Upper case characters should be 7.5 mm high, and lower case characters should be 5.5 mm high, for every 1 metre of viewing distance.
- Symbols shall feature a minimum line thickness of 0.86 mm per viewing distance.
- Critical details within symbols shall be a minimum of 2.6 mm per metre of viewing distance.
- The maximum ratio of critical detail to symbol size shall be 1:16.5.

Stage 4 - Symbol development and comprehension testing

The objectives of this stage were to:

- Generate alternative graphical concepts for each of the referents defined in Stage 2.
- Refine the design style for all the graphical symbols.
- Conduct comprehensibility judgement tests on up to ten symbol variants for each referent.
- Conduct comprehension tests on up to three of the best symbol variants for each referent.
- Conduct mutual confusion tests on the set of most comprehensible graphical symbols.

Generation of graphical concepts
Graphical symbol concepts to represent each referent were conceived during a brainstorm session amongst the project team, involving ergonomists, designers and engineers. The graphical symbol concepts were then drawn-up in line with the minimum sizes of line thickness and critical detail defined in Stage 3. Up to ten of the most promising graphical symbols for each referent were selected and taken forward to comprehensibility judgement testing.

Comprehensibility judgement testing
The test procedure used was based on that in ISO 9186:2001. Test sheets were produced for each referent with up to ten graphical symbol variants on each sheet (see Figure 2). Members of the public were approached on board trains and asked to complete booklets of several test sheets. The participant was informed of the symbol's intended meaning (i.e. the referent) and then asked for their estimation of the percentage of the general population that would correctly understand the meaning of the symbol. Over 300 train passengers were consulted for this test. Analysis of the data enabled the shortlisting of graphical symbol variants for comprehension testing. In some cases, none of the variants for a particular referent achieved the required 66% pass mark, and so the symbols were re-designed (or new symbols created) followed by further testing.

Comprehension testing
This test procedure was also based on that in ISO 9186:2001. There were up to three graphical symbol variants for each referent. Each test sheet showed one symbol variant together with information about the context of use of the symbol - but with no indication as to the meaning (see Figure 3). Participants were asked to write on each sheet what they thought the meaning of the symbol was. Over 300 train passengers were consulted for this test. The responses were then assessed by a panel of three independent judges and assigned one of seven possible categories. A weighted scoring system was then

used to calculate the overall level of comprehension for each symbol tested. Most symbols achieved the ISO pass mark of 66%. Some instruction symbols were re-designed and re-tested within the context of an appropriate instruction sign.

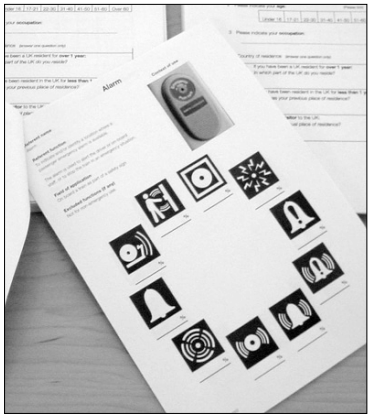

Figure 2 Example test sheet for the comprehensibility judgement test

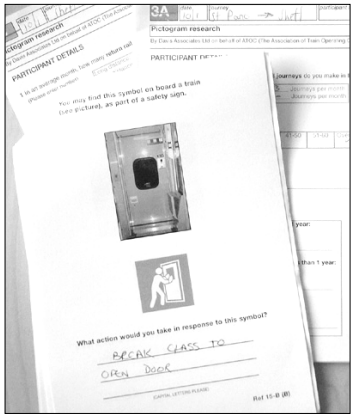

Figure 3 Example test sheet for comprehension test

Mutual confusion test

A mutual confusion test was then performed on the most successful graphical symbol for each referent in order to identify potential confusions between the meanings of any pair of symbols. A number of test sheets containing a matrix of symbols were compiled (see Figure 4). Symbols for similar referents (such as "Strike window in corner" and "Strike window on green dot") were placed on separate sheets because they would never appear together on the same train. Testing took place at major rail stations around the UK involving a total of 330 members of the public (see Figure 5).

Figure 4 A typical symbol matrix used for the mutual confusion test

Figure 5 Mutual confusion test being applied at a main railway station

At the end of Stage 4 the results of the symbol development process showed that:

- 23 referents achieved final comprehension scores of 66% or higher.
- 8 referents achieved final comprehension scores of between 50 and 65%.
- 4 referents achieved final comprehension scores of less than 50%.
- All symbols passed the mutual confusion test.

Any symbols that achieved less than 50% comprehension score were re-designed and subjected to further testing. In a few cases, it was concluded that the referent would have to remain text-only (e.g. "This hammer is alarmed") or use an existing symbol supported by text (e.g. "Emergency door release" in conjunction with the running–man symbol).

Stage 5 - Instruction comprehension tests in context

The objectives of this stage were:

- To verify the comprehensibility of the graphical symbols when presented within the context of a rail vehicle by means of user testing with a sample of the general public under stressed conditions.
- To evaluate the usability of the draft graphics guidelines through the production of signs for a specific vehicle.

The tests were conducted over three days at Connex South Eastern's Slade Green Maintenance Depot with 31 participants on board a BREL 465/0/ vehicle and a METRO-CAM 465-2 vehicle (see Figure 6). The devices to be tested were: passenger alarm, emergency door release, and emergency hammer.

Figure 6 User trials underway with the Passenger Alarm device in the rail vehicle

The appropriate instruction symbols for each device were compiled into signs following the draft "Graphics Guidelines" which were being developed in parallel with Stages 4, 5 & 6. The signs were test-fitted to the vehicle and various alternative concepts were also compiled for testing.

One participant at a time was briefed on a particular emergency scenario and then asked to execute the appropriate task, i.e. sound the alarm, open the doors, or break the window to escape (the latter task stopped short of actually breaking the window). Participants completed all three tasks in a balanced presentation order and were then interviewed. The tests were video recorded for detailed analysis.

The results of the instruction comprehension test in context showed that:

- Twenty one out of thirty one participants (68%) claimed not to have studied the signs, but instead acted on instinct, relying on their preconceptions and using whatever visual cues they could see from the devices themselves.

- Of those participants who did study the signs, most did not read past the header text or the first couple of instructions.
- Participants tended to return to the signs only when they got stuck at a particular stage of the task.
- Design attributes of the rail vehicles used for the tests significantly affected the results, making it difficult to draw conclusions about the signs themselves. For example:
  - The emergency devices in the doorway were mounted in the ceiling—out of normal line of sight for most people;
  - The upper door and ceiling was poorly illuminated—approx. 7-13 lux compared with 220 lux of the surrounding panels.
  - For operational reasons, two variants of the 465 vehicle had to be used during the tests. The design variations between the two vehicles also affected the results, making it difficult to compare different sign set-ups.
  - Inconsistency in the breaking strength of the device covers, meant that some participants had great difficulty in breaking the covers.
  - On two occasions, the emergency door release device was partially operated without the cover being completely removed. The doors partially opened and then slammed closed again when the participant let go of the handle.
  - Despite the practical difficulties described above, the user tests provided invaluable information about the effectiveness of the emergency devices and the effect of the signage.

The user tests lead to the following conclusions relating to the draft "Graphics Guidelines" for safety signs:

- Instruction symbols should not be reduced below standard size (33mm square) if at all possible, particularly if they are located in areas which are poorly illuminated.
- Some of the symbols were too complex and detailed for their meaning to be assimilated in stressed conditions. These symbols required re-design and re-testing.
- The words "Break glass" should be replaced with "Break cover".
- The size of the header words "Emergency door release" should be enlarged.
- User tests of this type provide invaluable information about the usability of the safety devices and associated signage. Such tests should be performed whenever a new installation or refurbishment takes place.

Stage 6 - Legibility and discriminability verification testing

This stage re-visited the viewing chamber in order to:

- Verify the text size, line thickness and critical detail size specified earlier in Stage 3.
- Evaluate each of the new symbols in terms of legibility and discriminability under adverse viewing conditions and identify opportunities for further improvements.
- Investigate any subjective differences in legibility between three different types of luminous material.

- Subjectively review the print quality limitations of the screen-printing process on luminous material.

To verify the legibility of the text and graphical symbols, the full set of symbols, and some example signs, were printed on to "Jalite AAA" luminous material. A sub-set of symbols were also printed on Class B and Class C materials. Thirty six participants then viewed the symbols and signs in the viewing chamber under various light conditions, in both clear and smoke filled conditions.

The results of the legibility tests showed that:

- The upper case text size recommended in Stage 3 was validated (i.e. 7.5 mm).
- The recommended symbol size of 33mm x 33mm at 1-metre viewing distance was validated.
- The absolute minimum recommended symbol size of 23.1mm x 23.1mm at 1-metre distance was validated.
- Symbols printed smaller than 23.1mm x 23.1mm were not reproduced reliably enough by the screen-printing process and the legibility was unsatisfactory.
- Five symbols required re-design in order to improve legibility and discriminability under adverse viewing conditions.
- In clear conditions, subjective ratings showed that Class C material was perceived to have the sharpest detail, compared to Class B and "Jalite AAA". In smoke viewing conditions, there was little difference between the three materials.

Stage 7 - Standardisation

In this final stage of the research programme, the following deliverables were produced with the aim of standardising a new Common System of Passenger Safety Signs:

- An initial set of 138 graphical symbols representing 43 different referents.
- A detailed set of graphics guidelines for the design of safety signs.
- An initial set of over 100 passenger safety signs for five different types of rail vehicle, developed according to the new graphics guidelines and incorporating the new graphical symbols.
- Design guidelines and testing procedures for the development of new symbols.

Through a parallel project, Interfleet produced the new ATOC website and all of the above deliverables are now available on a special section of the site. This website enables any authorised individuals and organisations to download all the necessary resources to design signs which are fully compliant with the new Common System of Passenger Safety Signs.

3 Recommendations

Standardisation
It is recommended that the Common Passenger Safety Sign System should be mandated for all UK rolling stock new-build and refurbishment projects, and that a date be set by which time all rail vehicles in the UK shall have to comply.

Other safety sign categories
The rail industry should undertake to extend the work of this research project to encompass those safety sign categories not currently covered (i.e.: hazard warning signs, prohibition signs and mandatory signs).

Guidance for defining signage requirements
Guidelines should be developed to ensure that an appropriate and consistent process is adopted throughout the rail industry for the definition of passenger safety signage requirements in each vehicle type. The requirements should include: information content, location within the vehicle and required viewing distances.

Standardise the design of devices
The design of safety devices (e.g. emergency door release devices) should be standardised as far as practicable. A study should be performed to identify the optimum designs, including user trial evaluations with a representative sample of train passengers.

Integrated signage design
It is recommended that safety signs should be considered as an integral part of the vehicle design process - the information content, sign locations and required viewing distances should be defined and suitable mounting spaces provided in the vehicles.

User trials
As part of the design process of new-build vehicles, and for major refurbishments, the vehicle safety system (including all safety devices and associated safety signs) should be evaluated by means of user trials involving a representative sample of train users.

4 Conclusion

The deliverables from this project have satisfied those specific recommendations from the Cullen Report listed in Section 1. The project has demonstrated that rigorous human factors research can be responsive to the needs of the rail industry and can deliver practical benefits which the industry can implement. It also demonstrates the benefits of effective cross-industry collaboration – in this case between RSSB, ATOC, the rolling stock leasing companies, and the consultants.

5 References

BS 5499-1: 2002 - Safety signs, including fire safety signs. Part 1: Specification for geometric shapes, colours and layouts. British Standards Institute.

ISO 9186: 2001. Graphical symbols – test methods for judged comprehensibility and for comprehension. International Organisation for Standardisation, Geneva.