Assessment of route and destination displays on public service vehicles: summary report.

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Assessment of route and destination displays on PSVs
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SUMMARY REPORT

Prepared for:
Department for Transport

Prepared by
ESRI Ltd
Loughborough University

February 2004
Abstract

This study investigated the readability of different display technologies used to present route and destination information on the front of buses and coaches. The research investigated different technologies and text designs in terms of reading distance, reading times, viewing angles and subjective performance ratings. The experimental participants were drawn from members of the public and included those whom had a visual impairment. The research found that overall the LED displays gained significantly greater reading distances, although their performance when viewed at an angle or close to was poor. However all the display technologies had positive and negative attributes and, in general, there were found to be generic characteristics that could be employed to improve their performance. These involved layout, font style, font size, colour, text and background contrast, the amount of information presented and the displays closeness to the window aperture. In addition visual aids to assist in recognising an approaching vehicle as a bus were found to be important.
# PSV displays – Summary report

February 2004

Department for Transport                               - i -                ESRI Ltd, Loughborough University

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1.0 Introduction

In response to the Disability Discrimination Act 1995, the Department for Transport funded this research to investigate the readability of bus route and destination displays for potential passengers, including those with visual impairments. The main objective of this study was to compare the performance of dot matrix displays with conventional roller blind displays in terms of readability, practicability, reliability and quantity of information for people with different levels of visual acuity. Findings from this work will be used to inform policy decisions on the appropriate requirements for the display of route and destination information systems on buses and coaches.

ESRI designed and conducted a suite of research and testing to establish both the performance of current PSVs display technologies and to validate the recommendations made as a result of the research.
2.0 The research

2.1 Part 1: Review of existing knowledge.

An investigation into visual impairments, sign readability and PSVs display technologies was conducted. Information was obtained from a range of sources and provided background information regarding the problems faced by visually impaired PSV users and the range of display technologies and designs that are currently in use.

2.1.1 Low vision groups

Serious non-correctable sight impairments affect 1.97 million people nationally in the UK; although only 1 in 25 of those who are registered blind have no vision at all. The effects of the main visual conditions include: reductions in peripheral vision, blurring, patchiness, multiple images, dazzling and visual difficulties in low light conditions. Discussions with representatives of low vision groups confirmed that: good contrast, sans serif fonts and mixed-case texts assist those with low vision, confirming the findings of the research review regarding clear sign/text design.

2.1.2 Display technologies

Three different types of display technology are currently employed by U.K bus operators these include:

- Printed displays (May be manually wound roller blind displays or electronically driven),
- Flip-dot displays (a form of dot matrix display),
- LED displays (a form of dot matrix display).
Printed displays can vary in colour, although yellow or white text on a black background were found to be the most commonly used across all the technologies. All forms of display have the potential to differ in font style, character size and character width.

Although research relating the performance of roller blind and dot matrix displays was not available, literature pertaining to the general design of visual information was obtained. Recommendations and guidelines for display design were gathered from a number of sources and included: colour; text size; character, word and line spacing; font and the use of upper and lower case. Findings supported the suggestions/preferences raised in discussions with the various visually impaired groups for improving display sign clarity and readability.

Comments from manufacturers and operators concerning the benefits and disbenefits of the display technologies are given below:

There is general consensus that::

- Printed blinds are more likely to be used on dedicated routes; dot matrix displays are more likely to be used across routes,
- Printed blinds provide better clarity under good lighting conditions and are more flexible in their fonts,
- Dot matrix displays are easier to update with new routes,
- Dot matrix displays are easier to adjust between different destinations; all displays can be updated from a control pad in the cab which is advantageous for the driver (although power blinds can now offer this),
• Dot matrix displays have greater reliability and less maintenance than printed blinds. LED displays have better reliability than Flip-dot displays,
• Dot matrix displays tend to have a longer life; however printed roller blind displays are often replaced due to route changes rather than the end of their life,
• Dot matrix displays require less installation space.

Other aspects raised included:
• The relative costs of the displays – These are difficult to compare directly although there was some indication that whilst roller blinds and flip dot displays have similar purchase costs, roller blinds incur greater maintenance costs,
• Advertising and/or graphics on the front of PSVs can be confusing to kerbside passengers.
2.2. Part 2: Research trials

Following from the research review undertaken as phase one of this project, experimental trials (laboratory and field trials) were undertaken to investigate and evaluate specific aspects of display design. The laboratory trials comprised technology trials (to examine the effects of technology) and text design trials (to examine the effects of text style). The field trials examined the effects of technology under ‘real world’ conditions.

2.2.1. Laboratory trials

Aim

The aims of the technology and text design trials were to consider the effects of the following variables on the readability of the displays. See Table 1.

<table>
<thead>
<tr>
<th>Technology trials</th>
<th>Text design trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim to investigate the effects of:</td>
<td>Aim to investigate the effects of:</td>
</tr>
<tr>
<td>Display technology (roller blind/printed, flip-dot, LED), Character size, Ageing, Ambient lighting conditions (day or night),</td>
<td>Text format (standard text; condensed text, raised descenders), Font style (Johnston, Tiresias sign font), Display colour formats, Amount of information presented.</td>
</tr>
</tbody>
</table>

Table 1: Aims of the technology and text trials
Participants
Fifty-three participants assisted in the trials comprising of 31 non-visually impaired participants, 16 visually-impaired participants and 6 dyslexic participants. A breakdown of the visual impairments is given in Table 2.

<table>
<thead>
<tr>
<th>Visual impairment</th>
<th>Number of participants</th>
<th>Visual impairment</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind in one eye</td>
<td>1</td>
<td>Macular degeneration</td>
<td>4</td>
</tr>
<tr>
<td>Cataracts</td>
<td>1</td>
<td>Myopia</td>
<td>1</td>
</tr>
<tr>
<td>Diabetic retinopathy</td>
<td>1</td>
<td>Optic neuropathy</td>
<td>1</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>4</td>
<td>Retinitis pigmentosa</td>
<td>2</td>
</tr>
<tr>
<td>Loss of central vision</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Causes of visual impairment

Procedure for the technology trials
The participant walked towards the display until they were just able to confidently read the route number. The viewing distance was recorded and the participant gave a rating of the readability of route number. Filters, which altered the contrast between the route number characters and their background, were placed in front of the participant’s eyes until the route number could no longer be clearly read. The participant then moved closer to the display until the final destination could be read and the same process was applied. This was then repeated for the intermediate place names.

At the closest distance to the display (the point at which the participant was able to clearly read all the information on the display), a shutter was drawn over the display and a new sign was mounted. The new sign was
identical to the previous display sign, differing only in the place names and numbers presented. When the display was revealed by removing the shutter, the participant was required to read all of the information on the display as fast as they could. If there were words that they could not read, they were asked to say pass and continue reading out the remaining information. The time from the shutter release to completing the reading of the display was recorded. A rating for the overall readability of the whole display was then given. This procedure was repeated for each technology (Printed, Flip dot and LED). The order of presentation varied in each test session.

**Procedure for the text design trials**

Only the printed displays were used to investigate changes in text format, colour, font style and the amount of information presented. This was due to the flexibility of the printed technology to display variations in font and letter spacing. In addition conducting the text design trials on all technologies would have seriously lengthened the time to undertake the trials. Conducting the text trials took approximately 40 minutes to complete.

For each of the text design aspects investigated (format, colour, font style and amount of information), the following procedure was used. The participant walked towards the display until they were just able to read confidently all of the information on it. The viewing distance was recorded and the participant gave a rating of the readability of the information displayed. A shutter was drawn over the display and a new sign was mounted. The new sign was identical to the previous display sign, differing only in the place names and numbers presented. When the display was revealed by removing the shutter, the participant was
required to read all of the information on the display as fast as they could. If there were words that they could not read, they were asked to say pass and continue reading out the remaining information. The time from the shutter release to completing the reading of the display was recorded. The participant then gave a rating of the readability of the information displayed. This procedure was repeated for each of the ticked cells in table 3 in this way a range of variables was assessed.

<table>
<thead>
<tr>
<th>Text Style</th>
<th>Colour</th>
<th>Amount of information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number and final destination</td>
</tr>
<tr>
<td>Normal (Johnston)</td>
<td>Flourescent yellow text on black</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Black text on Fluorescent yellow</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>White text on black</td>
<td>×</td>
</tr>
<tr>
<td>Condensed (Johnston)</td>
<td>Fluorescent yellow text on black</td>
<td>×</td>
</tr>
<tr>
<td>Raised descenders (Johnston)</td>
<td>Fluorescent yellow text on black</td>
<td>×</td>
</tr>
<tr>
<td>Tiresais</td>
<td>Fluorescent yellow text on black</td>
<td>×</td>
</tr>
</tbody>
</table>

Table 3: Procedure for text design trials
2.2.2. Field trials

The laboratory trials investigated the performance of different PSV display technologies in controlled conditions such that the type of technology was the main variable under assessment. The aim of the field trials was to assess displays in their real world setting and identify factors that influence their readability. The displays were assessed by members of the public, including those who were visually impaired, under day and night-time conditions.

Data was collected from a total sample size of 22 participants, comprising of 14 non-visually impaired participants and 8 visually impaired participants.

Measures of readability

Dynamic reading distances

The aim was to assess the readability of the display, in terms of reading distance, whilst the vehicle was moving. The participants and experimenters stood at one end of a straight stretch of road and a bus was driven towards them from the other end thereby simulating the approach of a bus to a bus stop. Refer to Figure 1. By a given point, marked by a cone, the vehicle reached a speed of 15mph, which was then maintained. Since, at this point, the majority of non-visually impaired participants were able to read the route number, the participants were asked to indicate to the experimenter working with them when the final destination became visible to them and when the intermediates became visible to them. When the vehicle reached the cone and the start of its constant speed, it flashed its headlights to
signal the experimenters to start their stopwatches. Split times were then taken for each participant for when they confirmed they could see the final destination and intermediates. From this data, viewing distances were then calculated under dynamic conditions. Due to the need to use intermediates, this was only undertaken using the printed, white on black display and the flip-dot display.

Figure 1: Dynamic assessment of display readability

**Static reading distances and angles**

Starting at distances at which the participants were unable to read any of the display information, each participant-experimenter pair approached the vehicle noting the distance at which the route number, final destination and intermediates could be confidently read; ratings were given at each point.

The participants then stood to the left of the vehicle, level with its front and facing forward. They then walked in an arc, whose radius was centred on the front centre line of the vehicle; until such time that all of the display information could be confidently read. At this point the angle formed by the participant and a tangent to the front of the vehicle was
noted and a rating given. Refer to Figure 2. This procedure was undertaken for all four display technologies.

![Diagram showing a bus display and a participant with viewing angle.]

**Figure 2: Assessment of reading angularity**

**Reading times**
Timings were taken for the participants to read the following amounts of information:
- Route number and final destination,
- Route number, final destination and one intermediate,
- Route number, final destination and three intermediates.
The aim of this was to determine the extent to which the addition of intermediate information significantly increased reading time above that taken to read just the route number and final destination.

**Questionnaire**
The participants also completed a questionnaire which covered various aspects of display design including:
- Layout preferences for relative locations of the route number, final destination and intermediate information,
• The relative importance of the route number, final destination and intermediate information,
• The relative importance of front, side and rear displays,
• Factors that make displays more or less readable.

3.0 Summary of overall findings

Combining the results of the background research, the laboratory trials and the subsequent field trials, the following aspects have been found.

3.1. Identification as a bus

Discussions with visually impaired groups indicated that actually identifying the approaching vehicle as a bus could be problematic for some passengers. Both groups of participants (visually impaired and non-visually impaired) use vehicle size and colour, followed by the presence of a route number, as a cue to whether or not the approaching vehicle is a bus.

3.2. Identification of the route information

Discussions with visually impaired groups also indicated that having identified an approaching vehicle as a bus, it was sometimes difficult to ‘locate’ the route information on the front of the bus due to the ‘clutter’ of advertising and graphics.

3.3. Location of display within vehicle

The front display was found to be significantly more important to the use of the bus by both groups of participants whilst the side was found to be more important to the visually impaired participants than the non-visually impaired participants.
Comments by operators were that modern vehicles are more curvaceous at the front causing the displays to be set further back and so more difficult to read. This was also the opinion of the experimenters in the field trials who considered that the relatively deeper recessing of one display within a vehicle contributed to its poorer angles of readability. The operators suggested that to improve display readability, the displays should be located close to the display window aperture and angled towards the road.

3.4. Amount of information

The findings indicate that for both participant groups the addition of even one intermediate stop significantly increases the reading time of the display information above that of just the route number and final destination.

3.5. Layout of display

The majority of the visually impaired participants expressed a preference for the route number to be to the right of the display whilst for the non-visually impaired there was no consensus. For the majority of participants in both groups the preferences given were rated as strong to very strong, although this was more pronounced for the visually impaired participants. In addition, where operators expressed a preference for the route number location, it was to the right of the display.

The majority of the participants in both groups also stated a preference for the final destination to be displayed below the route number and the preferences given were rated as moderate to very strong.
3.6. Display technology

The participant trials suggest that in terms of reading displays on stationary vehicles, the reading distance of the LED display was significantly greater. (In the laboratory trials this was true for both participant groups, by day and night. In the field trials this was only true for the non-visually impaired participants under daytime conditions).

When assessed dynamically it was found that reading distances were significantly reduced for the printed white on black (day and night) and flip-dot displays (day only) compared to when read statically.

In terms of the forward viewing angle, the printed yellow on black display could be viewed at significantly wider angles than the other technologies. This held for the non-visually impaired participants only by day and night.

Participant comments indicated that the printed displays were bold and clear and that the Flip-dot and LED displays, whilst clear at a distance, were difficult to read and lacked clarity close-up.

3.7. Display colour

Within the laboratory trials, the visually impaired participants read white text on a black background significantly more quickly than fluorescent yellow text on a black background. No preference was found between yellow text on a black background and black text on a yellow background.

Within the field trials, the fluorescent yellow text could be read at greater viewing angles than the white text.
3.8. Character size

Using the worst case figures for both groups in the above table, it was calculated that:

For the following percentages of visually-impaired participants to achieve the same reading distance as the equivalent percentages of non-visually impaired participants, character height would need to be increased by the following amounts:

<table>
<thead>
<tr>
<th>Percentage of participants</th>
<th>Increase in character height</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Route number</strong></td>
<td></td>
</tr>
<tr>
<td>95%</td>
<td>Increase by a factor of 13.3 to 2,666mm</td>
</tr>
<tr>
<td>50%</td>
<td>Increase by a factor of 3.7 to 741mm</td>
</tr>
<tr>
<td>25%</td>
<td>Increase by a factor of 1.8 to 355mm</td>
</tr>
<tr>
<td><strong>Final destination</strong></td>
<td></td>
</tr>
<tr>
<td>95%</td>
<td>Increase by a factor of 11 to 1,375mm</td>
</tr>
<tr>
<td>50%</td>
<td>Increase by a factor of 6.25 to 781mm</td>
</tr>
<tr>
<td>25%</td>
<td>Increase by a factor of 3.88 to 485mm</td>
</tr>
</tbody>
</table>

Table 4: Estimated character sizes

In addition, height increases described above would need to be further increased to compensate for reduced dynamic reading distances compared to static reading distances.

3.9. Typeface

Within the laboratory trials, it was found that: for the visually impaired and non-visually impaired participants:
- bold, broad characters can be read significantly more quickly,
- normal text can be read at greater distances than condensed text and text with raised descenders.
3.10. Ageing of displays

Due to difficulties in defining an aged system and knowing its relevance to the real world, the ageing of displays was assessed within the laboratory trials with respect to the reduced contrast due to the accumulation of dirt. The LED display had the highest contrast level, followed by the printed yellow on black display and then the flip-dot display. This was reflected in the results that showed that the LED displays (and printed displays for intermediaries only) could withstand equivalent or significantly greater levels of contrast reduction than the other technologies before becoming unreadable. It was concluded that the readability of higher contrast displays would not be affected as quickly by dirt as lower contrast displays.

4.0 Recommendations

4.1. Identification as a bus

Whilst vehicle colour and size were the most frequently mentioned methods for identifying a bus, the lack of standardised colouring due to deregulation and the ongoing amendments to corporate liveries as well as the confusability of buses with other large vehicles, meant that this was not a reliable strategy for use by the visually impaired passengers. This suggests that the use of a unique identifying feature that can be applied across all PSVs should be considered e.g. a broad fluorescent yellow horizontal band across the front of the bus.

4.2. Identification of the route information

It is recommended that advertising and graphics be removed from the areas of the display and replaced with a format which will not detract from the route information and preferably enhance it e.g. locating the
display within the broad fluorescent horizontal yellow band described in 3.1 above.

4.3. Location of display within vehicle

It is recommended that the displays are located immediately behind the display window aperture.

4.4. Amount of information

The route number was considered to be the most important type of information contained within the front display, followed by the final destination and then the intermediates. It was also found the addition of one or more intermediates significantly increased the reading time of the display above that required for reading just the route number and final destination. It is therefore recommended that intermediates only be used where they do not detract from the optimum provision of the route number and final destination information.

4.5. Layout of display

Where preferences were expressed it was for the route number to be to the right of the display and for the final destination to be displayed below the route number.

However it was noted by the experimenters that for deeply recessed displays, the right-hand side of the display might be obscured from the view of passengers standing on the kerbside at the front of the bus.

4.6. Display technology

It is recommended that the clarity of the flip-dot and LED displays be improved when viewed close up and that the viewing angularity of the
LED displays be increased. However the level of increase for these aspects that is ‘good enough’ is not known.

4.7. Colour

It is recommended that displays be used in which the text has a high colour contrast with the background.

4.8. Font size

It is recommended that priority be given to making the height of the route number be as large as possible followed by the character height of the final destination.

4.9. Typeface

It is recommended that bold, broad character typeface that employs conventional dropped descenders (opposed to raised descenders) be used.

4.10. Ageing of displays

It is recommended that displays with a high luminance contrast be used.

4.11. Variation in day and night time lighting conditions

This variable was taken into account in the assessment conditions and is reported within the other findings.

4.12. Displays lit and unlit

Through discussions with operators the displays are always operated lit both daytime and night-time.
4.13. Passenger perceptions

4.13.1. Relative importance of displays

There would appear to be merit to having displays to the front, side and rear and their continued use is recommended.

4.13.2. Display readability

Based on the visually impaired participants used within this research, there is a need to improve display readability. Means for achieving this are given within this recommendations section.

4.13.3. Display element

The route number is the key element in display use. Aspects to improve its readability should be prioritised.

4.13.4. Favourable features of display design

Large, clear, bold high contrast text should be used.

4.13.5. Unfavourable features of display design

Glare, reflection and the misalignment of information should be addressed by the display design.

4.13.6. Improvements

Larger numbers should be used.
5.0 Implications for display hardware

5.1. Location of display within vehicle

It is currently not possible on some vehicles to locate the display directly behind the display window aperture due to the curved nature of the front of the vehicle. To overcome this, either the design of the front of the vehicle must change to accommodate current display designs or the display design must change to accommodate the form of the vehicle. In line with the latter option, at least one manufacturer has developed a display that tries to follow the front curvature of the vehicle more closely than conventional displays.

5.2. Amount of information

The recommendation that intermediates only be used where they do not detract from the optimum provision of the route number and final destination information does not have major implications for the display hardware since most currently have the potential to accommodate intermediates.

5.3. Layout of display

Recommendations relating to the layout of the information do not have major implications for the display hardware since most displays can currently be manufactured or programmed in a variety of configurations.

5.4. Display technology

The recommendations given are requirements for all technologies. Refer to the other headings within this section for the display hardware implications. In addition it was recommended that the clarity of the flip-
dot and LED displays be improved when viewed close up and that the viewing angularity of the LED displays be increased. However since the extent to which the clarity and angle of view has to be increased is not known, the precise implications for the display hardware cannot be evaluated.

5.5. Display colour

The recommendation that displays be used in which the text has a high colour contrast with the background is currently being met by most technologies.

5.6. Font size

It is recommended that priority be given to making the height of the route number be as large as possible followed by the character height of the final destination. Since the space available for the front displays on both single and double deck vehicles is limited, there is little opportunity within current vehicle designs to increase font size by increasing the size of the display. Benefits may best be gained from improved use of the existing size of display.

The use of variable messages on LED and Flip dot technologies offers a means to enlarge font size without reducing the amount of information presented. However the practicalities of employing this method and the effectiveness and ease of use by people with visual impairments requires further consideration and is beyond the scope of this project.
5.7. Typeface

The recommendation that a bold, broad character typeface that employs conventional dropped descenders (opposed to raised descenders) be used should be achievable for most display technologies.

5.8. Ageing of displays

The recommendation that displays with a high luminance contrast be used is met by LED displays, although the printed and flip-dot displays may benefit from improvements to their luminous output. Since the optimum luminance levels for displays were not identified within the programme, the precise nature of further system requirements cannot therefore be defined although it is anticipated some additional hardware and power requirements will be required.

5.9. Variation in day and night time lighting conditions

This variable was taken into account in the assessment conditions and is reported within the other recommendations.

5.10. Displays lit and unlit

Through discussions with operators the displays are always operated lit both daytime and night-time.

5.11. Glare and reflection

Methods for reducing the affects of glare and reflection need to be identified and evaluated. Possible methods may include the:

• application of anti-reflective coatings to the display casing and the vehicle’s display window aperture,
• use of shielding to shade the display,
• automatic adjustment of display intensity to the ambient lighting conditions,
• forward tilting of the display.

5.12. Display misalignment

Display misalignment is predominantly eliminated through the use of electronic systems and is therefore mainly a feature of manually-adjusted printed displays. Investigations should be made to identify the causes for these misalignments in order to determine if they are related to display, vehicle or driver training factors.