Transport Research Laboratory

Safety Argument for Changes to Temporary Traffic Management Sign Sizes

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CLIENT PROJECT REPORT

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Safety Argument for Changes to Temporary Traffic Management Sign Sizes

Client: **Highways Agency, Client's Division/Department**

Paul Mitchell

This Client Report has been prepared for Highways Agency.

The views expressed are those of the author(s) and not necessarily those of Highways Agency.

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Technical Referee	Iain Rillie	20/06/2011

Contents

Executive summary

The Highways Agency Supply Chain (HASC) report that an increase in sign sizes is believed to have been introduced in the 2006 revisions to the Traffic Signs Manual: Chapter 8. The HASC indicated that the impact of this change on road worker safety was an increase in risk exposure and personal injury accidents as a result of the change in sign sizes and requested the HA investigate this issue.

Investigation of this issue showed that the signs did indeed increase significantly in size, but that the sizes of temporary signs was increased in the 2002 reprint of the Traffic Signs Manual: Chapter 8 and not in the 2006 revision as suggested by the HASC. Irrespective of when the change was made, it is accepted that the sizes of some of the signs identified is larger than is practicable and this has been demonstrated via ergonomic review of the issues associated with handling larger signs.

Although there is no specific evidence of a change in the accident risk or road user collision rate associated with the change in sign sizes in 2002 or the revisions to Chapter 8 in 2006, it is likely that the sizes of some of the temporary signs examined in this work can be reduced without compromising sign readability. In order to test this, sign reading times were measured using a computer simulation system that had been developed to evaluate VMS reading times for the HA's managed motorways programme.

From these data, it has been possible to calculate the recommended 'x-height' or absolute sign heights for the signs identified by the HA Supply Chain as presenting issues. These calculations show that three key signs could reduce in size in certain circumstances:

The diagram 7202 wicket sign could be reduced from 1575mm height to 1125mm height on three lane dual carriageways and the offside of four lane carriageways, a reduction in size of 29%

The diagram 7001.3 sign could be reduced from 200mm x-height (for the word "SLOW" off which the other words are scaled) to 150mm x-height when used on three lane dual carriageways, a reduction in size of 25%

The diagram 7306 sign could be reduced from an x-height of 200mm to 150mm on three lane carriageways or 175mm on four or five lane carriageways, assuming that works traffic approaching the works access is travelling at approximately 50mph at the point where the works access sign must be read

Calculations indicate the diagram 7301 sign should remain at the current x-height of 100mm and that four other informational signs have an 'x-height' that is insufficient for drivers to read the entirety of the sign information when travelling at the national speed limit. It is recommended that these signs should be redesigned to reduce the number of words on each sign, thus reducing the reading time and associated x-height.

1 Introduction

One of the highest risk activities for traffic management operatives is their exposure to live traffic. This is particularly of concern for operatives required to cross the live carriageway to the central reserve when setting out offside signs.

The Highways Agency Supply Chain (HASC) report that the increase in sign sizes believed to have been introduced in the 2006 revisions to the Traffic Signs Manual: Chapter 8 (the latest edition of which is available from the Stationary Office (TSO) (Department for Transport, 2009) is a safety issue. This is because some signs of the sizes specified in Chapter 8 must be carried across the carriageway by two operatives (thus doubling risk exposure), as well as requiring additional crossings of the carriageway to take additional ballast weights to stabilise the sign when deployed. In addition to this risk exposure issue associated with crossing the carriageway, the significantly increased sign sizes carry a risk of manual handling injury due to the additional weight and ergonomic issues associated with these signs.

The HASC has indicated that the sign sizes specified in Chapter 8 are impractical for use under real-world conditions and have requested a review of sign size. However, it is important that a balanced approach to risk is taken that weighs road worker risk against road user risk; this will ensure that the needs of one group are not favoured at the expense of any other.

1.1 Aims and objectives

The aim of this project was to develop an independent safety argument that would review the evidence for and against change to the current temporary traffic management sign sizes. This included examining the issue from both the road user and road worker safety viewpoints and providing a considered argument for change / no change to temporary traffic management sign sizes.

The main objectives of the project were therefore to:

- Review the current safety argument for sign sizes, through assessment of road worker and road user safety issues claimed or demonstrably associated with using signs as specified in Chapter 8
- Determine the key parameters associated with sign size from both road user and road worker safety perspectives
- Determine an optimum practicable sign size, based on the key parameters identified within the safety argument
- Provide a data-led and evidenced safety argument for recommended sign sizes for inclusion in the Traffic Signs Manual: Chapter 8

The project was conducted in two phases. The first phase of the project was designed to gather evidence on the scale and scope of the issues and included:

- Road user accident data analysis
- Road worker accident data analysis
- Ergonomic & manual handling review

The second phase built on the evidence base to develop the safety argument and included:

- Identification of the key parameter values for safety argument
- Development of the optimum practicable sign size

This report presents the results from the two project phases and presents the safety argument in support of sign sizes for future temporary traffic management signing.

2 Background information

This section presents background information relating to how the size of traffic signs is defined and research into how appropriate sign sizes should be calculated to ensure road users can see, read and understand them.

2.1 Defining sign sizes

The Traffic Signs Manual, Chapter 7 – The Design of Traffic Signs (Department for Transport, 2003), Section 2, specifies rules on the sizes of symbols used on traffic signs. In the context of alphabetical signs, it explains that:

> "The size of an alphabet is specified in terms of its *x-height*. This is the height of the lower case letter "x" ... The unit of measurement when designing a sign is the *stroke width* (sw) which is one quarter of the x-height and is not necessarily equivalent to the width of any given character."

Thus, within the Traffic Signs Regulations and General Directions 2002 (Department for Transport, 2002), signs are defined in terms of the x-height. A key exception to this is where a sign contains only a pictogram, such as in the case of the diagram 7202 "wicket" sign where the sign is defined in terms of the height of the sign plate rather than a x-height value.

2.2 Calculating appropriate sign sizes

The design of traffic signs is an established field of research and so a literature review was carried out to identify any relevant research relating to how the heights of symbols on traffic signs should be calculated and how this relates to the height of letters on alphanumeric signs.

The original research on sign letter height for alphanumeric signs was carried out in the US in the 1930s (Forbes and Holmes, 1939). Much work has been carried out since then on the ability to distinguish alphabetical and numerical symbols on road signs (or 'legibility of alphanumeric road signs' as this is often referred to). For example Jacobs and Cole (1978) calculated the relationship between the time necessary to read a sign, T, and the number of words on the sign, N, as:

$$T = 0.32\,N - 0.21$$

Clearly when driving, the time available for a driver to read a sign will be affected by factors such as the driver's vehicle speed and the height of the legend on the sign itself, which are factored in separately when defining sign sizes.

The initial literature search found nothing directly related to the current specifications for symbols on temporary signs, but a number of papers relating to the subject more generally were discovered incidentally by following references cited in other sources.

For example, Schieber (1998) discusses the relative distances at which symbols and textual signs are legible. The paper presents a mathematical approach to refining the design of symbols on traffic signs, and confirms that bold, simple symbols are more legible than complex symbols with fine detail. The elusivity of rules and guidelines for optimising legibility were commented on and the 'recursive-blur technique' described; this technique appears to be relevant to work aimed at identifying appropriate symbol sizes. Work on this technique appears to continue to the present day, for example McCall and Schieber (2010).

Work by Inclusive Mobility (Department for Transport, 2005), Section 10, contains guidance to ensure that signs can be used by people with disabilities, with Section 10.1.2 covering the size of symbols in particular. This refers to research by Transvision for Transport Canada which relates viewing distance to symbol size. Table 1 overleaf is reproduced from this publication.

Proctor and Kim-Phong (2005), and Chapter 13 – Road Warnings with Traffic Control Devices in particular, explains that:

> "*Legibility distance is the distance from which the driver can read or discern the contents of a [Traffic Control Device] in order to have time to take the necessary action. Drivers must have time to see, understand and respond to the warning. This time is a function of the vehicle speed and vehicle type (e.g. large trucks require greater distances to stop). Legibility of sign messages is often a problem because of [amongst other things] visual complexity of symbols.*"

Table 1. Viewing Distance and Symbol Size (Source: Transvision, obtained via the Department for Transport, 2005)

Viewing distance	Symbol size
3-6m	40mm
6-9m	60mm
9-12m	80mm
12-15m	100mm
15-18m	120mm
18-24m	160mm
24-30m	200mm
30-36m	240mm
36-48m	320mm
48-60m	400mm
60-72m	480mm
72-90m	600mm

Proctor and Kim-Phong (2005) continues:

> "*Several studies have reported greater legibility distances for symbol signs than for word signs. In an experiment by Dewar and Ellis (1974) [for example] symbol warning signs could be identified, on average, 48% farther than word signs.*"

The Proctor and Kim-Phong definition of legibility distance is different from the one generally used in the UK, which is not concerned with how long a driver needs to respond after reading and understanding the sign (this is dealt with separately). The table of viewing distance / size is simplistic, as the symbol size needed for a given viewing distance must also depend upon the complexity of the symbol. As other researchers have pointed out, for a given size a bold, simple shape will be more legible than a complex shape with fine detail that has to be discriminated.

Castro and Horberry (2004) also considered the design of traffic signs and issues such as visibility and conspicuity. The legibility distance is identified as a key factor in determining a sign's design, this being the maximum distance at which the smallest detail is to be seen. Applying 'minimum angle of resolution' data for the human eye, Castro and Horberry calculate that, for 90% of people with normal vision, the legibility distance is 3,500 times the stroke width (a definition of which is included above), though that this will vary for younger and older people.

Castro and Horberry quote research from the 1980s on legend legibility which suggests a legibility distance of 600mm for every 1mm of letter height. For around 45 years, the UK has used 6 metres per centimetre, or 50 feet per inch, which is the same. This was based on TRL research in the early 1960's. In other ways the UK would again seem to be ahead of the game: Castro and Horberry remark that dark letters on a light background are less legible on illuminated signs because the light regions overwhelm the legend owing to irradiation. The UK has overcome this since 1964 by prescribing a heavier alphabet (Transport Heavy) for dark letters on a light background, and the lighter Transport Medium for light letters on a dark background.

Castro and Horberry explain that Paniati notes that legibility was best for 'bold symbols of simple design', and that the mean legibility distance of symbol sizes was about double that of worded signs, but does not specify the relative sizes of symbols and legend. If the symbol were only the same height as a letter, the legibility would be expected to be rather worse than for a letter, not twice as good. An interesting point, however, is that the legibility distance of Transport Alphabet was slightly greater in daylight than at night.

McDougall, Tyrer and Folkard (2006) reports on a study that considered the effects of time-of-day, visual complexity, and grouping, on visual searching skills. The authors note that the visual search for icons (including symbols or signs) is an integral part of tasks involving computer or radar displays, head-up displays in aircraft, or attending to road traffic signs. The results showed that the speed with which participants searched icon arrays for a target was slower early in the afternoon, when icons were visually complex, and when information features in icons were not grouped together to form a single object. Participants responded much more quickly to single object icons in comparison to multifeature icons. The authors discuss theories of attention that account for both feature-based and object-based searches. They conclude by offering suggestions for practical implementation of these findings in icon design.

Cooper, Freeman and Mitchell (2004) investigated both the legibility and comprehension of text messages and of pictograms. Dynamic trials established the comprehension of text messages and pictograms seen by drivers travelling at motorway speeds. Static trials investigated the legibility of text messages and pictograms. The results of these trials were used to establish the size of the MS4 display panel and text messages proposed for the on-road trial. A clear conclusion was that (for light-emitting VMS) reading times were significantly longer at night; this is the reverse of the position with conventional signs.

Gale and Schieber (1998) explain that both the logic underlying the recursive blur technique for optimising the legibility of symbol signs and the computer algorithms for implementing the technique are based upon 2-dimensional (2D) Fourier analysis. The use of 2D-Fourier analysis for the description of complex spatial structures (such as highway signs) is introduced. This framework is extended to show how 2D-Fourier techniques can be used to "filter out" specific structural components from a sign stimulus and how this filtering approach has been employed to engineer highway signs with improved legibility.

The paper by Donald (1995) was developed for those involved in the design and testing of traffic signs and those interested in finding out more about how road traffic signs are designed and tested. It includes a general overview of the history of traffic signing; provides detailed explanations of much of the terminology frequently used in the traffic signing field; examines the methods used by previous researchers to develop and test (evaluate) new regulatory and warning traffic signs; and outlines the methods recommended in the relevant Australian Standards for the design and testing of road traffic signs. The report concludes by listing a number of principles for developing effective signs.

Standards Australia (1992) specifies principles and procedures for determining the need, and the selection, testing and design of graphic symbols which may be: (a) placed on equipment or parts of equipment to instruct or advise people handling the equipment as to its use and operation; (b) used in locations where people may work, assemble or move, to give them information or instructions, such as prohibitions, warnings, rules, limits, or directional guidance; or (c) used in pictorial representations on maps, plans, drawings, illustrations and similar documents. It also specifies principles and procedures for the design and use of information and safety signs using these symbols.

2.3 Summary

Whilst no work to determine symbol heights on signs previously was identified, more recent work on the subject has been found incidentally. It may be appropriate to conduct a more comprehensive literature review on the subject so as to ensure that any trial on identifying appropriate symbol heights follows best practice in this field. For example, Schieber's work on the recursive-blur technique seems to have changed the way that experiments in this field should be designed, and both Proctor and Kim-Phong, and Castro and Horberry appear to bring together many relevant results in this field.

3 Road user accident data analysis

Injury accidents on the road which are reported to and by the police are recorded in the national Stats19 database. The database includes data about the circumstances of the accident, the vehicles and casualties involved and any contributory factors.

The accident details include whether road works were present at the accident site, and whether temporary road layout was a contributory factor (2005 onwards only).

The change to sign specifications that the Highways Agency Supply Chain (HASC) claimed was introduced in 2006 may have resulted in a change in road user safety visible in the accident data.

Table 2 shows the number of injury accidents reported in each year that occurred at road works and those where temporary road layout was a contributory factor.

Table 2. Reported injury accidents on the HA network occurring at road works or with temporary road layout as a contributory factor (2005-09)

Accidents…		2002	2003	2004	2005	2006	2007	2008	2009
…at road works	No.	629	529	545	560	555	561	544	460
	%	3.9%	3.4%	3.4%	3.7%	3.8%	4.0%	4.3%	3.9%
…with temporary road layout as a contributory factor	No.	-	-	-	150	113	125	111	117
	%	-	-	-	1.2%	0.9%	1.0%	1.0%	1.1%

Accidents at road works and temporary road layout are two different variables and an accident may have none, one or other or both. Contributory factor data only available from 2005. Contributory factor data limited to those accidents attended by the police.

This gives the number of accidents at road works sites or those where road works was a contributory factor in each year. However, this cannot be used to determine any change in road user safety associated with the change to the sign specification for the following reasons:

- Nationally, there has been a reduction in the number of accidents each year; this background trend would need to be accounted for in any analysis.
- The number, length of carriageway, length of time installed and amount of traffic at road works sites in each of the years is not known; this will have an impact on the number of accidents which occurred at road works.
- Accidents linked with the advance road work signing or advance wicket signs may not be coded as having road works present as the signs are in advance of the road works.
- Most of the changes to the signs appeared in the 2002 reprint of Chapter 8, but seem to have gone unrecognised until 2006. This means that between 2002 and 2006 it is likely that both sign sizes were used.
- Other changes in the way road works are carried out have also occurred over the period, for example, an increasing number of sites using average speed cameras.

Overall, the data are too noisy and the sample sizes too small to reach any robust conclusion that there is or is not any issue. For this reason and the reasons given above, regional analysis was not carried out on the data.

4 Road worker accident data analysis

AIRSweb is the database of reported hazards, near misses and accidents involving road workers engaged in work for the HA. Contractors working on Highways Agency roads must complete these data as a contractual requirement, submitting the reports to the HA's National H&S Team via the AIRSWeb system. Although the majority of incidents – if not all incidents – resulting in a fatality or serious injury will be included there may be additional 'near misses' which are not included in the database. Near misses are less easily defined as they are subjective and have no measurable outcome. Thus it is possible that some near misses which should perhaps have been reported are not included in the database and some not required are collected.

The extracted AIRSweb data covered the period from 1997 up to 15th December 2010 and included details such as:

- Incident date
- Incident description (free text)
- Incident type (e.g. near miss, fatality, major injury, service strike, fire)
- Types of road works present
- Location within the road works
- Timing in relation to road works (e.g. during establishment or removal of road works)
- Speed limit
- Vehicle involvement
- Investigation causes

Since 2006 there has been a large increase in the total reported numbers of incident types and people involved. This increase is likely to be due to changes in reporting levels, at least in part driven by the reinforcement of the contractual condition to report incidents via AIRSWeb. As such, the change in incident numbers may not be because there have been more incidents in later years.

The following criteria were used to estimate the number of injuries, hazards and near misses in relation to temporary traffic management (TTM) signs:

- Investigation Level 4 causation code = 1.1.1.10, which means 'Worker injured lifting or handling materials' AND
- Description included "sign".

This resulted in 47 incidents. The text description for each of these was reviewed and categorised as incidents relating to signs, sandbags, or other. In total there were 10,414 incidents reported in the fourteen year period, and hence these 47 incidents accounted for less than 0.5% of all incidents.

There may be additional incidents in the AIRSweb data which relate to lifting of signs which were not selected using this filter; however, the large total number of records meant that reading through the free text and categorising individual incidents was not possible within the project timescale.

Table 3 shows the number of such occurrences by year. Over half of the incidents occurred within the last two years, but this is likely to be due to changes in reporting levels, especially of near misses and lower severity injuries, and therefore it is not possible to detect any change in risk.

Table 3. Incidents in AIRSweb relating to manual handling of signs by year

Year	Lifting Sandbags	Lifting Signs	Other	Total
2000	0	1	0	1
2001	0	1	0	1
2002	2	2	1	5
2003	0	1	2	3
2004	0	1	1	2
2005	0	0	1	1
2006	0	1	1	2
2007	0	1	1	2
2008	0	3	1	4
2009	1	7	3	11
2010	2	12	1	15
Total	5	30	12	47

The number of incidents by injury type is shown in Table 4.

Table 4. Incidents in AIRSweb relating to manual handling of signs by injury type

Injury type	Sub type	Lifting Sandbags	Lifting Signs	Other	Total
Injury Incident	Major Injury	0	2	2	4
	Lost Time > 3 days	3	8	7	18
	Lost Time ≤ 3 days	0	2	0	2
	Injuries - Medical Treatment	0	1	1	2
	Injuries - First Aid	0	2	0	2
	Injuries - Self/Non treatment	2	14	2	18
Near Miss		0	1	0	1
Total		5	30	12	47

Descriptions of these categories are taken from the Health and Safety Executive (2011)

There were no fatalities associated with these incidents. The most common incident types were 'lost time more than three days' and 'injuries requiring no or self-treatment', accounting for 18 incidents each. There were 4 incidents classed as 'major injury'.

In addition, of the 47 incidents:

- None involved a vehicle
- 38 were reported as being in a public place (i.e. on a road rather than at a given address)

- 6 of the incidents had non-zero entries in the 'location within road works' field; 3 were 'in or alongside the works area', 2 were 'upstream of the works' and 1 was 'within the taper'.
- 9 of the incidents had non-zero entries in the 'timing in relation to road works' field; 4 occurred when 'the scheme was fully in place and not being changed', 3 were 'during setting out' and 2 were 'during modification'.

The 'location within road works' and 'timing in relation to road works' fields had many zero entries and are likely not to have been completed correctly.

The detail recorded in the text description of the incident was variable, and did not include what type of sign was involved in an incident. It is not known whether the use of a smaller sign would have prevented or reduced the severity of each incident.

The two incidents involving major injury and signs were described as follows:

- Traffic Management operative was picking up a standard traffic sign frame from the verge [to put it] onto the back of a wagon. The frame slipped and fell onto the operative's left arm. 3 days later after visiting hospital he was informed he had a fractured left wrist and would be in plaster for 2 weeks. Operative returned to work to undertake light duties.
- Operative was unloading 'A-frames' from traffic management vehicle when sign securing strap detached. The 'A-frame' fell forwards, operative attempted to catch it.

4.1 Causation code analysis

The causation codes within AIRSWeb data use a hierarchical system which may be best explained by the use of an example. Taking the causation code 2.2.1.4, for example:

- The Level 1 code is 2., which means 'Direct Cause'.
- The Level 2 code is 2.2., which means 'Direct Cause' > 'Unsafe conditions'
- The Level 3 code is 2.2.1., which means 'Direct Cause' > 'Unsafe conditions' > 'Workplace Hazards'
- The Level 4 code is 2.2.1.4., which means 'Direct Cause' > 'Unsafe conditions' > 'Workplace Hazards' > 'Slippery surfaces'

Note that each incident can have multiple causes.

For the most common causes, reported for four or more incidents, the Level 3 causes were:

- 1.1.1* Circumstance: circumstance: circumstance
- 2.1.1 Direct cause: unsafe acts: individual behaviour / attitude
- 3.1.2 Indirect cause: people factors: mental capabilities
- 4.2.2 Root cause: Program / system aspects: risk evaluation

* 1.1.1.x where x is not 10 (1.1.1.10 was present in all 47 incidents)

Table 5 and Table 6 show the investigation causes of the incidents at Levels 3 and 4 respectively.

Table 5. Investigation causes (Level 3) of incidents relating to manual handling of signs

Level 3 Cause	Description	Lifting Sandbags	Lifting Signs	Other	Total
1.1.1.10 only	(Worker injured lifting or handling materials only)	4	20	5	29
2.1.1.	Individual behaviour/attitude	1	6	3	10
1.1.1.*	Circumstance	1	4	3	8
2.1.2.	Tools or equipment use	0	4	0	4
3.1.2.	Mental capabilities	0	3	1	4
4.2.2.	Risk evaluation	0	3	1	4
2.1.3.	Procedures implementation	0	3	0	3
2.2.3.	Tools and equipment condition	0	1	0	1
2.2.5.	Weather conditions	0	1	0	1
3.2.2.	Project level execution	0	1	0	1
4.1.1.	Resource management	0	1	0	1
4.1.2.	Leadership	0	1	0	1
Total		5	32	10	47

* 1.1.1.x where x is not 10 (1.1.1.10 was present in all 47 incidents)

Table 6. Investigation causes (Level 4) of incidents relating to manual handling of signs

Level 4 Cause	Description	Lifting Sandbags	Lifting Signs	Other	Total
1.1.1.10 only	(Worker injured lifting or handling materials only)	4	20	5	29
2.1.1.1	Poor decision making or lack of judgement	0	2	2	4
3.1.2.3	Poor judgement	0	3	1	4
4.2.2.1	Inadequate job safety/hazard analysis	0	3	1	4
2.1.1.4	Inattention or distraction (i.e. footing, surroundings, external sources, etc.)	1	2	0	3
1.1.1.2	Worker hit by falling object or construction equipment	1	1	1	3
2.1.1.3	Improper lifting	0	2	1	3
2.1.3.2	Safety Standards/ Procedures/ Guidelines not followed	0	2	0	2
2.1.2.6	Loss of control of tool or equipment	0	2	0	2
1.1.1.1	Worker injured while using mechanical equipment or hand tool	0	2	0	2
2.2.3.5	Maintenance of tool or equipment inadequate	0	1	0	1
4.1.1.3	Shortage of resources to perform the task safely	0	1	0	1
1.1.1.14	Worker tripped over object or equipment	0	0	1	1
1.1.1.40	Unintentional dropping of any load - manual	0	1	0	1
2.1.1.9	Taking unsafe position (line of fire)	1	0	0	1
1.1.1.16	Worker fell from construction vehicle or structure	0	0	1	1
2.2.5.2	Abnormal wind conditions	0	1	0	1
2.1.2.8	Improper use or failure to use proper PPE	0	1	0	1
3.2.2.2	Inadequate job placement (wrong worker assigned to the job)	0	1	0	1
1.1.1.18	Worker injured by chemicals, gas or other materials	0	0	1	1
4.1.2.7	Failure to follow recommendations of HSE personnel	0	1	0	1
2.1.3.4	Improper loading of materials or equipment	0	1	0	1
2.2.3.3	Improperly prepared tool or equipment	0	1	0	1
2.1.2.2	Improper placement of tool or equipment	0	1	0	1
Total		5	30	12	47

4.2 Summary

Analysis of the information within AIRSWeb was somewhat confounded by the major changes in reporting levels seen within the data. This rendered it impossible to identify any trends or step changes in reporting levels within the data.

The total number of cases within AIRSWeb identified as involving temporary signs was 47 out of a total sample of 10,414. This represented less than 0.5% of all incidents reported.

Examination of the data from causation factors was inconclusive as the sample size was too small to draw sound conclusions. In many cases, there was only one incident or accident assigned each causation code which made further analysis impossible.

5 The Evolution and Development of Temporary Lane Closure (Wicket) Signs

Signs to warn of a temporary lane closure are commonly referred to as "wicket" signs due to the arrangement of symbols on the sign resembling a set of cricket stumps. The current type of sign is an evolution of the first design for these signs which was developed in 1975.

This section of the report charts the development of the temporary lane closure "wicket" sign and examines the changes in sign design and size that have been introduced during the sign's evolution.

5.1 Origin of the "wicket" sign

Signs to warn of lanes closed ahead were first prescribed in the Traffic Signs Regulations and General Directions (TSRGD) 1975. (See the Department for Transport (2002) for the latest edition. This is referred to hereafter simply as 'TSRGD'.) These comprised black vertical arrows to indicate open lanes, and short black vertical bars surmounted by horizontal red bars to indicate closed lanes. These were placed on a white background in a red triangle, and prescribed as diagrams 564.2 (two lanes), 564.3 (three lanes) and 564.4 (four lanes), the latter two of which are shown in Figure 1. The more lanes shown, the shorter the arrows had to be in order to fit within the triangular space, thus lowering the legibility of the sign.

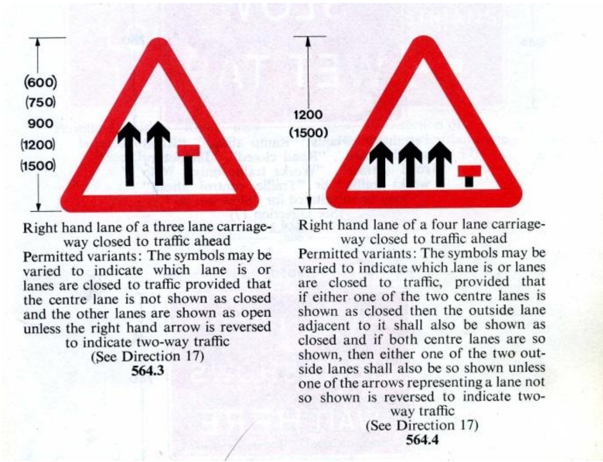
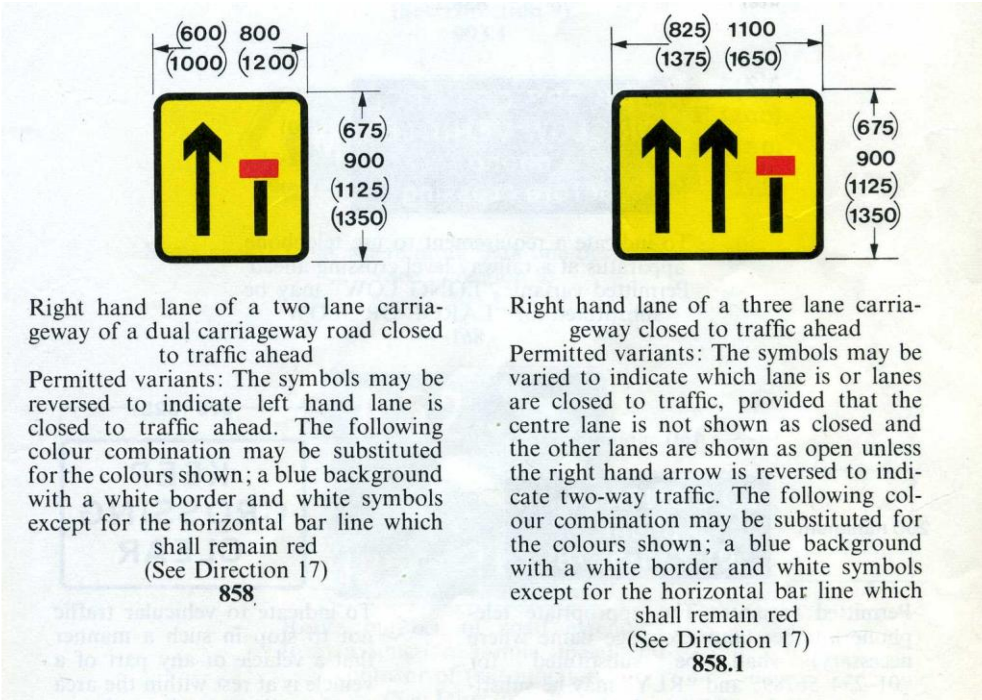


Figure 1. The TSRGD 1975 designs of signs to warn of a lane closure ahead

These signs were dropped in the 1981 Regulations, and replaced by wicket signs similar (but not identical) to the current design, prescribed as diagrams 858 (two lanes), 858.1 (three lanes) and 858.2 (four lanes)(the former two of which are shown in Figure 2 in sizes 675, 900, 1125 and 1350mm high.

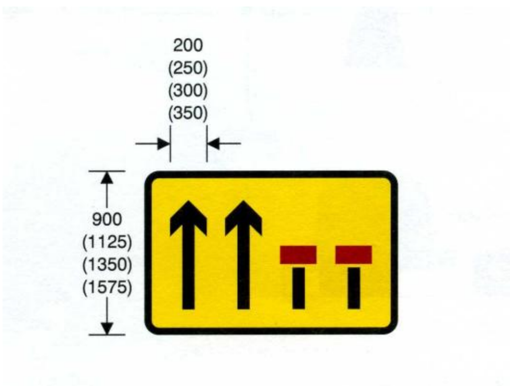


Right hand lane of a two lane carriageway of a dual carriageway road closed to traffic ahead
Permitted variants: The symbols may be reversed to indicate left hand lane is closed to traffic ahead. The following colour combination may be substituted for the colours shown; a blue background with a white border and white symbols except for the horizontal bar line which shall remain red
(See Direction 17)
858

Right hand lane of a three lane carriageway closed to traffic ahead
Permitted variants: The symbols may be varied to indicate which lane is or lanes are closed to traffic, provided that the centre lane is not shown as closed and the other lanes are shown as open unless the right hand arrow is reversed to indicate two-way traffic. The following colour combination may be substituted for the colours shown; a blue background with a white border and white symbols except for the horizontal bar line which shall remain red
(See Direction 17)
858.1

Figure 2. The 1981 designs of signs to warn of a lane closure ahead

Although, for a given size, this new design was much more legible than the previous designs, especially where more than two lanes were indicated, it was still difficult in poor ambient lighting conditions to distinguish between open and closed lanes. The design was therefore modified in the 1994 Regulations to shorten the vertical bar indicating the closed lanes to make the difference easier to detect at a distance. A new diagram number was allocated, 7202, as shown in Figure 3, with permitted variants to allow the number of lanes shown to be varied as appropriate. The previous designs were revoked, and existing signs could continue to be used only so long as they remained where they were when the new Regulations came into force on 12 August 1994. They could not lawfully be subsequently re-used at a different site, but had to be replaced with the new design. The prescribed sizes for diagram 7202 did not include the previous 675mm high version, but did include the 900, 1125 and 1350 sizes, as well as a new 1575mm version.



7202
Right hand two lanes of a four lane dual carriageway closed to traffic ahead

Figure 3. The TSRGD 1994 and TSRGD 2002 design of sign to warn of lane closures ahead

The version of TSRGD published in 2002 (Department for Transport, 2002) made no further changes to the 1994 design. This remains the current version.

5.2 Wicket sign sizes in Chapter 8 1991 edition

The correct use of these signs is not dealt with in the Regulations, but in the Traffic Signs Manual (TSM). Within the TSM, road works signing is covered in Chapter 8. This is referred to hereafter simply as 'Chapter 8'.) A new edition of Chapter 8 was published in 1991; this had relatively little to say about application of the wicket sign (the current version at that time being diagrams 858, 858.1 and 858.2), although the two and three-lane variants were included in the layouts illustrated in Volume 2. However, Volume 1 did indicate which sizes were to be used in which road scenarios. The recommended sizes were set out in Table B in Chapter 8, but, somewhat confusingly, were referred to by reference to the size of warning or regulatory sign set out in the accompanying Table A for the same road scenarios.

Matters were further complicated by the fact that only four sizes were shown in Table A: 600, 750, 1200 and 1500mm. The 900mm size was mentioned only in Note 3 to the table, which said that it should be used as a repeater where the initial sign was 1200 or 1500mm. It is not clear from Tables A and B whether wicket signs downstream of the initial sign were to be treated as simply repeaters, which could therefore be smaller, or not (the distance plates would of course be different each time). However, no evidence has been found to support the hypothesis that downstream signs have ever been treated as repeaters.

Table B recommended sizes for the wicket sign as follows:

- 675 where 600 used for warning/regulatory signs
- 900 where 750 or 900[1] used for warning/regulatory signs
- 1125 where 1200 used for warning or regulatory signs
- 1300[2] (sic) where 1500 used for warning or regulatory signs

The result of the above is that wicket signs were to be sized as follows:

- 675: all-purpose single carriageway roads restricted to 30mph
- 900: other all-purpose single carriageway roads and all-purpose dual carriageway roads without hard shoulders restricted to 40mph
- 1125: all-purpose dual carriageway roads without hard shoulders and unrestricted
- 1300: all-purpose dual carriageway roads with hard shoulders and motorways

When TSRGD 1994 came into force on 12 August 1994, diagrams 858 etc. were revoked and replaced by diagram 7202 (see Figure 3 above). It is not clear how long it took contractors to respond to the change in the Regulations. Chapter 8 would not be updated to recognise the changes for a further eight years.

TA61/94: The Currency of the Traffic Signs Manual (Highways Agency, 1994) did list in Annex B a variety of minor amendments to Chapter 8, but said nothing about any change in the design or sizes of the wicket sign. It is therefore probable that the old sizes (and perhaps the older, inferior design) continued to be used until at least 2002, when a revised edition of Chapter 8 was published. It may be that it was recognised that the smallest size, 675mm, had been withdrawn, and the 900 size substituted, but in any case this was used only on 30mph single carriageway roads.

[1] As explained above, no 900mm size was listed for warning or regulatory signs in Table A, except implicitly for repeater signs.

[2] In point of fact, the prescribed size was 1350mm, not 1300mm.

5.3 Wicket sign sizes in Chapter 8 2002 edition

In June 2002, Chapter 8 was reprinted with a number of significant amendments. (This is the first reprint available; these changes might have appeared in an earlier reprint, but copies are unavailable from the archives.) This included a revision to Table B in respect of the sizes of wicket sign (now diagram 7202). The road scenarios were unchanged. The earlier and the new sizes are set out Table 7.

Table 7. Comparison of Sizes Prescribed in Table B of the 1991 and 2002 Editions of Chapter 8

Category	1991 size	2002 size
All-purpose single carriageway roads restricted to 30mph	675	900
Other all-purpose single carriageway, and all-purpose dual carriageway without hard shoulders restricted to 40mph	900	1125
All-purpose dual carriageway without hard shoulders and unrestricted	1125	1575
All-purpose dual carriageway with hard shoulders, and motorways	1300[3] (sic)	1575

Two points are immediately striking. The first is that there was indeed a very considerable increase in the sizes of signs required. The second is that, although the 1350 size is listed, this was for use only where a warning or regulatory sign in Table A would have been 900mm – and as has been explained above, this size is not used in Table A except for repeater signs. The consequence of this is that there was in fact nowhere that the 1350 size could have been used in practice for the initial signs in the sequence. Nor is there anything to indicate that this size was intended to be used for subsequent (i.e. "repeater") signs when the initial sign was 1575mm.

This is believed to have been an oversight: in constructing the table, it appears that no-one noticed that the 900mm warning/triangular sign slot was not used for initial signs in any of the road scenarios on which the tables are based. This resulted in a huge increase, from 1125 to 1575mm, in the case of unrestricted dual carriageway roads without hard shoulders.

The change from 675 to 900mm on single carriageway roads subject to a 30mph speed limit was necessitated by the revocation of the old 675 size in TSRGD 1994. It is not known why all the intermediate sizes were also increased, or whether this was on the basis of an assessment of driver needs. The latter seems unlikely given the disproportionate increase in the size of the 1125mm sign.

5.4 Wicket sign sizes in Chapter 8 2006 edition

2006 saw the publication of a completely revised edition of Chapter 8. This provided much more comprehensive guidance on the use of diagram 7202 than had previously been available. The new table of sizes, Table A1.2, refined the road scenarios slightly, and sought to rationalise the recommended sizes. The 1350mm size was now to be used:

- on all-purpose single carriageway roads subject to a speed limit of 50mph or more

[3] In point of fact, the prescribed size was 1350, not 1300mm.

- on dual carriageway roads:
    - with no hard shoulder subject to a 50mph limit or
    - with hard shoulders and subject to a 50 or 60mph limit

(The last of these was previously not covered, except that it was 1575mm where the national speed limit applied.)

In certain circumstances, therefore, the 1575mm size formerly recommended was reduced to 1350mm. The sizes for other scenarios remained unchanged, except that where the 1575mm size would normally be used, a 1350mm version could be used on the central reservation.

5.5 Wicket sign sizes in Chapter 8 2009 edition

In the most recent version of Chapter 8 (Department for Transport, 2009), there was again some refinement of the road scenarios, but this did not materially affect the sizes of signs required, except that the use of the wicket sign on single carriageway roads was discontinued entirely. It is not clear how lane reductions are to be signed on those few single carriageway roads that have three lanes in each direction. It was made clear that the speeds referred to in the various scenarios were the permanent speed limit on the road.

5.6 Summary

The basic claim being made by the HA Supply Chain is that there was a significant increase in the size of wicket signs as a result of the 2006 version of Chapter 8. In fact, most of the changes appeared in the 2002 reprint of the 1991 edition, but seem to have gone unrecognised until 2006. Nevertheless, it is true that there has been a major increase in sign size since 1991.

The situation has been simplified slightly by the 2009 version of Chapter 8, in that wicket signs are now used in only three sizes, and their use has been discontinued on all single carriageway roads. However, it is not clear why most of the increases in sign size introduced in the 2002 reprint of Chapter 8 were thought necessary.

6 HA Supply Chain concerns over sign sizes

6.1 Sizes of prescribed signs stated by the HA Supply Chain

The HA Supply Chain (HASC) has identified six signs which it claims are excessively large. The purpose of this Section of the report is to check the sizes stated to ensure that they are correct, and to explore ways of achieving smaller sign sizes. Sign dimensions (whether x-height[4] or absolute) are given in millimetres as per the DfT Working Drawings. Where sizes have been corrected from those indicated by the Supply Chain, the corrected figures are shown in red.

6.1.1 "Wicket" Sign - Diagram 7202

Four sizes are prescribed: 900, 1125, 1350 and 1575mm high, with arrow heads of width 200, 250, 300 and 350mm respectively, as shown in Figure 3.

Table 8. Dimensions for Diagram 7202

Sign height	HASC cited width		Prescribed width	
	Four lane	Three lane	Four lane	Three lane
1575	2415	1890	2415	1890
1350	2070	1620	2070	1620
1125	1802	1410	*1725*	*1350*

Claimed widths are correct for the 1575 and 1350 signs, but slightly too large for the 1125 version. It appears that the width of the latter has been calculated on the basis of a height of 1175 instead of the prescribed height of 1125mm.

6.1.2 Diagram 7001.3

The prescribed x-height is 100 minimum, 250 maximum.

Table 9. Dimensions for Diagram 7001.3

x-height	HASC cited size	Prescribed size
200	3000 x 1800	*3030* x *1820*
100	1500 x 910	*1515* x 910

Claimed sizes are slightly smaller than prescribed for the 200mm x-height sign, and the width is slightly smaller (but the height correct) for the 100mm x-height version.

[4] The x- height is defined as the height of the lower case "x" in millimetres.

6.1.3 *Diagram 7306*

The prescribed x-height is 100 minimum, 250 maximum.

Table 10. Dimensions for Diagram 7306

x-height	HASC cited size	Prescribed size
200	3500 x 2200	3500 x 2200

The claimed sizes are correct.

6.1.4 *Diagram 7301*

Only one size is prescribed, 1050 wide by 750 high.

Table 11. Dimensions for Diagram 7301

x-height	HASC cited size	Prescribed size
750	1193 x 750	*1050* x 750

The claimed width is wrong; it is prescribed as 1050, and cannot be 1193. It is not clear how this error arose. Although the HASC asserts that the difference in x-height of the two signs "does not seem logical", each sign has a different purpose and includes different amounts of information, thus different x-heights might be justifiable. The point can only be settled by analysis of the required reading time for each sign.

6.1.5 *Diagram 7002A*

The prescribed x-height is 75 minimum, 250 maximum.

Table 12. Dimensions for Diagram 7002A

x-height	HASC cited size	Prescribed size
200	4250 x 2225	*4280* x 2225

The claimed width is slightly less than the prescribed width. However, a different approach can be taken with the layout of this sign face – see Section 6.2.1.

6.1.6 *Diagram 7003.1*

The prescribed x-height is 100 minimum, 250 maximum.

Table 13. Dimensions for Diagram 7003.1

x-height	HASC cited size	Prescribed size
200	4250 x 3550	4250 x 3550

The HASC sizes are correct, but there is too much information included on the sign; see Section 6.2.2.

6.2 Possible solutions

The dimensions cited by HASC are not always correct, but the discrepancies are relatively minor. Thus the differences between the sizes cited and the prescribed size make no significant difference to the issue that many signs are too large to be easily handled or sometimes even accommodated within the available space.

There are two possible approaches to the problem. The second approach is described briefly on page 28, but the first and easiest is to make better use of the flexibility provided in the Regulations. This allows variation of the sign layout in order to achieve the most efficient layout, or splitting of the information provided onto more than one sign. Examples are given below, followed by discussion of the more comprehensive approach.

6.2.1 Diagram 7002A

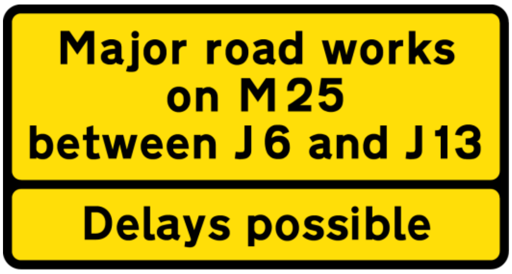


Figure 4. Current Version of Diagram 7002A

The designer might not have appreciated that this sign, shown in Figure 4, can be laid out in different ways to achieve a more economical design. This will obviously depend upon the precise legend to be accommodated. In this particular example, a narrower sign could be achieved by adopting the alternative illustrated on the working drawing, i.e. Major road works / on M25 between / Junctions 6 and 13 as per Figure 5.

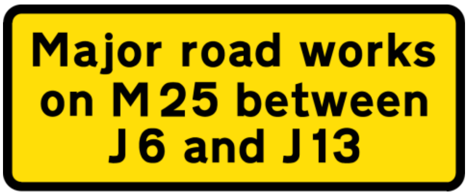


Figure 5. Recommended Revised Version of Diagram 7002A

The sign size then becomes 4000 x 2225 instead of 4280 x 2225mm. Although this would not actually make a significant difference to the overall size, it does suggest that road works sign designers may be unaware of the flexibility of layout which is prescribed in the Regulations and often illustrated on the working drawings.

6.2.2 Diagram 7003.1

Figure 6. Current Version of Diagram 7003.1

Where such a large sign, as shown in Figure 6, cannot be accommodated in the available space, one solution is to use one of the prescribed variants which enable some information to be omitted. The Highways Agency header could be omitted, reducing the height of the sign by 19.5 stroke widths, or 975mm at the specified x-height of 200mm.

The road works triangle and "Delays possible" legend may also be omitted; if all these options were adopted, the width of sign needed to accommodate the remaining legend reduces to 2670mm, and the height to 1950mm (compared to 4250 x 3550).

The road works warning triangle and "Delays possible" message would then be conveyed on a separate sign to diagram 7005. At the same 200mm x-height, the width of this would be 3450mm, and the height 2325mm.

An alternative to 7003.1 (4250 x 3550, area 15.09m^2) would therefore be 7003.1v (2670 x 1950, area 5.21m^2) plus 7005 (3450 x 2325, area 8.02m^2), as shown in Figure 7. The x-height would be the same, the total area of the two separate signs only 13.23m^2 instead of 15.09m^2, the maximum width 3.45m instead of 4.25m. The only loss of information is the HA header panel.

Figure 7. Recommended Replacements for Diagram 7003.1: 7003.1 and 7005

It is a point of note that whilst Chapter 8 specifies the use of diagram 7003.1, and considerable detail is given to how and when the sign should be used, no reference is made to the alternatives above, which are given in TSRGD.

Although better design, and the splitting of information onto more than one sign, might ameliorate some of the problems of sign size, as described earlier there is a second, more fundamental approach, to address the issue. This would be to return to first principles and establish what size these signs need to be in order to be legible to drivers and provide the necessary reading time.

It may be that at least some of them could be smaller than currently recommended in Chapter 8, and still be fit for purpose (see Section 7 regarding sign size optimisation for discussion of this more fundamental approach).

6.3 Recommendations

6.3.1 Wicket signs (diagram 7202)

It does seem probable that the old sizes recommended in the 1991 Chapter 8, at least those for use on dual carriageway roads and motorways, continued in use until at least 2002, after which they would gradually have been replaced by the larger sizes. However, the possibility that the 1575mm size prescribed in 1994 might sometimes have been used on motorways cannot be ruled out on present evidence. Moreover, the HASC has acknowledged that "*many traffic management providers use signs of reduced size … so that they can be carried and will fit in the verge and central reserve*". It is therefore doubtful that any evidence relating to sign effectiveness for the period 1991 – 2002 could confidently be assumed to relate to the same population of wicket signs. In 2006, sizes changed again, as described in Section 5.4, so data for the later period would also have to be excluded.

There were also many changes on the road network over this period, not only in traffic flows but also in speed limit enforcement techniques, further confounding any robust analysis. It is suggested that it would be better to go back to first principles and consider instead what size wicket signs actually need to be to ensure that they are adequately legible in the various scenarios in which they are used.

This requires establishing two measures:

- The time a driver needs to correctly assess which lanes are open and which closed, measured from the point where the sign first becomes legible
- The legibility distance of a sign of a given size, i.e. at what distance a driver can distinguish which lanes are open and which are closed, and how this compares with the legibility of the distance plate (diagram 7208)

Data for the first of these has been derived from computer simulation and is reported in Section 9. Given these data, it would be a straightforward matter to determine what size of sign is needed in each of the three basic road scenarios covered in the 2009 edition of Chapter 8. This could then be compared with the legibility distance of the distance displayed in the lower plate to determine which is critical.

6.3.2 Worded signs (diagrams 7001, 7001.3, 7002A, 7003.1, 7306 etc.)

For worded message signs, existing research should provide sufficient information. Australian researchers Jacobs and Cole looked at the reading time needed to assimilate worded messages (Jacobs and Cole, 1978).

Once reading time is known, the required legibility distance of worded signs, and hence the x-height, can be calculated and compared with current advice in Chapter 8. The necessary sign size, taking account of traffic speed and lateral sign offset, could then be determined.

As a hypothetical example, if the reading time needed for a sign were two seconds, and the sign were sited on a length of road where the speed limit was 50mph at the point from where the sign was to be viewed, the distance travelled by a driver whilst reading the sign would be 44m. If the lateral offset of the sign were, for example, 10m from the most disadvantaged lane, the cut-off distance would be 57m (10 cot 10 degrees), and the required reading distance 101m (44 + 57). In the case of wicket signs, the size of arrow, and therefore the size of sign, could then be determined from the legibility/arrow size plot from the field trial to determine the correct size of sign. In the case of worded signs, the sign size would be determined from the usual rule of thumb that x-height in millimetres is legibility distance in metres divided by 0.6, i.e. in this example 101/0.6 = 168mm. In practice, the x-height would be rounded to the nearest prescribed size.

It is also interesting that Chapter 8 does not take into account the prevailing speed limit at the time that the driver is attempting to read the sign, only the permanent limit for the road (see Section 5.5). In those road works where temporary speed limits apply, allowing for this would sometimes enable a smaller sign to be used, a consideration that should be explored further.

6.4 Conclusion

It would be a worthwhile exercise to establish what size arrows and legend height are actually necessary in the various road scenarios, in the hope that this will lead to reductions in current sizes. Recommended sizes could also be based on the temporary rather than the permanent speed limit. However, it should be borne in mind that there is no guarantee that the outcome will be a general reduction in sign size. There is the possibility that it will turn out that the existing sizes are generally appropriate, because this procedure may have been followed when the current sizes were recommended, but at least it will be known whether or not the current sizes are correct.

In the event that a sign size change was to be indicated, the outcome could require a move away from the current approach of a single recommended sign size within Chapter 8. This should consider the prevailing speed limits in the road works and the carriageway width as these have a critical impact on the legibility of the signs. Adopting such an approach would necessitate either a revision to Chapter 8 or, if considered acceptable, a change of sign size requirements enabled via an Interim Advice Note issued by the HA. This would require a process of stakeholder consultation via a Technical Project Board (or equivalent) to gain support for the change in sign size and/or approach to the recommendation of sign sizes for use at road works.

The key to identifying such future requirements are the evidence of safety and manual handling issues and the calculated size of signs required at road works. The remainder of this report seeks to identify whether a change in sign size is recommended, based on an analysis of reading times for "wicket" signs and calculation of required sign sizes (with appropriate safety margins to ensure road user safety).

7 Sign Size Optimisation

7.1 Size optimisation as opposed to sign re-design

It has been suggested that one way to reduce sign size would be to re-design the current signs but there are several difficulties with this approach. Any change in design would require amendment of the Traffic Signs Regulations and General Directions to prescribe the new signs. This would inevitably be a time-consuming exercise, and require substantial administrative input from the Department for Transport centrally and from Legal Branch. Given their already limited resources, likely to be further reduced this year, it is unlikely that they would be able to give priority to such an amendment. This might easily take well over twelve months to implement, even after any revised sign had been settled.

Additionally, no details are available of the form the proposed changes might take. It is essential that any new designs be at least equally legible and comprehensible as the current versions; it would not be easy to achieve this in a reduced space. In the case of the wicket sign, if the new design would still require each lane to be separately indicated by an arrow or lane-closed symbol, there seems little scope for saving. Placing the arrows closer together would be likely to reduce legibility, and would require testing to ensure that this was not compromised. The design and testing process would take a considerable amount of time, and would be expensive.

The size-optimisation approach recommended in this report has several advantages over the re-design approach:

- It would not require any change to the Regulations, and could be implemented quickly by a simple instruction from the Highways Agency (perhaps a Chief Highway Engineer's memorandum).
- By returning to first principles and assessing what size a sign needs to be in order to be legible at the appropriate distance – an exercise that does not appear to have been carried out previously for road works signs – there is a much greater prospect of achieving significant reductions in the sizes employed in the various scenarios.
- By avoiding re-design and the consequent re-evaluation of the new designs, it will be considerably cheaper as well as quicker to implement.

A major reason why certain signs are so large is that there is simply too much information on them, or, to a lesser extent, that the sign face is not laid out as efficiently as it might have been. For example, the Regulations permit diagram 7003.1 to be varied substantially and the information split onto two much smaller signs as described previously. The scope for this is explored in more detail below.

7.2 Variation of wicket sign lateral offset with number of lanes

The greater the lateral offset of a sign from a driver's line of approach, the greater the cut-off distance (the point in advance of the sign where drivers have to stop reading the sign and return their attention to the road ahead). Where the cut-off distance is greater, drivers have to start reading the sign earlier in order to complete the reading task before passing the cut-off point. This will often require the sign to be larger.

The offsets for the six cases (for the most disadvantaged lane in each case) are summarised in Table 14 below. W is the width of the sign, and will depend not only upon the sign offset but also upon the required reading time, still to be established. The calculations and assumptions made are set out in Appendix D.

Table 14. Sign offsets for the most disadvantaged lanes on three, four and five lane motorways

	Sign offset (m)	
	Hard shoulder	**Central reserve**
D3	6.125 + W/2	6.075 + W/2
D4	9.775 + W/2	6.075 + W/2
D5	9.775 + W/2	9.725 + W/2

The difference in offset between the best case (hard shoulder sign on a D3 motorway) and the worst case (central reserve sign on a D5 motorway) is 3.6m, increasing the cut-off distance by 22.6m and the required x-height by 34mm. The actual sizes required cannot be determined, of course, until the required reading time for the sign has been established.

7.3 Use of smaller signs where mandatory speed limit in force or signs are non safety-critical

The required size of the legend on a sign is critically dependent upon the approach speed of a driver trying to read the sign. The faster the speed, the greater the distance travelled during the reading process, and the earlier reading must start in order to be completed in the time available. Normal practice with fixed permanent signs is to design on the basis of 85^{th} percentile speeds. This can of course result in reduced sign sizes where prevailing traffic speeds are below the speed limit. Use of 85^{th} percentile speeds is impracticable in the case of temporary signs. Although Chapter 8 (Table A1.2) indicates that the permanent speed limit of the road should be the basis for selecting sign size (making no allowance for any lower speed imposed through the works) there are arguments for using the temporary limit instead, where one applies, especially for non safety-critical signs. This will usually be more realistic, and will generally result in signs being smaller. This would be appropriate, of course, only where the temporary limit applied over the whole of the approach within the legibility distance of the sign.

As an example, if the reading time were two seconds, the distance covered during the reading process at 50mph would be 44m, whereas at 70mph it would be 62m. The 18m difference would require an x-height increase of 30mm, equivalent to a one-step size increase in the case of the road works ahead informatory sign to diagram 7002A, if this was situated in an area subject to a temporary road works limit of 50mph.

The reason for using the permanent speed limit is presumably concern that a significant proportion of drivers might be disobeying the temporary limit, and might not have time to read the signs at the higher speed. However, in the case of non safety-critical signs, this would hardly seem to justify the use of very large signs for the benefit of speeding drivers. However, no analysis has been carried out at this stage to identify specific signs which would normally be sited within the area of a temporary limit, and an examination needs to be made of the Chapter 8 layout drawings in order to do this.

An alternative method for reducing the size of diagram 7003.1 is to take advantage of the permitted variants in TSRGD that allow information to be omitted altogether, or split onto two separate signs. This has been discussed in detail in Section 6. The Highways Agency header can be omitted, reducing the sign height by almost a metre at the x-height specified in Chapter 8 (200mm). The road works triangle and "Delays possible" legend may also be omitted; together with omission of the header, this would reduce the overall width of the sign from 4250 to 2670mm, and the height from 3550 to 1950mm. Moreover, the reduction in the quantity of information displayed would reduce the reading time, and be likely to allow a smaller x-height to be used, yielding a further reduction in size.

The road works triangle and "Delays possible" message would then be conveyed on a separately located sign to diagram 7005. At the same 200mm x-height, the width of this would be 3450 and the height 2325mm. However, the reduced sign content would again reduce reading time and might allow a reduction in x-height also, giving further savings. The only overall loss of information by splitting the signs in this way is the HA's header panel, which it might not wish to lose.

There is also sometimes scope for reducing sign size by more efficient layout of the sign face, as discussed in Section 6. Diagram 7002A could be reduced in width by 280mm if the flexibility permitted by the working drawings were exploited.

7.4 Recommendation

- HA should consider whether road works signs should be sized according to the prevailing speed limit instead of the permanent limit.
- If the HA is willing to forgo the Highways Agency header on diagram 7003.1, the remaining information should be split onto a permitted variant of diagram 7003.1 supplemented by a separate sign to diagram 7005.
- Road works sign designers should familiarise themselves with the Department for Transport's working drawings for road works signs, and take advantage of opportunities to lay out sign faces as efficiently as possible whilst still respecting the design rules.

8 Ergonomic and Manual Handling Review

This Section documents an assessment of the ergonomic and manual handling issues relating to the use of roadside signs, focussing primarily on signs used to provide drivers with advance warning of lane closures (Diagram 7202 in the Traffic Signs Regulations and General Directions 2002, commonly referred to as 'wicket' signs). The assessment is based on an observational study of sign deployment, carried out in a controlled environment, intended to provide a representation of the physical actions required to carry out a sign deployment on the Highways Agency (HA) network.

8.1 Method

During the demonstrations of sign deployment the operatives were recorded using a video camera. This video was used to generate still images of body postures, together representative of each core element of the overall deployment task. These postures were analysed using the REBA (Rapid Entire Body Assessment) tool to quantify the potential risk of musculoskeletal injury associated with the actions required to deploy the different sign materials. These findings were then used to evaluate any potential benefits to changing current sign materials or deployment practices.

8.1.1 Trial setup

The observational study was conducted incorporating the previously recommended wicket sign (diagram 7202) as a focal point, along with a number of other traffic management signs for comparative purposes. The decision was taken that this observation could not be undertaken in real-world deployment conditions for safety reasons; therefore the study was conducted in a controlled environment which was as representative as possible. Two researchers from TRL undertook a site visit to a Temporary Traffic Management (TTM) depot during which a series of typical sign deployment activities were demonstrated by depot staff. Two traffic management operatives (TMOs) took part in the demonstrations, each one having experience of carrying out these activities on the HA network. All the demonstrations were carried out in the site yard using equipment that was regularly used for traffic management activities.

8.1.2 Trial procedure

A Traffic Management (TM) vehicle was initially loaded with the materials required for the demonstrations, including:

- Steel sign-mount A-frames (approximately 16kg each)
- Sandbags for stabilising the frame (mass around 10-15kg depending on fill level)
- A four-lane 'rigid' wicket sign (approximately 16kg)
- A four-lane horizontally folding 'split' wicket sign (approximately 16kg)
- A selection of smaller works access related signs

The two TMOs were told the purpose of the study and that the intention was to observe them carrying out activities in as realistic a way as possible. The procedure was:

A. Setting out

1. Unload the frame from the TM vehicle
2. Carry the frame a short distance (roughly 10m, representing a typical carriageway crossing) away from the vehicle
3. Establish the A-frame (including sandbags)
4. Unload a sign from the vehicle

5. Carry the sign to the frame
6. Establish the sign on the frame

B. Clearing away

7. Dismantle the sign from the frame
8. Carry the sign back and load onto the vehicle

   (Repeat stages 4 to 8 for each sign)

9. Dismantle the A-frame
10. Carry the frame back and load again on the vehicle

Five key activities were therefore observed for the A-frame and for each sign:

- Unloading
- Carrying
- Establishing
- Dismantling
- Loading

The full procedure above was completed twice, with each run being filmed from a different angle (approximately as shown in Figure 8) to capture accurately the relative trunk, neck and limb positions of the TMOs.

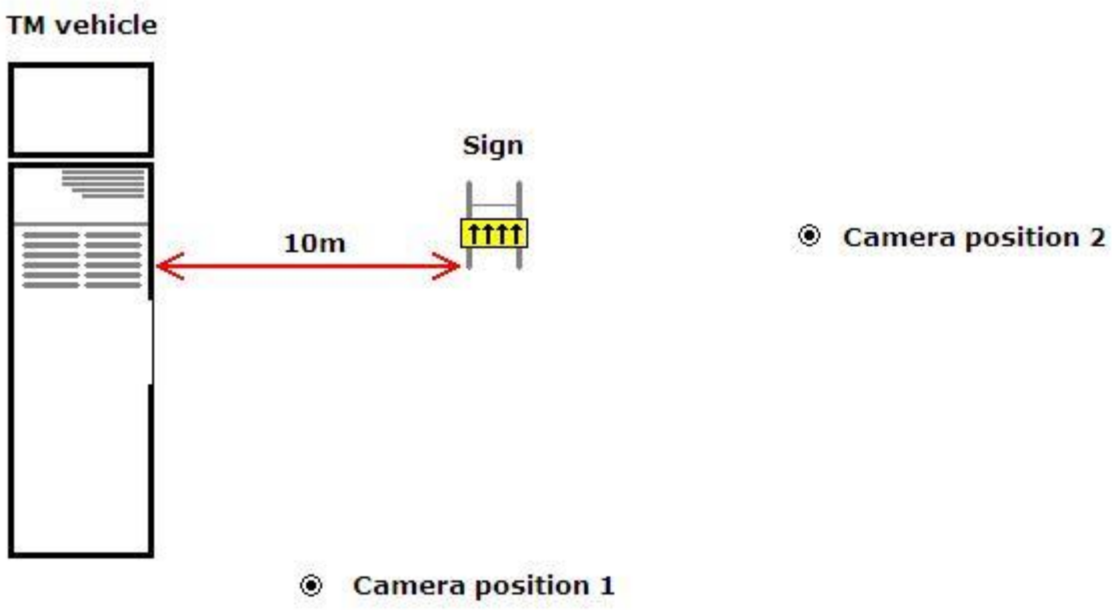


Figure 8. Relative positioning of items within the trial environment

8.1.3 Data analysis

Following the site visit the video was reviewed and key postures identified - chosen to be representative of the main stresses placed on the body during the task. These postures typically represent the most extreme body position required in order to complete each activity (i.e. unloading, carrying, establishing, dismantling and loading) although for some activities more than one posture was selected, either because there were clearly different movements within an activity or because multiple ways of conducting an activity were observed. Thirty postures in total were selected for analysis, as shown in

Table 15. The postures chosen include those relating to the two 4-lane wicket signs plus those relating to the handling of the mounting frame. As the frame is the same regardless of the sign being used, its inclusion in the postural analysis is partly for completeness and partly to provide context, showing the difficulty of the task as a whole as well as for the sign-specific parts. Postures associated with the handling of a 'works traffic only' sign are also included as an example of a smaller sign against which to compare the wicket signs.

Each posture was subjected to review using the REBA coding tool. This is a widely-used and accepted method for coding postures according to:

- the relative positioning of different component parts of the body and
- a broad categorisation of the actions being performed, including:
    - how much load or force is being supported
    - how this load is applied and
    - how good the hand-holds are on the object being interacted with.

The scoring system works by combining scores for individual body parts to give an overall score for the posture. This score is initially out of 12 with an additional three points available depending on:

- whether or not the posture is held static for long periods
- the involvement of repetitive movements, or
- whether the action causes large range changes in posture or an unstable base.

Thus the lowest possible score is one, the maximum 15. A low score implies a low risk and vice versa. There is no defined threshold over which a score is considered to be unacceptable; rather the aim is to change the task where possible to make the individual scores as low as practicable. The highest scores indicate the task elements that should be tackled as a priority.

The coding was carried out by one researcher. For quality purposes, a random subset was coded independently by another researcher to check for consistency in the application of the coding scheme. Only slight differences were seen in a small number of coding categories, which indicates that the overall scoring was consistent. The final scores are presented in Table 15.

8.2 Results and Discussion

8.2.1 Overview

Table 15. The postures analysed and their corresponding REBA scores

Component	Activity	Posture ID	Description	REBA Score
Frame	Unloading	FU1	standing on TM vehicle, lowering frame down	7
		FU2	standing on ground, receiving frame	4
	Carrying	FC1	carrying frame on its side	8
		FC2	carrying frame upright	5
		FC3	lifting frame after dismantling	4
	Erecting	FE1	placing sand bar	4
		FE2	opening a-frame	2
	Dismantling	FD	pulling frame closed	4
	Loading	FL1	loading, raising frame off ground	9
		FL2	passing frame to partner on TM vehicle	8
		FL3	carrying frame on TM vehicle bed	7
		FL4	rotating frame on TM vehicle	8
Rigid wicket sign	Unloading	RU	pulling sign off TM vehicle bed	9
	Carrying	RC	carrying	10
	Erecting	RE1	positioning sign holes over pins	8
		RE2	standing on sand bar to close pins	9
	Dismantling	RD	pulling sign off pins	9
	Loading	RL	putting sign back on TM vehicle bed	10
Split wicket sign	Unloading	SU	pulling sign off TM vehicle bed	8
	Carrying	SC	carrying	8
	Erecting	SE1	positioning sign holes over pins	10
		SE2	flipping up top section	9
		SE3	Standing on bar to close pins	9
	Dismantling	SD	pulling sign off pins	9
	Loading	SL	putting sign back on TM vehicle bed	10
'Works traffic only' sign	Unloading	WU	pulling sign off TM vehicle bed	4
	Carrying	WC	carrying	2
	Erecting	WE	positioning sign holes over pins	5
	Dismantling	WD	pulling sign off pins	5
	Loading	WL	putting sign back on TM vehicle bed	4

The postural coding yielded a wide range of risk scores, ranging from 2 to 10. As stated previously, there is no defined threshold above which a posture is considered unacceptable. However, the scores of 8, 9 or 10 are relatively high and the activities associated with these scores should be tackled with the highest priority.

The rigid wicket sign and the split wicket sign scored reasonably similarly, with scores consistently between eight and ten. Activities associated with the frame generally obtained lower scores, which ranged from two to nine. The 'works traffic only sign' scored the lowest of all four components, with scores ranging from two to five, and compared particularly favourably against the two wicket signs. This is unsurprising given that it is both smaller and lighter than the wicket signs, though the size of the difference is notable: the increased size and weight of the wicket signs caused the operatives to modify their posture significantly.

8.2.2 Interpreting the postural scores

Whilst efforts were taken to ensure that the postures observed during the trial were coded reliably and consistently, this can only be related within the trial. It cannot be guaranteed that the postures seen during the trial provide an accurate representation of the postures typically seen amongst road workers in the real world. This is partly because other individuals may use different techniques and partly because there may be additional factors associated with real-world deployment that modify the workers' behaviours, however subtle these factors may be. For example, time pressures, distractions and adverse weather conditions may influence how the activities are performed. These factors are likely to make the task more difficult and so it might be expected that postures would become more extreme. For these reasons the scores calculated from the trial may be towards the lower end of those that might occur in the real world.

In addition, different individuals may use different techniques that may result in "better" or "worse" postures than those observed in the trial (according to the REBA scoring scale). Initially this was not thought to be an issue as it was anticipated that operatives would generally find the easiest way to carry out their activities and that reasonably standardised techniques would emerge. Whilst this may be the case, comments received after the trial suggested that the two TMOs who participated in the trial may not have been particularly familiar with the signs being deployed and that more practised individuals might adopt different techniques. The ergonomist conducting the assessment believes that the following three actions are examples of where the coded postures and techniques could be improved upon:

- Placing the signs on the frame pins
- Removing the signs from the frame pins and
- Loading the signs back on the TM vehicle.

It is possible, therefore, that other TMOs could adopt postures that would receive lower scores. Where these actions are mentioned in later sections, therefore, it should be considered that the corresponding REBA scores may exaggerate the risk slightly, and possible improvements to the techniques adopted are discussed.

There were several variations in the techniques observed in relation to the smaller signs, which is likely to be a reflection of the greater ease with which such signs can be handled. The posture that scored lowest during the observations was used as higher scoring postures are likely to be due to the personal choice of the operatives rather than requirements of the tasks themselves.

8.2.3 The effect of sign size

In the trial, larger signs were clearly more awkward to handle than the smaller ones: the TMOs appeared to be more unsteady on their feet and took longer to complete each activity. Figure 9 shows TMOs carrying the rigid wicket sign and the smaller 'works traffic only' signs on the left and right respectively.

Figure 9. TMO carrying rigid wicket sign (left) and 'works traffic only' sign (right)

The wicket sign is clearly more awkward both in terms of its shape and weight: the TMO is observed using his head to support the weight of the sign, leaning back to bring the load close to his centre of gravity, and twisting his body to the left. All of these actions increase the REBA risk score. With the 'works traffic only' sign, the TMO is clearly more comfortable with the task, choosing to hold the sign at the top rather than at the sides, which would have made gripping the sign easier.

Although the wicket signs are approximately 16kg, the forces exerted could be substantially higher:

- due to the need to compensate for wind and
- because forces are not applied in line with the centre of gravity, resulting in lever effects.

As described above, REBA attributes additional points based on force/loading on the operator, with one point added for loads of 5-10kg and two points added for loads greater than 10kg. This means that the REBA score will not increase further if the effective loading is more than 16kg, but the greater the load, the greater the potential difficulty for the TMO in carrying out the task.

It is likely that if it the TMO had been observed carrying the largest size of sign, the posture seen would have been an exaggerated version of that seen with the rigid wicket sign - which already scores relatively highly - as the TMO would need to support a greater weight and the greater size of the sign would make it even harder to keep the centre of gravity of the sign close to the body. Gusts of wind could become difficult to deal with due to the increased surface area of the sign behaving like a sail.

8.2.4 Rigid versus split signs

The rigid and split signs scored similarly on most of the activities. Despite slight differences, it may initially appear as though there is very little to differentiate between them in terms of which would be regarded as being the more attractive option to use.

However, there are additional factors that suggest that the split sign may be the favourable one.

Firstly, as mentioned above, it appeared that the activity of placing the sign over the pins on the frame was not carried out in the most efficient manner possible during the demonstration, perhaps because the TMOs were not used to using that particular sign. The method observed involved semi-opening the sign first, which resulted in the TMOs holding the top half up awkwardly whilst attempting to line up the lower half with the pins. It was this that contributed to the higher score for this activity compared to the rigid sign. An alternative technique might be to place the sign on the bottom pins whilst it is still fully folded, then to flip the top half up once this has been achieved. This would negate the need to hold one arm up above shoulder height, which appears to be awkward, and would result in a lower REBA score. If this approach had been adopted, the scores with the two signs would have been very similar, apart from action SE2 (which is unique to the split variant) and those actions which involved carrying the sign (postures RC and SC). However, folding the sign up and securing the upper fasteners is a difficult activity, as the antiluces on which the signs mount can tend to rotate or drop before the sign is in place. This increases the complexity of the task, requiring the operatives to reach up to realign the upper fasteners.

‘Carrying’ is the only activity carried out under specific time constraints and distractions because it needs to be done while crossing a potentially busy road. This makes the carrying phase arguably the most risky activity within the whole procedure. Carrying the split sign was better than carrying the rigid sign, scoring eight rather than ten, even without taking account of the possibility of windy conditions. During the trial there was little wind to contend with, but sign deployment on the HA network could be carried out in far worse conditions. The larger the surface area of the sign, the more likely it is that wind will cause a problem, and the split sign has half the surface area of the rigid as shown in Figure 10.

In summary, the split sign appears to be more favourable for the carrying activity and, given the added significance of this activity, is ergonomically viewed more favourably overall. However, operational difficulties associated with split signs must be considered when reviewing the propensity for sustaining injury associated with this sign type.

Figure 10. TMOs carrying the Rigid (left) and Split (right) wicket signs

8.2.5 Sign availability

It was suggested by some depot staff that were present during the trial that the current sign is not considered practical for use by sign crews and that the majority of sign deployment companies do not use it. This is anecdotal and cannot be verified, and was purely the opinion of some individuals at the trial site. However, the sign is not stocked at that particular depot. This appears to suggest that operatives generally do not consider the larger sign to be practical to use.

8.3 Conclusions

- The split sign variant appeared to be easier to carry than the rigid variant and achieved a lower REBA score. Given that the carrying task involves crossing the carriageway this activity is considered to take on particular significance. For this reason the split sign is considered to be preferable to the rigid sign, although further input from road workers regarding the operational difficulties associated with these signs would be required to verify this.
- The use of the previously recommended (smaller) wicket sign in the trial environment resulted in some REBA scores that are relatively high, despite the trial being carried out in favourable environmental conditions. The TMOs appear to see the task of handling the sign awkward.
- Anecdotally it seems that TMOs regard the currently recommended (larger) wicket sign to be too cumbersome to use.
- It is believed that the larger wicket sign, used under real-world conditions (increased time pressures, tiredness, distractions and wind) could prove to be unwieldy and would represent more risk to operatives than the smaller version.
- It is felt that if the smaller wicket sign can be shown to perform adequately in its task of informing motorists, there is good reason not to require sign operatives to use the larger wicket sign.

9 Assessment of road works wicket sign reading times

The 2002 reprint of Chapter 8 of the Traffic Signs Manual – Traffic Safety Measures and Signs for Road Works and Temporary Situations (the latest edition of which is available from the Stationary Office (TSO) (Department for Transport, 2009) resulted in a step change increase in the size of wicket signs used to warn of lanes closed ahead compared to the original 1991 edition. Isolating the effect of these specific changes in size sign on road safety is challenging as many other changes in the road network have taken place over the same period.

A lane closure wicket sign is a symbolic traffic sign which, by the means of upward pointing black arrows, tells drivers which lane(s) ahead are open to traffic and by a 'wicket' symbol, or symbols, tells drivers which lane(s) ahead are closed. This particular sign - diagram 7202 in The Traffic Signs Regulations and General Directions (Department for Transport, 2002), includes a supplementary distance plate - diagram 7208 – to inform drivers of the distance of the lane closure ahead from the sign.

An example of an offside lane closure at a distance of 800 yards ahead on a 3-lane dual carriageway is shown in Figure 11.

Figure 11. Wickets sign with supplementary distance plate sign showing an offside lane closure at 800 yards ahead

As discussed in Section 2, previous research has established formulae to calculate the reading times of alphanumeric traffic signs. Jacobs and Cole (1978) developed a formula to calculate the reading times of alphanumeric warning signs. Earlier work by Mitchell and Forbes (1942) developed a formula to calculate the reading times of a sign comprising more than three words. However, little research has been undertaken previously to establish methods of finding the reading times of symbolic traffic signs.

For a standard wicket sign, the formula developed by Jacobs and Cole (1978) or by Mitchell and Forbes (1942) can be used to calculate the reading time of the alphanumeric supplementary distance plate sign. However, there are no established methods of determining the reading times of the symbolic wicket sign, or more importantly, the combination of the wicket sign plus distance plate sign.

A computer based simulation study, using a Visualisation and Response Monitoring (VRM) software tool developed by TRL, presented the opportunity to investigate the reading times of wicket signs. The VRM software tool was originally developed and approved by the Highways Agency (HA) for a research project into the safety and effectiveness of Variable Message Signs (VMS) and has been adapted by TRL and approved by the HA for the Managed Motorways project. Successful adaptation of the VRM software tool allowed investigation of the reading times of wicket signs

9.1 Task objectives

The objective of the task reported in this Section was to investigate the required reading times of a lane closure wicket sign plus supplementary distance plate sign.

From this reading time information, the legibility distance required to read correctly all of the information shown on a wicket sign can be calculated for a range of approach speeds and hence calculate the required size of wicket sign.

9.2 Methodology

TRL's Visualisation and Response Monitoring (VRM) computer based software tool was adapted to provide a simple technique for investigating the reading times of road works wicket signs.

9.2.1 Sample size and demographic split

There were 48 participants in the trials, who were allocated into eight groups that were equally split by gender. This sample size was regarded as being sufficiently large to be representative of the driving public and to give a satisfactory level of statistical confidence in the results. It was not possible to split the participants equally with respect to age group.

9.2.2 Visual stimulus

A simulated three-lane dual carriageway scenario in darkness was used as the stimulus material for the trial, with standard three-lane wicket signs positioned in their normal positions on both sides of the carriageway, i.e. towards the back of the hard shoulder and close to the central reserve.

The visual scene was presented so that a driver would be viewing the two wicket signs on opposite sides of the carriageway from the middle lane position. This road scene also contained vehicles which acted as distracters to prevent participants becoming focussed only on detecting the wicket signs.

Two configurations of lane closure wicket sign were used for the trial:

- Lane 1 closure
- Lane 3 closure

For both configurations of lane closure wicket sign, the supplementary distance plate sign was used with one of three alternative distances ahead to the lane closure:

- 500 yards[5]
- 600 yards
- 800 yards

In addition to these wicket sign / distance plate combinations, the symbolic wicket sign minus its distance plate sign was shown on a selection of images to participants to investigate the reading time of the wicket sign on its own.

All of the wicket sign / distance plate combinations shown to trials participants are shown in Figure 12.

[5] The 500 yard distance plate is not a recommended distance for advance warning of static closures specified in Chapter 8 but was included to increase the number of variants of distances and to balance the design of the experiment.

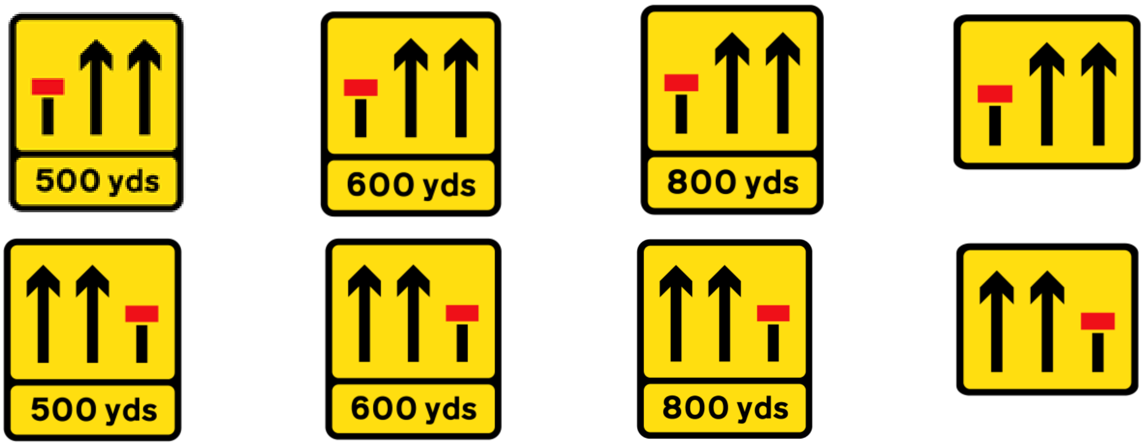


Figure 12. Range of wicket sign combinations shown to trials participants

Eight different exposure times of the images shown to participants were investigated in the pilot trial:

- 0.25s
- 0.5s
- 0.75s
- 1.0s
- 1.25s
- 1.5s
- 1.75s
- 2.0s

The results of the pilot trial were used to reduce these eight exposure times to four which were used in the main trial:

- 0.25s
- 0.5s
- 0.75s
- 1.75s

The longest exposure time (1.75s) was included to ensure a near 100% accuracy of responses.

The combinations of the different wicket sign / distance plate shown with each of the four different exposure times are listed in Table 16.

Table 16. Wicket sign / distance plate combinations with exposure times

Wicket sign 7202	Supplementary distance plate 7208			Exposure times
Lane 1 closure	500yds	600yds	800yds	0.25s, 0.5s, 0.75s, 1.75s
Lane 3 closure	500yds	600yds	800yds	0.25s, 0.5s, 0.75s, 1.75s
Lane 1 closure		None		0.25s, 0.5s, 0.75s, 1.75s
Lane 3 closure		None		0.25s, 0.5s, 0.75s, 1.75s

9.2.3 *Pre-trial eyesight screening*

Before commencing the trial, each participant was given an eye screening test to ensure they were able to read the text based information shown on the display screen. To achieve this, a 3m Snellen visual acuity chart (designed for assessment of vision) was shown on the display screen used for the trial, with the size of lettering scaled down proportionally. Participants were asked to read the bottom line of letters shown on the Snellen chart. Participants were also asked to wear driving glasses, if they required them for driving, for the trial. As part of the eyesight screening procedure, checks were made that driving glasses were appropriate for participants viewing the display screen at a distance of 1.6m. During the trial, two participants, who normally wear driving glasses, had some difficulty in correctly identifying all of the letters on the Snellen chart when wearing their glasses, but could read the bottom line of the chart correctly without them and chose not to wear them for the trial.

9.2.4 *Trials procedure*

Each participant sat at a distance of approximately 1.6m in front of the display screen. This enabled each image containing the wicket signs to be presented in a realistic geometric location and offset from the central fixation point. In the 'real life' situation, this would equate to viewing 1125mm high wicket signs from a distance of approximately 50m in the middle lane of a three-lane dual carriageway. Each participant first saw a masking screen with a central fixation point '+', as illustrated in Figure 13, to bring their gaze back to the centre of the screen.

Figure 13. Display screen with central fixation point '+'

A set of images of the wicket signs in the context of a three lane dual carriageway road layout were shown to participants over a range of short time intervals. An example of the road scene image containing nearside and offside wickets signs shown to participants is shown in Figure 14.

Figure 14. Example of display screen showing a pair of wicket signs warning drivers of a lane 1 closure ahead at 200 yards

Each image was shown to participants for a specific time interval (varying from 0.25s to 1.75s, as described above) before the grey masking screen returned with a question mark '?' replacing the cross in the centre of the display screen.

With the masking screen in place and the '?' present, participants were asked two specific questions:

- Which lane was closed to traffic?
- What distance from the sign did the closure occur (if applicable)?

After each participant gave their responses verbally to the two specific questions, the masking screen reappeared again displaying the central fixation point to bring the participants gaze back to the centre of the screen. The sequence of images was then repeated with each participant seeing a total of 16 scenarios.

9.3 Results

9.3.1 Lane closure information only

The percentage accuracies of participants' responses for the lane closure wicket signs (not including the distance plates) are given in Table 17 and are shown graphically in Figure 15.

Table 17. Accuracy of responses – lane closure wicket only

Exposure time (s)	Accuracy (%)
0.25	95.3
0.50	100
0.75	99.5
1.75	100

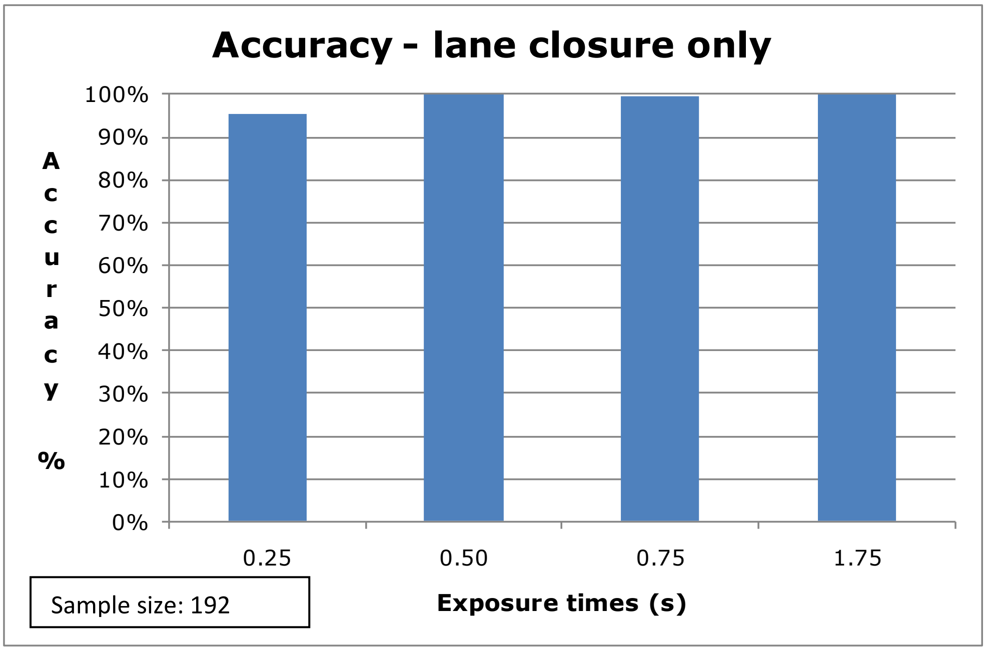


Figure 15. Accuracy of responses – lane closure wicket only

Even for the shortest exposure time (0.25s), participants' responses in recalling the lane closure information shown on a wickets sign had over 95% accuracy. For longer exposure times, more than 99% of all participants correctly recalled the correct lane closure.

9.3.2 Distance information only

For the first stage of the analysis, the distance information (i.e. 500 yards, 600 yards, 800 yards or no distance plate) shown on the supplementary distance plate sign was grouped together and the accuracy of responses was investigated for each exposure time.

For this particular scenario, the percentage accuracies of participants' responses for the supplementary distance plate sign are given in Table 18 and are shown graphically in Figure 16.

Table 18. Accuracy of responses – distance plate information only

Exposure time (s)	Accuracy (%)
0.25	69.3
0.50	92.7
0.75	95.8
1.75	98.4

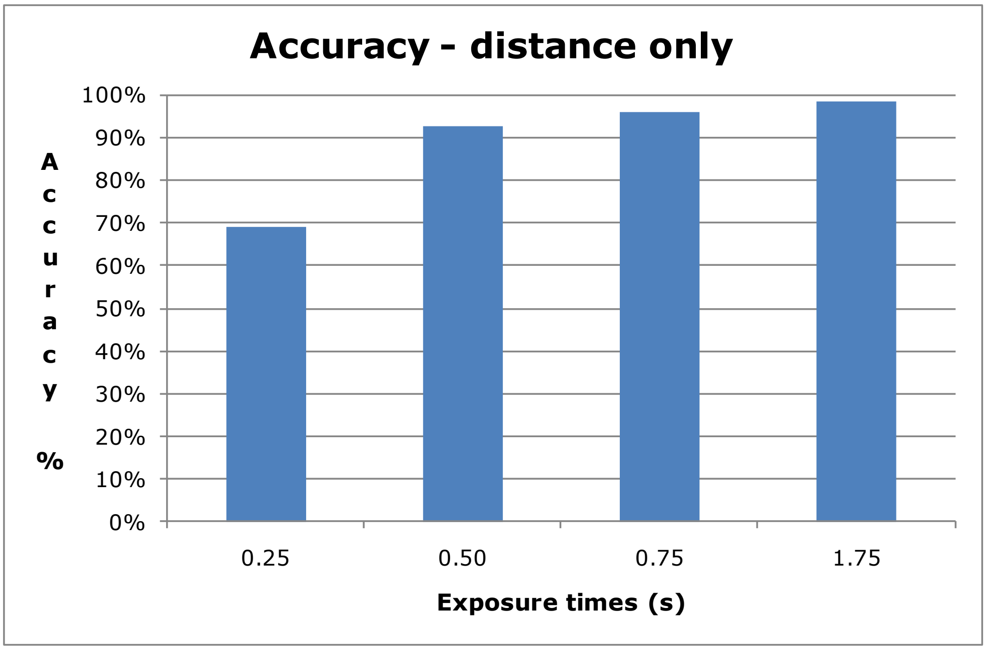


Figure 16. Accuracy of responses – distance plate information only

For the shortest exposure time (0.25s), approximately 70% of participants correctly recalled the distance shown on the supplementary distance plate sign. With each increase in the exposure time, there was an increase in the percentage of correct responses, with the highest accuracy level of 98.4% being associated with the use of the longest exposure time (1.75s).

The second stage of the analysis process split the different distances into separate variables and investigated the accuracy of participants' responses for each of these variables for the four different exposure times. These results are shown graphically in Figure 17, Figure 18, Figure 19 and Figure 20 for the four different exposure times.

Note that on each graph, for the horizontal axis labelling, D500 refers to the 500 yards distance plate, D600 refers to the 600 yards distance plate, etc. NDP refers to the cases where no distance plate was present.

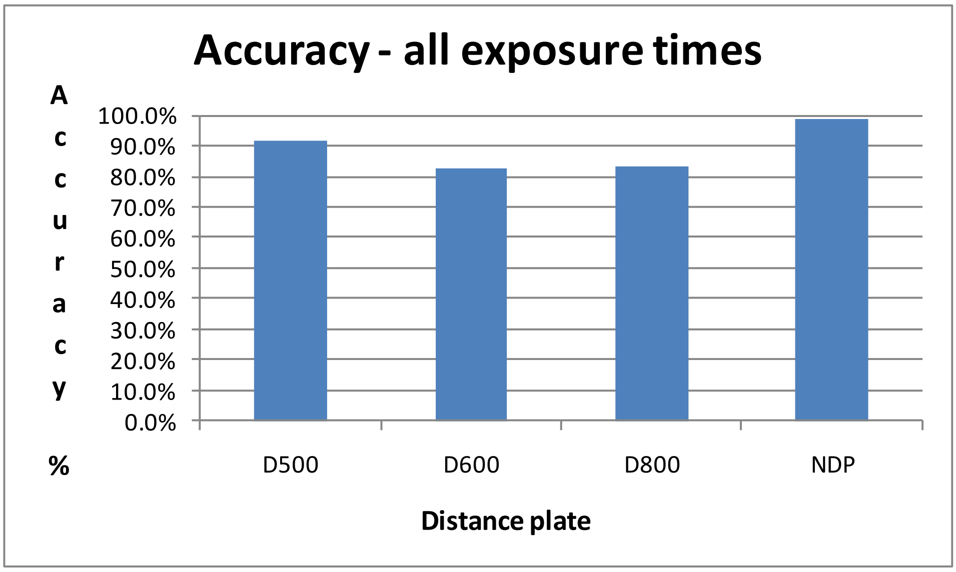


Figure 17. Accuracy of responses: distance plate information – all exposure times

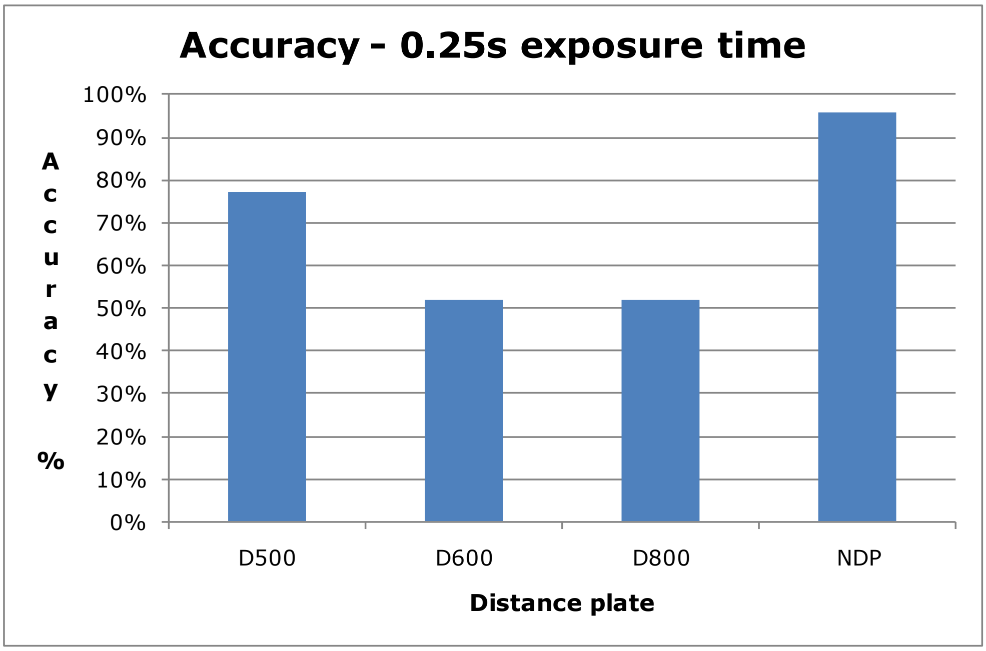


Figure 18. Accuracy of responses: distance plate information – 0.25s exposure time

For the shortest exposure time (0.25s) the accuracy of responses for both the 600 yard and 800 yard distance plate were low – approximately 50% for each category. This may have been due to the similarity in the letter shapes of the '6' and the '8', with some participants finding it difficult to differentiate between these particular numbers when a short exposure time was used. The accuracy of responses for the other numerical distance shown (500 yards) was over 75% and the accuracy of responses for the 'no distance' plate (NDP) was over 95%.

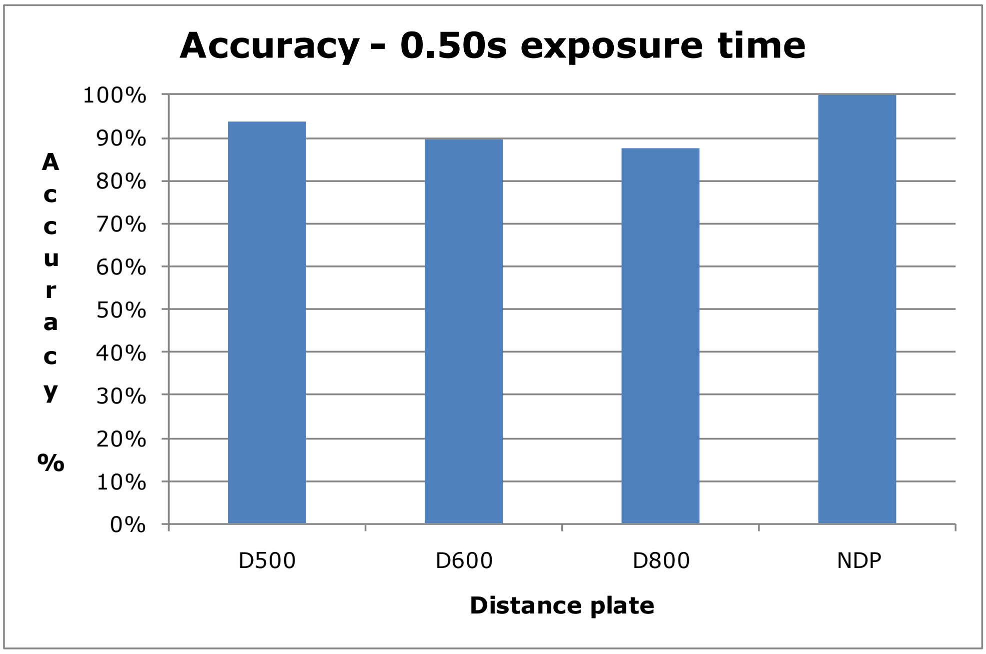


Figure 19. Accuracy of responses: distance plate information – 0.5s exposure time

For a 0.5s exposure time, there was a considerable improvement in the accuracy of responses of both the 600 yard and 800 yard distance plates – over 85% for both signs. There was also an increase in the accuracy of responses for the 500 yards distance to over 90%.

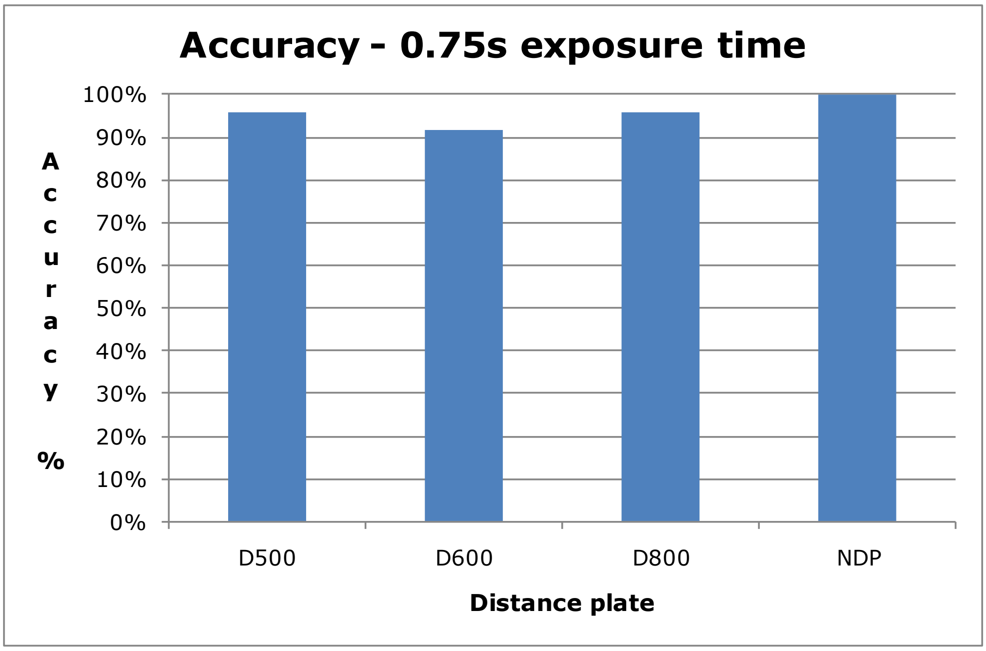


Figure 20. Accuracy of responses: distance plate information – 0.75s exposure time

The accuracy levels of participants' responses were over 90% for each of the distance plate signs shown when the 0.75s exposure time was used, with all being over 95% but for the 600 yards sign.

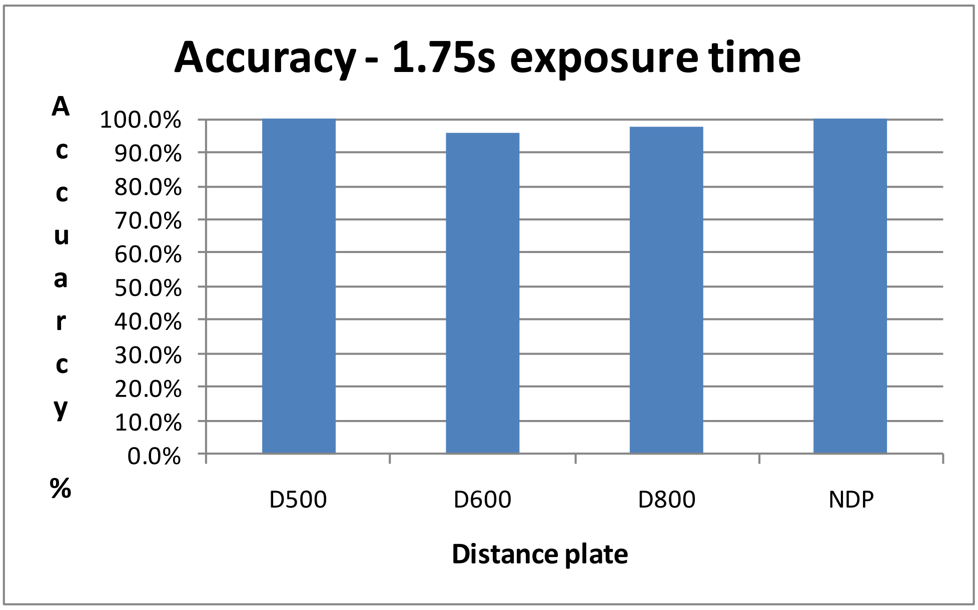


Figure 21. Accuracy of responses: distance plate information – 1.75s exposure time

For the longest exposure time (1.75s) there were very few incorrect responses, with no incorrect responses occurring for either the 500 yards sign or for the absence of the distance plate.

9.3.3 Lane closure plus distance information

The percentage accuracy levels of participants' responses for the combined lane closure wicket and distance plate information are given in Table 19, with the same information presented graphically in Figure 22.

Table 19. Accuracy of responses –lane closure wicket and distance plate information

Exposure time (s)	Accuracy (%)
0.25	68.8
0.50	92.7
0.75	95.3
1.75	98.4

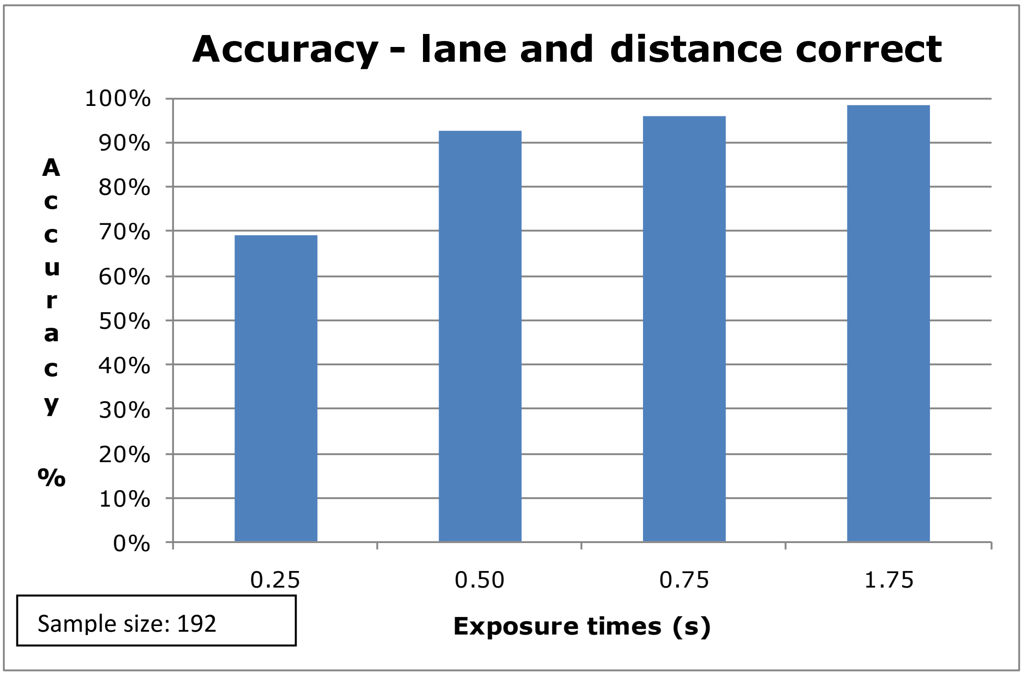


Figure 22. Accuracy of participant's responses – lane closure wicket and distance plate information

The results obtained for the accuracy of recalling both elements of the complete wicket sign, i.e. lane closure and distance information, were almost identical to those results obtained for the distance-only information (see Table 18). The only difference was a slightly lower accuracy (68.8%) for the shortest exposure time (0.25s); the results obtained for the three longer exposure times were identical.

9.3.4 Statistical significance testing

Understanding whether the results from the experimental work were statistically significant was undertaken via the application of statistical modelling. The aim of the modelling procedure was to detect which factors affect the variation in the proportion of participants correctly observing a sign. The procedure modelled a variable which records whether the observation is correct or incorrect, with repeated measurements taken. Therefore a particular statistical procedure, a Generalized Estimating Equations procedure, is used. This is similar to a more common generalised linear model procedure, but allows for correlated observations (such as one participant observing more than one sign).

Variables *lane, distance plate, time* and participant related factors *gender* and *age* were added to the model to assess whether they could explain the variability in the response. The response here is whether the distance and lane were both observed correctly.

The variables which contribute significantly to the chance of observing the distance and lane correctly are *time* ($p<0.01$), *distance* ($p<0.01$) and the covariate *age* ($p<0.05$).

The model is defined as:

$$Prob(p/1-p) = \alpha + \beta_i * distance + \gamma_j * time + \delta * adjusted\ age + \varepsilon \quad (1)$$

where:

- p is the proportion of participants who correctly observed the distance and lane on a sign
- *adjusted age* is calculated as the participant age – mean age of participants in each distance time combination (for modelling purposes),

- α, β_i, γ_j and δ are parameters to be estimated and
- ε is an error term.

Table 20. Parameters of model (1)

Model parameter	Parameter	B	Std. Error	95% Wald Confidence Interval	
				Lower	Upper
α	(Intercept)	6.7	0.75	5.2	8.1
β_1	[Distance=D500]	-1.9	0.62	-3.1	-0.7
β_2	[Distance=D600]	-3.0	0.56	-4.1	-1.9
β_3	[Distance=D800]	-2.9	0.59	-4.1	-1.8
γ_1	[Time=0.25s]	-3.6	0.60	-4.8	-2.4
γ_2	[Time=0.50s]	-1.6	0.66	-2.9	-0.3
γ_3	[Time=0.75s]	-1.2	0.62	-2.4	0.1
δ	Adjusted age	-0.03	0.01	-0.06	-0.01

Time 1000ms and Distance - NDP are reference parameters.

Table 21 shows the estimated model proportions of correct observation for the four different exposure times.

Table 21. Overall modelled proportion of correct observations for different exposure times

Time (ms)	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
250	0.75	0.043	0.67	0.83
500	0.96	0.013	0.93	0.98
750	0.97	0.010	0.95	0.99
1000	0.99	0.005	0.98	1.00

Pair-wise comparisons within the model show that:

- The proportion of participants observing signs for 250ms correctly is significantly lower than all other longer exposure times
- The proportion of participants observing signs for 500ms correctly is significantly lower than exposure time 1000ms, and
- All other combinations are non-significant

Table 22 shows the estimated model proportions of correct observation for the four different distances.

Table 22. Overall modelled proportion of correct observations for different distances

Distance	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
D500	0.96	0.014	0.93	0.99
D600	0.89	0.027	0.84	0.94
D800	0.89	0.026	0.84	0.95
NDP	0.99	0.003	0.99	1.00

Pair-wise comparisons within the model show that

- The proportion of participants observing D500 signs correctly is significantly different to signs with other distances
- The proportions of participants observing D600 and D800 signs correctly are significantly lower than the proportions observing D500 and NDP signs correctly, and
- The proportion of participants observing D500 signs correctly is significantly higher to signs with other distances

9.4 Summary

- The accuracy of recalling lane-closure information only from a wicket sign was over 95% for each of the four exposure times in the range 0.25s to 1.75s
- The accuracy of recalling distance-only information from the supplementary distance plate was over 95% for exposure times equal to or greater than 0.75s
- The accuracy of recalling all of the information shown on a wicket sign, i.e. lane closure and distance to the closure was over 95% for exposures times equal to or greater than 0.75s

9.5 Discussion

For the symbolic lane-closure wicket sign, an accuracy of greater than 95% was achieved for the shortest exposure time (0.25s) with nearly 100% being achieved for all the longer exposure times. This strongly indicates that the 95th percentile reading time of the symbolic element of a wicket sign is less than or equal to 0.25s.

A good estimation of the reading time of the supplementary distance plate could be obtained by calculating the difference in the 95th percentile reading times for the wicket sign / distance plate combination (i.e. 0.75s) and the symbolic wicket sign only (i.e. 0.25s). This would give an estimated reading time for the supplementary distance plate of 0.5s.

For the combined lane closure and distance information, an accuracy of over 95% was achieved for an exposure time of 0.75s or more. This indicates that the 95th percentile reading time of a wicket sign/distance plate combination is of the order of 0.75s. This would be the time available to read the wicket sign from the moment it first becomes legible to the 10 degree cut-off point where the sign should no longer be viewed when driving.

It is desirable to add in a margin of safety for road users to increase the likelihood that the sign text and pictogram can be read and thus provide an effective warning to road users of the hazard ahead. One potential approach explored was that of modifying the reading time figure to increase the 'window' available for drivers to read the wicket sign, allowing them sufficient time to read the text and pictogram on the sign twice. This is a very risk-averse approach (although similar to the approach taken by Odesalchi et al (1962)) and would set a reading time of 1.5s, thus giving a 100% margin for safety for road users. This approach does not, however, take any consideration of road worker safety or the operational challenges faced using extremely large signs.

While the approach of doubling the sign reading time would minimise risk to road users, it does not address any of the practical and/or operational risks to the road workers involved in setting out or removing temporary traffic management signs. The alternative approach adopted in the remainder of this report attempts to balance road worker and road user risk by providing a sign that is of minimum practicable size while still providing road users with adequate hazard warning.

In order to determine the recommended sign size, the standard reading time figure is used to calculate the legibility distance of the wicket sign for different approach speeds using the Jacobs and Cole (1978) formulae. From this calculation, the required x-height[6] of the numeric part of the sign (i.e. the supplementary distance plate) for a road user in the most disadvantaged lane[7] can be calculated.

This calculated value represents a theoretical minimum x-height that would provide the required reading time for a road user in the most disadvantaged lane. However, in order to add a further margin of safety for road users the recommended x-height is the calculated x-height plus one step-size increment. This is subsequently used to derive the physical size of the sign using the working drawings for the sign.

[6] x- height is defined as the height of the lower case "x" in millimetres
[7] the lane from which it would be most difficult to see the sign

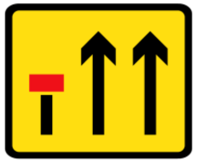
10 Conclusions and Recommendations

The work carried out for this task has shown that the sizes of temporary sign were increased in the 2002 reprint of the 1991 Traffic Signs Manual: Chapter 8 and not in the 2006 revision as suggested by the HA Supply Chain. Irrespective of when the change was made, it is accepted that the sizes of some of the signs identified is larger than is practicable and this has been demonstrated via ergonomic review of the issues associated with handling larger signs.

Although there is no specific evidence of a change in the accident risk or road user collision rate associated with the change in sign sizes in 2002 or the revisions to Chapter 8 in 2006, it is likely that the sizes of some of the temporary signs examined in this work can be reduced without compromising sign readability. In order to test this, sign reading times were measured using a computer simulation system that had been developed to evaluate VMS reading times for the HA's managed motorways programme.

From these data, it has been possible to calculate the recommended 'x-height' or absolute sign heights for the signs identified by the HA Supply Chain as presenting issues. These suggest that three safety-critical signs could reduce in size under some circumstances

Safety critical signs



TSRGD diagram number 7202

Carriageway		Current Chapter 8 (Table A1.2) Recommended Sign Size		Proposed Sign Size (Based on Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	1575	1575/1350*	1125	1125
D4	70mph	1575	1575/1350	1575	1125
D5	70mph	1575	1575/1350	1575	1575

TSRGD diagram number 7208

Carriageway		Current Recommended x-height		Proposed Sign Size (Based on Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	175	175/150**	125	125
D4	70mph	175	175/150	175	125
D5	70mph	175	175/150	175	175

* Reference Chapter 8, note b, Table A1.2, "diagram 7202 – For works for which relaxations apply, the size of signs to diagram 7202on the left-hand side of the carriageway should be given as above but the signs on the central reservation may be reduced to 1350mm. The x-height on the supplementary plate to diagram 7208 should be reduced proportionally."

* * The x-height of supplementary plate to diagram 7208 reduced proportionally

TSRGD diagram number 7306

Carriageway		Current Chapter 8 (Table A1.2) Recommended x-height mm		Proposed x-height (Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph (Note 1)	200	200	150	150
D4	70mph (Note 1)	200	200	175	150
D5	70mph (Note 1)	200	200	175	175

Note 1: For Works Access signs 7306 and 7301, assumptions in the calculations that works traffic is travelling at no more than 50mph when approaching the sign location

TSRGD diagram number 7001.3

Carriageway		Current Recommended x-height mm*		Proposed x-height (Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	200	N/A	150	N/A
D4	70mph	200	N/A	200	N/A
D5	70mph	200	N/A	200	N/A

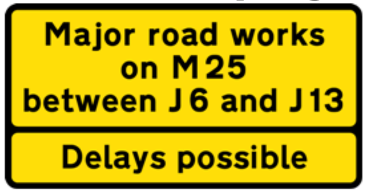
Note: “Workforce in Road Slow” sign is sited on nearside only, ref Chapter 8, O3.6.3

TSRGD diagram number 7301

Carriageway		Current Recommended x-height mm*		Proposed x-height (Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph (Note 2)	100	100	100	100
D4	70mph (Note 2)	100	100	100	100
D5	70mph (Note 2)	100	100	100	100

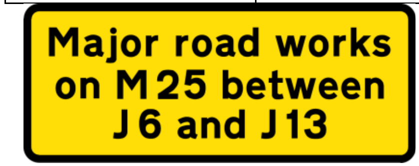
Note 2: For Works Access signs 7306 and 7301, assumptions in the calculations that works traffic is travelling at no more than 50mph when approaching the sign location

Informatory signs



TSRGD diagram number 7002A

Carriageway		Current Chapter 8 (Table A1.2) Recommended x-height mm		Calculated x-height mm (Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	200	N/A	275	N/A
D4	70mph	200	N/A	300	N/A
D5	70mph	200	N/A	300	N/A



TSRGD diagram number 7002A Permitted variant

Carriageway		Current Chapter 8 (Table A1.2) Recommended x-height mm		Calculated x-height mm (Appendix E)	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	200	N/A	250	N/A
D4	70mph	200	N/A	275	N/A
D5	70mph	200	N/A	275	N/A

The current maximum prescribed x-height for sign to diagram 7002A and permitted variant is 250mm
Signs 7002A and permitted variant sited on nearside only

TSRGD diagram number 7003.1

Carriageway		**Current Chapter 8 (Table A1.2) Recommended x-height mm**		**Calculated x-height mm (Appendix E)**	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	200	N/A	275	N/A
D4	70mph	200	N/A	325	N/A
D5	70mph	200	N/A	325	N/A

TSRGD diagram number 7003.1 Permitted variant

Carriageway		**Current Chapter 8 (Table A1.2) Recommended x-height mm**		**Calculated x-height mm (Appendix E)**	
Type	Speed limit	Nearside	Offside	Nearside	Offside
D3	70mph	200	N/A	225	N/A
D4	70mph	200	N/A	250	N/A
D5	70mph	200	N/A	250	N/A

The current maximum prescribed x-height for sign to diagram 7003.1 and permitted variant is 250mm
Signs 7003.1 and permitted variant sited on nearside only

The results from the calculations presented in the above tables show that:

- Three key signs could reduce in size:

The diagram 7202 wicket sign could be reduced from 1575mm height to 1125mm height on three lane dual carriageways and the offside of four lane carriageways, a reduction in size of 29%

The diagram 7001.3 sign could be reduced from 200mm x-height (for the word "SLOW" off which the other words are scaled) to 150mm x-height when used on three lane dual carriageways, a reduction in size of 25%

The diagram 7306 sign could be reduced from an x-height of 200mm to 150mm on three lane carriageways or 175mm on four or five lane carriageways, assuming that works traffic approaching the works access is travelling at approximately 50mph at the point where the works access sign must be read

Calculations indicate the diagram 7301 sign should remain at the current x-height of 100mm and that four other informational signs have an 'x-height' that is insufficient for drivers to read the entirety of the sign information when travelling at the national speed limit. It is recommended that these signs should be redesigned to reduce the number of words on each sign, thus reducing the reading time and associated x-height.

Supporting calculations are shown in the sign size spreadsheets which can be found in Appendix E.

Acknowledgements

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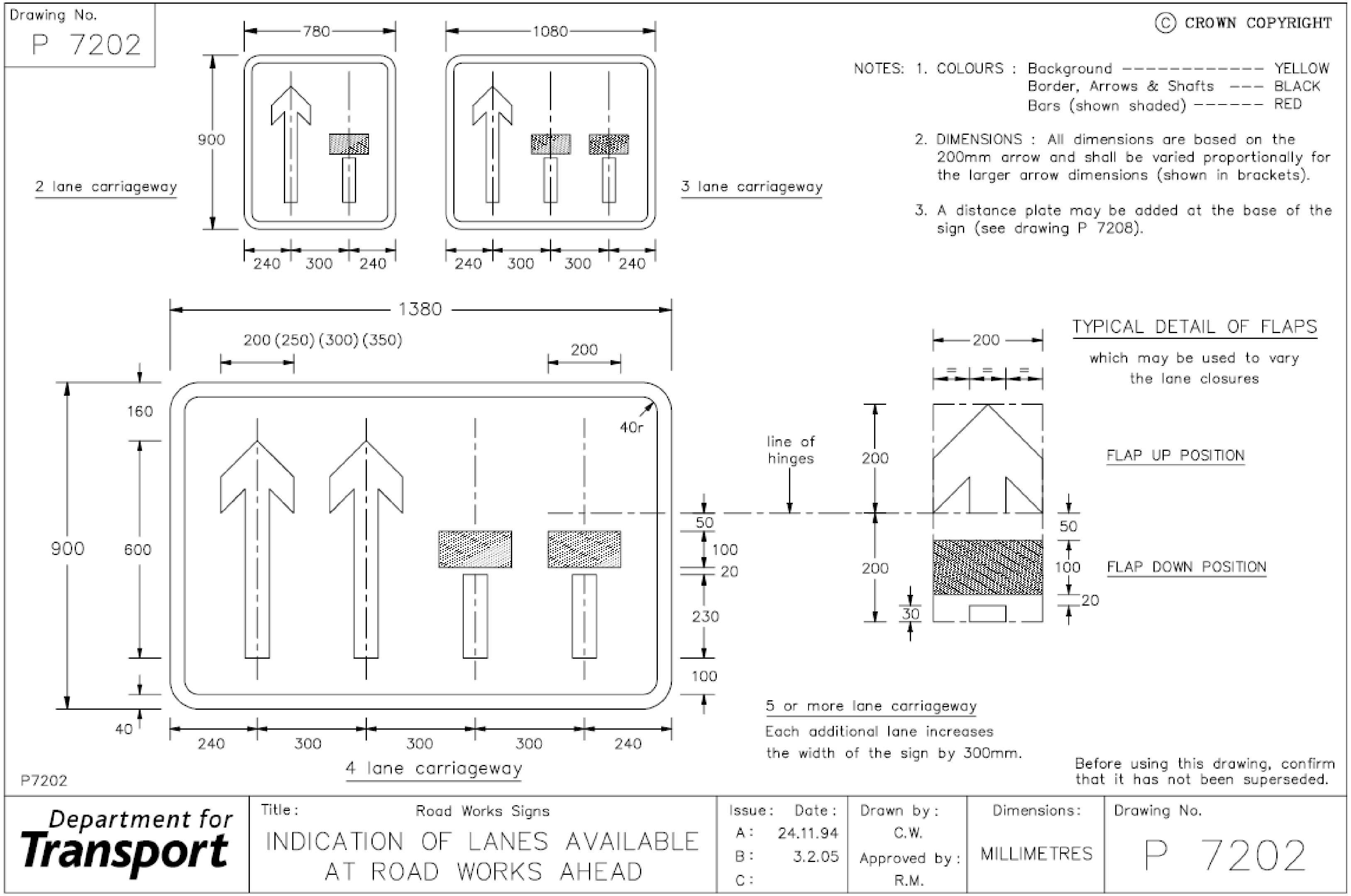
Appendix A Additional Large Sign Usage Pictures

Figure 23. Additional Large Sign Usage Pictures

Appendix B Example Working Drawing (Wicket Sign)



Appendix C Calculations of the Appropriate Size of Road Works Signs – Worked Examples

Size of Workforce in road slow sign (diagram 7001.3)

Sign to diagram 7001.3

The reading time (T) needed to assimilate worded messages on a sign can be calculated using the formula developed by Jacobs and Cole (1978):

$$T = 0.32\ N - 0.21\ \text{seconds}$$

where N is the number of words on the sign.

For the 'Workforce in road slow' sign (diagram 7001.3), N = 4

T = (0.32 x 4) – 0.21 seconds = 1.28 seconds

If the sign is sited on a length of 3-lane dual carriageway road where the permanent speed limit is 70mph (approximately 31.3 m/s), at the point from which the sign was to be viewed, the distance travelled by drivers reading the sign would be:

31.3 m/s x 1.28s = 40m

Assuming the lateral offset is 7m when viewed from the most disadvantaged lane, the cut-off distance would be:

7 cot 10 degrees = 38m

Therefore, the required reading distance (i.e. legibility distance) is:

40m + 38m = 78m

This is illustrated in Figure 24.

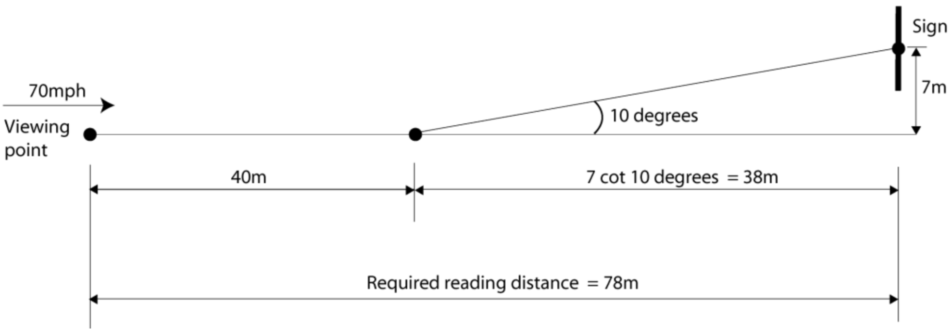


Figure 24. Diagram demonstrating calculation of legibility distance

The usual 'rule of thumb' states that the x-height (in mm) of characters shown on a sign equals the legibility distance (in metres) divided by 0.6. For this example, the legibility distance of the distance plate sign is 70.5m.

Therefore, the x-height would be:

78m / 0.6 = 130mm

This would be rounded to the nearest prescribed size. For sign 7001.3, the nearest prescribed size of x-height is 125mm**.**

The above calculations were repeated using typical 85th percentile speed data for all vehicle types[8], obtained for both low traffic flows (400 vehicles per hour per lane) and high traffic flows (2000 vehicles per hour per lane):

- High flows: 73mph
- Low flows: 81mph

Revised calculations, using the same reading time (1.28s), and lateral offset (7m), as used previously, for both high and low traffic flows are summarised in Table 23 below.

Table 23. Measurements associated with sign sizes at different flow levels

Traffic flow	85th percentile speed	Distance travelled by drivers reading the sign	Required reading distance	Calculated x-height	Nearest prescribed size of x-height
High	73mph	42m	80m	133mm	125mm
Low	81mph	46m	84m	140mm	150mm

[8] Source of data: two typical weekdays in 2001 and 2002 on the M25/M42

Size of 'Works access only' sign

Figure 25. Sign to diagram 7306

For this particular sign, the number of words N = 4. Using the formula developed by Jacobs and Cole to calculate the reading time:

$$T = (0.32 \times 4) - 0.21 \text{ seconds} = 1.07 \text{ seconds}$$

The case considered here is for a 50mph speed limit with the sign being viewed from the inside lane.

Lateral offset of sign = 3m (approximately)

Distance travelled by drivers reading the sign at 50mph:

$$22.3\text{m/s} \times 1.07\text{s} = 23.9\text{m}$$

Therefore, the required reading distance is:

$$23.9\text{m} + 3 \cot 10 \text{ degrees} = 41\text{m}$$

Using the 'rule of thumb' to calculate x-height, i.e. legibility distance/0.6, therefore, the x-height would be:

$$41\text{m} / 0.6 = 68\text{mm}$$

This would be rounded to the nearest prescribed size. For sign 7306, the nearest prescribed size of x-height is 100mm.

Appendix D Sign Offset Calculations

Three carriageway widths are considered: dual three lane (D3), dual four lane (D4) and dual five lane (D5) motorways with hard shoulders.

Assumptions: Lane width 3.65m, hard shoulder width 3.3m, edge clearance to sign 1.0m on hard shoulder, 0.6m on central reserve.

It is also assumed that drivers will look at the sign with the smaller lateral offset, i.e. the sign nearer to their line of travel, which is also the one least likely to be obscured by traffic on either side.

Hard shoulder sign offset is S_H, central reserve sign offset is S_C, sign width W m.

Each carriageway width, D3, D4 and D5 is considered in turn, with the sign offset calculated for each lane, numbered consecutively from the near side. The sign with the smaller lateral offset in each pair is shown in bold type.

D3

Lane 1

S_H = 1.825 + 3.3 + 1.0 + W/2 = **6.125 + W/2**

S_C = 1.825 + 3.65 + 3.65 + 0.6 + W/2 = 9.725 + W/2

Lane 2

S_H = 1.825 + 3.65 + 3.3 + 1.0 + W/2 = 9.775 + W/2

S_C = 1.825 + 3.65 + 0.6 + W/2 = **6.075 + W/2**

Lane 3

S_H = 1.825 + 3.65 + 3.65 + 3.3 + 1.0 + W/2 = 13.425 + W/2

S_C = 1.825 + 0.6 + W/2 = **2.425 + W/2**

D4

Lane 1

S_H = 1.825 + 3.3 + 1.0 + W/2 = **6.125 + W/2**

S_C = 1.825 + 3.65 + 3.65 + 3.65 + 0.6 + W/2 = 13.375 + W/2

Lane 2

S_H = 1.825 + 3.65 + 3.3 + 1.0 + W/2 = **9.775 + W/2**

S_C = 1.825 + 3.65 + 3.65 + 0.6 + W/2 = 9.725 + W/2

Lane 3

S_H = 1.825 + 3.65 + 3.65 + 3.3 + 1.0 + W/2 = 13.425 + W/2

S_C = 1.825 + 3.65 + 0.6 + W/2 = **6.075 + W/2**

Lane 4

S_H = 1.825 + 3.65 + 3.65 + 3.65 + 3.3 + 1.0 + W/2 = 17.075 + W/2

S_C = 1.825 + 0.6 + W/2 = **2.425 + W/2**

D5

Lane 1

S_H = 1.825 + 3.3 + 1.0 + W/2 = **6.125 + W/2**

S_C = 1.825 + 3.65 + 3.65 + 3.65 + 3.65 + 0.6+ W/2 = 17.025 + W/2

Lane 2

S_H = 1.825 + 3.65 + 3.3 + 1.0 + W/2 = **9.775 + W/2**

S_C = 1.825 + 3.65 + 3.65 + 3.65 + 0.6 + W/2 = 13.375 + W/2

Lane 3

S_H = 1.825 + 3.65 + 3.65 + 3.3 + 1.0 + W/2 = 13.425 + W/2

S_C = 1.825 + 3.65 + 3.65 + 0.6 + W/2 = **9.725 + W/2**

Lane 4

S_H = 1.825 + 3.65 + 3.65 + 3.65 + 3.3 + 1.0 + W/2 = 17.075 + W/2

S_C = 1.825 + 3.65 + 0.6 + W/2 = **6.075 + W/2**

Lane 5

S_H = 1.825 + 3.65 + 3.65 + 3.65 + 3.65 + 3.3 + 1.0 + W/2 = 20.725 + W/2

S_C = 1.825 + 0.6 + W/2 = **2.425 + W/2**

The sign with the smaller lateral offset (of the hard shoulder and central reserve pair) for each lane on each carriageway type is shown in Table 24. S_H or S_C indicates whether this is the sign on the hard shoulder or the sign on the central reserve in each case. Offsets shown in bold type are the worst-case hard shoulder and worst case central reserve sign for each carriageway type. For example, on a dual four-lane motorway, the worst offset for the hard shoulder sign occurs for a driver in Lane 2, and the worst offset for the central reserve sign occurs for a driver in Lane 3.

Table 24. Lateral offsets for each lane on each carriageway type

	L1	L2	L3	L4	L5
D3	**6.125 + W/2 S_H**	**6.075 + W/2 S_C**	2.425 + W/2 S_C	-	-
D4	6.125 + W/2 S_H	**9.775 + W/2 S_H**	**6.075 + W/2 S_C**	2.425 + W/2 S_C	-
D5	6.125 + W/2 S_H	**9.775 + W/2 S_H**	**9.725 + W/2 S_C**	6.075 + W/2 S_C	2.425 + W/2 S_C

Table 25 shows the worst case offset for the hard shoulder and central reserve signs on D3, D4 and D5 dual carriageway motorways, i.e. the offsets shown in bold type in Table 24.

Table 25. The worst case offsets

	Sign offset (m)	
	Hard shoulder	Central reserve
D3	6.125 + W/2	6.075 + W/2
D4	9.775 + W/2	6.075 + W/2
D5	9.775 + W/2	9.725 + W/2

Appendix E Sign Size spreadsheets

Wicket sign diagram 7202 + supplementary distance plate 7208

Assumptions used for the calculations:

- The width of each of the running lanes is 3.65m
- The width of the hard shoulder is 3.3m
- The viewing position is in the centre of the lane of travel
- The sign cut off angle is 10 degrees
- The safety clearance for signs located on the verge is 1.0m
- The safety clearance for signs located on in the central reservation is 0.6m
- The x-height (in mm) of characters shown on a sign = legibility distance (in metres) / 0.6

D3 – Hard shoulder

The most disadvantaged lane for D3 for a sign located on the hard shoulder is for a vehicle travelling in travelling in lane 1

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7202 +7208 (three lane)	175	1.89	n/a	0.75	1.00	1	0.95	3.30	7.07	70	31.29	23.47	40.10	63.57	105.94	100

D3 – Central reservation

The most disadvantaged lane for D3 for a sign located in the central reservation is for a vehicle travelling in lane 2

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7202 +7208 (three lane)	175	1.89	n/a	0.75	0.60	2	0.95	7.02	70	31.29	23.47	39.81	63.28	105.47	100

D4 – Hard shoulder

The most disadvantaged lane for D4 for a sign located on the hard shoulder is for a vehicle travelling in lane 2

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7202 +7208 (four lane)	175	2.415	n/a	0.75	1.00	2	1.21	3.30	10.98	70	31.29	23.47	62.28	85.75	142.92	150

D4 – Central reservation

The most disadvantaged lane for D4 for a sign located in the central reservation is for a vehicle travelling in lane 3

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7202 +7208 (four lane)	175	2.415	n/a	0.75	0.60	3	1.21	7.28	70	31.29	23.47	41.30	64.77	107.95	100

D5 – Hard shoulder

The most disadvantaged lane for D5 for a sign located on the hard shoulder is for a vehicle travelling in lane 2

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7202 +7208 (five lane)	175	2.94	n/a	0.75	1.00	2	1.47	3.30	11.25	70	31.29	23.47	63.77	87.24	145.41	150

D5 – Central reservation

The most disadvantaged lane for D5 for a sign located in the central reservation is for a vehicle travelling in lane 3

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7202 +7208 (five lane)	175	2.94	n/a	0.75	0.60	3	1.47	11.20	70	31.29	23.47	63.49	86.96	144.93	150

Works Access signs 7306 and 7301

Assumptions used for the calculations:

- The width of each of the running lanes is 3.65m
- The viewing position is in the centre of the lane of travel
- The sign cut off angle is 10 degrees
- The verge mounted signs are located close to the carriageway edge allowing for a 0.6m safety clearance
- The safety clearance for signs located on the verge and in the central reservation is 0.6m
- Vehicles will only approach these particular signs at a maximum speed of 50mph
- Signs will only be viewed from the adjacent lane
- The reading time (T) of worded messages is calculated using the Jacobs and Cole formula T = 0.32N - 0.21 where N is the number of words
- The x-height (in mm) of characters shown on a sign = legibility distance (in metres) / 0.6

D3 – Hard shoulder

The most disadvantaged lane for D3 for a sign located on the hard shoulder is for a vehicle travelling in lane 1.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7306	200	3.50	4	1.07	1.00	1	1.75	3.30	7.88	50	22.35	23.92	44.66	68.58	114.30	125
7301*	100	1.05	2	0.43	1.00	Adjacent	0.53	3.30	6.65	50	22.35	9.61	37.71	47.33	78.88	75

D3 – Central reservation

The most disadvantaged lane for D3 for a sign located on the central reservation is for a vehicle travelling in lane 2.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7306	200	3.50	4	1.07	0.60	2	1.75	7.83	50	22.35	23.92	44.38	68.29	113.82	125
7301*	100	1.05	2	0.43	0.60	Adjacent	0.53	6.60	50	22.35	9.61	37.43	47.04	78.40	75

D4 – Hard shoulder

The most disadvantaged lane for D4 for a sign located on the hard shoulder is for a vehicle travelling in lane 2.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7306	200	3.50	4	1.07	1.00	2	1.75	3.30	11.53	50	22.35	23.92	65.36	89.28	148.80	150
7301*	100	1.05	2	0.43	1.00	Adjacent	0.53	3.30	6.65	50	22.35	9.61	37.71	47.33	78.88	75

D4 – Central reservation

The most disadvantaged lane for D4 for a sign located on the central reservation is for a vehicle travelling in lane 3.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7306	200	3.50	4	1.07	0.60	3	1.75	7.83	50	22.35	23.92	44.38	68.29	113.82	125
7301*	100	1.05	2	0.43	0.60	Adjacent	0.53	6.60	50	22.35	9.61	37.43	47.04	78.40	75

D5 – Hard shoulder

The most disadvantaged lane for D5 for a sign located on the hard shoulder is for a vehicle travelling in lane 2.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7306	200	3.50	4	1.07	1.00	2	1.75	3.30	11.53	50	22.35	23.92	65.36	89.28	148.80	150
7301*	100	1.05	2	0.43	1.00	Adjacent	0.53	3.30	6.65	50	22.35	9.61	37.71	47.33	78.88	75

D5 – Central reservation

The most disadvantaged lane for D5 for a sign located on the central reservation is for a vehicle travelling in lane 3.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7306	200	3.50	4	1.07	0.60	3	1.75	11.48	50	22.35	23.92	65.08	88.99	148.32	150
7301*	100	1.05	2	0.43	0.60	Adjacent	0.53	6.60	50	22.35	9.61	37.43	47.04	78.40	100

* Note: Sign 7301 has only one prescribed x-height (100mm)

Signs 7001.3, 7002A / 7002A(variant) and 7003.1/7003.1(variant)

Assumptions used for the calculations:

- The width of each of the running lanes is 3.65m
- The width of the hard shoulder is 3.3m
- The viewing position is in the centre of the lane of travel
- The sign cut off angle is 10 degrees
- The safety clearance for signs located on the verge is 1.0m
- The safety clearance for signs located on in the central reservation is 0.6m
- The reading time (T) of worded messages is calculated using the Jacobs and Cole formula T = 0.32N - 0.21 where N is the number of words
- The x-height (in mm) of characters shown on a sign = legibility distance (in metres) / 0.6

D3 – Hard shoulder

The most disadvantaged lane for D3 for a sign located on the hard shoulder is for a vehicle travelling in lane 1.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7001.3	200	3.03	4	1.07	1.00	1	1.52	3.30	7.64	70	31.29	33.48	43.33	76.81	128.02	125
7001.3	200	3.03	4	1.07	1.00	1	1.52	3.30	7.64	50	22.35	23.92	43.33	67.25	112.08	100
7002A	200	4.28	11	3.31	1.00	1	2.14	3.30	8.27	70	31.29	103.58	46.87	150.45	250.75	250
7002A	200	4.28	11	3.31	1.00	1	2.14	3.30	8.27	50	22.35	73.99	46.87	120.86	201.43	200
7002AV	200	3.80	9	2.67	1.00	1	1.90	3.30	8.03	70	31.29	83.55	45.51	129.06	215.11	225
7002AV	200	3.80	9	2.67	1.00	1	1.90	3.30	8.03	50	22.35	59.68	45.51	105.19	175.32	175
7003.1	200	4.25	12	3.63	1.00	1	2.13	3.30	8.25	70	31.29	113.59	46.79	160.38	267.30	250
7003.1	200	4.25	12	3.63	1.00	1	2.13	3.30	8.25	50	22.35	81.14	46.79	127.93	213.21	225
7003.1V	200	2.67	8	2.35	1.00	1	1.34	3.30	7.46	70	31.29	73.54	42.31	115.85	193.08	200
7003.1V	200	2.67	8	2.35	1.00	1	1.34	3.30	7.46	50	22.35	52.53	42.31	94.83	158.06	150

D3 – Central reservation

The most disadvantaged lane for D3 for a sign located in the central reservation is for a vehicle travelling in lane 2.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7001.3	200	3.03	4	1.07	0.60	2	1.52	7.59	70	31.29	33.48	43.05	76.53	127.55	125
7001.3	200	3.03	4	1.07	0.60	2	1.52	7.59	50	22.35	23.92	43.05	66.96	111.60	100
7002A	200	4.28	11	3.31	0.60	2	2.14	8.22	70	31.29	103.58	46.59	150.17	250.28	250
7002A	200	4.28	11	3.31	0.60	2	2.14	8.22	50	22.35	73.99	46.59	120.57	200.96	200
7002AV	200	3.80	9	2.67	0.60	2	1.90	7.98	70	31.29	83.55	45.23	128.78	214.63	225
7002AV	200	3.80	9	2.67	0.60	2	1.90	7.98	50	22.35	59.68	45.23	104.91	174.85	175
7003.1	200	4.25	12	3.63	0.60	2	2.13	8.20	70	31.29	113.59	46.50	160.10	266.83	250
7003.1	200	4.25	12	3.63	0.60	2	2.13	8.20	50	22.35	81.14	46.50	127.64	212.74	225
7003.1V	200	2.67	8	2.35	0.60	2	1.34	7.41	70	31.29	73.54	42.02	115.56	192.60	200
7003.1V	200	2.67	8	2.35	0.60	2	1.34	7.41	50	22.35	52.53	42.02	94.55	157.59	150

D4 – Hard shoulder

The most disadvantaged lane for D4 for a sign located on the hard shoulder is for a vehicle travelling in lane 2.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of trave	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7001.3	200	3.03	4	1.07	1.00	2	1.52	3.30	11.29	70	31.29	33.48	64.03	97.51	162.52	175
7001.3	200	3.03	4	1.07	1.00	2	1.52	3.30	11.29	50	22.35	23.92	64.03	87.95	146.58	150
7002A	200	4.28	11	3.31	1.00	2	2.14	3.30	11.92	70	31.29	103.58	67.57	171.15	285.25	250
7002A	200	4.28	11	3.31	1.00	2	2.14	3.30	11.92	50	22.35	73.99	67.57	141.56	235.93	225
7002AV	200	3.80	9	2.67	1.00	2	1.90	3.30	11.68	70	31.29	83.55	66.21	149.76	249.61	250
7002AV	200	3.80	9	2.67	1.00	2	1.90	3.30	11.68	50	22.35	59.68	66.21	125.89	209.82	200
7003.1	200	4.25	12	3.63	1.00	2	2.13	3.30	11.90	70	31.29	113.59	67.49	181.08	301.80	250
7003.1	200	4.25	12	3.63	1.00	2	2.13	3.30	11.90	50	22.35	81.14	67.49	148.63	247.71	250
7003.1V	200	2.67	8	2.35	1.00	2	1.34	3.30	11.11	70	31.29	73.54	63.01	136.55	227.58	225
7003.1V	200	2.67	8	2.35	1.00	2	1.34	3.30	11.11	50	22.35	52.53	63.01	115.54	192.56	200

D4 – Central reservation

The most disadvantaged lane for D4 for a sign located in the central reservation is for a vehicle travelling in lane 3.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of trave	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7001.3	200	3.03	4	1.07	0.60	3	1.52	7.59	70	31.29	33.48	43.05	76.53	127.55	125
7001.3	200	3.03	4	1.07	0.60	3	1.52	7.59	50	22.35	23.92	43.05	66.96	111.60	100
7002A	200	4.28	11	3.31	0.60	3	2.14	8.22	70	31.29	103.58	46.59	150.17	250.28	250
7002A	200	4.28	11	3.31	0.60	3	2.14	8.22	50	22.35	73.99	46.59	120.57	200.96	200
7002AV	200	3.80	9	2.67	0.60	3	1.90	7.98	70	31.29	83.55	45.23	128.78	214.63	225
7002AV	200	3.80	9	2.67	0.60	3	1.90	7.98	50	22.35	59.68	45.23	104.91	174.85	175
7003.1	200	4.25	12	3.63	0.60	3	2.13	8.20	70	31.29	113.59	46.50	160.10	266.83	250
7003.1	200	4.25	12	3.63	0.60	3	2.13	8.20	50	22.35	81.14	46.50	127.64	212.74	225
7003.1V	200	2.67	8	2.35	0.60	3	1.34	7.41	70	31.29	73.54	42.02	115.56	192.60	200
7003.1V	200	2.67	8	2.35	0.60	3	1.34	7.41	50	22.35	52.53	42.02	94.55	157.59	150

D5 – Hard shoulder

The most disadvantaged lane for D5 for a sign located on the hard shoulder is for a vehicle travelling in lane 2.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Hard shoulder width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7001.3	200	3.03	4	1.07	1.00	2	1.52	3.30	11.29	70	31.29	33.48	64.03	97.51	162.52	175
7001.3	200	3.03	4	1.07	1.00	2	1.52	3.30	11.29	50	22.35	23.92	64.03	87.95	146.58	150
7002A	200	4.28	11	3.31	1.00	2	2.14	3.30	11.92	70	31.29	103.58	67.57	171.15	285.25	250
7002A	200	4.28	11	3.31	1.00	2	2.14	3.30	11.92	50	22.35	73.99	67.57	141.56	235.93	225
7002AV	200	3.80	9	2.67	1.00	2	1.90	3.30	11.68	70	31.29	83.55	66.21	149.76	249.61	250
7002AV	200	3.80	9	2.67	1.00	2	1.90	3.30	11.68	50	22.35	59.68	66.21	125.89	209.82	200
7003.1	200	4.25	12	3.63	1.00	2	2.13	3.30	11.90	70	31.29	113.59	67.49	181.08	301.80	250
7003.1	200	4.25	12	3.63	1.00	2	2.13	3.30	11.90	50	22.35	81.14	67.49	148.63	247.71	250
7003.1V	200	2.67	8	2.35	1.00	2	1.34	3.30	11.11	70	31.29	73.54	63.01	136.55	227.58	225
7003.1V	200	2.67	8	2.35	1.00	2	1.34	3.30	11.11	50	22.35	52.53	63.01	115.54	192.56	200

D5 – Central reservation

The most disadvantaged lane for D5 for a sign located in the central reservation is for a vehicle travelling in lane 3.

Sign diag.number	Prescribed x - height mm	Sign width (m)	Number of words N	T (s)	Safety clearance (m)	Lane of travel	Half the sign width (m)	Lateral offset (m)	Speed limit (mph)	Speed limit (m/s)	Distance travelled (m)	Cut off distance (m)	Legibility distance (m)	x-height (mm)	Nearest prescribed x-height size (mm)
7001.3	200	3.03	4	1.07	0.60	3	1.52	11.24	70	31.29	33.48	63.75	97.23	162.05	150
7001.3	200	3.03	4	1.07	0.60	3	1.52	11.24	50	22.35	23.92	63.75	87.66	146.10	150
7002A	200	4.28	11	3.31	0.60	3	2.14	11.87	70	31.29	103.58	67.29	170.87	284.78	250
7002A	200	4.28	11	3.31	0.60	3	2.14	11.87	50	22.35	73.99	67.29	141.27	235.46	225
7002AV	200	3.80	9	2.67	0.60	3	1.90	11.63	70	31.29	83.55	65.93	149.48	249.13	250
7002AV	200	3.80	9	2.67	0.60	3	1.90	11.63	50	22.35	59.68	65.93	125.61	209.35	200
7003.1	200	4.25	12	3.63	0.60	3	2.13	11.85	70	31.29	113.59	67.20	180.80	301.33	250
7003.1	200	4.25	12	3.63	0.60	3	2.13	11.85	50	22.35	81.14	67.20	148.34	247.24	250
7003.1V	200	2.67	8	2.35	0.60	3	1.34	11.06	70	31.29	73.54	62.72	136.26	227.10	225
7003.1V	200	2.67	8	2.35	0.60	3	1.34	11.06	50	22.35	52.53	62.72	115.25	192.09	200