Transport Research Laboratory

# Driver Interaction with Temporary Traffic Management

Technical Report from Phase 1

**by M. Chattington, R. Beesley, E. Gould and I. Rillie**

**CPR820**

**593(387)**

**CLIENT PROJECT REPORT**

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|---|---|---|
| **Prepared for:** | **Project Record:** | **593(387)** |
| | | **Driver Interaction with Temporary Traffic Management** |
| | **Client:** | **Highways Agency, SSR Corporate Health & Safety** |
| | | **(Paul Mitchell)** |



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## Contents Amendment Record

This report has been issued and amended as follows

| Version | Date | Description | Editor | Technical Referee |
|---|---|---|---|---|
| 1 | 20/1/09 | First draft following review of TTM layouts by Project Sponsor | MC | IR |
| 2 | 5/4/09 | Second draft following technical review | SC/MC | IR |
| 3 | 30/06/09 | Final draft incorporating comments from G Coe | IR | IR |

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# Executive summary

This report has been produced from Phase 1 of a Highways Agency project examining how drivers interact with temporary traffic management and whether there is scope to simplify the temporary signing currently used on the approach to road works on dual carriageway roads.

Previous work (Baguley, 1996) has identified that there is scope to reduce the number of signs and simplify temporary traffic management. This project aims to provide the Agency with a data-led case for any recommended changes. This will be based on objective measurements of driver reaction to current and simplified sign layout on the approach to work sites, and moving forward to a controlled limited area roll-out of any simplified temporary traffic management sign layout.

***Task objectives and specification***

The main objectives of the task are:

- Measure driver visual behaviour and car control in a simulated environment and hence establish driver reactions to the simplification of current temporary traffic management (TTM) signage on the approach to road works on a dual carriageway road.
- Carry out a limited area roll-out of the best alternative TTM layout identified in the simulator trial.
- Monitor the limited area roll-out and report the key findings regarding road worker risk and driver reaction to the Agency

These objectives will be delivered through the following sub-tasks:

**Phase 1:**

- Sub-task 1: Review of previous research and consultancy;
- Sub-task 2: Stakeholder workshops and test layout design;

**Phase 2:**

- Sub-task 3: Simulator study of three simplified TTM layouts

**Phase 3:**

- Sub-task 4: Network trial of one simplified layout;
- Sub-task 5: Analysis and reporting

This project will enable the Highways Agency to examine whether sign simplification is a viable way of reducing the risk to road workers on the network, while still maintaining or improving road user safety.

The aim of the first phase of this project was to engage with stakeholders, and develop three alternative temporary traffic management designs that could be used in place of the current Chapter 8 principles for signing the approach to work sites on a dual carriageway road. In addition, a literature review was conducted to inform further decisions on the TTM layout designs.

There is little reliable evidence on driver behaviour through road works, or the effect of changing the current signage in any way. Therefore, the stakeholder group felt that Phase 2 of this project (simulator study) would produce useful information on driver behaviour in road works. This will also give the first direct measure from eye tracker data of drivers' visual behaviour and interaction with signage. With the assistance of stakeholders, the three alternative TTM layouts for use in this phase of the project have been developed.

The first two layouts developed for the simulator study included direct involvement from stakeholders during the workshop. The third was developed subsequently by TRL using information gained from within the workshop. The main aim of each layout is to reduce the overall number of signs within the 'lead in' zone to the road works, while still maintaining a strong message. The first layout removes a small number of signs from the standard configuration; the second layout removes some signs and uses different sign content with the intention of improving compliance; the third layout uses a minimal signage configuration. The three designs move progressively away from the principles described in Chapter 8 of the Traffic Signs Manual, permitting investigation as to the safe minimal signage level.

The layouts developed all have theoretical benefits to their use, either in terms of reducing visual clutter or improving the clarity instructions given to drivers. However, there needs to be conclusive evidence before a change in the current Chapter 8 is considered. The simulator trial will provide useful insight into driver behaviour with the new layouts. If behaviour is at least as safe as the current Chapter 8 configuration with any of the new layouts, the other benefits may suggest that they may be preferable. If driving behaviour improves, then there would be a strong case for change.

The simulator study is currently in preparation. Prior to the study being approved, stakeholders will be given the opportunity to examine the trial and comment on the traffic management that will be presented to the study drivers. When results are available, they will be circulated to stakeholders to gain further insights into the implications of the results.

# 1 Introduction

This report has been produced from Phase 1 of a Highways Agency project examining how drivers interact with temporary traffic management and whether there is scope to simplify the temporary traffic management layouts currently used on the network.

One of the highest risk activities for traffic management operatives is identified as exposure to live traffic whilst installing and removing temporary traffic management (TTM) signs. It is intuitive that if the number of signs can be reduced, the risk to operatives from carriageway crossings will drop. However, the Highways Agency must consider risk to both the road worker and the travelling public when considering any change in current policy or practices.

Previous work (Baguley, 1996) has identified that there is scope to reduce the number of signs and therefore simplify temporary traffic management. This project aims to provide the Agency with a data-led case for any recommended changes. This will be based on objective measurements of driver reaction to current and simplified sign layouts on the approach to work sites, and moving forward to a controlled limited area roll-out of any simplified temporary traffic management sign layout.

***Task objectives and specification***

The main objectives of the task are:

- Measure driver visual behaviour and car control in a simulated environment and hence establish driver reactions to the simplification of current temporary traffic management signage on the approach to work sites on a dual carriageway road.
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These objectives will be delivered through the following sub-tasks:

**Phase 1:**

- Sub-task 1: Review of previous research and consultancy;
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**Phase 2:**

- Sub-task 3: Simulator study of three simplified TTM layouts.

**Phase 3:**

- Sub-task 4: Network trial of one simplified layout;
- Sub-task 5: Analysis and reporting.

This project will enable the Highways Agency to examine whether sign simplification at work sites is a viable way of reducing the risk to road workers on the network, while still maintaining or improving road user safety. Safety improvements may be achieved by reducing the number of signs needed for temporary traffic management, possibly resulting in the drivers finding directions easier to understand; resulting in an associated reduction in accident risk.

A reduction in signage would also provide a significant improvement to road worker safety. The Highways Agency wishes to reduce risk to road workers, and has set a goal of eliminating or significantly reduces the number of carriageway crossings required to implement a lane closure. A reduction in signage would decrease road worker exposure to live traffic and could significantly reduce the need to cross the carriageway.

This project will address both these issues, and will enable the Highways Agency to have an immediate impact on the safety of Supply Chain and Highways Agency staff working

on the network. This report sets out the results of the first phase of a project, which conducted a literature review to examine the background to TTM signage and also conducted a stakeholder workshop to gain insight into current practices and opinion. TRL has used this information to design three alternative TTM configurations that are presented in Section 4.5 of this report. These designs will be taken forward to Phase 2 of the project, with members of the public being invited to take part in a driving simulator trial. This trial will assess the safety implications of changing TTM configurations and produce recommendations for the remaining phases of this project.

When considering the wide-ranging topic of "temporary" traffic management at road works, the most important factor is to maximise the safety both of motorists and road workers. Analysis of accident data shows that the UK has a good safety record in terms of injury accidents at road works (e.g. Freeman, Mitchell and Coe, 2004); this will at least in part be due to the principles applied in design and deployment of temporary traffic management signing. However, the review of literature has indicated there may be an opportunity to simplify the traffic management used in road works, and influence how drivers interact with signage in different forms. This project will aim to address this by providing comprehensive data on driver reaction to the signing encountered by the driver on approach to road works. This will be provided through detailed assessments of drivers' behaviour in a controlled simulator environment, and will then examine driver behaviour during a limited roll-out on the highway of the design considered to have the most potential (see Section 4.5).

Whilst simplifying the information provided at and before road works has benefits to implementation of traffic management measures, there remains a risk that simplification may have a negative impact on safety. Drivers need to have as long as possible to comprehend and act on information provided to them. There is therefore a balance to be struck between sign clutter and situations where the visibility of signs may be compromised by external factors such as obscuration by heavy traffic. It is also important to understand how mandatory and prohibitory messages influence behaviour and the extent to which each should be used in road works.

The literature review has highlighted that the driving task can place heavy demands on a driver's attention. It has also indicated that a person has a fixed capacity to process information gained from their environment. Sign clutter, duplication of messages or overcomplicated signs may produce a negative effect on behaviour. For instance, a driver may attempt to read both signs of a duplicate pair, which may stretch their ability to process the available information. They may therefore fail to observe another critical sign resulting in an increased likelihood that they will behave in an undesirable/unsafe manner. Such factors should be considered when designing any further traffic management layouts; the focus of the next phase of this project must therefore be to improve/maintain driver behaviour whilst using traffic management layouts that are straightforward to implement.

The majority of messages to motorists are communicated using fixed signage. With limited information processing and attentional capabilities, there is a need to ensure that all signage provides a relevant and clear message to drivers. It is clear that additional signs may not clarify the message. Excessive, unnecessarily complicated and unclear signs can have a detrimental impact on the quality of the driving task and therefore the safety of all road users. This review has not identified any existing evidence to indicate the signs to which drivers attend when travelling through road works. Phase 2 of this research (a driving simulator trial of various TTM configurations) will assess whether the current Chapter 8 layout for the approach to a works site on a dual carriageway road contains 'too much' information for drivers, or whether drivers simply disregard a large portion of this information.

Various studies have aimed to pinpoint how best to convey a message to motorists – using action messages, mandatory or prohibitive statements or using symbols instead of alpha-numeric signs. The literature generally suggests that the simplest message, and

therefore the simplest sign, is the clearest. It also suggests that using a mandatory message may improve sign comprehension and increase the likelihood that a driver will take action as a result. The relative influence of sign shapes and colour has also been explored in the review, and although both parameters can improve the conspicuity of a sign, they may be outside the scope of this current research project. This study will aim to reduce the complexity of the message in specific cases and examine whether the 'action potential' for drivers is increased. It is hoped that this will demonstrate how subtly changing current signage can deliver a stronger message to drivers, resulting in improved compliance.

# 2 Literature summary

## 2.1 Introduction

Work on carriageways must be undertaken periodically and whilst this work is taking place it is necessary to manage the traffic at the works site. Various traffic management techniques are used to ensure traffic passes safely through road works and that the road works are thus safe for both road users and road workers. The aim of this project is to provide objective information on whether sign simplification could lead to safety benefits for the travelling public and road workers. Therefore, as a first step, this literature summary examines existing guidance and research that relates to the information provided to drivers at temporary road works, and how this affects safety.

It is generally accepted that it is important to deliver a clear message to drivers without cluttering the road environment with too many traffic signs. Traffic sign "clutter" (Byard *et al*, 1995) describes an excessive number of traffic signs used in any given situation. In temporary traffic management, such clutter may distract drivers and affect their ability to obtain and process information quickly and accurately. Chapter 8 of the Traffic Signs Manual (2009)[1] has been written to provide guidance to practitioners on working practices in relation to road work design and operations, and contains advice on the use of signage in road works. The level of signing in Britain is higher than that found in comparable countries (Baguley, 1996); while the UK has a good road safety record in road works, it is unclear whether the increased number of signs plays a significant role in achieving this.

A driver's ability to understand road signs and directions has clear implications for driver safety. Employing techniques that make road works environments more self-explanatory have the capacity to reduce the number of collisions within road works; for example, anecdotal evidence of the effectiveness of sequentially flashing road danger lamps demonstrates the benefit of a simple, self-explanatory message at reducing taper strikes. These benefits can also bring financial savings through reducing the need for equipment purchase, replacement and maintenance and potentially prevent road worker fatalities. However, there is at present little objective research data in support of such claims.

It is important to base changes in legislation or regulation on hard evidence, as this provides both the justification for the change and the control condition for the subsequent assessment of effectiveness of the change(s) made. Consultations and requests from the HA's Supply Chain have suggested a number of changes that could be made to the current layout of road works, particularly with regard to advance warning signs. However, the effect of changes to procedures needs to be properly understood to support or refute the case for change to working practices. This project addresses this issue and will provide evidence of drivers' visual behaviour during the approach to road works. This research will give key information on how best to change the display of information and position of signage to maximise driver safety and minimise exposure of traffic management operatives to live traffic.

This literature summary will explore the interaction between the factors which may affect driver behaviour at road works. This information is taken from a variety of sources, and summarises the current evidence base relating to simplifying information provided to drivers.

## 2.2 Comprehension of signs

Recent trials conducted for the Highways Agency (WSP, 2008) tested sign comprehension accuracy and speed. The study sampled 40 drivers of various ages and of both genders. The study used a tachistoscope to present participants with a series of

[1] Hereafter referred to as 'Chapter 8'

images of standard road works signs for a specific length of time. Participants were asked to recall the signs that they had seen, with accuracy and response times recorded and analysed. The study found low levels of comprehension of road works signs. Unsurprisingly, performance was particularly poor for signs that are complex or used infrequently on the network, corroborating the findings of Cooper (1989); Dewer *et al.* (1997) and Zakowoska (2001). Tachistoscopic presentation of images does not take into consideration the additional sensory demands of the driving task and therefore the participants in such trials are less likely to suffer overload than they would whilst driving. Consequently, these studies offer a useful guide as to drivers' likely ability to comprehend signs but cannot be considered comprehensive as they do not take account of perception within the context of the driving task.

Board and Freeman (2000) used an extensive questionnaire to assess the degree to which drivers understand roadwork signs, finding that annual motorway mileage was correlated with accuracy. This suggests that increased exposure to road work signs has a positive influence on the recognition and memory of such signs. However, as with presentation of sign images by tachistoscope, this methodology lacks the full context of engagement in the driving task, which may have a significant effect on a driver's ability to comprehend the information presented.

## 2.3 The effect of information levels on driver comprehension

Understanding drivers' comprehension of road works signing and their driving behaviour is crucial to ensuring any simplification measures have positive benefits to the driving task, without compromising safety. The following key question is posed by the Department for Transport in its publication:"Safety at Street Works and Road Works - Code of Practice" (2002):

> *"Will someone coming along the road in either direction understand exactly what is happening and what is expected of them?"*

Influencing driver behaviour relies on presenting clear information to the driver such that the desired response is intuitive and within drivers' capabilities. Research has shown that the ability to process information can be dramatically affected by a number of external factors. Certain models of behaviour (e.g. Wallace, 2003) suggest that a driver will continuously monitor the situation before them, and then adjust their behaviour according to the requirements of the road or any information they receive. Some of the driving-relevant processes that are vital to safe driving are:

- Perception (of external environment and of vehicle status),
- Awareness (of the actions of other road users; of information presented) and
- Judgement (of appropriate speed choice; gap acceptance etc.).

The task of driving requires accurate processing of such information with timely responses to produce safe behaviour. The driver has a limited time to see, interpret and act upon information provided whilst travelling (ARTSM & RSMA, 1998). With greater message clarity comes a greater likelihood that a driver can act safely on the information presented.

In any given road work situation, a large amount of information must be conveyed to ensure drivers have a safe and efficient passage through road works. The former DETR (Department for the Environment, Transport and the Regions) (1995) suggested that it is necessary to limit the amount of information shown on any sign to ensure that information is clear to those travelling at speed (motorway driving). However, there is scope to explore how best to present information to drivers in a manner that is simple, legible and intuitive.

Previous research has suggested that there may be a danger that too much information is given to drivers. Quimby and Castle (2006) suggested that providing too much

information to drivers can produce mental overload. This is an application of Broadbent's (1958) limited channel capacity theory of perception where information processing of external stimuli is limited such that the brain must filter information based on what is perceived to be relevant. This 'attentional focussing' (Byard, Tolladay and Cooper, 1995) is also documented by Theewes (1991) and Hughes and Cole (1986 & 1988). Where more information is presented, there is a greater probability that important information could be ignored or missed.

Baguley (1997) terms the point at which a driver begins to filter out irrelevant messages as a 'saturation point', after which drivers are unable to absorb any further information. This may have implications for the use of different traffic management layouts in areas of high sign saturation. For example, the Active Traffic Management (ATM) scheme on the M42 uses many gantries, signs and Variable Message Signs (VMS) to manage traffic. Use of a traditional lane closure as specified within Chapter 8 under these circumstances may exceed a driver's 'saturation point'.

Hoyos (1988) proposes that mental overload is a cumulative effect and relates to the intensity of information provided and the duration of exposure to that information. Again, signs used to indicate approaching lane closures or temporary speed restrictions may cause drivers to become overloaded with the consequence that they may miss safety critical information. Indeed, research undertaken by Baguley (1997) suggested that positioning signs in pairs close together (defined as less than one second apart) reduces the ability of drivers to absorb information from both the signs, confirming similar research by Rados *et al* (1985) and Johnson (1982). Drivers are only capable of absorbing a certain amount of information, in a certain time frame. Sign layouts should be designed around these limitations rather than assuming that all information can be processed by the driver.

## 2.4 Summary

This brief summary has demonstrated that a number of factors must be considered when designing optimal sign layouts for temporary traffic management. The signs should be simple, clear and should present information in such a manner that does not cause a driver to become overloaded and thereby potentially miss safety critical information. Drivers should understand what is happening, what is required of them, and when and how they are required to respond. Testing of such sign layouts should consider not only drivers' basic comprehension of signs but comprehension within the context of the driving task, where the additional visual demands may affect drivers' ability to take in all information presented.

# 3 Road works simplification

## 3.1 Introduction

The current Regulations, i.e. The Traffic Signs Regulations and General Directions 2002 (TSRGD, 2002), govern the design of all traffic signs and must be considered when planning the optimal information that a sign should contain when used in road works. This section outlines the different factors relevant for sign simplification, primarily focussing on sign regulation.

## 3.2 Sign evaluation criteria

Work undertaken by TRL in 1965 (reviewed in Baguley, 1996) identified a number of key factors that determine the effectiveness of a sign. These have been developed by Dewer and Ells (1982) and supplemented by McCarthy and Hoffmann (1977) and Donald (1995). Table 1 presents an amalgamated list of the criteria proposed by these authors.

**Table 1: Evaluation criteria for assessing signage**

| Criteria | Explanation |
|---|---|
| Legibility Distance | The maximum distance at which a sign can be read |
| Understandability | The ease with which a symbol can be understood |
| Attention Value | The extent to which a sign can be easily detected or seen in a visually complex environment |
| Learnability | The extent to which the meaning of a symbol can be easily learnt and remembered |
| Glance Legibility | The ease with which a sign can be read when it is viewed for only a short time, e.g. a fraction of a second |
| Reaction Time | How quickly the driver can understand the meaning of a sign, and react to it |
| Visibility Distance | The maximum distance at which a sign can be seen |
| Message Coding | What message is provided, the shape of the sign and the colour of the information provided |
| Sign Graphics | The size of the font, letter shapes and symbol design |

The remainder of this section focuses on *message coding* and *sign graphics* since these overarching criteria have an impact on all others listed in Table 1.

### *3.2.1 Message Type*

Temporary traffic management signs can be characterised into those either carrying either *regulatory*, *warning* or *information* messages. This categorisation is known as the 'primary message'.

*Regulatory* messages indicate where a legal requirement applies, such as speed restriction or a lane closure, and can either carry a mandatory ("*must* do") or prohibitive ("*must not* do") message.

*Warning* messages indicate to drivers the presence of an unexpected or hazardous road condition, such as queuing traffic or advance notification of works.

*Information (referred to as ' Informatory' in TSRGD)* messages give guidance and advise road users of directions and distances (e.g. service areas) and aside from courtesy signs advising about advance notification of road works, are used less frequently in temporary traffic management at work sites.

Several studies examine whether mandatory or prohibitive signs are more effective in terms of their ability to influence driver behaviour. McCarthy and Hoffmann (1977) found evidence that mandatory signs or a combination of mandatory and prohibitive messages are more effective than prohibitive messages alone. Macdonald and Hoffmann (1981) also found that mandatory signs can be comprehended faster and more accurately than equivalent prohibitive messages.

Baguley (1992) analysed road work signs in terms of their 'action potential' – the degree of obligation on the driver to act upon the information presented in the sign. It is suggested that signs that require drivers to take action are more important than other messages, regardless of whether the action required is mandatory or prohibitory. This suggests that it is appropriate to use signs of either a mandatory or prohibitory nature, as they are the most likely type of sign to create the right "action potential", and result in the driver taking the intended direction/action.

The current "wicket board" design used in Chapter 8 to indicate a lane closure (i.e. Diagram 7202 in TSRGD, 2002, shown on the left below) has a *"prohibitive"* emphasis due to the red bar across the closed lane. This indicates the lane cannot be used but does not give explicit information as to what behaviour is required.

The "hooked arrow" design (Diagram 872.1) gives a *"mandatory"* focus, directing the driver to move out of the closed lane. This gives clear information to the driver as to what behaviour is required and thus communicates the need to take action.

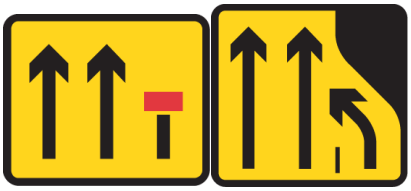

**Figure 1: "Wicket board" and "hooked arrow" lane closure signs**

Drivers may therefore be more responsive to a format of sign that communicates a need to take action; this approach should be considered as an option for simplifying the message on such a sign. This concept was discussed further in the stakeholder workshop (see Section 4), and has been included in some of the TTM designs proposed for trial in the TRL car simulator (Phase 2 of this project, see Section 5).

The primary message, whether mandatory or prohibitory, can be displayed in one of the following three ways:

- Alphanumeric only;
- Symbolic only; and
- Hybrid signs, containing both alphanumeric and symbolic messages.

A sample of each of these different displays of primary messages, taken from the Traffic Signs Regulations and General Directions (2002), are shown below (Figure 2). These examples have been chosen because they also appear in Chapter 8 of the Traffic Signs Manual.


Alpha-numeric Symbolic Hybrid

**Figure 2: Different forms of signage that are in use at road works**

Symbolic and hybrid signs are generally regarded as more effective than alphanumeric signs in terms of the speed at which their message is conveyed, comprehension by the widest possible audience and the distance from which the message may be understood (see Standards Australia, 1992). There is conflicting evidence as to whether symbolic or hybrid signs are the most effective and it is likely that this is dependent on the message that is being conveyed. However, it is clear that, where possible, the addition of a symbolic element to a sign has benefits for legibility and comprehension.

### *3.2.2 Sign Shape*

The primary message of a sign influences the shape and colour of the signage used. Therefore the shape and colour of the sign also communicate information to the motorist. McCarthy and Hoffmann (1977) term this supplementary information the 'secondary messages'. In Britain, circles usually communicate orders; triangles for warnings and rectangles for information. Baguley (1996) noted, however, many of the signs at major road works on high speed carriageways and motorways are rectangular whether they order, warn or inform, for example, triangular warning signs such as 'slippery road ahead' are mounted on rectangular backing boards. The secondary information which could be gleaned quickly and effectively may therefore be lost. Care must therefore be taken in specifying sign schemes, taking into account whether there is a conspicuity advantage to mounting a sign on a rectangular backing board or whether there is benefit to retaining the original sign shape and therefore preserving the secondary message.

### *3.2.3 Sign Colour*

The colour of a sign is part of the message that is conveyed to driver by the sign's presence, independent of the need for interpretation of symbols or text. Many of the rectangular signs included in Schedule 12, Part III, of TSRGD, 2002 have a yellow background colour which indicates that these signs are temporary signs. However other signs have white backgrounds which is not consistent within the works site; additionally, non-rectangular signs used at road works sites are sometimes mounted on rectangular backing boards.

The mounting of these sign faces on rectangular backing boards (which are normally yellow but are sometimes grey) results in not only the loss of sign shape as a form of communication with the driver but also the loss of the secondary message of sign colour. Indeed, Chapter 4 of the Traffic Signs Manual (which describes the use of warning signs on any roads) suggests that the:

> "*…over use [of yellow backing boards] could eventually devalue their attention-attracting benefits*"
>
> (DfT, 2003)

Ensuring that the shape and colour of signs is consistent with the message being communicated by the sign is an important part of the sign's function. Within road works sites the use of a definitive colour to communicate the presence of road works is used in other countries such as Norway, France, Belgium, the Netherlands and Ireland. Associating a specific colour with signs used to denote road works could create a

consistent message that may mitigate the over-use of yellow backing boards in other environments and the dilution of message that this causes. This approach is a significant departure from current practice and would require careful selection of a colour that is not in use for other signs. This technique would simplify the message at a fundamental level and so could allow the driver to identify road works before they are able to read the text/graphic on the sign face.

### *3.2.4 Size of Signs*

The size of signs is determined by the concept of x-heights (defined as the height of a lower case 'x', with all other characters scaled from it). Much research has been conducted into updating the formula derived for calculating x-heights, with different x-heights being proposed to take account of the reduction in speed limits through work sites, the increased complexity of temporary works messages, and the varying sideways displacement of signs from vehicles over the width of a motorway carriageway (Baguley, 1996; Baguley and Flint, 2000). These two studies focussed on updating two of the parameters used for calculating x-heights; the *maximum divergence angle* and the *reading time of signs* (see Appendix A). The outcome of previous research suggests that there would be insufficient benefit in investigating changes to x-heights, divergence angles or reading times beyond the current standards within this project.

### *3.2.5 Symbol Design*

For all symbols, and as with alpha-numeric signage, driver comprehension is related to the visibility and legibility of the symbol, as well as the ability to understand the message that it conveys. The literature covering symbol design is well established (e.g. Eliot, 1960; Cairney 1981a; Cairney 1982b; Swanson et al., 1994; Donald, 1995). Consequently, there is likely to be little benefit in examining symbol design within this project. However, there is certainly scope to examine optimisation of the choice of symbol used on the signs for temporary traffic management.

## 3.3 Relevant studies investigating road works sign simplification

Research suggests that driver behaviour and expectation changes over time so that sign layouts at road works should be reviewed to ensure all signs are both necessary and effective. For example, the "50mph ¾ mile ahead" (diagram 7290) sign was first introduced to prevent sharp braking at the start of a temporary traffic management site. However, Baguley (1997) recommended that the use of the sign was unnecessary as temporary speed limits at road works are commonplace. Freeman and Geston (1999a) conducted an on-road trial of the effectiveness of the sign, finding that it made little difference to overall traffic speeds. Consequently, Chapter 8 (paragraph D3.7.20) says that the use of the "50mph ¾ mile ahead" sign is no longer recommended.

A study by Baguley (1996) highlighted that the use of white arrows as temporary road markings is not necessarily effective, as they may not be identified by drivers and are duplicated by other signs, such as wicket signs, cones, studs and temporary markings. Consequently, such white arrows are no longer used and are not referred to in the 2009 version of Chapter 8.

Freeman (2000) demonstrated that increasing the number of 50mph mandatory temporary speed limit roundel signs (diagram 670) on the approach to road works reduced traffic speeds through the works by approximately 4mph. This is an example of salient information provided by a mandatory sign resulting in a change in behaviour. When simplifying road work layouts, it important to identify the most relevant information to the driver, and ensure this is reinforced.

A driving simulator trial relating to the omission of the 600 yard wicket signs was undertaken by Freeman and Geston (1999b). This study relied on vehicle path through

the road works in order to measure driver behaviour as no method was available to directly measure eye fixation on sign faces. The 1999 study found late merging was more likely in the absence of the 600 yard sign; participants' subjective responses in a questionnaire indicated a general lack of understanding about the lane closure signing system. However there was no direct measure of how drivers were gaining information through the road works, nor why the late merging behaviour was more likely. This study demonstrates the usefulness of gaining evidence about behaviour in relation to sign simplification through driving simulation and the benefit that can be gained by understanding where and how drivers gain information when approaching the lane closure.

Research can demonstrate, in some cases, that signs that may have been rightfully deemed appropriate when first implemented may now be superfluous or superseded. In other cases the evidence is unclear or supports retention of a sign; this needs to be weighed against the risk to road users and road workers from omission of the sign. Driving simulation offers a useful technique for gathering data to feed in to quantified risk assessment for road users and road workers, which can support or refute the case for sign simplification.

## 3.4 Sign Visibility Factors

There are external factors which have a bearing on the visibility of signage and therefore an impact on the feasibility of signage simplification, particularly where this relates to fewer or smaller signs. An example is duplication of signs on both sides of the carriageway where the view to the sign to the left of the carriageway may be obscured by heavy traffic or high sided vehicles. This is recommended in Chapter 8 for most types of road works on dual-carriageway roads.

Drivers are unlikely to use every sign on the carriageway to gain information and may alter their visual behaviour to gain the relevant information needed to perform a task. A driver may simply pay more attention to the signs that are on the right side of the carriageway, which are unlikely to be obscured by high-sided vehicles. Removing the right hand side signs may thus bring a large safety benefit to road workers but at a significant risk to some road users. Such external factors must be considered in any sign simplification scheme.

## 3.5 Summary and Conclusions

When considering the wide-ranging topic of "temporary" road works, the most important factor is to prioritise the safety both of motorists and road workers. The UK has a good safety record in terms of temporary works and this may be due to the design and deployment of temporary traffic management signing. However, the review of literature has indicated there may be an opportunity to simplify the traffic management used in road works, and influence how drivers interact with signage in different forms.

This project will aim to address this by providing comprehensive data on driver behaviour through different types of traffic management layouts on the approach to road works on a dual carriageway road. This will be provided through detailed assessments of drivers' behaviour in a control simulator environment, and will then examine driver behaviour during a limited use of a design from section 4.5 on a live carriageway.

Whilst simplifying the information provided at and before road works has benefits to implementation of traffic management measures, it is important to balance this with safety for road users. Drivers need to have as long as possible to comprehend and act on information provided to them. There is therefore a balance to be struck between sign clutter, an appropriate level of signing and situations where the visibility of signs may be compromised by external factors. It is also important to understand how mandatory and prohibitory messages influence behaviour and the extent to which each should be used in road works.

The literature has highlighted that the driving task can place heavy demands on a driver's attention. It has also indicated that a person has a fixed capacity to process information gained from their environment. Sign clutter, duplication of messages or overcomplicated signs may produce a negative effect on behaviour. For instance, a driver may attend a duplicated sign and this may stretch their ability to process the available information. They may therefore fail to attend another critical sign resulting in an increased likelihood that they will behave in an undesirable/unsafe manner. Such factors should be considered when designing any further traffic management layouts. The focus of the next phase of this project must be to improve/maintain driver behaviour whilst using traffic management layouts that are straightforward to implement.

The majority of messages to motorists are communicated using fixed signs. With drivers having limited information processing and attentional capabilities, there is a need to ensure that all signage provides them with a relevant and clear message. It is clear that additional signs may not clarify the message. Excessive, unnecessarily complicated and unclear signs can have a detrimental impact on the quality of the driving task and therefore the safety of all road users.

This review has not identified any existing evidence to indicate the signs which drivers pay attention to when travelling through road works. Phase 2 of this research (a driving simulator trial of various TTM configurations) will assess whether the current Chapter 8 principles for the signing on the approach to a short term works on a dual carriageway road contain 'too much' information for drivers, or whether drivers simply disregard a large portion of this information.

Various studies have aimed to pinpoint how best to convey a message to motorists – using action messages, mandatory or prohibitive statements or using symbols instead of alpha-numeric signs. Literature generally suggests that the simplest message, and therefore the simplest sign, is the clearest. It also suggests that there is a hierarchy of message, with the use of a simple mandatory message (e.g. 50 mph speed limit sign) improving driver comprehension, which increases the likelihood, that a driver will take action as a result.

The relative influence of sign shapes and colour has also been explored in the review, and although both parameters can improve the conspicuity of a message, they may be outside the scope of this current research project.

This study will aim to reduce the complexity of the message in specific cases and examine whether the 'action potential' for drivers is increased. It is hoped that this may result in discovering a way of subtly changing current signage to deliver a stronger message to drivers, resulting in improved compliance.

Given there some simplification of signs has been viewed as appropriate (i.e. omission of the "50mph ¾ mile ahead" sign) and the principles behind Baguley's (1996) recommendations still hold true, there is sound basis for continuing research in this field. There are also a clear set of 'rules' that should be used when designing traffic management layouts, which have been taken into consideration when developing the three traffic management layouts that will be examined in Phase 2 of this project (Section 4.5 of this report).

# 4 Stakeholder workshop

A stakeholder workshop was held to obtain views on simplifying the layout for the signing on the approach to the short term temporary closure of a lane at a works on a dual carriageway road, and how best this could be achieved. By engaging with key stakeholders at this time it ensured that the suggested changes would be practicable and would facilitate involvement of supply chain partners in any trial of the layout on the network.

Attendees invited to the workshop were selected to represent a diverse range of opinion in relation to TTM. Representatives from the following bodies were invited:

- Supply chain partners
- Road user organisations
- Highways Agency Chapter 8 team

Members of the Department for Transport, Association of Chief Police Officers and the Health and Safety Executive were also invited but were unable to send representatives on the day. A full list of attendees is shown in Appendix B.

The workshop started with a presentation that outlined the aims and objectives of the day and topics for the discussion sessions. Attendees were then split into three groups to discuss the ideas and themes. Each group contained at least one supply chain partner, one member of the Highways Agency team and one member of TRL staff to facilitate discussion. After these sessions, the groups reconvened to decide on three layouts that would be put forward for testing in a driving simulator trial.

Discussions centred on the Chapter 8 layout for a relaxed[2] lane 3 closure, as shown in Figure 3 below:

[2] Relaxation schemes are appropriate for certain types of works for short-term situations with good visibility and low traffic flows

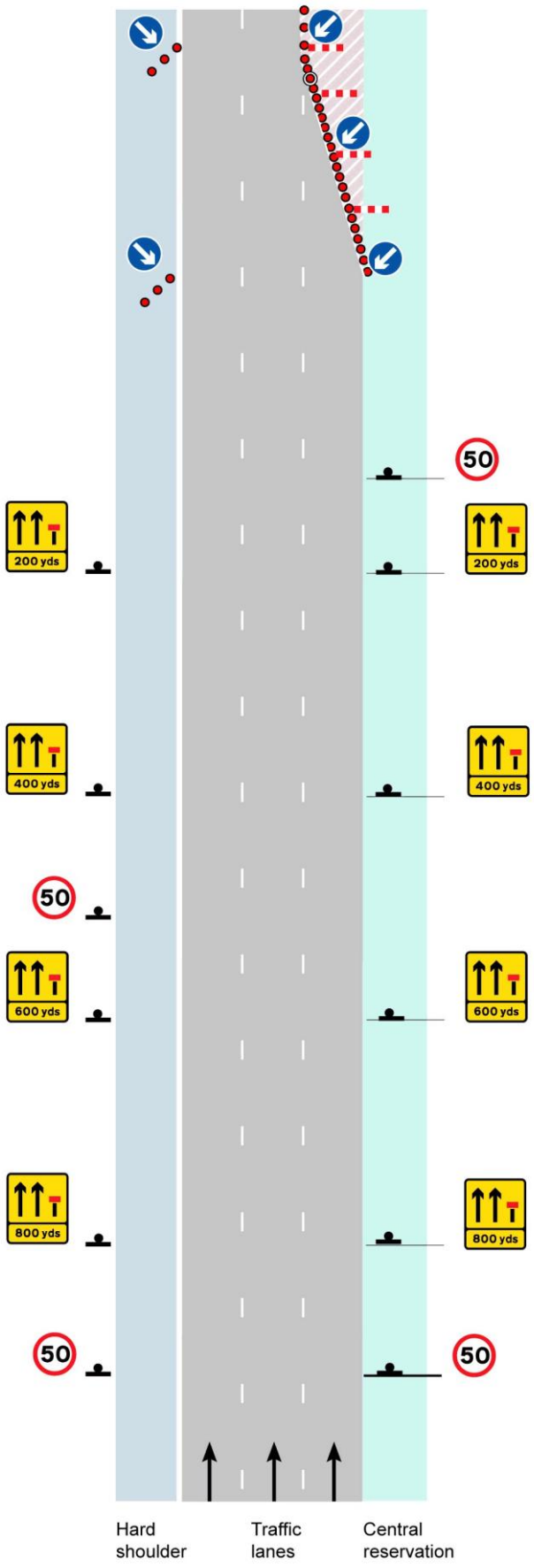


**Figure 3: Layout for a relaxed Lane 3 closure discussed at workshop**

This configuration is the most widely used on the network, sometimes several times a night by a team of operatives. For relaxation lane closures, imposing and enforcing mandatory speed limits is currently impractical (though work is ongoing to develop average speed enforcement equipment suitable for use in these situations). Until it is possible to enforce speed limits at such works, this type of temporary traffic management carries the greatest risk for road workers due to the speeds at which traffic passes the works site.

A glossary of terms used in the workshop (and referred to in this Section) is contained in Appendix C.

## 4.1 Session 1: *Ideal driver behaviour*

The first discussion session addressed the type of behaviour that stakeholders would consider ideal for drivers to adopt when travelling through TTM. The following questions were posed:

- "What would we like drivers to do?"
- "When would we like them to do it?"
- "What information should be given?"
- "When should information be given so it is useful to drivers?"

### *4.1.1 Discussion summary*

Stakeholders stated that ensuring drivers complied with all speed limits (either temporary or permanent), would immediately improve safety through road works. Stakeholders then indicated that on approach to road works, drivers should:

- see the signs,
- understand the signs,
- and then obey them at the appropriate time.

It was felt that under the current conditions drivers do not obey the signs for a variety of reasons. Drivers may fail to see, fail to understand, or choose not to comply with the traffic management measures applied.

There was discussion over the point upstream of the lane closure at which drivers should move out of the lane to be closed. Stakeholders agreed that a driver in the lane to be closed should start planning their lane change manoeuvre no later than the 800 yard "wicket board" sign. The manoeuvre should start between the 600 yards and 400 yards signs (within the current layout – see Figure 3), and that all drivers should be out of the closed lane by the 200 yard wicket board.

Discussions highlighted that timely presentation of appropriate information is an important feature of TTM. An example identified by stakeholders as to where there may be a shortcoming in the signs used currently was the existing "wicket board" signs (see Table 5). These indicate a lane closure but fail to provide the driver with an instruction what to do and when. Stakeholders felt that an alternative that would give an appropriate order was the "hooked arrow" sign.

The issue of speed and compliance with posted limits was a key discussion topic. It was generally felt that the lack of enforcement in relaxed works resulted in excessive speed and that this was often a contributory factor in accidents[3]. Where advisory speed limits are in place the stakeholders felt that only when the speed limit is reduced to 40mph is there a noticeable reduction in speed.

[3] This issue is being addressed by work looking at average speed enforcement in short-term overnight road works

## 4.2 Session 2: *Critique of current Chapter 8 principles*

In the second session, the Chapter 8 principles for the closure of lane 3 on a motorway were discussed. Talks were guided by the following questions:

- "How does the Chapter 8 configuration for relaxation works address those needs identified in session 1?"
- "What are its good points?"
- "What are its bad points?"

Stakeholders felt that the current Chapter 8 design does not address all the needs of the road user or the road worker. The good and bad points of the current layout are detailed in Table 2. The points raised are recorded as direct quotes.

**Table 2: Critique of relaxed Chapter 8 lane 3 closure**

| Good Points | Bad points |
|---|---|
| Lots of signs - Less chance of missing information if signs obscured | Too many signs– visual clutter – information overload - confusion |
| Established information - consistency | People do what they have always done – not necessarily what is safe |
| People do take the action they see necessary at the time | Wicket says lane is closed but there is a taper there – not closed as the sign says |
| Taper gives people a last opportunity to merge | Illumination of signs – retro reflective signs |
| Sign size – seen in time | No instructions |
| Guidance – risk assessment (back-up) | Established information leads to complacency |
| Well laid out document with a lot of relevant information | Reluctance to adapt to actual situation – risk assessments etc |
| Common standard across the network – consistency | Size and weight of signs causes manual handling problems |
| | Some drivers don't understand some road works signs |
| | A perplexed driver is an unsafe driver |
| | Diagrams split into 5 sections |
| | Approved Code of Practices (ACOPS) are easier style to read |
| | Being asked incorrectly: at design stage should make decisions but tends to be "just do a Chapter 8" |
| | Picking out relaxed layouts not that simple |
| | Do drivers understand the signs: particularly the wickets? |
| | If Variable Message Signs are available, can the number of wicket signs be reduced? |
| | Inconsistency between permanent and temporary signs (e.g. hooking arrow) |

Table 2 shows that several points appear on both lists demonstrating that there can be a conflict between the respective requirements of traffic management operatives and motorists. Manual handling of signs was the greatest concern expressed by stakeholders; particularly members of the group who work in the traffic management industry. Moving large signs across the carriageway can be a cumbersome and awkward task resulting in the operatives responsible being exposed live traffic. An operative moving a large sign may also be obscured from the view of motorists and therefore may not register as a significant hazard. Such signs also present a danger to motorists if dropped, or fall into the carriageway at any point during operations.

## 4.3 Session 3: *Ideas for change*

In this session, stakeholders discussed how the Chapter 8 layout could be changed to help promote the ideal behaviours discussed in session 1 and to address the shortcomings identified in session 2, without sacrificing the advantages that were also recognised.

Numerous ideas were put forward by the stakeholders; these are listed in Table 3. These ideas covered a wide range of issues relating to the current layout. Most centred on reducing the number of signs, reducing the size of the signs and increasing the clarity of the message that is conveyed to the motorist.

Not all ideas were practical steps to be taken at this stage; however, they have been included in the table below for completeness. Although some are not practical due to technological limitations, they are worth considering for future changes and have been noted as a matter of record.

It was felt that pictograms are better than text as they can be understood by those with limited comprehension of written English and take less time to comprehend that text-based signs.

**Table 3: List of proposed changes or alternations to current Chapter 8 layout**

| Proposed change to layout |
|---|
| Fewer signs – removal of a "wicket board" sign (views differed as to the distance from which the sign should be removed) |
| "Hooked arrow" rather than "wicket board" sign either for all signs or at 400 yards and 600 yards only with standard wicket at 200 yards |
| Men at work warning triangle at 800 yards rather than a mile |
| Keep pictograms within "wicket board" sign or "hooked arrow" sign, but lose words (i.e. distance indicators) |
| "Wicket board" sign at 1 mile or 1200m |
| Men at work warning triangle at 1 mile sign on nearside only |
| Replace men at work warning triangle with a "wicket board" sign |
| Reducing sign size to 1200mm (from 1500mm, e.g. 610 arrow sign) |
| Placing two electro-luminescent "active" 610 arrow signs in the taper, replacing the current 610 arrow signs |
| Different coloured sequential flashing cone lamps (red, orange, green were discussed) – in case yellow isn't the most conspicuous/appropriate colour |
| Remove one or both Detail A's from the current layout |

| Proposed change to layout |
|---|
| Use of a symbol instead of yards in numbers e.g. **** = 800 yards; *** = 600 yards etc or countdown markers as used at junction exits. |
| Using metres rather than yards on distance plates / "wicket board" signs |
| Use words "merge now" at some point during the closure to present the driver with information on expected behaviour. |
| Use of other materials –different types of retro-reflective materials to gain the best clarity and conspicuity of signage |
| Use of fluorescent yellow/orange as a background colour as a replacement for the current "flat" yellow (used in the majority of signs) |
| This would simplify the message given to motorists, as they would associate the colour with being in road works. Yellow currently does not provide this |
| Remove "WORKFORCE IN ROAD SLOW" sign at 1 mile |
| Combine "WORKFORCE IN ROAD SLOW" sign with men at work warning triangle |
| Use of flashing beacons on men at work warning triangle to enhance conspicuity |
| Remove lighting of temporary signs |
| Remove men at work warning triangle |
| White legend on blue background for motorway signs (white on green for A roads) to improve consistency with other signs present |
| No taper, horizontal line of cones with barrier behind |
| Hooked arrow with plate underneath that states "Now" |
| **Other changes discussed** |
| More permanent fixed taper positions & hard standings for signs – changes may allow the use of more technology e.g. power sources to electro-luminescent signs |
| Reducing speed limits to 50mph or 40mph in all road works |
| Variable speed limits depending on circumstances e.g. day or night |

Of the changes discussed, stakeholders agreed that the most promising was to remove signs with the aim of simplifying the message given to drivers and a secondary benefit of reducing the exposure of traffic management operatives to live traffic when implementing the lane closure.

## 4.4 Session 4: *Effects of any change to Chapter 8 principles*

In Session 4, stakeholders focussed on the potential benefits from the proposed changes to current temporary traffic management on the approach to a lane closure on a dual carriageway. Although each change has its own benefits, it was thought that applying several of the changes may bring a greater cumulative benefit than that for the sum of the benefits of each individual change.

It is important to note that although the focus of this session of the workshop was the benefits that could be gained from altering the current Chapter 8 layout, any change has the potential to bring disadvantages.

**Table 4: Potential benefits of proposed changes to Chapter 8 layout**

| Change | Benefit |
|---|---|
| **Reducing the number of signs** | Less risk to operatives deploying the signs<br>- Less risk to drivers of hitting an operative carrying a sign across the carriageway<br>Reduces cost to contractors<br>Increased speed of deployment and retrieval increasing the working window<br>Improved clarity of message increases driver compliance<br>Reduces congestion<br>- Directly (traffic flow is smoother)<br>- Indirectly (fewer accidents)<br>Better consistency across the network – less chance of misinterpretation<br>Signs all up quicker reducing the time for misunderstanding from traffic<br>Reduced wear on traffic management vehicles, reduction in fuel costs if vehicle load can be made lighter |
| **Use of "countdown" instead of numbers** | Easier to understand (including foreign drivers)<br>Increased flexibility of placement |
| **Reduce size of signs** | Reduces manual handling<br>Easier to carry thus less likely to have an accident |
| **Sign Self Illumination** | Reduces unnecessary equipment being carried across the road<br>Possible increase in the conspicuity of the sign, and it may also increase the distance at which a driver receives information (giving them more time to plan actions) |
| **Improved reflectivity of cone sleeves** | Remove longitudinal lamps – reduces road worker exposure<br>Reduce cost – no lamps and no batteries<br>Reduce exposure of road workers to live traffic as don't have to replace lost or broken lamps |

Discussions highlighted the difficulties and financial cost of implementing changes to the layout on a national scale but did not identify any perceived risk from late merging. There was a concern that, were any changes to be introduced gradually, there would exist the potential for a driver to experience inconsistency of traffic management layout in a single journey, possibly leading to confusion. Any changes implemented would also require an information campaign to ensure motorists were aware of the new scheme and this campaign would have its own associated costs.

From the list of changes, it was decided that this project would focus on reducing the number of signs and improving the clarity of the message given to drivers.

## 4.5 Outcomes from the workshop

Three ideas to be tested were developed from the workshop: a minor change, a moderate change and a large change from the current Chapter 8 layout for the approach to a lane closure on a dual carriageway road. The changes simplify the layout but still give the driver all the important information required to negotiate the approach to the road works safely. Changes applied consist of a reduction in the number of signs on the approach, simplification of the message given to drivers and adjustment to the distances at which some of these signs are placed.

### *4.5.1 Current layout: Chapter 8 "relaxed" layout*

Below is an example of the "control" layout that is the basis for relaxed closures on dual-carriageway roads:

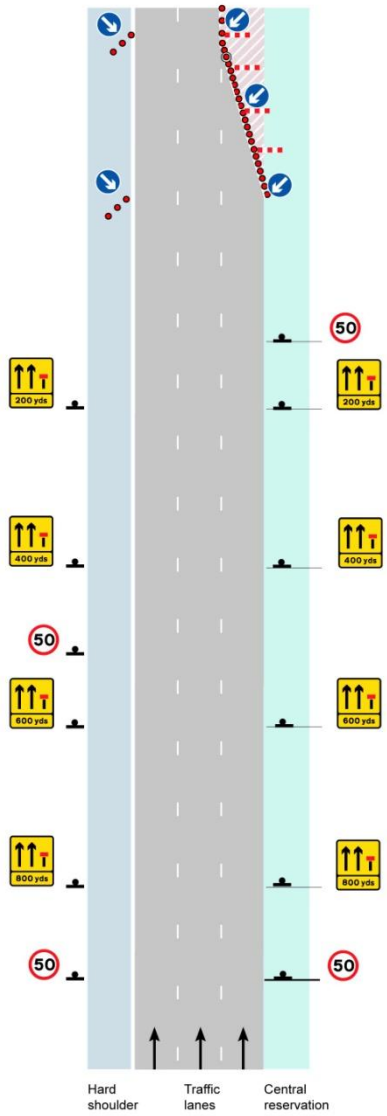


**Figure 4: Proposed closure layout control – Current Chapter 8 layout**

The proposed approach was to use this current layout as a template, and adjusts the signage in various ways. Maintaining a familiar overall layout of TTM is of benefit; drivers are more likely to except changes that are based on an existing layout.

### *4.5.2 Proposed layout change 1: Minor change*

Within this proposed layout (shown in Figure 5) the Detail 'A' has been removed from the hard shoulder since under normal circumstances traffic should not use the hard shoulder and removing the Detail 'A' improves access for vehicles that have broken down and for emergency vehicles attempting to respond to any incident. A Keep left/right arrow sign and two lane closure signs have also been removed from within the taper. The 600 yard "wicket board" sign has also been removed on both sides of the carriageway.

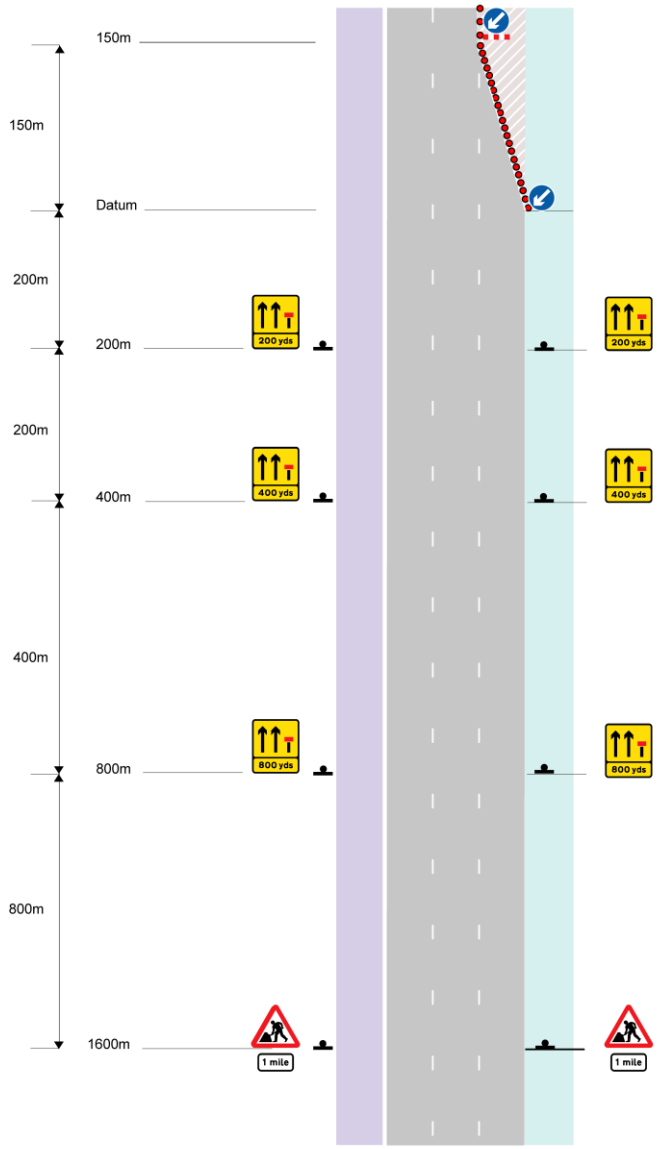


**Figure 5: Proposed closure layout 1 – Simple sign reduction**

### *4.5.3 Proposed layout change 2: Moderate change*

For the moderate change shown in Figure 6, the changes in and around the taper remain the same. The 800 yard "wicket board" sign is removed, replaced by a "road works" (Diagram 7001) triangular warning sign. The 1 mile supplementary plate underneath it is also removed. The 600 yard and 400 yard "wicket board" signs are replaced with "hooked arrow" signs. The distance information on these signs is removed completely; however at the 400 yard position the distance information has been replaced with a bottom panel containing the advisory message 'Now'.

Replacing the "wicket board" signs with "hooked arrow" signs is a move towards harmonisation with permanent road signs. It may also provides the driver with a clearer message of what they have to do unlike a standard "wicket board" sign that shows that the lane ahead is closed, but gives the driver no instruction.

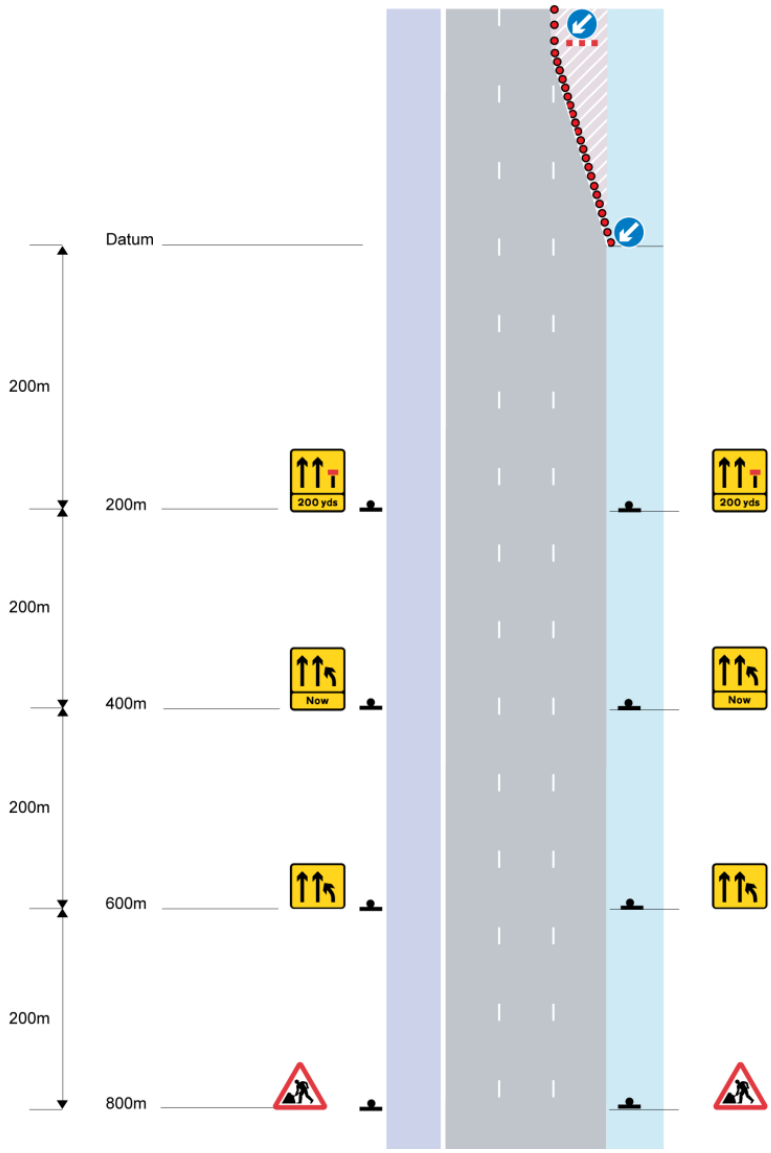


**Figure 6: Proposed closure layout 2 – Use of hooked arrows**

### 4.5.4 *Proposed layout change 3: Large change*

*Minimal signage (Figure 7)*

This change did not come out of the workshop directly but was developed by TRL using a number of concepts from the literature and the workshop. The changes within this layout build on the use of a "hooked arrow" sign and removal of signage. Only one Keep left/right arrow sign and lane closure sign is used in the taper; this is located approximately in the middle of the taper (subject to clearance/road space availability). This change in position brings the sign into the driver's direct sightline, which research suggests (Wilkie and Wann, 2002) will increase the chances that a driver will detect the sign from a greater distance.

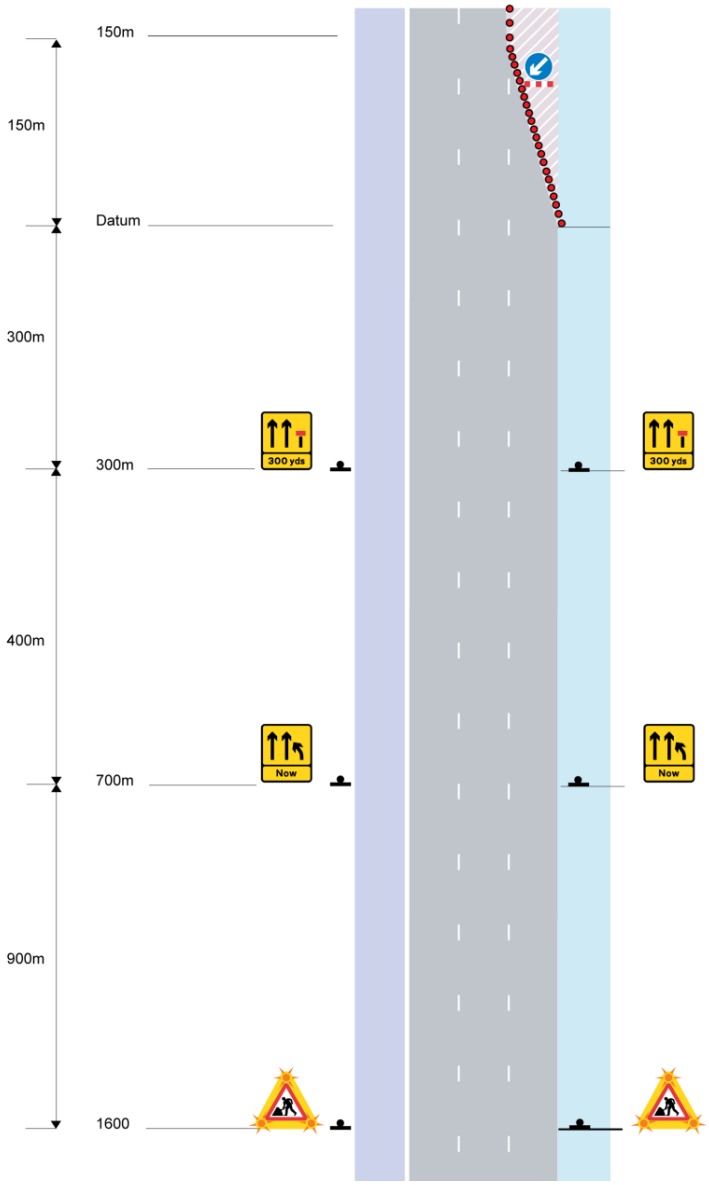


**Figure 7: Proposed closure layout 3 – Minimal signage**

Based on research into conspicuity, there is a change to the men at work warning triangle, which gives the driver their first indication they are travelling into a road works area. The distance plate has been removed and synchronous amber flashing lights attached to the corners of the sign face. The intention is that the lighting would aid the conspicuity of the sign, communicating the triangular "hazard" shape to approaching drivers and thus ensuring that drivers would not pass the sign without looking at it. The

removal of the supplementary distance plate is intended to cause the driver to seek information on how far away from the road works they are, looking past the signs to the road works, taper and cone. This may focus a driver's attention on the traffic conditions and may lead to drivers merging earlier. The distances have been altered slightly, moving the 200 yard "wicket board" sign to 300 yards and moving the 600 yard "wicket board" sign to 700 yards. It is anticipated that giving information earlier to drivers would encourage earlier decisions to change lane in some drivers who follow the advance merge sign.

## 4.6 Other ideas that emerged from the workshop

As the workshop progressed, other ideas associated with the changes to temporary traffic management emerged. These are presented within this section.

It was felt that before changes are implemented on the network, it would be beneficial to ask representatives from the Institute of Advanced Motorists, the Freight Transport Association and the Road Haulage Association their views on the proposed changes.

The stakeholders indicated that sites with average speed cameras see a greater compliance to speed limits, and as such would like to see a comparison of accident rates at road works with average speed cameras and those without, to use as evidence to support mandatory speed limits at all sites where temporary traffic management is applied.

It was agreed by all the stakeholders that whatever changes are implemented, education of the drivers about the changes needs to be given serious consideration and effort. There is a perception amongst the stakeholders that a section of the motoring public deliberately do not obey road works signs and that a cultural change is needed in order to improve driver behaviour through road works. This needs significant investment and an appropriate method of conveying the message to the right people.

An alternate layout was also suggested (see Figure 8), though it was for a Lane 1 and 2 closure from the hard shoulder whereas the other ideas were based on a Lane 3 closure from the central reservation. This layout has been adopted in the 2009 version of Chapter 8 (paragraph D6.13.11) and has no signs in the central reservation at all. Lane 1 is closed followed by Lane 2; for the Lane 1 closure the signing used is the same as for a standard layout, but is only placed on the hard shoulder. For the Lane 2 closure the signs are placed within the closed Lane 1 and depict a two lane road being reduced to one lane. This layout has the advantage of eliminating carriageway crossings by operatives completely.

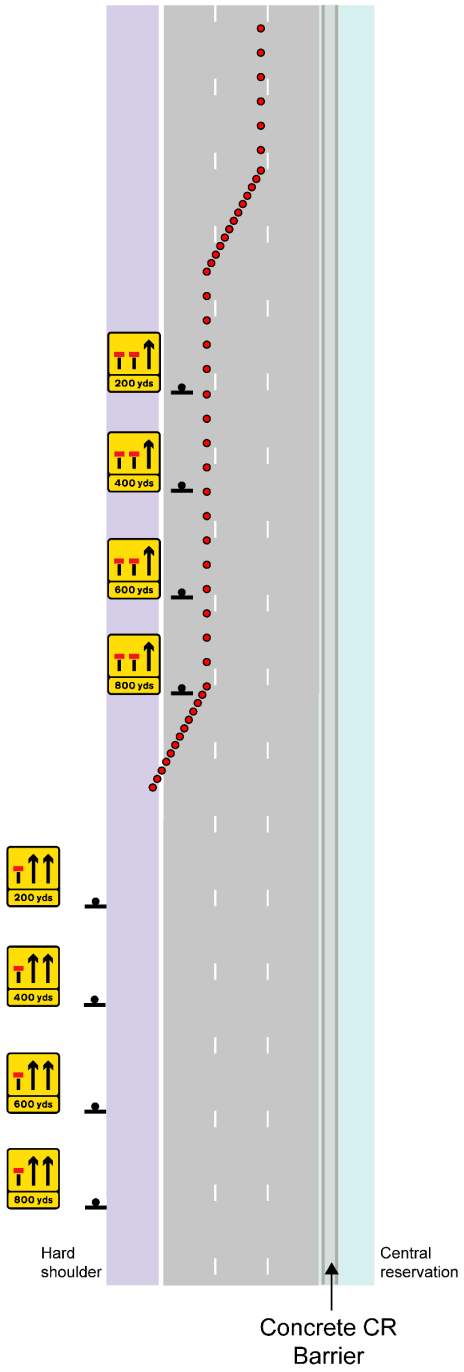


**Figure 8: Additional idea for TTM on motorways with concrete barrier**

There were a number of further ideas that have developed through this first phase of the project. These include:

- Changing the colour of signs used at work sites e.g. fluorescent orange, fluorescent Saturn Yellow
- Use of smaller signs
- Use of electro-luminescent signage

While some of these changes would not be technically possible at this stage, the idea of changing sign colour is a possible way of improving driver awareness of road works. Research conducted by TRL has discovered that a 'dedicated' sign colour is used on the continent to identify road works (Norway, Belgium, Netherlands, and Ireland). From the literature review it is clear that a dedicated colour could allow a driver to identify road works quicker, possibly without directly seeing the text/pictograms on the signage. This may be an area for further exploration in future studies.

Similarly, it would be useful to understand the effect of sign size since the use of smaller signs would have significant benefits for traffic management operatives and contractors. Carrying large signs across 'live' lanes is a significant risk to workers and the travelling public. If the same sign could be made smaller and still maintain its conspicuity and legibility, this may lead to reduced risk to road workers in a number of areas and reduced sign cost.

# 5 Discussion

The aim of the first phase of this project was to engage with stakeholders, and develop three alternative temporary traffic management designs that could be used in place of the current Chapter 8 layouts for the approach to a lane closure on a dual carriageway road. In addition, a literature review was conducted to inform further decisions on the TTM layout designs.

There are concerns that there may be more signs and information than is required for a driver to pass through a road works safely however, there is little reliable evidence on driver behaviour through road works, or the effect of changing the current signage in any way. Therefore, the stakeholder group felt that Phase 2 of this project (the simulator study) would produce useful information on driver behaviour at road works. This will also give a real-time direct measurement of which signs road users look at when approaching road works, which will assist in determining which signs are most effective.

With the assistance of stakeholders, the three alternative TTM layouts for use in this phase of the project have been developed. The first two layouts developed for the simulator study included direct involvement from stakeholders during the workshop. The third was developed subsequently by TRL using information gained at the workshop. The main aim of each layout is to reduce the overall number of signs within the 'lead in' zone on the approach to the road works, while still maintaining a clear message. The first layout removes a small number of signs from the standard configuration; the second layout removes some signs and uses different sign content with the intention of improving compliance; the third layout uses a minimal number of signs . The three designs move progressively away from Chapter 8 principles, permitting investigation as to the safe minimal signage level.

The layouts developed all have theoretical benefits to their use, either in terms of reducing visual clutter or improving the clarity instructions given to drivers. However, there are also potential disbenefits, for example, an increase in late merging when signs are removed, as found by previous simulator research. There is therefore a need to provide conclusive evidence before a change in the current Chapter 8 principles is considered.

The simulator trial will provide a useful insight into driver behaviour with the new layouts. If behaviour is at least as safe as the current Chapter 8 configuration with any of the new layouts, the other benefits to road worker safety may suggest that a change is, on balance, preferable. If driving behaviour improves, then there would be a strong case for change.

The simulator study is currently in preparation. Prior to the study being approved, stakeholders will be given the opportunity to examine the trial method and proposed TM layouts that will be presented to the study drivers. When results are available, they will be circulated to stakeholders to gain further insights into the implications of the results.

## Acknowledgements

The work described in this report was carried out in the Human Factors and Simulation Group of the Transport Research Laboratory. The authors are grateful to Iain Rillie who carried out the technical review and auditing of this report.

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# Appendix A Sign configuration concepts

## A.1 X-height

The calculation related to the size of letterings on signs is based on the simple premise that drivers should be able to finish reading a sign before being too close to it (RRL, 1965 and Donald, 1995).

The size of lettering is measured by x-heights. This is the distance between the base line and the mean line in a type face. This is usually the size of the lower case letter 'x'.


**Figure 9: X-heights of fonts**

The calculation for x-heights is based on a formula which includes the time needed to read the sign, the traffic speed and the lateral distance of the sign from the path of the driver which originally appeared in Research on Road Traffic (1965). The x-height is inversely proportional to the legibility of lettering used (Baguley and Flint, 2000). The accepted formula for calculating letter height is:

$$\mathbf{X} = 0.745\ \mathbf{V}\ \mathbf{T} + 9.45\ \mathbf{S}\ \text{mm}$$

*Where:*

**X** is the x-height,

**V** is the 85$^{th}$ percentile approach speed of vehicles (mph)

**T** is the reading time of the sign (seconds)

**S** is the sideways displacement of the sign (metres)

## A.2 Maximum Divergence Angle

The angle through which a driver must turn their gaze from the road ahead in order to fixate a sign is termed the divergence angle. Reading a sign from a greater distance results in a smaller divergence angle such that a driver would be better able to maintain awareness of what is happening on the carriageway. The closer a driver gets to the sign, the larger the divergence angle. In addition to the driver having less awareness of the environment in front of them, the driver has less time to act on the information the sign is providing.

Mitchell and Forbes (1942) calculated that a divergence angle of 10° would enable drivers to retain awareness of the carriageway in front of them. This value is still in use today, but Baguley and Flint (2000) cited research by Rockwell (1972) and Spijkers (1992) to suggest that there is scope to increase this value based on improvements in drivers' ability to combine the driving task and monitor the road environment. It is suggested that a divergence angle of 20° would allow drivers to retain situation awareness.

## A.3 The Reading Time of Signs

The reading time of signs is linked to the level of information on a sign, with simple messages requiring shorter reading times than signs with multiple or more complex messages. Mitchell and Forbes (1942), in studying the mechanics of vision, found that the shortest possible glance at a simple and well known symbolic road sign and the road was one second. This time included comprehension of the sign and response to a simple

symbolic sign. The findings of Mitchell and Forbes have been the standard figure tested and applied to symbolic road sign reading since, whereas 4 seconds is the recognised standard reading time of complex signs i.e. signs including text and symbolic information. This supports the theory that viewing tasks requiring complex interpretation require longer glance times (Byard *et al.*, 1995). It is usually the case that for more complicated signs, or signs where the driver has to pick out relevant pieces of information, drivers glance between the road and the sign in question. This is an example of 'visual sampling' rather than holding a fixed gaze. This would be an anticipated response from a driver, as looking away from the path of travel for large periods of time effects a driver's ability to steer the car correctly (Marple-Horvat *et al.,* 2006).

In temporary road work situations, however, there is a case to suggest that drivers may not recognise signs they rarely see, particularly when signs are complex. Exposure times can also be limited at high speeds, and high sided vehicles may restrict lines of sight to signage. Baguley and Flint (2000) suggest that there is a great body of work surrounding the reading time of signs since work conducted after Mitchell and Forbes, but that most work is concentrated on directional signs. At the time of Baguley and Flint's work, minimal research had been conducted into the reading of temporary signs at road works.

A trial of 95 participants was carried out by Baguley and Flint (2000), which utilised the computer-based software tool named Enhanced Driver Information Decision Assessment System (EDIDAS). This tool displayed signs for a period between one and five seconds[4], after which respondents were asked to make a decision based on the information given on the sign. For more complex signs, the percentage of participants who gave the correct answer increased as the display time of the sign increased, but at a low rate. After the maximum exposure time of five seconds, more than 40% of subjects did not give correct answers. This either suggests that commonly used standards of sign reading times are not sufficient for drivers to adequately process information on signs, or alternatively could indicate that there is a general lack of understanding of these particular signs.

Given that it is difficult to find evidence to support or reject either claim, Baguley and Flint suggest that the reading time of 4 seconds must be maintained as the standard. While approaching the road works, where visual and motor workload is likely to be high it may be important to increase the time between signs. While it is outside the scope of this current study to research a driver's direct understanding of signage, there will be data available through car control measures and eye tracking data which can examine where and how the information was acted upon when it was seen.

## A.4 Visibility and legibility

Since traffic signs are intended to be viewed from large distances, the size and level of detail provided in the symbol image is highly significant. Donald (1995) provides a few key points to note:

- It is advisable to use a solid rather than an outline form to improve legibility;
- Too much detail or complexity on an image can reduce its legibility;
- Individual details on an image need to be of sufficient size to ensure visibility from larger distances, but should not obscure or reduce visibility of other parts of the image (i.e. when considering a prohibitive sign where the use of a slash may obscure an image behind);
- The symbol should suit the shape of the sign (i.e. rectangles, circles and triangles); and

[4] The standard reading time for complex signs is taken as 4 seconds

- Colour contrast should be provided and take into account the effect of lighting changes throughout the day. Increased width may be required to improve contrast during certain time periods.

## A.5 Communicating the message

Symbols used on traffic signage can be either literal or abstract and there can be difficulties associated with interpretation of meaning by drivers for both types of symbol (Donald, 1995). For example, literal symbols may have different meanings to people of different nationalities or cultures (Eliot, 1960) and abstract symbols require an arbitrary meaning to be derived through association, rather than the meaning being directly obvious from the graphic itself. With this in mind, any altered design of signage in this current study should use literal symbols, which require no further interpretation.

Research suggests that the use highly stylised symbolic representations on road signs is potentially dangerous (Cairney, 1982b). This is because if the image content or meaning is not immediately obvious and the reader is doubtful of the first meaning ascribed to the sign, then the reader will search for alternatives by perceiving the image in a different way rather than reassigning a new meaning to their initial perception of the image. Swanson *et al*., (1994) also conclude that legibility and comprehension are improved when symbols consist of realistic images rather than abstract or stylised images.

In a different study, Cairney (1981a) highlighted the potential for other misinterpretations of meaning relating to the image content. The results of his testing suggested that using arrows to represent traffic flows can lead to such arrows being interpreted as representing curves or other features of road geometry. Within British road signs, the use of a single arrow to represent opposing traffic flows, "irrespective of the number of opposing lanes" could potentially lead to confusion (DfT, 2003).

There is also a danger that risk may be perceived differently relating to the size of the symbols used. For example, within road work signage the use of arrows of varying colour may lead to inferred priority as opposed to representations of different entities (e.g. normal flow and contra flow, which is denoted by a white arrow surrounded by a black border).


**Figure 10: Contra-flow signs (Diagrams 7203 and 7209)**

Cairney (1981a) observed that the direction in which symbolic images face can be interpreted as a directional indication, which may not been have the intention of the symbol designer. For example, if a vehicle is facing towards the right on the symbol, the driver interprets the overall message of the symbol as only relevant to vehicles travelling towards the right.

Road work signs in Britain can often be highly complex and contain multiple symbols and text to convey a number of messages (see Figure 11).


Source: DfT, 2003

**Figure 11: A typical road work sign which carries multiple messages**

As already outlined in this review, it is generally accepted that increased information complexity or several messages on one sign will increase the time needed by the driver to read and process the information. This may affect their ability to recognise and comprehend what actions or awareness is required. Increased content also requires larger signs, which can create additional risk to road worker safety when installing temporary traffic management, in particular when carrying signs across the carriageway. This research project should supply important data that could be used to identify where there is opportunity for simplification of such signs.

Donald (1995) points out that it is important to maintain consistency between symbols and graphic style, both within and between different road works signs. This includes factors such as size and colour, but also more subtle factors such as the angle of the vehicle to the sign and whether a human figure is included. Chapter 7 of the Traffic Signs Manual provides guidance for sign designers when the standard sizes for symbols produce out of balance pictorial representation (i.e. a car symbol is larger than a lorry), which may also infer unintended meanings of priority. Achieving a change in signs policy would require high-level agreement within DfT as well as public consultation. It would thus be best to work within the current principles provided this enables delivery of an appropriate solution.

The information within this section has indicated that any changes to symbolic signage should consider a number of different factors. These types of ambiguous message should be avoided when tying to simplify road work symbolic signage. It is also important to identify where contrast can be maintained and the use of literal symbols should be encouraged.

# Appendix B Stakeholders present at workshop

| Person | Organisation |
|---|---|
| Richard Pearson | TMCA |
| Kim Yates | Chevron/TMCA |
| Paul Goward | HA Chapter 8 team |
| Graham Coe | TRL/HA Chapter 8 team |
| Norman Kellock | Ringway |
| Andrew Reeve | RAC/Survive |
| Andy Hicks | Carillion |
| Paul Fillis | Amey |
| Iain Candlish | Carillion |
| Dave Neal | BBISL |
| Matthew Youell | HA Chapter 8 team |

# Appendix C Glossary of workshop terms

For the avoidance of confusion between common terms used to describe items used within TTM, definitions were agreed as shown in Table 5.

**Table 5: Glossary of terms used in the Stakeholder Workshop**

| Sign | TSRGD Diagram number | Meaning according to TSRGD | Term used in this report |
|---|---|---|---|
|  | 610 | Vehicular traffic passing the sign must keep to the left of the sign where the arrow is pointed downwards to the left, or to the right of the sign where the arrow is pointed downwards to the right. | Keep left/right arrow sign |
|  | 7105 | Position of barrier to mark length of road closed to traffic or to guide traffic past an obstruction | Lane closed sign |
|  | 7001 | Road works or temporary obstruction of the carriageway ahead | Road works warning sign |
|  | 7202 (variant) | Right hand lane of a three lane dual carriageway closed to traffic ahead | "Wicket board" sign |
|  | 7208 | Distance ahead at which conditions indicated by sign shown above start to apply | Supplementary distance plate |
|  | 872.1 (proposed variant)[1] | The number of traffic lanes ahead on a dual carriageway or a one-way street reduces from three to two. Traffic in the right hand lane must move into the lane on the immediate left | "Hooked arrow" sign |

[1] Sign 872.1 is currently only permitted with either a white, blue or green background

A keep left arrow with three cones placed at a 45° angle upstream of the sign is referred to in Chapter 8 as 'Detail A' (see Figure 12).

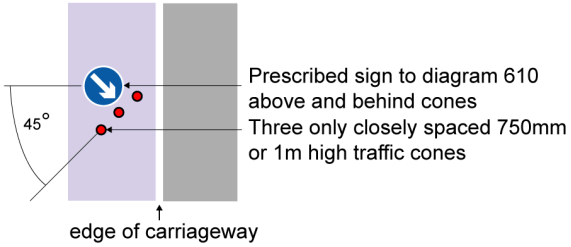


**Figure 12: Detail A**