Transport Research Laboratory

Improving Stability of Emergency Traffic Management Signs

by M Palmer, C Sharratt and I Rillie

CPR1003

561(387)HTRL

CLIENT PROJECT REPORT

Transport Research Laboratory

CLIENT PROJECT REPORT CPR1003

Improving Stability of Emergency Traffic Management Signs

by M Palmer, C Sharratt and I Rillie (TRL)

Prepared for: Project Record: **561(387)HTRL**

Improving Stability of Emergency Traffic Management Signs

Client: **Highways Agency, National Health and Safety Team**

Paul Mitchell

	Name	Date Approved
Project Manager	Paul Walton	XX/YY/ZZZZ
Technical Referee	Iain Rillie	XX/YY/ZZZZ

When purchased in hard copy, this publication is printed on paper that is FSC (Forest Stewardship Council) registered and TCF (Totally Chlorine Free) registered.

Contents Amendment Record

This report has been issued and amended as follows

Version	Date	Description	Editor	Technical Referee
1	30/03/10	First Draft	MJP	IR
2	9/06/10	Draft for submission to client	MJP	IR

Contents

List of Figures

List of Tables

Executive summary

The Highways Agency Traffic Officer Service (TOS) undertakes general traffic and road management tasks on the network, with the intention of improving safety, reducing congestion and freeing up police resources. One of the tasks routinely undertaken by the TOS is the deployment of emergency traffic management (ETM) for protection of incident scenes. This requires the Service to set out lightweight folding 600mm diameter keep left/keep right signs to Diagram 610 of the Traffic Signs Regulations and General Directions 2002 ("610 arrow" signs).

These lightweight signs are easily blown over by only moderate winds or backdraught from vehicles. The signs also collapse, making them ineffectual as a warning to approaching drivers. Unstable signs increase the risk to the Traffic Officers both from the potentially increased risk as their traffic management signs are no longer correctly displayed and the need to enter a live lane in order to recover signs that have moved.

TRL were commissioned to conduct research into the causes of sign instability and develop solutions for the problems with the current generation of signs used by Traffic Officers. Restrictions were placed on the design of any new sign, in that they should be of a weight and dimensions that can be carried in current TOS vehicles.

The initial work undertaken, including discussions with Traffic Officers, provided a thorough understanding of the difficulties faced by Traffic Officers using the current design of sign. As part of the work being carried out to develop a new design sign, it was quickly established that some of the major problems with stability of the existing sign could easily be overcome by small design improvements:

- Side-arm locking detent improved - improved rigidity of sign when deployed
- Side-arms moved to rear of sign – removed obstruction of larger sign faces, could help deployment and retrieval as Traffic Officer does not need to lean over sign face
- Improved pivot at base of sign frame – more rigid, and stiffer, to resist wind forces

At the request of the HA, a short-run batch of signs incorporating the alterations was manufactured so that a short trial could be undertaken. However, although the problems of signs collapsing had been solved, the trial was terminated when the modified sign type was less likely to collapse and thus was more susceptible to vehicle-induced turbulence, and so more likely to be drawn into live lanes.

Throughout the project, design work continued on identifying a range of concepts for new sign frame formats. Those designs selected for further development were tested in an off-road evaluation programme, from which a single sign design was selected as suitable for continuing development, but this work was placed on hold since the on-road modified signs trial showed that the maximum weight criteria restricted resistance to turbulence which could only be overcome by the addition of ballast. This was verified by testing with additional ballast. This necessity for additional ballast poses problems for the use of signs by the Traffic Officer Service, as the weight and dimensions would mean carrying fewer signs in TOS vehicles. The use of a new design sign of increased mass, or with separate ballast, could have manual handling implications.

Also, the risks associated with the use of ETM signs by the Traffic Officer Service needs to be placed in the context of the benefits obtained from the use of the signs. Re-evaluation of the use of signs by the TOS may suggest using fewer signs or indeed none at all.

As a result of these findings, recommendations are made to address the issues raised, to be undertaken in three-stages:

1. Re-evaluate temporary sign use at ETM

The use of temporary signs at emergency traffic management should be re-evaluated based on the operational experience of the TOS. A re-evaluation review should be conducted in conjunction with TOS operational staff to determine the level of signing, type of signing, number of signs specified and supporting equipment used at ETM. This should be benchmarked against operational knowledge and current research into road user behaviour and be fed into any wider review of equipment carried in the TOS vehicles.

Serious consideration should be given to revising the Traffic Officer procedures that require the use of ETM on the hard shoulder. If Traffic Officers are permitted to work from the premise that their vehicle acts as a highly conspicuous warning of the presence of a hazard on the hard shoulder, additional ETM (signs and cones) should only be deployed when the Traffic Officer assesses this as being beneficial. This would reduce the number of sign and cone deployments (and retrievals), reduce the length of time Traffic Officers and their vehicles are on the hard shoulder, and so reduce time vulnerable to impacts.

As part of the review of temporary sign use and equipment, alternative methods for informing drivers should be revisited, such as illuminated arrow signs mounted on the roof of the vehicle, and these implemented where appropriate.

This process should determine whether the continued widespread use of temporary signs at ETM (and potentially ETM itself) remains beneficial, particularly when carried out as a default task rather than in response to the particular requirements of each individual incident.

2. Determine minimum number, size and weight of signs to be used by TOS

Certain signs may be required by the TOS as part of the implementation of specific ETM layouts when necessary to deal with certain situations. The re-evaluation process in Recommendation 1 will identify the minimum equipment level which should be carried.

Rationalising the use of ETM signs and cones, and determining the minimum requirement, will determine the weight saving possible from removal of extraneous signs and cones currently carried within the vehicles. This will establish what 'spare' payload can be replaced by increased individual sign weight and/or additional ballast.

Existing recommendations for ballast on sign frames used at roadworks specify considerable quantities; in order to maintain stability it is likely that the current sign would need to have a total mass of approximately 30kg, compared to the existing sign that weighs only 7kg. However, increasing the weight of the sign is likely to have manual handling implications, so it will be necessary to consider how the sign (and any ballast) is removed from, and replaced in, the vehicle, and whether the heavier sign is practical for deployment at significant distances from the vehicle.

An expert group (perhaps drawn from the existing National Safety User Group) should be convened to define the acceptable operational parameters for a new sign, which will define the maximum weight of any new sign design. This will provide guidance as to the number of signs and sign faces that should be carried in the vehicle.

If the signs expert group recommend the quantities of signs and cones carried on the vehicles be reduced, and their use rationalised, then it will be necessary to modify TOS procedures and training where appropriate, with this cascaded to Officers currently working on-road.

3. Finalise design of 'X' sign for deployment in TOS vehicles

If the Expert Group recommends a new signs is developed and delivered for use by the TOS, the TRL "X-sign" should be further developed for use by the Traffic Officer Service, as its significantly increased (50% larger) sign area and elimination of finger trap hazards in the mechanism will offer considerable visibility and safety advantages.

This larger sign face will allow:

- Existing rectangular message sign faces to be displayed 300mm higher, so easier for approaching drivers to see
- 900mm diameter '610' arrows can be displayed instead of the current 600mm diameter signs (with a circular sign face area 225% larger), so visible to drivers from 50% further away

During trials this design was found to be significantly quicker and easier to deploy, even under wind loading, than other designs. Also, this sign removes any necessity for the Traffic Officer to put their fingers near the mechanism, unlike the existing signs, so reducing the likelihood of injuries.

However, the larger sign will be significantly more susceptible to wind and turbulence, so it will be essential to ensure that the sign has sufficient mass to remain stable while deployed. This may be achieved either by increasing the mass of the sign, or by designing specific additional ballast to be carried on the TO vehicle and used when necessary, with the evaluation process detailed in Recommendations 1 and 2 determining whether sufficient weight can be carried on the vehicles for the number of signs to be deployed.

Due to the increased weight of the signs (or signs and separate ballast), it may be necessary to investigate mechanisms within the vehicle to aid removal and replacement, and consider incorporating a carry handle or strap, and/or wheels, within the new sign design.

Highways Agency Task Specification 561(387)HTRL

This section links the Highways Agency's original task specification with the project output, identifying the areas within this report that answer each requirement.

The objectives of this work programme were:

- Undertake research to understand and identify the key problems with the current signs used by the Traffic Officer Service
- Undertake development work to demonstrate how the key problems may be addressed
- Evaluate potential solutions identified through a programme of practical off-road testing
- Undertake on-road evaluation of solutions identified to demonstrate in-service effectiveness
- Produce an updated specification for ETM signing for use by Traffic Officers

Task Requirement:	Objective is met by:	Within:
Understand and identify the key problems	Identiy problems experienced by Traffic Officers	Section 2
	'Perfect Sign' list created	Section 2
	Ballast tests	Section 6
Undertake development work	Essential modifications of existing sign	Section 3
	New sign designs	Section 4
Evaluate potential solutions	New sign design prototype testing	Section 4
On-road evaluation of solutions	Trial of modified signs	Section 5
Updated specification for ETM signing	Recommendations for re-evaluation of signs use in ETM	Section 7

Further details of comments obtained from Traffic Officers during interviews and on-road observation, and of the modified signs on-road trial, are contained in the appendices.

1 Introduction

The Highways Agency Traffic Officer Service (TOS) undertakes general traffic and road management tasks on the network, with the intention of improving safety, reducing congestion and freeing up police resources.

One of the tasks routinely undertaken by the TOS is the deployment of emergency traffic management (ETM) for protection of incident scenes. This requires the Service to set out lightweight folding 600mm diameter keep left/keep right signs to Diagram 610 of the Traffic Signs Regulations and General Directions 2002 ("610 arrow" signs).

These lightweight signs are easily blown over by only moderate winds or backdraught from vehicles. The signs also collapse, making them ineffectual as a warning to approaching drivers.

Unstable signs increase the risk to the Traffic Officers both from the potentially increased risk as their traffic management signs are no longer correctly displayed and from the need to enter a live lane in order to recover signs that have moved.

TRL were commissioned to conduct research into the causes of sign instability and develop solutions for the problems with the current generation of signs used by Traffic Officers. Restrictions were placed on the design of any new sign, in that they should be of a weight and dimensions that can be carried in current TOS vehicles.

This report presents the findings from the investigations and research carried out, identifies the key issues and presents potential solutions to increase the safety of Traffic Officers using temporary signs.

2 Defining the 'Perfect Sign'

In order to determine the level of problems experienced by Traffic Officers, TRL researchers visited outstations in each of the seven Highways Agency regions and took part in a ride-out from one outstation in the South West region.

2.1 Problems experienced by Traffic Officers

Through discussion with the Traffic Officers and their managers several problems were identified with the current signs, together with their causes. The main issues were:

- Signs collapsing due to side arms not staying rigid
- Wind and/or turbulence from passing traffic causing signs to move
- Signs falling over with the wind and/or turbulence from passing traffic
- Manual handling issues:
    - trapped fingers in the arm mechanisms and "bashed legs" from the bottom arm swinging around;
    - inadequate quality of the signs material including edges of the signs tearing and the front of signs coming off or scraping off particularly when put away wet;
- Difficulties with the sign construction:
    - incompatibility between different signs so parts and sign faces were not interchangeable
    - similar signs had difficulties with the "poppers" holding the sign face onto the backing
    - problems with the bottom supporting leg bolt bending, causing the sign to lean back
    - Issues with the base / supporting leg snapping off
- Different coloured signs being confusing and having different level of perceived visibility
- No procedures for bring traffic back onto the main carriageway after using the 'use hard shoulder' sign

Figure 1: Figure 1: Typical problems: collapsed side arm (left) and weak base pivot joint (right)

Collapsing side arms was the most common problem reported, and Traffic Officers felt that this represented a serious safety concern due to the following reasons:

- The travelling public cannot read the sign properly and therefore do not receive critical information. In particular the use of the 610 arrow signs was viewed as a legal requirement and "*if they fail to recognise that sign it is serious… they could enter the closure*";
- Traffic Officers have to re-erect signs which collapse putting them in the "*firing line*" for a longer time;
- The whole job would take longer as Traffic Officers cannot deal with the incident whilst re-erecting the sign(s); and
- Replacing signs diverted the attention of the Traffic Officer away from the traffic and incident.

Figure 2: ETM, with rolled sign used to aid stability

The stability problems were most commonly dealt with by the Traffic Officers using ballast weights on the sign to stop them moving or falling over. Ballast used was either spare cones or spare signs, as shown in Figure 2. The cones tended to be used one on top of the other (up to five at a time) on the bottom supporting arm. When asked whether this method of overcoming the problem was effective it was generally thought to be effective. One Traffic Officer stated that it was:

> "*Sometimes it helps and sometimes we give up, if it's too windy, we'll give up and take the signs away because they're becoming a hazard and distracting us from what we need to do*"

There were several implications relating to this:

- There were often insufficient cones available. As Traffic Officer from the North West region said "*if you've got a big closure before it's been reinforced by an ISU you may not have that equipment available*"
- If the sign did collapse then there would be more equipment to potentially go out into the live carriageway (though this was said to happen infrequently and usually only with passing HGVs sweeping them underneath the vehicle)
- Because there is extra equipment to take out of the vehicle to weight the signs down, it then takes longer to deploy and put away after dealing with the incident and the more the Traffic Officer has to carry

It was reported that:

> "*In extreme winds there's no chance of putting them out*"

This would be reflected in the dynamic assessment of risk involved with putting out the signs. Another TO commented that:

> "*If you've got winds at 60 and 70mph there is no point in trying to put the signs up*."

It was known that the procedure in cases of the signs not being used was to report to the RCC and manager and for a joint decision to be reached before filing it on the form. In some cases however, this would not be reported mainly due to time constraints.

In some instances, where it was deemed to be too dangerous, signs which had collapsed or fallen over were not re-erected. In dealing with incidents on the hard shoulder the signs were generally not erected if they were to be there for only a short period of time because:

> "*If you've got to do it quickly there might not be time to put the signs up*"

In addition, the scrolling VMS arrows would be used in place of the ETM signs.

Signs were sometimes placed away from traffic, or at a slight angle:

> "*We try to angle them to counteract the wind but it doesn't always work*."

Injuries from the side arms were commonly reported, however some explained that the lesson is learnt and "*you only do it once*".

The Traffic Officers interviewed showed a good awareness of the issues, and were able to give a number of ideas for solutions and alternatives, compiled in Appendix A.

Signs which had failed in various ways were provided to TRL for examination, including one which had been drawn into a live lane and subsequently run over.

2.2 'Perfect sign' list

Once the review was completed, a list of key features of the 'perfect' sign was developed from the feedback given by the Traffic Officers interviewed.

The 'perfect' sign was defined as one that was:

- Easy and quick to deploy with gloves on (i.e. not too "fiddly")
- Relatively quick to dismantle – though less important than quick deployment
- Small when folded
- Stable when erected i.e. once up would remain up
- Robust to handle (due to being 'thrown around')
- Constructed of quality material
- Regulation size and shape (i.e. sign complies with Traffic Sign Regulations)
- Very similar in weight to the current sign
- Designed with more emphasis on stability than speed of deployment
- Visible when wet (i.e. waterproof / water repellent)
- Made with the fewest number of moving parts so as not trap fingers

An assessment of the existing sign was undertaken to identify whether the design had weaknesses which contributed to the problems Traffic Officers were experiencing. Each of the requirements of the 'perfect' sign was evaluated in any new sign designs.

3 Modifying the current sign design

During the development of new sign designs, mathematical modelling of the existing sign was undertaken in order to determine wind forces and resistance. This resulted in the discovery that the support strut was the correct length (it must be equal to or longer than half the height of the sign face) to ensure that the sign cannot blow over in high winds.

The problems from signs being blown over were therefore identified from failure mode analysis. This showed that weaknesses at both the base rail/support strut joint and the manufacturing detail of the side arm mechanism were the cause of failures. Other construction details meant that the sign fixings would not stay at the correct tension during use.

Due to the way the sign was assembled (with the rubber 'feet' at either end of the support strut holding the strut holding it away from the sign's base rail), the base rail to support strut joint would not remain tight when in use. This, in turn, allowed movement between the sign and strut while deployed. Any movement reduced the effective length of the strut relative to the sign height, and wind force on the sign face helped to rotate the sign further relative to the strut – with the inevitable result that the sign would fall.

The second cause of signs failing was the folding side arms not remaining in position once the sign is deployed. Examination of signs showed that, while earlier signs used a 'peg', later signs used a cut-out in one of the arms and a folded 'tab' on the other. However, it was identified that the cut-out was not deep enough to allow the side arm joint to go sufficiently over-centre and so remain stable.

Traffic Officers often attempted a simple 'fix', by tightening the nuts and bolts on the joint but the success of this was restricted by construction limitations, as washers were not specified at all necessary locations and the bolts did not fully engage into the nylon retaining material within the locking nuts.

As those two causes of the two main stability issues were identified very quickly, it was decided to create a prototype sign to examine whether these changes would help to overcome the stability problems. The modifications incorporated were:

- **Modified side arms:** larger cut-out to improve over-centre detent
- **Modified base pivot:** Belleville spring washers added to improve rigidity
- **Improved fixings:** longer bolts used to ensure threads engaged with thread locking material within nuts, and plain washers under all nuts and bolts
- **Move side arms to rear:** current sign arms are in front of the sign face, potentially obscuring; moving the arms to the rear of the sign meant the Traffic Officer would not have to lean over the sign to adjust the arms

The prototype sign was demonstrated to Highways Agency staff and Traffic Officers. Feedback was favourable, with the subsequent request made that TRL procure signs incorporating these enhancements and equip the vehicles at one Traffic Officer outstation for an on-road trial of the modified sign.

During the manufacturing process an additional change was incorporated, of a large white marking on the rear of the sign backing. This marking had been identified as a benefit by the Traffic Officers and was intended to aid then when trying to identify whether the signs has fallen while deployed in low-light conditions.

The details of the trial are contained in Section 4.

Figure 3: Modified sign, identifying key dimension for side arm, and showing modified base pivot with spring washers

3.1 TRL 'Evolved' Sign – Further Options

Solutions were identified to two further problems identified by the TOS, although these were not incorporated into the TRL modified design. These were:

- Tearing of the sign backing
- Press stud difficulties

Two methods for reducing the backing sheet damage were identified:

- Reinforce the edge of the sign backing by hemming, applying an edge trim, or by melting and sealing the edge of the material to reinforce it
- Insert storage tubes within the vehicle's storage cage, to avoid the fabric catching on the cage

The newer design of sign in use with the Traffic Officer Service used a metal press-stud to hold alternate sign faces onto the backing material. Older signs used plastic press studs. The two types do not match, so sign faces with the metal press-stud cannot be affixed to the earlier, plastic, sign frames.

The Traffic Officers interviewed stated that both types of press studs can cause difficulties, and any alternative should be usable while gloves are worn, and be operated by 'feel' so that the TO does not have to look away from oncoming traffic.

A 3M heavy duty, two-part, plastic fastener was identified from the research which should be suitable to replace the press studs. Similar to 'Velcro', but more robust, it would remove the need for accuracy of placement during deployment.

3.2 Wind Testing

As part of the development and research process, the opportunity was taken to wind test a range of signs. This was undertaken during the procurement testing of incident screen systems on behalf of the Highways Agency. Signs manufacturer Quazar International provided a selection from their range, including free standing and barrier-mount signs, a prototype sign under development and others included within the Home Office Scientific Development Branch's Manual of Road Policing Equipment.

Figure 4: First set of signs, before and during wind testing

During the testing of first set of signs, peak wind speed reached 58mph. The pyramid sign with additional square sign face blew over at about 40mph.

Figure 5: Second set of signs, prior to testing

Figure 6: Second set during wind testing (note: TRL protype moved during test to fill space left by blown-over 'Ambulance' sign)

During the second test, the green 'Ambulance' sign blew over at about 25mph. Peak wind speed reached 45mph on the calibrated anemometer, which was tripod-mounted and so positioned higher than the signs; at the level of the signs, wind speeds reaching 60mph were recorded using a hand-held anemometer. The TRL prototype sign (yellow rectangle) was moved into the 'Ambulance' sign's position after its collapse. The grey rectangular sign visible was a modified Highway Stand, with improved side arms, but with a rubber block in place of the Belleville spring washers specified at the support rail pivot (the correct washers were not available in time for testing). As a result, the pivot bolt bent during the test.

A subsequent part of the incident screen test process involved HGV buffeting; a small number of signs, including the TRL modified sign, were placed in a line parallel to and as close as possible (around 0.6m) from the path of a 13t rigid HGV. Each sign was perpendicular to the path of the HGV, which passed the signs at approximately 56mph. The signs remained stable during this test which suggested that they were likely to be acceptable for on-road trials.

3.3 Summary

The research carried out to understand the current sign indicated that improvements could be made to the current sign design to eliminate the problems associated with signs collapsing and rotating/falling over. As a learning exercise, an existing sign was modified to produce a prototype sign which was tested and found to have superior performance to an unmodified sign.

As a result of favourable feedback from the TOS, an on-road trial of the modified signs was requested and facilitated as an additional deliverable within the project. This was carried out in parallel with the development of new sign designs (as detailed in Section 5), with the intention that the on-road trials of the modified sign would provide additional data for the development process.

4 Modified Sign Design On-Road Trials

At the request of the Strategic Development and Consistency Group Safety Sub-group (see Section 3), a trial of the modified sign design was carried out. A batch of signs was built by the TOS signs original equipment manufacturer, with modifications to TRL specifications. These were provided to two TOS outstations along with training for the Traffic Officers. The training provided was in both operation of the modified sign and the requirements of the on-road trial reporting system.

The trial procedure is detailed in Appendix B, feedback forms in Appendix C and Appendix D.

However, after only six weeks the signs were withdrawn from service by the North-East Operations Manager. The reason cited was *"the injuries sustained by our Officers when using the new signs are unacceptable"*. Investigation revealed three minor injuries had been reported (IRIS data for the trial period and area is presented in Appendix E) but no control data had been collected. This made it impossible to state whether this was an average or unusual rate of injury, nor why the modified signs (which were an evolution of the design of signs already in use) were apparently more hazardous than the unmodified sign.

The greater concern in the reports returned was that the modifications to overcome stability problems had proved too effective. The modified signs had effectively eliminated the previous problems of signs falling, but this had changed the way in which signs were affected by wind and/or vehicle turbulence. Evidence suggested that rather than the signs rotating/collapsing and thus falling over as the previous model had tended to, the modified signs would remain upright. This resulted in the sign being drawn towards the live lanes when large vehicles passed close to the sign. This could lead, in some cases, to the sign being drawn into the live carriageway.

Although no control data was received to allow comparison with numbers of unmodified signs collapsing (it is known from the early on-road interviews that reports are often not completed due to time constraints), NHST IRIS data was available for near misses. Examining these data showed cases where "*high winds disabled 4 x 610 arrows and NO ENTRY signs blowing them into live lane*" and that unmodified signs were also drawn into live lanes when large vehicles passed close to the signs. Significantly, another report involved a sign that was "*…weighted down but still moved by wind/passing traffic.*"

The injuries reported may be a consequence of the modified fixings, since the earlier on-road interview report noted: "*It was also said to be very difficult to get the balance right between having the nuts too loose so that the sign collapses and too tight so that it is difficult to deploy and are more likely to lead to trapped fingers*". However, outstation managers were advised by e-mail that the pivots could be adjusted if necessary.

Subsequent interviews with Traffic Officers indicated that the general consensus regarding the signs was that they were the least effective piece of equipment carried in the TOS vehicle. This may have also coloured the reports from the Traffic Officers, as the modified signs were very similar to the existing sign stock. Further evidence obtained from the Traffic Officers indicated that it was common for signs to be weighted down using a second (and potentially third) rolled-up sign placed on the leg at the rear of the deployed sign. However, even in these cases it was not guaranteed that the deployed sign would remain upright. Mitigations developed for this issue was to place the sign as far away from passing traffic as possible or undertake a Dynamic Risk Assessment and not deploy the signs in the first place.

4.1 Summary of feedback from trial

Reports from the feedback forms received from the users of the modified signs are tabulated in Appendix F. However, the main aspects are:

- No signs collapsed because side arms did not remain locked, indicating the collapsing sign issue had been solved
- Few instances (4 of 41 cases, <10%) were reported of signs rotating and falling over after base leg folded
- Few signs (<10%) needed immediate repairs or adjustments
- No signs needed non-urgent repairs
- Few signs (around 7%) suffered damage which resulted in them being written off, mostly due to damaged press studs

The majority of additional comments (13, some with incident reports) detailed concerns over signs being drawn into live lanes due to the turbulence from passing vehicles.

Other comments mentioned the change of side arms to being positioned on the rear of the sign face. This had been included to improve the visibility of the sign to oncoming drivers but Traffic Officers indicated it left the retro-reflective sign face more exposed during storage and so more liable to damage. One report mentioned this was a '*good development*' (presumably due to the improved visibility to drivers) despite the increased likelihood of damage to the sign face.

5 New Sign Designs

In order to produce an improved sign for the Traffic Officer Service, a number of prototype concepts were developed in parallel with the on-road trial of existing signs. During this process, criteria from the Traffic Officers' 'perfect sign' list were used as the primary design parameters. These led to a specification that indicated that a new sign should be:

- Suitable for use in all weather and lighting conditions
- A single-part sign with optional additional sign faces if possible
- 0.9m x 0.6m minimum dimensions when deployed
- Stable
- Deployed and/or operated with the TO standing facing oncoming traffic
- Safe, with a low or nil risk of finger trap hazard
- Within current weight and size limits

Concern from the Traffic Officers regarding sign visibility set an additional criterion which was that, if possible, the sign should be 0.9m square. If such a sign could be developed, with all other criteria maintained, this would allow a 900mm diameter '610' arrow sign to be displayed. This would represent an increase of 50% in the surface area of the sign face displayed to oncoming vehicles, with obvious benefits to visibility and conspicuity of the sign.

A variety of sign designs were produced, exploring a variety of styles. Some designs retained elements of the existing signs, particularly since its support strut had been shown to provide ample support when correctly deployed. Other designs incorporated a removable sign face, so would require the frame and face to be carried separately and combined during deployment. Five designs were taken to the prototype stage; the three-part strut, the X-sign, the Pyramid, the T-strut and the Roller.

5.1.1 Three-Part Strut

This design maintains the existing base and upper rails, and support leg. However, the pivoting side arms are replaced by a three-part mechanism at each side. The mechanism's small centre section has a click-lock mechanism to hold the arm rigid, with a press-to-release button.

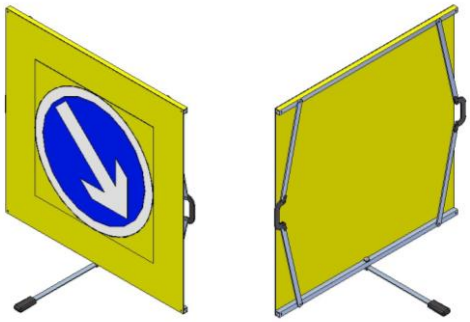

Figure 7: Three-part strut design, front and rear views

5.1.2 X-sign

This design maintains the existing base and upper rails, and support leg. However, the pivoting side arms are replaced by a 'cross-brace' mechanism, where the pairs of braces are interlaced, so aiding the signs rigidity.

When the sign is deployed, the centre pivots will meet (guided by the interlaced mechanism), and the two halves are retained by magnets to keep sign upright

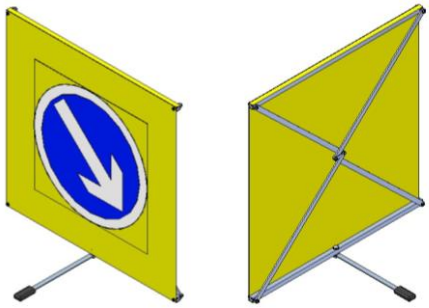

Figure 8: X-sign design, front and rear view views

5.1.3 Pyramid

This is a two-part design. The frame has four legs, which when deployed are in the shape of a square-based pyramid. The sign face is a separate item, which hooks into place. On the rear of the pyramid is a lightweight infill panel (grey in illustrations) to increase the sign's wind performance when the wind direction is from the rear of the sign.

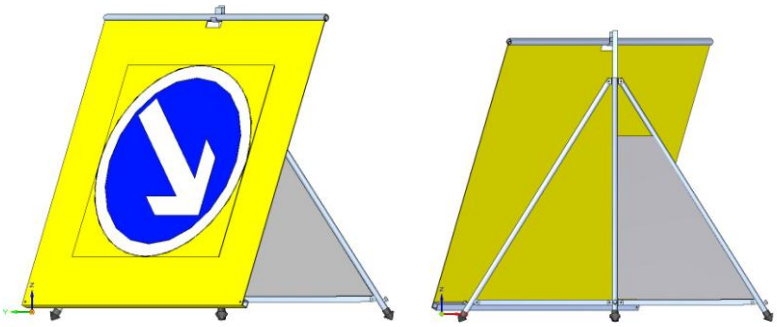

Figure 9: Pyramid design, front and rear views

For use in high wind conditions, the use of 'ground effect' was explored to provide additional downforce on the Pyramid sign. A concept was worked up whereby the sign legs could be fitted onto a slim base panel (which would need separate storage within the vehicle). In high winds, the intention was that the base would work by using the wind to produce a 'ground effect' to hold itself onto the road surface.

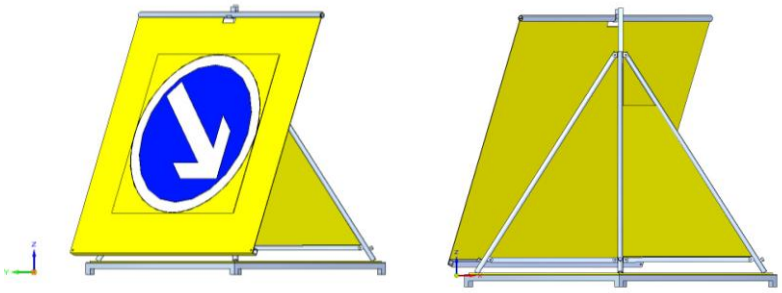

Figure 10: Pyramid + base, front and rear views

However calculations of wind speeds required to provide a significant level of ground effect indicated that the concept would not be practicable in service and thus this design option was not taken forward to construction.

5.1.4 Roller

This sign is deployed by rotating out the support strut, then pulling the rolled sign vertically until fully extended, where it is supported by two of the three-part side arm mechanisms. The sign face would incorporate the Type 610 'Right' arrow, other alternate sign faces could be added during deployment, and removed prior to the sign face being rewound into the casing. Since this sign is a single unit (with optional alternate signs faces), the casing could be fitted with a carry handle or strap.

A commercially-available advertising display panel was obtained to demonstrate the concept.

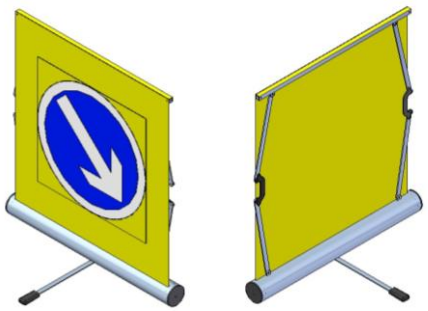

Figure 11: Roller design, front and rear views

5.1.5 T-Strut

This is a three-part design with a two-part base/stand connected by a 'plug and twist' action to form an inverted 'T' shape. The stand is stored inside the main base section. The sign face is attached with a spring or screw mechanism to provide tension.

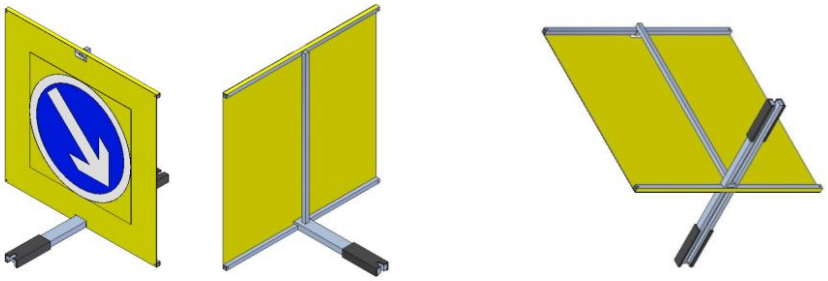

Figure 12: T-strut design, front, rear and base views

As a further part of the incident screens project, a number of HA staff attended a workshop session held at TRL's offices, along with representatives of the emergency services. The opportunity was taken to display the prototype signs for their comments. The ease of use of the "X-sign" and "Roller" designs gained most approval.

5.2 New Designs Prototype testing

Four designs were prototyped and taken forward for wind and user testing. The 'Roller' sign was not tested as it was not specifically designed for external use

It should be noted that these signs were pre-production models intended to develop specifications and this testing was designed as a "proof of concept" trial in order to identify general sign performance and design modifications that could be made.

5.2.1 Current sign – TRL modified

TRL modified the sign currently in use by the Traffic Officer Service to improve its rigidity and stability. The three-part strut sign was essentially identical to the TRL modified sign, but with an improved detent mechanism and modified foot.

5.2.2 T-strut – TRL Prototype

One of the designs that TRL developed was a rigid, 3-part sign that was light-weight. This is pictured below on the right of Figure 13 (right). This prototype did not have rubber feet on it and the foot length was less than the required 900mm.

Figure 13: Modified version of current TOS sign (left), TRL designed "T-strut" rigid aluminium 900mm high prototype (right)

Rigid sign performance was significantly worse than the current TRL modified sign as it was difficult to set up in windy conditions. It slid before it toppled, confirming its design principle, but it toppled at a lower speed than all other signs.

5.2.3 X-sign – TRL prototype

To improve the deployment safety and speed of deployment of the sign, TRL designed a cross-over magnetic "locking" mechanism which would not require the Traffic Officer to place their hands near any of the moving parts of the sign. The officer can simply extend the sign foot, stand on the sign foot and pull the sign up into position.

The prototype was a 900mm square sign that could display a 900mm diameter arrow sign. The size of the foot on the prototype was 50-80mm shorter than it could potentially be and the weight of the prototype sign was below the weight limit originally specified by the HA, despite the sign being made in steel rather than aluminium.

The "X-sign" performance was similar to that of the current TRL modified sign. This sign was also the quickest and easiest to set up in windy conditions and was the design most favoured by all the operational Traffic Officers and Trades Union representatives who reviewed the signs during the project.

Figure 14: TRL designed "X-sign" 900mm high prototype, front and rear views

5.2.4 Pyramid Sign - TRL prototype

The third prototype developed was based on a different, pyramid design. This was intended to slide before it toppled. The rear was partially "masked off" to provide some resilience to the effects of wind turbulence acting on the rear of the sign face.

The pyramid sign proved very stable when the air flow was incident on the sign face. However it was difficult to set up in windy conditions and both slid and toppled when turned 180° so that the air flow was directed onto the rear of the sign.

Figure 15: TRL designed "Pyramid Sign" prototype during wind testing

5.3 Test Conclusions

All sign designs responded to wind testing as expected, but at lower wind speeds than measured during the earlier wind testing. This is thought to be due to more turbulent air flow created by the smaller wind machine used for the tests, which was potentially more representative of conditions on the highway than the first set of wind tests carried out alongside the incident screen trial.

The testing indicated the best design to proceed to on-road trials was the "X-sign", both for its stability, ease of manual handling and reduced injury potential when deploying the sign. However stability in windy conditions was recognised as an issue for all sign types, due to the restricted weight of the signs when compared to the surface area on which the wind and/or air turbulence acted.

6 Additional Ballast Tests

The on-road trials of the TRL modified sig were intended to provide feedback as input to the development of new design signs. These trials instead indicated that the main issue was one of wind and turbulence resistance.

Enhancement of wind resistance can only be obtained by increasing effective sign weight. Using aerodynamics to increase the effective sign weight was explored (e.g. see Section 5.1.3) but an aerodynamic effect relies on relatively constant and predictable airflow. The turbulent nature of the wind flow past signs and large pressure variations caused by vehicle turbulence do not generate conditions where aerodynamic effects can be used.

Thus, increasing the effective weight of the sign requires either an increase in the basic sign weight or addition of optional ballast weight. This is the practical solution used unofficially by Traffic Officers who use additional rolled signs or stacked cones in an attempt to provide additional stability. Contact with the TOS indicated that up to three rolled signs can be used to provide additional stability.

A set of tests were undertaken in order to determine how using these additional rolled-up signs or cones affected the signs' ability to move. Ballast was restricted to additional equipment carried (or similar to that carried) the TOS:

- A 450mm cone representative of those used by the TOS was not available, so a lighter 300mm cone was substituted.
- Rolled signs were tested in two conditions:
    - balanced on the ETM sign 'foot'
      (giving maximum additional weight onto the displayed sign)
    - rested with one end of the rolled sign on the ETM sign 'foot'
      ('worst case' condition, with minimum additional weight onto the sign)

The effects of these additional ballast weights on the sign are shown in Table 1 and Figure 16:

Table 1: Effect of additional ballast

Ballast	Ballast (Kg)	Test 1 (N)	Test 2 (N)	Test 3 (N)	Average (N)
None	0	67.8	67.4	77.9	71.0
300 Cone	1.95	103.3	96.4	87.9	95.9
1 Rolled Sign (end only on foot)	3.35 (est.)	103.3	114.6	99.6	105.8
1 Rolled Sign	6.7	136.3	139.6	147.2	141.0
2 Rolled Signs	13.4	203.7	188.8	184.7	192.4

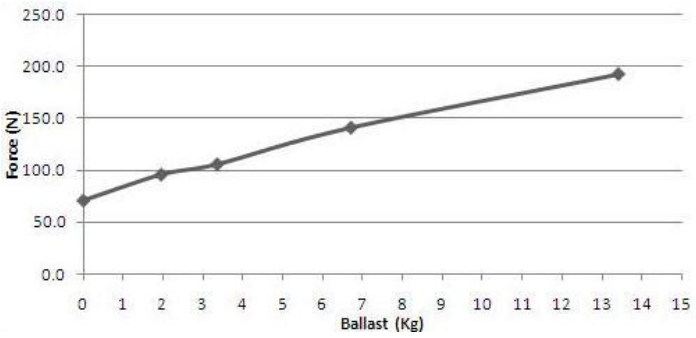

Figure 16: Effect of additional ballast

Unsurprisingly, these results show that increasing the ballast causes a proportional increase in the force required to move the sign. The small variations in the graph are probably a result of variations in the surface texture. Increases in sign resistance to motion as extra signs are added are not linear, as additional signs are put further from the centre of the sign support, which provides a reduced additional benefit from each extra rolled sign added.

For actual sign deployment, a higher force to move the sign would equate directly to resistance to higher wind speed or greater turbulence. Thus, addition of 13kg of ballast (equivalent to two additional rolled signs) would increase the force required to move the sign from 71 Newtons (≈ 7kg) to 192 Newtons (≈ 19kg).

7 Discussion

The review and testing work carried out for this project identified that the three key areas for improvement were reducing injury risk, improving the engineering of the current sign used by the TOS and improving the stability of signs of any type (whether to the new or current design).

7.1 Reducing injury risk

The primary personal injury mechanism for the Traffic Officers using current signs is a finger trap hazard from both the bottom support strut and the side arms. The risk from the side arms can be eliminated by engineering design; for example the 'X' sign only requires the Traffic Officer to pull the sign vertically into its locked position using a handle on top of the sign. This has a number of benefits such as reducing the time taken to deploy and collapse the sign, eliminating the finger trap hazard from the side arms on the current sign and enabling the Traffic Officer to watch approaching traffic while deploying the sign.

The risk of finger traps from the bottom support strut can be significantly reduced by using Bellville washers to provide both clearance and resistance to rotation. This eliminates the "scissor" action between the bottom support strut and the bottom rail of the sign, and significantly reduces the likelihood of the bottom support strut rotating freely.

The modified current signs used in the on-road trial had this modification to eliminate the "scissor" action between the bottom support strut and the bottom sign rail, but unfortunately data obtained from the trial did not provide sufficient information to determine the effectiveness of this modification. Additionally, in the absence of accurate control data to compare injury rate for modified and unmodified signs it is not possible to demonstrate a definitive safety improvement from the changes to the bottom rail/support strut and the side arms.

The project has demonstrated that it is clearly possible to reduce the personal injury risk associated with Traffic Officers' use of temporary signs by a significant amount. As the signs must have some moving parts it would not be possible to completely eliminate the risk of injury, but the 'X' sign has the potential to reduce the risk compared to the current signs used by the Traffic Officer Service.

7.2 Improving sign performance

The current signs used by the Traffic Officer Service have a number of elements that can be improved.

1. Bolts which loosen, leading to falling signs, hand and leg injuries
   Solution: Use longer bolts with locking nuts that fully engage
2. Bolts snapping due to fatigue/bending of the bolt
   Solution: Use improved bolt to give adequate support to bottom support strut
3. Injury risk from bottom support bar freely rotating ("scissor" effect)
   Solution: Use spring washers on pivot of sign base to prevent free rotation
4. Collapsing side struts (poor design of detent, bolts loosening)
   Solution: Modify design of detent, fit longer bolts with fully engaged locking nuts
5. Finger trap on side struts
   Solution: Re-engineer sign to remove finger traps (e.g. the 'X' sign)

Wind testing of a sign including these modifications indicated that they reduced the tendency of the sign to rotate and collapse. These improvements could be retrofitted to current signs (including the stock of signs held by HA for issue).

The 'X' sign design would improve sign performance by providing a greater sign face size (900mm diameter as opposed to the current 600mm). This would provide better advance warning for approaching drivers, as well as increasing the safety of Traffic Officers engaged in emergency traffic management.

7.3 Improving sign stability

Sign stability is the key issue that was raised by all Traffic Officers interviewed. Stability issues involve signs collapsing in-situ and signs being blown away. The engineering changes to the current design of signs and the new generation of signs (such as the 'X' sign) can eliminate the problems associated with signs collapsing in-situ. Unfortunately this increases the likelihood of signs being blown away, potentially into live lanes, as the signs do not collapse and thus experience the full force of wind and vehicle turbulence.

Wind testing is a valid method of comparing the performance of two signs but cannot accurately replicate conditions on-road. The on-road trial was intended to do this and was carefully designed to ensure the results would be robust and could be used to guide the development of a new sign design. The wind testing indicated that the sign collapsing/rotating issue had been largely eliminated; the lorry turbulence tests carried out also suggested the signs would not be seriously affected by passing traffic. However, the effect of larger vehicles and multiple vehicles passing the sign could not be tested; it is potentially this that is the main cause of stability problems.

The NHST IRIS data reports from the trial indicated there were cases where *"high winds disabled 4 x 610 arrows and NO ENTRY signs blowing them into live lane"* and that unmodified signs were also drawn into live lanes when large vehicles passed close to the signs. Significantly, another involved a sign that was "…w*eighted down but still moved by wind/passing traffic."* This suggests that the weight of temporary signs is, in itself, insufficient to provide a stable sign, which is supported by the real-world examples of Traffic Officers using additional signs as ballast weights, providing a total weight for the sign of between 13 and 20kg.

The literature and standards confirm the ballast requirement; for example, to stabilise a 600mm square sign to the normal wind loading classification in BS 8442 (Miscellaneous road traffic signs & devices) requires 20kg of ballast, over double the current sign weight of approximately 7kg. Testing of signs with additional ballast weight showed the expected linear relationship between the weight of ballast on the sign and the force required to move it. This indicates that a ballasted sign will be able to withstand wind up to a point greater than an unballasted sign, but that the level of ballasting required to ensure the stability of a sign in all weather conditions is unrealistic.

7.4 Potential solutions

This project suggests that the criterion used during the project, namely that any new sign should be *"sufficiently small and light to be carried in the current generation of TOS vehicles"* is probably unrealistic. Providing a sign that is ballasted to the requirement of BS8442 would require an estimated sign weight of around 30kg for the current 600x900mm signs; assuming the 'X' sign is adopted, this would need to have a similar mass to provide stability in most conditions.

Increasing the mass of the signs by a factor of four would present issues both in terms of manual handling and vehicle payload. Risk of manual handling injuries associated with lifting and carrying heavier signs would need consideration; if ballast weights were required this would increase the time spent to deploy a sign, thus increasing risk to Traffic Officers involved in deploying and removing traffic management.

Considering the issue of sign stability, the most effective way to eliminate the risk of signs blowing into live carriageways is to not deploy the signs in the first instance. This

adopts the approach of a risk hierarchy (eliminate risk – mitigate risk – manage risk), which suggests a number of potential avenu.

Eliminate risk: **Do not routinely use temporary signs in ETM**

Issues to consider: Can effective ETM implemented without signs?

Why do other countries not use temporary signing at ETM?

What is the risk balance for TOS and road users for ETM?

What do road users understand from ETM signs? Do they pay attention to them?

Does the use of ETM signs increase risk to Traffic Officers and road users by extending time the TOS vehicle is on the hard shoulder?

Mitigate risk: **Minimise the use of temporary signs in ETM**

Issues to consider: BS8442 suggests that sign deployment without ballast should only be undertaken when ambient wind is light – is this in the procedures?

Could current TOS procedures (and the use of DRAs) for use of signs in high winds/close to heavy vehicles be reviewed or clarified?

Should the presumption be not to use ETM signs, with a DRA carried out when their use would be beneficial?

Could the proposed approach in the revised IAN115/08 be applied, namely using the vehicle as the primary source of advance warning?

Manage risk: **Improve the stability of temporary signs in ETM**

Issues to consider: How much weight needs to be added to the sign to make it stable in windy conditions?

Could TOS vehicles carry fewer signs, each of sufficient weight to maintain sign stability of those signs carried?

Could new signs be designed to incorporate ballast, and a limited number of those signs (with ballast) carried on each vehicle?

Could alternative sign display methods be used, such as mounting a 900mm square folding sign on the rear of the TOS vehicle?

It is certain that in some conditions the use of ETM signs would be a benefit to road user safety and incident management. Thus, the requirement to carry a number of temporary signs will remain valid. However, it is likely to be beneficial to challenge the original assumptions regarding the number and type of signs that are carried, in order to ensure that signs provide the greatest possible safety benefit to both Traffic Officers and road users when ETM is deployed.

8 Conclusions and Recommendations

The Highways Agency Traffic Officer Service (TOS) routinely deploy emergency traffic management (ETM) for protection of incident scenes using their lightweight folding 600mm diameter keep left/keep right signs to Diagram 610 of the Traffic Signs Regulations and General Directions 2002 ("610 arrow" signs).

These lightweight folding signs were identified by the TOS as a source of personal injury accidents and near-misses. The aim of this project was to conduct research into the causes of sign instability and develop solutions for the problems with the current generation of signs used by Traffic Officers. Restrictions were placed on the design of any new sign, in that they should be of a weight and dimensions that can be carried in current TOS vehicles.

8.1 Conclusions

The conclusions that can be drawn from this work are:

1. Initial work provided a thorough understanding of the main difficulties faced by Traffic Officers using the current design of sign.
2. The main issues were personal injury accidents, signs collapsing, signs blowing over and signs blowing away.
3. Research and development work showed that the signs can be engineered to eliminate most of the injury risk to Traffic Officers
4. The signs can be engineered to resist collapsing and blowing over. However, these modifications make the signs more prone to blowing away.
5. Solving the problem of signs blowing away can only be achieved by increasing the mass of the signs, either by increasing the mass of each sign or adding ballast.
6. This poses problems for the use of signs by the Traffic Officer Service as the weight and dimensions would mean carrying fewer signs in TOS vehicles.
7. The risks associated with the use of ETM signs by the Traffic Officer Service needs to be placed in the context of the benefits obtained from the use of the signs.
8. Re-evaluation of the use of signs by the TOS may suggest using fewer signs or indeed none at all.

8.2 Recommendations

The conclusions should be addressed in three-stages:

1. Re-evaluate temporary sign use at ETM

The use of temporary signs at emergency traffic management should be re-evaluated based on the operational experience of the TOS. A re-evaluation review should be conducted in conjunction with TOS operational staff to determine the level of signing, type of signing, number of signs specified and supporting equipment used at ETM. This should be benchmarked against operational knowledge and current research into road user behaviour and be fed into any wider review of equipment carried in the TOS vehicles.

Serious consideration should be given to revising the Traffic Officer procedures that require the use of ETM on the hard shoulder. If Traffic Officers are permitted to work from the premise that their vehicle acts as a highly conspicuous warning of the presence of a hazard on the hard shoulder, additional ETM (signs and cones) should only be deployed when the Traffic Officer assesses this as being beneficial, deployment should be the exception and not the rule. It is likely that ETM should only be deployed where the stopping sight distance to the 'incident' is insufficient, e.g. the incident is over the brow of a hill/round a corner etc. where the approaching driver's sight line to the incident is restricted.

This would reduce the number of sign and cone deployments (and retrievals), reduce the length of time Traffic Officers and their vehicles are on the hard shoulder, and so reduce time vulnerable to impacts.

Also, as part of the review of temporary sign use and equipment, alternative methods for informing drivers should be revisited, such as illuminated arrow signs mounted on the roof of the vehicle, and these implemented where appropriate.

The guidance for this is to be subject to a subsequent review of procedures as part of the RAR Phase 2 project. This process should determine whether the continued widespread use of temporary signs at ETM (and potentially ETM itself) remains beneficial, particularly when carried out as a default task rather than in response to the particular requirements of each individual incident.

2. Determine minimum number, size and weight of signs to be used by TOS

Certain signs may be required by the TOS as part of the implementation of specific ETM layouts when necessary to deal with certain situations. The re-evaluation process in Recommendation 1 will identify the minimum equipment level which should be carried.

Rationalising the use of ETM signs and cones, and determining the minimum requirement, will determine the weight saving possible from removal of extraneous signs and cones currently carried within the vehicles. This rationalisation should be included as part of the TOS equipment review, and will establish what 'spare' payload can be replaced by increased individual sign weight and/or additional ballast.

Existing recommendations for ballast on sign frames used at roadworks specify considerable quantities; in order to maintain stability it is likely that the current sign would need to have a total mass of approximately 30kg, compared to the existing sign that weighs only 7kg. However, increasing the weight of the sign is likely to have manual handling implications, so it will be necessary to consider how the sign (and any ballast) is removed from, and replaced in, the vehicle, and whether the heavier sign is practical for deployment at significant distances from the vehicle.

An expert group (perhaps drawn from the existing National Safety User Group) should be convened to define the acceptable operational parameters for a new sign, which will define the maximum weight of any new sign design. This will provide guidance as to the reduced number of heavier signs and sign faces that should be carried in the vehicle.

If the signs expert group recommend the quantities of signs and cones carried on the vehicles be reduced, and their use rationalised, then it will be necessary to modify TOS procedures and training where appropriate, with this cascaded to Officers currently working on-road.

3. Finalise design of 'X' sign for deployment in TOS vehicles

If the Expert Group recommends a new signs is developed and delivered for use by the TOS, the TRL "X-sign" should be further developed for use by the Traffic Officer Service, as its significantly increased (50% larger) sign area and elimination of finger trap hazards in the mechanism will offer considerable visibility and safety advantages.

This larger sign face will allow:

- Existing rectangular message sign faces to be displayed 300mm higher, so easier for approaching drivers to see
- 900mm diameter '610' arrows can be displayed instead of the current 600mm diameter signs, so visible to drivers from 50% further away

During trials this design was found to be significantly quicker and easier to deploy, even under wind loading, than other designs. Also, this sign removes any necessity for the Traffic Officer to put their fingers near the mechanism, unlike the existing signs, so reducing the likelihood of injuries.

However, the larger sign will be significantly more susceptible to wind and turbulence, so it will be essential to ensure that the sign has sufficient mass to remain stable while deployed. This may be achieved either by increasing the mass of the sign, or by designing specific additional ballast to be carried on the TO vehicle and used when necessary, with the evaluation process detailed in Recommendations 1 and 2 determining whether sufficient weight can be carried on the vehicles for the number of signs to be deployed.

Due to the increased weight of the signs (or signs and separate ballast), it may be necessary to investigate mechanisms within the vehicle to aid removal and replacement, and consider incorporating a carry handle or strap, and/or wheels, within the new sign design.

Acknowledgements

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

References

Sharratt C (2009). *Improving the Stability of Emergency Traffic Management Signs used by the Traffic Officer Service, Qualitative Research to Understand and Identify the Problems.* Unpublished Project Report RPN446. Crowthorne: TRL Limited

Glossary of terms and abbreviations

TO = Traffic Officer

TOS = Traffic Officer Service

ETM = Emergency Traffic Management

DRA = Dynamic Risk Assessment

Appendix A Traffic Officers' Comments

This table details the suggested amendments to the signs, with advantages and disadvantages of each, as made by Traffic Officers during the Out Station visits .

Solution	Pros	Cons
Sleeves to slide over the side arms so the mechanism is locked in place	Address the problem of collapsed arms	More fiddly and time consuming
A quick release design so you shake it out like you'd put an umbrella up, e.g. hydraulic arms	Easy to deploy	Likely to trap fingers
Using fixed frame signs already erect in the vehicle	Quicker to deploy Quick to put away No trapped fingers	Not much quicker to deploy Re-design of the back of the vehicle necessary to fit in cage Potential access issues May act as a sail when out of the vehicle so challenging to move to where need to position
A heavier sign and specifically making the centre of gravity as low down as possible with a solid steel base	Stop the sides of the signs collapsing and the whole sign falling over	Can't be much heavier (although taught only to carry one at a time, already carry 2+ at a time and reports of Traffic Officers off work with slipped discs) Vehicles at weight limit May slow down deployment
Type of bolt which can easily be tightened by hand and more substantial bolts, e.g. 13ml instead of 10ml	Easy to use at roadside without use of tools Less likely to loosen	May come off entirely
High visibility stripe or marking on the back so the TO can see if it has blown down or not	Enable the Traffic Officer to discern if the sign has fallen over in the dark	May be confusing to traffic on the other side of the carriageway
Using perforated material for the signs or strips of material with gaps in between	Wind should blow through the signs so they don't fall over as easily	May not be feasible as the front of the sign has to fulfil legal requirements
Using mesh type material for the signs instead of plastic	Save weight and allow wind to blow through	May not be feasible for front of sign
Double-sided signs – whole frame	Less signs needed in the vehicle so can be heavier Reduce the risk of popper failure	Need all 10 signs anyway especially in more rural regions Less signs to weight down Could be confusing to traffic on the other carriageway
Double-sided front of the signs	Less signs needed in the vehicle so could be heavier	Need all 10 signs anyway Less signs to weight down More timely to change the sign around. Would need double-sided poppers.
Washers to keep the tension between the zipped frame	May enable the arms of the signs to 'lock' out	Could create more of a risk for trapping fingers
Two supporting bars at the bottom rather than one and especially at the front and back	Should be more stable	Re-design of sign
Supporting bars from the top horizontal bar leaning back	Should be more stable	Re-design of sign
Fixing the x bar at the bottom somehow, e.g. wing nut	This can be tightened at the roadside if required	Not necessary to use tools to tighten Should enable signs to be more stable on the roadside
Use of velcro to attach the front of the signs to the back	This would be quick to use and change signs	Was considered likely to fail quickly

Use a spring from the base of sign	Can flex with wind and turbulence	May be more difficult to deploy and more likely to fail quickly as well as more likely to trap fingers
Tripod design as used by police and previously by some TOs with detachable clip on sign faces	More stable Carry less of them in vehicle	More likely to trap fingers Takes longer to erect Heavier than current ETM signs More fiddly to attach sign More awkward to store
Ensure the base of the bottom supporting bar touches the floor	This should make it more stable than currently where there is a gap and the two ends of the bar rest on the floor	Re-design of sign
Use a tube to slide the rolled up signs into	Should prevent tears to the signs from the cage	More time consuming to take out and put back in
Wider or thicker supporting bar at the bottom	Could improve stability	Is likely to be heavier
Removing interchangeable signs	If fixed to background then no problems with studs	Less flexibility with signs needed

Appendix B On-Road Trial Procedure:

Aim of Trial:

The aim of this trial, undertaken in line with the HA's Guide for the Design, Management and Delivery of Pilots and Trials on the Highways Agency Network (GDMDPT) document, is to place the modified design sign into active use with the Traffic Officer Service, and gather feedback from the TOs.

Although the GDMDPT has been written with more substantial projects in mind, this trial has been reviewed and planned with reference to the document.

Feasibility

- Following on from the initial research into problems experienced by Traffic Officers using the existing signs, TRL produced a modified sign which overcame many of those deficiencies
- The modified sign was demonstrated to HA staff, including Traffic Officers
- TRL was asked obtain sufficient modified signs to conduct an on-road trial at a single Traffic Officer out station

Objectives of Trial:

- To obtain data on the performance of existing Highway Stand signs and TRL modified version
- Data to be provided to TRL on collection forms supplied, submitted weekly
- Trial to take place at an existing Traffic Officer Service out station
- Signs supplied by TRL to replace those carried on TOS vehicles
- Complete trial to be undertaken over a three month period
- Compiled data to guide development of new signs for TOS

Costs

Costs of supplying modified signs, analysis of data and TRL staff time are included within the current Traffic Officer Signs Stability project budget. No additional costs incurred within the TOS out stations are to be covered within the project budget.

Trial Location

The TOS out station to carry out the trial of modified signs, and that which will act as 'control' by continuing to use the existing signs, will be identified and confirmed by the HA.

Data Collection

Draft examples of the data collection forms are included within this document. These have been designed to provide sufficient information in order to compare the performance of the modified sign against the original signs. It will be the responsibility of the out station managers to ensure forms are completed and returned, weekly, to TRL for analysis.

Data Compilation and Analysis

Data returned to TRL will be analysed, and used to contribute towards the development of stable signs for TOS use.

Reporting and Further Development

Data from the trial will be used to validate the results of the intial interviews with Traffic Officers, and to aid further development of new sign prototypes.

Results will be included within reports provided as part of the project task.

- ***Signs delivered to one TOS out station***

  TRL has had a batch of signs manufactured which incorporate modifications intended to overcome the main issues faced by Traffic Officers using the current signs.

  This batch of signs would be delivered to a single out-station, to equip their vehicles. These signs would be delivered with '610' arrows, and it would be necessary to ensure that all other sign faces in use at the out-station are compatible with the new signs.

- ***Reason for tests, and modifications, explained to TOs***

  A member of TRL staff would visit the out-station to 'introduce' the modified sign, and explain the purpose of the trial.

  From a cursory glance, the new signs do not appear significantly different from existing signs as the modifications are minor:
  - Improved, sprung, base pivot
  - Side arm detent improved
  - Side arms moved to rear of sign face
  - Conspicuous marking on rear of sign to aid detection of sign collapse

  It would also be explained that the reason for signs falling is likely to be the base 'foot' pivotting, and that correct adjustment will help overcome the problem.

  The trial would involve recording of sign use during the duration of the trial, with a second summary feedback form used at the end of the trial.

  It will also be necessary to visit the 'control' out-station to introduce the trial and feedback form '1'.

- ***Feedback forms 1 & 2***

  Feedback form '1' is used to record the frequency and types of problems experienced by Traffic Officers while using their temporary signs. The form is applicable to both the existing and modified signs, which allows a comparison of the problems experienced.

Feedback form '2' is a 'summary' sheet, to be completed by those Traffic Officers who have used the modified signs, and is to record their views when comparing the modified signs against the original, standard issue, sign.

Traffic Officers at the control out-station would not be asked to complete feedback form '2'

- ***Reporting process explained to responsible person***

  We will liaise with the Out-station Manager (or other responsible person) to ensure that the forms are completed by each TO at a convenient time, for example at the end of each shift rotation. The completed questionnaires will then be forwarded to TRL on a weekly basis in prepaid envelopes supplied by TRL.

  It is anticipated that a three month trial would be sufficient to allow the modified signs to get full use by all Traffic Officers, and for the signs to have been put through a range of typical deployments.

Reporting:

- ***Weekly using feedback form 1, and returned weekly to TRL***

  Completed weekly by all TOs at the out stations involved

- ***Results compiled onto recording system***

  Forms returned to TRL will be batched for data entry

- ***At end of trial, out station crews using modified sign to complete feedback form 2***

  TRL will liaise with the Out-station Manager to ensure that these forms are completed once by each TO, gathered, and submitted to TRL

- ***Results compiled onto recording system***

  Forms submitted to TRL will be compiled electronically onto a recording system, from which analysis will be made.

Appendix C Feedback Form 1

Using Temporary Signs - Feedback Form 1

Please circle the appropriate answer, and give extra detail when you can on the back of this sheet.

Thinking about the temporary signs carried on your vehicle, during the last week:

1.	Have any signs collapsed because the side arms have not remained upright?	Yes ☐	No ☐
	If 'Yes', how often	1-2 times ☐ 3-5 times ☐ more than 5 times ☐	
2.	Have any signs collapsed after the base 'leg' has folded?	Yes ☐	No ☐
	If 'Yes', how often	1-2 times ☐ 3-5 times ☐ more than 5 times ☐	
3.	Have your signs needed immediate repairs or adjustments during the week?	Yes ☐	No ☐
	If 'Yes', how many repairs	1 ☐ 2-3 ☐ 4-5 ☐ 6-All signs ☐	
	Please give details of the type of repairs or adjustments on the back of this sheet		
4.	Have your signs needed repairs or adjustments which could wait for a convenient time?	Yes ☐	No ☐
	If 'Yes', how many repairs	1 ☐ 2-3 ☐ 4-5 ☐ 6-All signs ☐	
	Please give details of the type of repairs or adjustments on the back of this sheet		
5.	Have signs suffered damage which resulted in them being written off	Yes ☐	No ☐
	Please describe this damage on the back of this sheet		

If you have any other comments about the signs, add them on the back of this sheet.

Thank you for your help.

[Back of sheet:]

Immediate repairs or adjustments required during the week

Please describe the details of the type of repairs or adjustments below

Repairs or adjustments which could wait for a convenient time

Please describe the details of the type of repairs or adjustments below

If signs have suffered damage which resulted in them being written off

Please describe this damage below

Appendix D Feedback Form 2

Using the New Design Temporary Signs – Feedback Form 2

If you have been using the new, modified design signs, could you comment on how they compare with your experience of the original, unmodified signs?

Please circle the answer you think is most appropriate

The new signs are	more stable	less stable	than the original signs
The new signs are	easier	more difficult	to deploy than the original signs
The new signs are	easier	more difficult	to retrieve than the original signs
The new signs are	faster	slower	to deploy than the original signs
The new signs are	faster	slower	to retrieve than the original signs
The new signs are	safer	less safe	to deploy than the original signs
The new signs are	safer	less safe	to retrieve than the original signs
I prefer the	new design	original	signs

If you have any other comments about the signs, add them on the back of this sheet.

Thank you for your help.

Appendix E IRIS Data for trial period

Incident data was supplied to TRL by the HA, extracted from the HA's IRIS system. This data was for the entire HA network, covering the trial period. The final entry TOS NE entry is dated after the trial had been suspended, so presumably refers to the use of original, unmodified, signs. Also of note, the entry from TOS NW which states:

> "*Signs collapsed. + Weighted down but still moved by wind.passing traffic*"

Extract:

Incident Description	Name	Date	Initial Cause	Directorate/Division Or Re
Whilst attending an RTC the TO was implimenting ETM, whilst deploying a 610 arrow they got 2 metal splinters in the base of their right hand index finger.	Tony Booth	10/10/2009	Lack of Care By	Network Ops - TOS - Eas
Whilst collapsing a 610 portable sign, the sign slipped and part of the frame logged behind the TO's wrist watch breaking the skin and bruising the back of their wrist.	Tony Booth	17/10/2009	Other	Network Ops - TOS - Eas
610 signs kept blowing over by passing LGV	A KING	09/11/2009		Network Ops - TOS - NE
The new prototype 6/10 signs when used at H/S incident and placed close to Marginal strip, were blown over and dragged into Lane 1 by LGV slipstream. (Weather - slight wind &	A KING	20/11/2009		Network Ops - TOS - NE
Whilst Erecting new 6/10 signs and wearing debris gloves, trapped thumb in the side clasps causing bruising/bleeding.	A KING	18/11/2009	Incorrect Use of	Network Ops - TOS - NE
At BD Tanker on H/S, had to withdraw new 6/10 signs as were drawn to L1 by passing LGV's drafts.	A KING	20/11/2009		Network Ops - TOS - NE
New 6/10 Signs too rigid so blowing over constantly, removed to avoid live lane entry	A KING	27/11/2009		Network Ops - TOS - NE
At L1 closure, 610 sign was sucked into L 2 by passing LGV	A KING	04/12/2009		Network Ops - TOS - NE
While deploying new style 6/10 sign, trapped coat cuff in sign locking arm.	A KING	04/12/2009		Network Ops - TOS - NE
In H/S box, trail 6/10 signs affected by LGV back draft, so needed to be reposition and when folded 6/10 front face outside difficult to store as catch on each other, damaging signs	A KING	04/12/2009		Network Ops - TOS - NE
New style 610 sign kept blowing over into L1 when LGV's went past	A KING	14/12/2009		Network Ops - TOS - NE
Trapped Finger in 610 locking mechanism (Cut finger despite wearing debris gloves)	A KING	21/12/2009		Network Ops - TOS - NE
610 sign kept collapsing due to high winds	A KING	12/10/2009		Network Ops - TOS - NE
Implementing L1 closure and 610 sign kept blowing over in not partially strong winds	A KING	19/10/2009		Network Ops - TOS - NE
Whilst at BDV L/Lane at top of slip just past traffic lights, 610 signs kept blowing over due to passing traffic.	A KING	09/11/2009		Network Ops - TOS - NE
Due to lack of ventilation / flexibility makes signs dangerous to use in high winds, signs not used until ISU arrived with better signs.	A KING	27/11/2009		Network Ops - TOS - NE
HATO trapped Right Thumb in 6/10 sign. Received cut to thumb, despite wearing PPE (Gloves) at time	A KING	11/12/2009	Mech/Elec Fault	Network Ops - TOS - NE
610 sign blew over in heavy rain & wind into Lane 1 from closed Lane 2 , so stopping slow moving traffic	A KING	30/12/2009		Network Ops - TOS - NE
Log 1246 19/11/09.2 X 610 Frames broke in wind on a lane 1 closure	Alison Grave	26/11/2009		Network Ops - TOS - NW
Log 1040.'610' signs collapsed..+ Weighted down but still moved by wind/passing traffic	Alison Grave	26/11/2009		Network Ops - TOS - NW
610 blew along hard shoulder because of draft from LGV	Amanda Hamne	21/12/2009		Network Ops - TOS - NW
Log 814 Hard shoulder box completed to protect vehicle. Both 610's failed. Falling down due to passing traffic, poor quality	Amanda Hamne	21/12/2009		Network Ops - TOS - NW
Breakdown Log 602. Hard shoulder box completed to protect young family no area to stand. 610 failed falling down due to passing traffic.	Amanda Hamne	21/12/2009		Network Ops - TOS - NW
Traffic Officer 1392 was on beat 2 SW11 + was on the M5 B c/way at marker post 115/5 log 587. Weather conditions were foggy + cold. TO had to put in place a Lane 1 closure c	Karen Moore	14/12/2009		Network Ops - TOS - SW
TO took debris glove off to push poppers back on arrow sign then pushed hinge straight, trapping finger without placing my glove.	Jo Mahon	10/12/2009		Network Ops - TOS - SW
Whilst erecting a 610 sign at an MSA event Dominic trapped his left little finger in the hinged frame of the sign. This had a guillotine effect and sliced into the fleshy part of his finger	Karen Moore	01/12/2009		Network Ops - TOS - SW
TO had a full closure in place directing traffic off at the juliet slip J14. Whilst monitoring closure, high winds disabled 4 x 610 arrows and NO ENTRY signs blowing them into live lane	Chris Hudson	14/12/2009		Network Ops - TOS - W M

Appendix F Feedback from On-road trials of 610 signs.

41 replies were received from the trial Out-stations (Barton and Carrville). No feedback was received from the Control Out-stations.

Q	Question	No	Yes
1	Have any signs collapsed because the side arms have not remained locked?	41	0
2	Have any signs collapsed after the base "leg" has folded?	35	6
3	Have your signs needed immediate repairs or adjustments during the week?	37	4
4	Have your signs needed repairs or adjustments which could wait for a convenient time?	41	0
5	Have your signs suffered damage which resulted in them being written off?	38	3

Q2 Collapse after base leg folded

There were 4 reports of this happening. In 3 cases this had happened 2-3 times during the week. In the remaining case it had happened once.

Q3 Signs needing immediate repairs

There were 4 reports of signs needing immediate repairs. Supplementary notes were as follows:

- The 610 part of the sign needs refitting because it comes off in the back of the TOV when taking in and out of storage
- Due to the way the 610 frames roll up the replaceable sign panes are being damaged on return to vehicle storage area.
- Blown out of taper into L/Lane and then down hard shoulder *(no further details)*

Q5 Signs damaged and written off

- Press stud detached
- The press-stud hold arrow sign down had been damaged, so had to be replaced as if wind caught sign could blow arrow sign resulting in not being seen.
- Press studs damaged due to being placed into vehicle face side down.

F.1 Other comments received:

- Trial 610s seem as prone (if not more so) to being drawn into live lanes by draft of LGVs. It may be that because they are more "rigid" there's no give at all. If it was mounted on a sprung-loaded base it may work better.

- Deployment of and removal of 610s, to me, more difficult and awkward with the side arms being on the rear rather than front. Also, the "arrow" itself more prone to damage due to the way they now fold (sign on outside rather than inside).
- Hard shoulder box deployed on windy day. 610 sign nearest to carriageway seriously affected by slip stream created by LGVs. Sign blown over (x2) and dragged into carriageway. "Near Miss" submitted due to potential danger arising.
- The side arms at the rear of the sign is a good development. However, the sign faces may deteriorate as the face is exposed when collapsed and may wear with removal/replacement in the TOV storage compartment.
- Signs "dance" around when erected in high winds or when LGVs pass
- Safety incident [form] completed. Unable to deploy 610s due to their rigidity in high winds. Lack of venting on the sign effectively turned it into a sail.
- I think in time because signs are "rolled up" with the 610 on the outside that wear and tear on these new signs will become apparent.
- Signs now lock into place better. However the legs need to be on the front side of the sign. When you fold the sign into itself, the hi-vis front fascia of the sign is being damaged as it isn't protected like it was with the original signs, eg due to rubbing onto bolts.
- In cold weather, the hi-vis fascia acts as a "sticky" surface, so you can end up pulling all signs out of the vehicle, and it is harder to fold the sign "fascia out" when the fabric is cold.
- Signs moving with wind from passing lgvs
- Hard shoulder box. Sign nearest carriageway turned and fell twice due to the draft caused by passing lgvs. No wind due to weather.
- 610 repeatedly blows over because it is too rigid
- When stored in a vehicle signs are wrapped around frame so that 610 sign is outermost. This is resulting in early wear on reflective surface. Also, when wet, signs grip each other preventing easy storage and removal of signs from vehicle.
- On two occasions when these signs were deployed at separate incidents, passing lgvs sucked them into live lane. On another occasion my coat sleeve got trapped in the locking arm.
- On several occasions the 610 signs had to be removed from the hard shoulder closures as when the wind or back draught from lgvs were causing them to blow into the live lane.

F.2 Near Miss reports received:

- Near Miss report: whilst present at incident on hard shoulder, a "hard shoulder box" was deployed in accord with H/A procedures using 2 x 610 signs. The 610 signs presently in use are prototypes from TRL. The signs were found to be blown over and dragged by the slip stream created by LGVs, on one occasion sign entered Lane 1. Weather at time was slight wind and rain. Sign affected was in position close to marginal strip. Other sign was unaffected.
- Near miss report: 1. The new 610 are too rigid and were constantly blowing over. 2. They had to be removed to stop them possibly entering L/L causing further hazards.

- Near miss report: I was trialling the new 610 sign on a hard shoulder closure. When I was erecting the sign my thumb got trapped in the side clasps and caused bruising and bleeding even though I was wearing gloves.
- Log 1585. H/S box deployed for protection. 610 signs drawn into L1 by passing lgv. Log 360: while deploying the new 610 sign, the cuff of my coat got trapped in the locking arm on the front of the sign, prolonging the time to deploy, leaving me vulnerable to oncoming traffic. Log 360: whilst we had a lane 1 closure in place, the second 610 sign was sucked into Lane 2 by passing lgv.
- Accident record: 19/12/09 Barton outstation. Whilst opening a 610 sign on a Lane 1 closure, left hand ring finger got trapped in locking mechanism, cutting the side of the finger through debris glove