

Synthesis title:

# Roadworks

Category: Roads



## Other Relevant Topics:

- ▶ Distraction (Drivers)
- ▶ Speed (Drivers)
- ▶ Road Design (Riders)
- ▶ Safe Route Planning (Pedestrians)
- ▶ Telematics (Vehicles)
- ▶ Motorways (Roads)
- ▶ Speed Limits (Roads)
- ▶ Signing/Marking (Roads)
- ▶ Cameras (Compliance and the Law)
- ▶ Speeding (Compliance and the Law)

## Keywords:

**Traffic Management,  
Road Worker Safety,  
Work Zones, Signs,  
Speed Management**

# About the Road Safety Observatory

**The Road Safety Observatory aims to provide free and easy access to independent road safety research and information for anyone working in road safety and for members of the public. It provides summaries and reviews of research on a wide range of road safety issues, along with links to original road safety research reports.**

The Road Safety Observatory was created as consultations with relevant parties uncovered a strong demand for easier access to road safety research and information in a format that can be understood by both the public and professionals. This is important for identifying the casualty reduction benefits of different interventions, covering engineering programmes on infrastructure and vehicles, educational material, enforcement and the development of new policy measures.

The Road Safety Observatory was designed and developed by an Independent Programme Board consisting of key road safety organisations, including:

- ▶ Department for Transport
- ▶ The Royal Society for the Prevention of Accidents (RoSPA)
- ▶ Road Safety GB
- ▶ Parliamentary Advisory Council for Transport Safety (PACTS)
- ▶ RoadSafe
- ▶ RAC Foundation

By bringing together many of the key road safety governmental and non-governmental organisations, the Observatory hopes to provide one coherent view of key road safety evidence.

The Observatory originally existed as a standalone website, but is now an information hub on the RoSPA website which we hope makes it easy for anyone to access comprehensive reviews of road safety topics.

All of the research reviews produced for the original Road Safety Observatory were submitted to an Evidence Review Panel (which was independent of the programme Board), which reviewed and approved all the research material before it was published to ensure that the Key Facts, Summaries and Research Findings truly reflected the messages in underlying research, including where there may have been contradictions. The Panel also ensured that the papers were free from bias and independent of Government policies or the policies of the individual organisations on the Programme Board.

The Programme Board is not liable for the content of these reviews. The reviews are intended to be free from bias and independent of Government policies and the policies of the individual organisations on the Programme Board. Therefore, they may not always represent the views of all the individual organisations that comprise the Programme Board.

Please be aware that the Road Safety Observatory is not currently being updated; the research and information you will read throughout this paper has not been updated since 2017. If you have any enquiries about the Road Safety Observatory or road safety in general, please contact [help@rospa.com](mailto:help@rospa.com) or call **0121 248 2000**.

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## How do I use this paper?

This paper consists of an extensive evidence review of key research and information around a key road safety topic. The paper is split into sections to make it easy to find the level of detail you require. The sections are as follows:

<b>Key Facts</b>	A small number of bullet points providing the key facts about the topic, extracted from the findings of the full research review.
<b>Summary</b>	A short discussion of the key aspects of the topic to be aware of, research findings from the review, and how any pertinent issues can be tackled.
<b>Methodology</b>	A description of how the review was put together, including the dates during which the research was compiled, the search terms used to find relevant research papers, and the selection criteria used.
<b>Key Statistics</b>	A range of the most important figures surrounding the topic.
<b>Research Findings</b>	A large number of summaries of key research findings, split into relevant subtopics.
<b>References</b>	A list of all the research reports on which the review has been based. It includes the title, author(s), date, methodology, objectives and key findings of each report, plus a hyperlink to the report itself on its external website.

**The programme board would like to extend its warm thanks and appreciation to the many people who contributed to the development of the project, including the individuals and organisations who participated in the initial consultations in 2010.**

## Key Facts

### Note

This review includes statistics from Reported Road Casualties Great Britain 2010, which were the latest available data when the review was written. More recent statistics are available in [Reported Road Casualties Great Britain 2013](#) and [Reported Road Casualties Great Britain 2014](#). An evidence table for each of these reports has been added to the Evidence section of the review.

- It is now thought that, in the UK, there is no significant increase in RTI risk to road users when roadworks are present.  
(DfT, 2004)
- Rear end RTIs are the most frequent type of incident recorded at roadworks.  
(M. Freeman *et al.*, 2000)
- Setting up Temporary Traffic Management (TTM) is regarded as one of the most dangerous activities for road workers. The simplification and rationalisation of roadworks signing is being reviewed to address this situation.  
(S. Clark *et al.*, 2011; R. Wood *et al.*, 2011)
- Speed management is seen as an effective intervention; however drivers must perceive that an enforcement regime is in place in order for behaviour to be positively influenced  
(HA, 2006)
- Road users often report being frustrated by '*phantom*' roadworks; where no workers appear to be present. It has been suggested that this frustration leads to increased dangerous driving.  
(S. Jamson, 2008)

## Summary

This document has been compiled to highlight and summarise road safety aspects related to roadworks, primarily in the United Kingdom. Research from outside of the UK is also included as and when necessary where it was felt that UK-based research was incomplete.

There are two main stakeholders in terms of safety at roadworks; these are the general public (predominantly road users) and the road workers. The safety of both these groups is achieved through the implementation of Temporary Traffic Management (TTM).

The key document regarding TTM is the Traffic Signs Manual (TSM) Chapter 8. This guidance document is the industry standard, and represents best practice for designing and operating TTM. The safety aim established by this document when setting up roadworks is:

*“Underlying the design of temporary traffic management at road works should aim to produce a safety performance no worse than the rate for non-works conditions.”*

TSM Chapter 8 goes on to set out the principles for TTM design:

- *Provision of clear and early warning of obstructions in the highway;*
- *Optimisation of road space and the provision of an adequate safety zone and working space at works locations;*
- *Clear directions relating to decisions/actions required from road users;*
- *Minimisation of potential conflict between road users, and between road users and road workers and their operations;*
- *Credibility of traffic signs and temporary requirements; and,*
- *Speed limits and restrictions appropriate for the temporary highway geometry and safety features.*

By following these principles and the guidance contained within TSM Chapter 8 (at a minimum) it is expected that the subsequent roadworks will be safe for purpose.

The following paragraphs summarise the findings of this synthesis relating to each of the principles stated in TSM Chapter 8:

Signing provides the ‘clear and early warning’ and gives ‘clear directions’. This synthesis has identified that setting out signs on high speed roads presents a particular challenge. Carriageway crossings are a high risk activity but are a common method of setting up signs for roadworks. Studies have examined driver comprehension and identified approaches to reduce carriageway crossing risk, by removing the need altogether or by making signs smaller and easier to carry.

Intelligent design of the roadworks layout optimises road space and provides the safe working space. The approach to road works and lane drops have been identified as areas of particularly high risk for conflict. One study in North America concluded that diversion of heavy vehicles away from the works zone was a particularly effective intervention. A semi-automatic cone laying machine trialled in the UK has shown potential to reduce road worker risk.

Barriers and a highly conspicuous workforce help to 'reduce conflicts' between road users and road workers. A Quick Moveable Barrier (QMB) has been successfully trialled in the UK; it gave the roadworks layout flexibility and reduced overall road worker risk exposure. Although road workers (and Traffic Officers) wear high visibility clothing, a study in the UK indicated that they typically over-estimated their conspicuity to drivers. This may induce complacency and increase safety risk.

'Credibility of traffic signs' has been found to be adversely affected when drivers perceive that road workers are not actually present. Similarly, an unpublished study showed poor understanding of and very poor compliance with advisory speed limits.

'Speed limits and restrictions' are widely acknowledged as a credible safety intervention. However, drivers must perceive that limits are enforced, otherwise compliance levels are low. Time over distance (average speed) cameras tend to produce a more stable speed reduction; spot speed enforcement is known to cause 'surfing' as drivers slow down only at the camera. Variable speed limits have been trialled both by simulation and on-road and have been shown to actually reduce speed variance (hence reducing RTI risk).

## **Methodology**

This synthesis includes studies relevant to any aspect of driver or road worker safety in roadworks (also known as ‘work zones’ outside of the UK).

This synthesis was compiled during August – September 2012.

### **Note**

This review includes statistics from Reported Road Casualties Great Britain 2010, which were the latest available data when the review was written. More recent statistics are available in [Reported Road Casualties Great Britain 2013](#) and [Reported Road Casualties Great Britain 2014](#). An evidence table for each of these reports has been added to the Evidence section of the review.

A detailed description of the methodology used to produce this review is provided in the Methodology section of the Observatory website, at <http://www.roadsafetyobservatory.com/Introduction/Methods>.

An outline of the steps taken to produce this synthesis are outlined below:

- **Identification of relevant research** – searches were carried out on pre-defined research (and data) repositories. As part of the initial search some additional information sources were also consulted, which included <http://www.ingentaconnect.com> and various project archives. Search terms used to identify relevant papers included but were not limited to:
  - ‘Roadworks’;
  - ‘Road workers’;
  - ‘Road worker safety’;
  - ‘Work zones’;
  - ‘Work zone safety’; and,
  - ‘Traffic Management’.

A total of 53 pieces of potentially relevant research were identified.

- **Initial review of research** – primarily involved sorting the research items based on key criteria, to ensure the most relevant and effective items went forward for inclusion in this synthesis. Key criteria included:
  - Relevance – whether the research makes a valuable contribution to this synthesis, for example robust findings from a field trial of road works signing.
  - Provenance – whether the research is relevant to drivers, road safety policies or road safety professionals in the UK. If the research did not originate in the UK the author and expert reviewer have applied a sense check to ensure that findings are potentially relevant and transferable to the UK.

- Age – the design and expectations around road works in the UK have developed rapidly in the last decade, hence findings may quickly become dated and not applicable. Priority is given to the most up to date titles in the event of over-lap or contradiction.
- Effectiveness – whether the research credibly proves (or disproves) the effectiveness of a particular road works initiative or intervention.

Following the initial review, 25 pieces of research were taken forward to form the basis for this synthesis, 19 of which were published in the UK.

- **Detailed review of research** – key facts, figures and findings were extracted from the identified research to highlight pertinent road safety issues and interventions.
- **Compilation of Synthesis** – the output of the detailed review was analysed for commonality and a synthesis written in the agreed format. Note that the entire process from identifying research to compiling the synthesis was conducted in a time bound manner.
- **Review** – the draft synthesis was subjected to extensive review by a subject matter expert, proof reader and an independent Evidence Review Panel appointed by DfT.

## **Key statistics**

Most statistics relating to safety at roadworks recount RTIs and casualties. The other key area of statistics relates to speed and compliance.

### **Casualty statistics**

- Roadworks were cited in almost half (49.8 per cent) of RTIs where a 'special condition' was recorded. However, it should be noted that only 2.5 per cent of all reported casualty RTIs had any special condition recorded.

(Kilby *et al.*, 2011; Table RAS10008)

- In 2004 it was stated that the personal injury RTI rate at roadworks reduced from 0.174 (in 1992) to 0.101, indicating *"that there is... no significant difference in the accident risk to road users when roadworks are present"*.

(DfT, 2004)

### **Location of incidents**

Regarding road worker incidents or near misses as reported by the Highways Agency's supply chain using AIRSWeb between 1997 and December 2010:

- Of those entries where the field 'roadworks which part' had been completed:
  - The most frequently reported location was 'within works area / safety zone (adjacent to a live carriageway)', the next most frequently reported was 'on a live carriageway (i.e. open to traffic)'.
- Of those entries where the field 'which part of TTM' had been completed:
  - The most frequently reported location was 'in, or alongside, main works area', the next most frequently reported was 'within the entrance taper'.

As a Highways Agency tool AIRSWeb covers only incidents which occur on England's Strategic Road Network. Note that AIRSWeb data is available from 1997 to 2010, however there are many more reports filed in the latter years of operation. This suggests under reporting in the first decade of AIRSWeb operation. For this reason only relative comparisons are noted above and absolute figures not quoted. The report also notes that fields relating to TTM, "were not completed for the majority of incidents".

(C. Fowler *et al.*, 2011)

Regarding pedestrians killed or injured in the course of roadworks on the Highways Agency's network between 2005 and 2009; according to STATS19 data:

- Reported pedestrian locations:
  - 5 per cent were crossing the carriageway;
  - 6 per cent were on a footway or verge;
  - 5 per cent were on a refuge, central island or central reservation;
  - 68 per cent were in the carriageway, not crossing; and,
  - The location of 15 per cent was unknown or other.
- Commonly reported vehicle manoeuvres:
  - 50 per cent were struck by a vehicle reported as going ahead;
  - 16 per cent were struck by a vehicle reported as parked (suggesting that the parked vehicle had been struck and shunted into the pedestrian); and,
  - 10 per cent were struck by a vehicle reported as reversing (resulting in one fatality and eight injuries).
- Where contributory factors were reported:
  - The most frequently reported factors allocated to pedestrians were, 'failed to look properly', followed by 'dangerous action in the carriageway'.
  - The most frequently reported factors allocated to vehicles were, 'failed to look properly', followed by 'careless, reckless or in a hurry'.

(C. Fowler *et al.*, 2011)

## **Speed management**

Speed is a well known contributory factor for RTIs. The following statements demonstrate the poor understanding and compliance with speed limits at roadworks.

- One UK study in 2002 showed very poor compliance with the posted 50 mph mandatory speed limit at roadworks on the M61 (albeit measured over a very short timeframe):
  - 23 per cent of vehicles in lane 1 were travelling below the speed limit; 11 per cent of vehicles in lane 2 were travelling below the limit.

(S. Yousif, 2002)

- An unpublished UK study found that 64 per cent of respondents do not correctly understand the meaning of an advisory speed signal, most frequently mis-identifying it as a mandatory instruction. However, the same study found that vehicle speeds typically remained 20 mph higher than a posted 50 mph advisory limit, which indicated a disparity between reported understanding and compliance, and actual behaviour.

(R. Wood *et al.*, 2010)

## **Research findings**

Summaries of key findings from the identified research reports are given below. Further details of the studies reviewed, including methodology and findings, and links to the reports are given in the References section.

The following sections are presented in an order which aligns to the TSM Chapter 8 principles for TTM design.

### **Signing**

This is used at roadworks to ensure that road users understand how to act and behave on the approach to and through the roadworks. Therefore, the safety of the road user is directly affected by their understanding of these signs.

- In a recent UK study, drivers exhibited good comprehension of lane drop and narrow lane signs. There was less comprehension of contraflow signs, however, these signs were not testing in context. Therefore, drivers actual understanding of these signs at roadworks may be better than measured.

(S. Jamson, 2008)

A further consideration with regards safety and signing is that of the road workers. Setting out and maintaining TTM signs can be dangerous from a manual handling perspective and the potential to come into contact with errant vehicles. The following statements discuss these aspects:

- Approach signing to roadworks on high speed roads usually requires that some signs are placed in the central reservation. This necessitates road worker carriageway crossing, which has been identified as a particularly high risk activity. When identifying safe gaps in which to cross, workers are advised to apply the *'3 seconds per lane'* rule.
- However, the volume of traffic on many motorways is such, *"that there are not enough safe crossing opportunities between the hours of 7am and 7pm on weekdays and between 10am and 6pm at weekends for workers to cross without having to wait more than 5 minutes."*

(HSE, 2011)

- Current TTM sign specifications are set out in TSM Chapter 8. However, the workforce has indicated that the size of some signs present operational, in particular manual handling, risks to road workers.
- There is potential to reduce sign size whilst maintaining acceptable levels of driver readability in the following circumstances:
  - Diagram 7202 wicket sign could be reduced in size by 29 per cent on three lane dual carriageways and the offside of four lane dual carriageways.
  - Diagram 7001.3 'workforce in road' sign could be reduced in size by 25 per cent on three lane dual carriageways.

- Diagram 7306 'works access' sign could be reduced in size on three lane dual carriageways, and to a lesser degree on four and five lane dual carriageways, assuming that approaching traffic is travelling at 50 mph.
- Signs which were not eligible for size reduction should be considered for revision to reduce their word count. This would lead to reduced reading times and enable size reduction.

(S. Clark *et al.*, 2011)

- A simulator study, followed up by on-road trials, showed that modifying TTM layouts by omitting the 200 and 600 yard advanced signs and the Detail 'A' element on the hard shoulder did not prompt significant changes in driver safety behaviour.
- This indicates that certain relaxed layouts have the potential to reduce road worker risk whilst setting out by reducing the number of signs on the network, with no detrimental effects on driver behaviour.

(R. Wood *et al.*, 2011)

- Traditional temporary traffic management 'A' frame signs typically cannot be used as designed when a concrete barrier is present, i.e. they tend to straddle the barrier without touching the ground and require weighing down with sandbags.
- This adds time and complexity to setting out operations – which are already high risk activities for road workers.
- A variety of potential solutions exist: affixing brackets and straps or regular eyelets to barriers appear to be promising (but have not yet been trialled).

(A. Chequer *et al.*, 2007)

## Layout and works design

The layout and design of roadworks should aim to minimise conflict between road users and road workers. This section discusses various aspects of this topic:

- Traffic management proposals must follow the hierarchy of risk prevention and protection:
  - *Avoid hazards to health and safety, i.e. change or alter the design to remove hazards.*
  - If this is not possible,*
  - *Tackle the hazard at source to reduce the impact of the risk, i.e. design in details that reduce risks, e.g. impact resistant barriers etc.*
  - If this is not possible,*
  - *Provide as much information as possible to allow those undertaking or managing the work to reduce and control the effects of any remaining project specific risks.*

(HA ,2002)

- A study of RTIs in road works on UK motorways showed that locations within the road works layout most commonly associated with RTIs were: approaches to lane closures, diverges, entry slips and contra flows. Very few RTIs were recorded at works exits.

(M. Freeman *et al.*, 2000)

- Trials have demonstrated that use of a semi-automated cone laying machine (Conemaster) is a quick and effective method of setting out single lane closures. Although this trial was carried out by contractor only, use of such machines is indicated to reduce road worker risk exposure.

(RoWSaF, 2011)

- A simulation study carried out in Florida gives indicative evidence that dynamic merge systems (which give differing instructions to merging traffic upstream of a lane drop according to pre-programmed parameters) can increase throughput. They are more effective still when used alongside variable speed limit systems.

(E. Radwan *et al.*, 2011)

- A study of countermeasures employed during works on an Indianapolis interstate showed that rerouting heavy goods vehicles (over 13 tons) was the single most effective intervention with regards to improving safety.

(A. Tarko *et al.*, 2009)

## Minimising conflict

Minimising conflict between all groups at roadworks is essential to reduce RTI risk. Both signing and layout, as previously discussed, can help to reduce conflict. However, physical separation between road users and roadworks (which comprise of dangerous elements such as road workers, machinery and excavations) can be achieved through the use of barriers:

### Barriers

- The key document of reference for barrier performance standards is: *BS-EN 1317-2:2010 Road restraint systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers.*
- The main criteria for the categorisation of barriers are:
  - The containment level – in which the barrier system is rated by its ability to contain a vehicle of a particular mass, speed, configuration and approach angle.
  - The impact severity level – in which a barrier is rated from A to C, with A offering the greatest level of safety for vehicle occupants.
  - The deformation – which describes the maximum dynamic lateral displacement of the barrier system and thus defines the levels of working width.

Volume 2 Section 2 Part 8 of the Design Manual for Roads and Bridges (TD 19/06) describes containment levels required for permanent and temporary systems. There are many types of barrier system available for use at roadworks, some of which are discussed in an unpublished report for the Highways Agency (J. Uff, 2010). All barriers will be evaluated against the previously mentioned standards, and the choice of barrier should be made according to individual circumstances. One new and flexible barrier system which is particularly relevant for major road works is QMB:

- A Quick Moveable Barrier (QMB) has been used on major road works schemes in the UK to allow swift and safe changes to TTM layouts (typically by adding or closing an additional lane). This has helped to accelerate construction programmes and so reduce overall road worker exposure time.

(P. Boulton and P. Owlett, 2008)

### **Conspicuity**

Improved conspicuity can also minimise conflict between road user and road worker. This is achieved by ensuring that road users are aware of road worker presence, which subsequently has a positive effect on their behaviour (via reduced speeds and extra care). However some aspects of conspicuity which require further consideration include:

- Roadworkers and Traffic Officers should be educated as to their levels of conspicuity to drivers – there is evidence that these parties over-estimate detection distances, especially at night.
- Drivers typically do not expect to see road workers; they should be educated that roadworkers may be present in many everyday driving scenarios.
- It is suggested that white vehicles are more visible than other colours at night. However, there is some risk that a combination of white vehicles and yellow high visibility clothing could lead to ‘blending’ and reduce worker conspicuity.

(S. Helman and M. Palmer, 2010)

### **Speed management**

Effective speed management is necessary in order for road users to read signs, act on instructions, to ensure that barriers are suitable for speeds, and to reduce the severity of RTIs should they occur. The following statements relate to the understanding and compliance of speed limits:

- Advisory speed limits have been shown to be ineffective in an unpublished UK study. Although a small reduction in vehicle speeds was sustained through sections with a 50 mph advisory limit displayed, average vehicle speeds remained around 70 mph.

- Many drivers perceive that advisory signal setting are inaccurate and over one third of drivers do not correctly understand the purpose of an advisory signal. Therefore use of advisory signals at or approaching roadworks may have a very limited affect on vehicle speed.

(R. Wood *et al.*, 2010)

- An unpublished study for the Highways Agency compared Spot Speed (SS) and Time Over Distance (TOD, i.e. 'average speed') enforcement systems:
  - TTM personnel typically favour TOD due to greater perceived effectiveness. However, additional complexity to install is noted.
  - Driver reaction on passing cameras varies: at TOD cameras 12 per cent change their speed at the last minute; at SS cameras 28 per cent of drivers brake at the 'last minute'.
  - 'Surfing' behaviour (i.e. slowing down only in the vicinity of the camera) is prevalent at SS sites with speed recovery observed 500m downstream; there is some evidence of low magnitude surfing behaviour at TOD cameras.
  - No change in driver glance pattern at TOD systems could be established – some subjects checked speed more frequently, some less.
  - A slight reduction in average headway was observed at TOD sites with a greater likelihood of sub- two second headways.

(M. Brackstone, 2008)

- A qualitative survey of higher risk drivers and of improvement professionals in the UK indicated that using factual Variable Message Signs (VMS), variable speed limits and displaying the speed of vehicles entering roadworks is likely to improve safety behaviour.
- Improvement professionals felt that enforcement initiatives would be successful; however this view was not shared by high risk driver groups (potentially since they are naturally inclined not to favour enforcement).

(HA, 2006)

- The use of Stepped Speed Limits on the approach to roadworks has shown potential to influence a positive effect on driver behaviour (through improved speed profile and headway).
- Options for implementing Variable Speed Limits (VSL) through roadworks has been researched and proposed in the UK, with the expectation that reduced frustration would lead to improved behaviour and speed compliance. However, on-road trials have not been conducted to date therefore VSL at roadworks is unlikely to be implemented in the UK.

(J. Uff, 2010)

- Use of VSL signs posting a 65 mph limit in a trial in Utah did not change average vehicle speeds by a statistically significant amount compared to static 65 mph signs. However, VSL signs did reduce speed variation by a significant amount.

- When VSL signs were used to lower the speed limit to 55 mph during the day (i.e. when workers were present), average speeds did decrease by a significant amount. However, levels of actual compliance with the posted limit were typically less than 30 per cent.

(T. McMurtry *et al.*, 2008)

- A North American computer simulation study also concluded that variable speed limits significantly reduced speed variance at road works.

(P. Lin *et al.*, 2004)

### **How effective?**

Little quantitative analysis has been conducted into how effective the various elements of TTM are. This may be attributed to the prescriptive nature of roadwork guidance and risk aversion (with regard to trying approaches different to that stipulated by the guidance).

The following statements are the few quantitative measures of effectiveness found during compilation of this synthesis:

- Quantitative risk analysis of Temporary Traffic Management (TTM) operations has shown that simple changes to the layout can reduce the risk index score for road workers.
  - Omitting the 200 and 600 yard advanced signs and the Detail 'A' element on the hard shoulder has the potential to reduce the risk index by up to 22 per cent and to decrease carriageway crossings by up to 52 per cent.
  - Eliminating offside signs when setting out nearside lane closures has the potential to reduce the risk index by up to 28 per cent and reduce carriageway crossings by 100 per cent.

(C. Fowler *et al.*, 2011)

- Application of LED speed display and automated enforcement in Illinois resulted in significant speed reductions in work zones. Comparing before and during enforcement speeds at three separate work zone locations, the percentage of free-flowing vehicles exceeding the speed limit decreased from 93, 40 and 30 per cent to 45, 8 and 4 per cent respectively.

(P. Tobias, 2011)

## Gaps in the research

- An unpublished study for the Highways Agency found little research considering the overall effectiveness (as distinct from simply compliance) of time over distance (average speed) enforcement systems, particularly when used in roadworks.

(M. Brackstone, 2008)

- An assessment of driver understanding of roadworks at a scheme level should be conducted in order to identify potential opportunities for rationalisation of signing. Currently only individual types or elements of signing are considered at any one time.
- On-road trials of VSL technology in the UK should be conducted in order to identify whether this can be safely deployed. VSLs have the potential to offer many benefits to road users and road workers.
- Existing studies predominantly cover road works on high speed roads. As more RTIs tend to occur on low speed urban roads, there remains scope to further investigate safety issues around road works in this environment.
- The single most effective action that could improve road safety at roadworks is likely to be assessed education. Research into how this could be implemented (technically and financially) and the potential benefits would be valuable.
- To promote research and innovation in the UK emphasis should be given towards the understanding that TSM Chapter 8 is a guidance document, and is not a 'rule book'. Encouraging more innovation, backed up by robust research, should lead to improved safety for all road users.

## References

### Department for Transport research and statistics

<b>Title: Reported Road Casualties Great Britain: 2014 annual report</b>
<b>Author / organisation:</b> Department for Transport <b>Date:</b> September 2015 <b>Format:</b> Pdf <b>Link:</b> <a href="https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/463797/rrcgb-2014.pdf">https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/463797/rrcgb-2014.pdf</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> This report delivers statistics relating to all road accidents and casualties reported to the police in Great Britain in 2014.
<b>Methodology:</b> Statistics are compiled from the STATS19 database of road traffic incidents (RTIs).
<b>Key Findings:</b> <ul style="list-style-type: none"><li>• RTIs can be reported by special conditions at the site of the accident; of which the most frequently assigned is road works.</li><li>• In 2014, 1,562 road accidents were recorded as occurring in roadworks, 1,134 of which occurred in daylight.</li></ul>
<b>Themes:</b> RTI statistics, pedestrian contributory factors
<b>Comments:</b> The national road casualty statistics remain the single largest source of RTI data.

<b>Title: Reported Road Casualties Great Britain: 2013 annual report</b>
<b>Author / organisation:</b> Department for Transport <b>Date:</b> September 2014 <b>Format:</b> Pdf <b>Link:</b> <a href="https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/359311/rrcgb-2013.pdf">https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/359311/rrcgb-2013.pdf</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> This report delivers statistics relating to all road accidents and casualties reported to the police in Great Britain in 2013.
<b>Methodology:</b> Statistics are compiled from the STATS19 database of road traffic incidents (RTIs).
<b>Key Findings:</b> <ul style="list-style-type: none"><li>• RTIs can be reported by special conditions at the site of the accident; of which the most frequently assigned is road works.</li><li>• In 2013, 1,409 road accidents were recorded as occurring in roadworks, 1,024 of which occurred in daylight.</li></ul>
<b>Themes:</b> RTI statistics, pedestrian contributory factors
<b>Comments:</b> The national road casualty statistics remain the single largest source of RTI data.

<b>Title: Reported road casualties Great Britain: 2010 annual report</b>
<b>Author / organisation:</b> P. Kilby, D. Wilson, W. Huang, P. McEvoy, A. Bhagat. (Department for Transport)
<b>Date:</b> September 2011
<b>Format:</b> Pdf
<b>Link:</b> <a href="http://assets.dft.gov.uk/statistics/releases/road-accidents-and-safety-annual-report-2010/rrcgb2010-complete.pdf">http://assets.dft.gov.uk/statistics/releases/road-accidents-and-safety-annual-report-2010/rrcgb2010-complete.pdf</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> This report delivers statistics relating to all road RTIs reported to the police in Great Britain in 2010.
<b>Methodology:</b> Statistics are compiled from the STATS19 database of road traffic RTIs.
<b>Key findings:</b> <ul style="list-style-type: none"> <li>• RTIs can be reported by special condition; of which the most frequently assigned is road works.</li> </ul>
<b>Themes:</b> RTI statistics, pedestrian contributory factors
<b>Comments:</b> The national road casualty statistics remain the single largest source of RTI data. It includes contributory factors, which give an indication of the role that safe routes for pedestrians might play.

<b>Title: Traffic Signs Manual Chapter 8</b>
<b>Author / organisation:</b> Department for Transport
<b>Date:</b> 2009
<b>Format:</b> pdf
<b>Link:</b> <a href="http://www.dft.gov.uk/publications/traffic-signs-manual/">http://www.dft.gov.uk/publications/traffic-signs-manual/</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> To set out and minimise the effects that roadworks have on road users through a uniform minimum standard for signing and marking.
<b>Methodology:</b> This document is a code of practice based on a large body of research and empirical knowledge of good practice.
<b>Key findings:</b> <p>Chapter 8 sets out the principles which should underpin effective roadworks / traffic management design:</p> <ul style="list-style-type: none"> <li>• Provision of clear and early warning of obstructions in the highway;</li> <li>• Optimisation of road space and the provision of an adequate safety zone and working space at works locations;</li> <li>• Clear directions relating to decisions/actions required from road users;</li> <li>• Minimisation of potential conflict between road users, and between road users and road workers and their operations;</li> <li>• Credibility of traffic signs and temporary requirements; and,</li> <li>• Speed limits and restrictions appropriate for the temporary highway geometry and safety features.</li> </ul> <p>The document goes on to set out standard practices in some detail (down to the level of, for example, cone spacing).</p>
<b>Themes:</b> code of practice, layout, signing
<b>Comments:</b> Chapter 8 is the 'industry standard' and has typically been adopted as normal practice amongst road work designers and traffic management organisations.

<b>Title: Tomorrow's roads – safer for everyone   The first three year review</b>
<b>Author / organisation:</b> Department for Transport (DfT) <b>Date:</b> April 2004 <b>Format:</b> pdf <b>Link:</b> <a href="http://webarchive.nationalarchives.gov.uk/20100104171434/http://www.dft.gov.uk/pgr/roadsafety/strategytargetsperformance/tomorrowsroadssaferforeveryo4866">http://webarchive.nationalarchives.gov.uk/20100104171434/http://www.dft.gov.uk/pgr/roadsafety/strategytargetsperformance/tomorrowsroadssaferforeveryo4866</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> To review progress against the government's ten year road safety strategy.
<b>Methodology:</b> A comprehensive study of progress against stated targets, supplemented by a review of road casualty data.
<b>Key findings:</b> The personal injury RTI rate at roadworks on Highways Agency roads has been reduced such that there is no significant difference in RTI risk to road users when roadworks are present.
<b>Themes:</b> risk, personal injury RTI rate
<b>Comments:</b> This review was indicative of the status in April 2004. The second three year review from 2007 did not update personal injury RTI rates at roadworks.

<b>Title: Cyclists at road works</b>
<b>Author / organisation:</b> Department for Transport (DfT) <b>Date:</b> December 1999 <b>Format:</b> pdf <b>Link:</b> <a href="http://assets.dft.gov.uk/publications/tal-15-99/tal-15-99.pdf">http://assets.dft.gov.uk/publications/tal-15-99/tal-15-99.pdf</a> <b>Free / priced:</b> Free
<b>Objectives:</b> To examine the safety of cyclists at road works and formulate recommendations to improve cyclists' safety.
<b>Methodology:</b> This document is a code of practice based on a large body of research and empirical knowledge of good practice.
<b>Key Findings:</b> The following recommendations are made: <ul style="list-style-type: none"> <li>• Make use of temporary speed limits, particularly where motor vehicles are unable to safely pass cycles;</li> <li>• Lane widths should be maximised wherever possible and lane widths of 2.75m and 3.25m should be avoided;</li> <li>• Traffic signal timings should give cyclists sufficient time to pass through road works;</li> <li>• Cyclists are unlikely to accept lengthy detours or long delays – access should be maintained;</li> <li>• Routes and facilities for cyclists should be well signed; and,</li> <li>• Surface courses should be kept as level as possible.</li> </ul>
<b>Themes:</b> cyclists, road works, casualties
<b>Comments:</b> Although dated, this study gives historical trends on cyclist casualties at road works.

## Other works

<b>Title:</b> Automated speed enforcement slows down drivers in work zones
<b>Author / organisation:</b> P. Tobias (Illinois Department of Transportation) <b>Date:</b> November 2011 <b>Format:</b> pdf <b>Link:</b> <a href="http://onlinepubs.trb.org/onlinepubs/trnews/trnews277rpo.pdf">http://onlinepubs.trb.org/onlinepubs/trnews/trnews277rpo.pdf</a> <b>Free / priced:</b> Free
<b>Objectives:</b> To reduce the frequency and severity of work zone RTIs by reducing instances of speeding in work zones.
<b>Methodology:</b> A speed detection van fitted with 'up the road' and 'across the road' radar measured the speed of approaching traffic. Up the road speed was displayed on a large LED to provide information to approaching drivers. Across the road radar then measured speed again; vehicles with speeds above a defined threshold were automatically issued with court summons and fines. Speeds were also measured 1.5 miles downstream, and for a period of 1 hour after the enforcement van had left the work zone.
<b>Key Findings:</b> It was found that, with the speed enforcement van in place: <ul style="list-style-type: none"><li>• Vehicle speeds were significantly reduced in work zones.</li><li>• The percentage of free-flowing vehicles exceeding the speed limit reduced significantly.</li><li>• The speeds of vehicles 1.5 miles downstream were reduced.</li><li>• There was a limited halo effect – vehicle speed reductions after the van departed were less significant.</li></ul>
<b>Themes:</b> speed, enforcement, speed display
<b>Comments:</b> This paper presents a strong set of results and this trial led to similar initiatives in other States. The enforcement intervention itself is characterised by being highly conspicuous in the form of an obvious detection van and large LED speed sign.

<b>Title: On-road trial of the Conemaster automated cone laying machine</b>
<b>Author / organisation:</b> Road Workers' Safety Forum Trials Team (RoWSaF) <b>Date:</b> September 2011 <b>Format:</b> Pdf <b>Link:</b> <a href="http://www.highways.gov.uk/knowledge_compendium/BE843B0BEFF244E88837FC74298D7E48.aspx">http://www.highways.gov.uk/knowledge_compendium/BE843B0BEFF244E88837FC74298D7E48.aspx</a> <b>Free / priced:</b> Free
<b>Objectives:</b> This report compares manual cone laying and retrieval with that using the semi-automatic Conemaster machine.
<b>Methodology:</b> An on road trial took place on the M40 between September 2009 and February 2010. The machine was operated by Carillion staff experienced in Temporary Traffic Management (TTM).
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• The Conemaster is capable of laying and retrieving cones to Chapter 8 standard and relaxation taper and longitudinal layouts.</li> <li>• The Conemaster operated reliably in all conditons in which TTM operatives could reasonably be expected to work.</li> <li>• Manual handling is reduced when using the Conemaster.</li> <li>• The Conemaster must operate behind an Impact Protection Vehicle (IPV), which means that an additional operative is required.</li> <li>• The Conemaster quickly and effectively deployed single lane closures (nearside or offside). However, it had difficulties with more complicated layouts and closing more than one lane required an additional IPV.</li> </ul>
<b>Themes:</b> TTM, cones, Conemaster
<b>Comments:</b> The trial was undertaken by a single Service Provider and hence cannot be considered to be generic.

<b>Title:</b> Operational evaluation of dynamic lane merging in work zones with variable speed limits
<b>Author / organisation:</b> E. Radwan, Z. Zaidi, R. Harb (University of Central Florida)
<b>Date:</b> June 2011 <b>Format:</b> pdf
<b>Link:</b> <a href="http://ac.els-cdn.com/S1877042811010135/1-s2.0-S1877042811010135-main.pdf?_tid=5679e17857570d58c40707f5ba2550cf&amp;acdnat=1344510931_faa26c49fd6283cde329437685a11fb1">http://ac.els-cdn.com/S1877042811010135/1-s2.0-S1877042811010135-main.pdf?_tid=5679e17857570d58c40707f5ba2550cf&amp;acdnat=1344510931_faa26c49fd6283cde329437685a11fb1</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> To report on the operational effectiveness of Dynamic Lane Merge Systems (DLMS) in the presence of a Variable Speed Limit (VSL) system. In this case, increased traffic throughput is associated with reduced flow breakdown and better safety.
<b>Methodology:</b> Scenarios of early and late DLMS, with and without VSL were simulated for differing vehicle numbers, compliance levels and proportions of goods vehicles.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• For “low to medium” (i.e. 500 to 1500 vehicles per hour) traffic volume levels there was no significant differences between traffic management scenarios.</li> <li>• For higher traffic volume levels, late DLMS both with and without VSL produced higher mean throughputs for almost all compliance rates and proportions of goods vehicles.</li> <li>• “It can be inferred from the simulation results that integrated SDLMS and VSL systems have better performance in terms of traffic mobility than existing individual controls and also shows that this integration has more potential than each individual systems.”</li> </ul>
<b>Themes:</b> dynamic lane merge systems, variable speed limits, throughput
<b>Comments:</b> The results of this study are reliant on the accuracy and credibility of the simulation software and the way in which this was used.

<p><b>Title: Driver interaction with temporary traffic management   Final report</b></p> <p><b>Author / organisation:</b> R. Wood, M. Palmer, L. Walter and I. Rillie (TRL)</p> <p><b>Date:</b> June 2011</p> <p><b>Format:</b> Pdf</p> <p><b>Link:</b>  <a href="http://www.highways.gov.uk/knowledge_compendium/assets/documents/Driver_Interaction_with_Temporary_Traffic_Management.pdf">http://www.highways.gov.uk/knowledge_compendium/assets/documents/Driver_Interaction_with_Temporary_Traffic_Management.pdf</a></p> <p><b>Free / priced:</b> Free</p>
<p><b>Objectives:</b> This project investigates the effects on driver behaviour when simplified Temporary Traffic Management (TTM) layouts are used. It seeks to establish whether amending the layout to simplify for road workers has a detrimental effect on driver behaviour.</p>
<p><b>Methodology:</b> The project developed three modified designs from a stakeholder workshop. These layouts were then tested in a driver simulator to gauge behaviour. A favoured layout was identified, which was then used in on-road trials in two Areas. Roadside video recorded the driving behaviour of over 120,000 vehicles, and the implementing contractor's feedback was sought. Control layouts were used for comparison in simulator and on-road trials.</p>
<p><b>Key Findings:</b></p> <ul style="list-style-type: none"> <li>• The simulator trial showed that there were no significant differences in safety critical behaviour between the control and the modified layouts.</li> <li>• Few drivers looked directly at TTM signs regardless of the control layout used.</li> <li>• Stakeholder feedback was therefore used to identify the layout to take forward to on-road trials: omission of the 600yd warning sign and Detail 'A' (in the hard shoulder).</li> <li>• Subsequent stakeholder discussions also suggested that the 200yd warning sign be omitted in a successive on-road trial.</li> <li>• Following on-road trials "there was no evidence to suggest a difference in lane movement of vehicles under the different experimental conditions."</li> <li>• Contractors did not report any vehicles entering the hard shoulder after Detail 'A' was removed. Contractors expressed satisfaction with using the modified layout which omitted both the 600yd and 200yd signs and Detail 'A'.</li> </ul>
<p><b>Themes:</b> modified TTM, reduced risk, road worker crossings</p>
<p><b>Comments:</b> This report focuses on the on-road trial elements of this study; details on the simulator section are thin, and the actual layout taken forward for trials was selected more by stakeholder feedback than simulator results. However, results of on-road trials are encouraging and suggest that road worker risk can be reduced by modifying layouts (see 'Development of the Measurement of Injury Risk (MIRi) Index') without prompting significant change in driver behaviour.</p>

<p><b>Title: Development of the Measurement of Injury Risk (MIRi) Index</b></p> <p><b>Author / organisation:</b> C. Fowler, S. Clark, I. Rillie, R. Cuerden and L. Smith (TRL)</p> <p><b>Date:</b> April 2011</p> <p><b>Format:</b> Pdf</p> <p><b>Link:</b>  <a href="http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Development_of_the_Measurement_of_Injury_Risk_(MIRi)_Index_Issue_-_514707.pdf">http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Development_of_the_Measurement_of_Injury_Risk (MIRi) Index Issue - 514707.pdf</a></p> <p><b>Free / priced:</b> Free</p>
<p><b>Objectives:</b> This report aims to quantify risk associated with on-road traffic operations in order to prioritise activity contributing towards the Highways Agency's Aiming for Zero targets.</p>
<p><b>Methodology:</b> The report considers the relationship between vehicle speed and injury outcome and investigates RTI data from STATS19 and AIRSWeb databases. A methodology which assigns risk to tasks is then derived.</p>
<p><b>Key Findings:</b></p> <p>STATS19 showed that:</p> <ul style="list-style-type: none"> <li>• Between 2005 and 2009 there were 94 pedestrians killed or injured in RTIs on the strategic road network who were reported to be 'in the course of on the road work'.</li> <li>• Approximately one third of these were at locations where road works were present, suggesting that these were road workers.</li> <li>• Of pedestrians hit by a vehicle, 27 from 49 were in RTIs with vehicle factors only, i.e. no fault factors were attributed to pedestrians.</li> <li>• Of pedestrians hit by a vehicle, 20 from 49 were in RTIs with pedestrian factors only, i.e. no fault factors were attributed to vehicles.</li> </ul> <p>AIRSWeb data showed that:</p> <ul style="list-style-type: none"> <li>• There were 6,920 injuries and near misses reported between 2006 and 2010, of which about two thirds were near misses.</li> <li>• Where data was available identifying that an RTI or near miss took place in a works area, 56 per cent occurred in the works area or safety zone, 21 per cent on a live carriageway; 62 injuries and near misses occurred during the setting out of temporary traffic management, 26 occurred during removal.</li> </ul> <p>The MIRi Index calculations showed that:</p> <ul style="list-style-type: none"> <li>• There is no 'one size fits all' approach to reducing risk.</li> <li>• Eliminating the 200 yard and 600 yard advance signs and Detail A on the hard shoulder has the potential to reduce the MIRi Index by up to 22 per cent, and reduce carriageway crossings by up to 52 per cent.</li> <li>• Eliminating the need for offside signs in the event of nearside lane closures has the potential to reduce the MIRi Index by 28 per cent and reduce carriageway crossings by 100 per cent.</li> </ul>
<p><b>Themes:</b> risk, road workers, traffic management</p>
<p><b>Comments:</b> This report presents a useful section on quantifying the problem via RTI statistics and then takes a method based approach to calculating risk associated with tasks. It is therefore highly relevant to those wishing to review operational procedures around temporary traffic management. Note that risk index reductions discussed here consider only risk to road workers and assume that operational changes will not alter driver behaviour (which would affect likelihood and hence risk scores). This is investigated in report 'Driver Interaction with Temporary Traffic Management'.</p>

<p><b>Title:</b> Safety argument for changes to temporary traffic management sign sizes</p> <p><b>Author / organisation:</b> S. Clark, B. Lyus, J. Mitchell, B. Lawton, L. Smith, A. Weare and L. Walter (TRL)</p> <p><b>Date:</b> April 2011</p> <p><b>Format:</b> Pdf</p> <p><b>Link:</b>  <a href="http://tna.europarchive.org/20120903171844/http://www.highways.gov.uk/knowledge_compendium/publications/554EE8EA854E439B8CA9BF68E1C9EBC8.aspx">http://tna.europarchive.org/20120903171844/http://www.highways.gov.uk/knowledge_compendium/publications/554EE8EA854E439B8CA9BF68E1C9EBC8.aspx</a></p> <p><b>Free / priced:</b> Free</p>
<p><b>Objectives:</b> This report aimed to investigate supply chain indications that larger Temporary Traffic Management (TTM) sign sizes may have increased roadworker risk exposure and instances of personal injury RTIs.</p>
<p><b>Methodology:</b> The report determines the changes in sign size and carries out an observed ergonomic handling review. A computer simulation measured sign reading times with reduced sign sizes to determine whether sizes could be reduced. The simulation was 48 participants.</p>
<p><b>Key Findings:</b> Three key signs could be reduced in size in certain circumstances:</p> <ul style="list-style-type: none"> <li>• Diagram 7202 wicket sign could be reduced in size by 29 per cent on three lane dual carriageways and the offside of four lane dual carriageways.</li> <li>• Diagram 7001.3 'workforce in road' sign could be reduced in size by 25 per cent on three lane dual carriageways.</li> <li>• Diagram 7306 'works access' sign could be reduced in size on three lane dual carriageways, and to a lesser degree on four and five lane dual carriageways, assuming that approaching traffic is travelling at 50mph.</li> <li>• Signs which were not eligible for height reduction due to readability concerns should be re-designed to reduce the number of words (thus reducing reading time).</li> </ul> <p>The study uncovered "no specific evidence of a change in the RTI risk or road user RTI rate associated with the change in sign sizes" made in TSM Chapter 8 in 2002 and again in 2006.</p>
<p><b>Themes:</b> signs, reading time, manual handling</p>
<p><b>Comments:</b> This report attempts to reconcile operational feedback from the supply chain with an evidence-led approach to determining sign readability. However, only a fairly specific set of signs and circumstances have been identified here.</p>

<b>Title: Assessment of current guidance in relation to Safe Carriageway Crossing (CIS53) on high speed roads</b>
<b>Author / organisation:</b> Health and Safety Executive (HSE) <b>Date:</b> 2011 <b>Format:</b> Pdf <b>Link:</b> <a href="http://www.hse.gov.uk/research/rrhtm/rr885.htm">http://www.hse.gov.uk/research/rrhtm/rr885.htm</a> <b>Free / priced:</b> Free
<b>Objectives:</b> To review the adequacy of existing guidelines in CIS53 – regarding carriageway crossing of high speed roads.
<b>Methodology:</b> The worked included a literature review, observations of workers in the field setting up temporary traffic management, and analysis of traffic flow data.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• The rules in CIS53 are broadly supported.</li> <li>• However, traffic flows for many motorways make crossing impossible in practice for much of the time. Observed workers did not appear to be waiting for safe gaps as defined by the ‘3 seconds per lane’ rule.</li> <li>• “At less than 20 vehicles per minute across all lanes, it is likely that sufficient safe gaps occur so that workers would not have to wait more than 5 minutes to cross.</li> <li>• Between 20 and 40 vehicles per minute, it is suggested that site specific assessment is undertaken to determine if sufficient safe gaps exist.</li> <li>• At greater than 40 vehicles per minute it is very unlikely that the carriageway can be crossed safely on foot.”</li> </ul>
<b>Themes:</b> road workers, temporary traffic management, carriageway crossings
<b>Comments:</b> The study highlights the operational challenges associated with offside signing on high speed roads, concluding that although the guidance is fit for purpose the realities of traffic levels present considerable challenges in applying it.

<b>Title: Factors influencing severity to highway workers in work zone intrusion accidents</b>
<b>Author / organisation:</b> J. Wong, M. Arico and B. Ravani <b>Date:</b> Traffic Injury Prevention, 12(1): 2011 <b>Format:</b> pdf <b>Link:</b> <a href="http://www.ncbi.nlm.nih.gov/pubmed/21259171">http://www.ncbi.nlm.nih.gov/pubmed/21259171</a> <b>Free / priced:</b> £27.00
<b>Objectives:</b> To analyse factors pertinent to highway worker injury severity.
<b>Methodology:</b> Ten years of California work zone injury were collated and analysed to determine trends in injury. Statistical evaluation was then carried out.
<b>Key Findings:</b> The four most significant variables relating to work zone injury severity were: <ul style="list-style-type: none"> <li>• RTI / work zone location – where highway locations with stationary locations were found to be worse than city streets.</li> <li>• Work zone duration – where short term stationary and short-duration work zones were worse than mobile work zones.</li> <li>• Time of day – where off peak periods were found to be worse than peak periods.</li> <li>• Type of activity performed by the worker – where those on foot were found to be worse than those in vehicles.</li> </ul>
<b>Themes:</b> location, time, duration, activity, risk
<b>Comments:</b> Although the absolute results may be particular to Californian motorists, the method and approach shown in this paper may be of interest to road safety professionals in the UK.

<p><b>Title: Road worker conspicuity   Daytime and night time</b></p> <p><b>Author / organisation:</b> S. Helman and M. Palmer (TRL)</p> <p><b>Date:</b> September 2010</p> <p><b>Format:</b> pdf</p> <p><b>Link:</b>  <a href="http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Combined_Conspicuity_Final_Report_Complete.pdf">http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Combined_Conspicuity_Final_Report_Complete.pdf</a></p> <p><b>Free / priced:</b> Free</p>
<p><b>Objectives:</b> This project focused on the following research questions:</p> <ol style="list-style-type: none"> <li>1. What are the perceptions and opinions of road workers with regard to their conspicuity?</li> <li>2. At what distances are road workers seen in a naturalistic but controlled track study under daytime and lit/unlit night time conditions?</li> <li>3. Do different colours of [Personal Protective Equipment (PPE)] vary in their visibility under daytime and lit/unlit night time conditions?</li> <li>4. Are there differences between subjective ratings of visibility for different coloured materials (representing PPE) against different background colours (representing works vehicles)?</li> <li>5. What are the expectancies of drivers regarding the likelihood of encountering road workers in the proximity of vehicles stopped at the side of the road with flashing lights or beacons?</li> </ol>
<p><b>Methodology:</b> The researchers undertook four activities:</p> <ol style="list-style-type: none"> <li>1. <i>Consultation with road workers about their perceptions of conspicuity.</i></li> <li>2. <i>Track studies during night time and daytime conditions, in which participants were driven past one of two mocked-up scenarios on the [test] track, and asked to comment on the things that grabbed their attention. This was designed to measure detection distance of PPE-wearing mannequins under relatively naturalistic driving conditions.</i></li> <li>3. <i>A study in which participants rated the subjective visibility of difference combinations of PPE material and background colours.</i></li> <li>4. <i>A post-drive interview in which participants were asked about their expectancies on encountering vehicles with flashing lights and beacons in their everyday driving.</i></li> </ol>
<p><b>Key Findings:</b></p> <ul style="list-style-type: none"> <li>• Road workers are not highly conspicuous, even wearing high visibility PPE. Low detection distances (25 to 45m) were observed from some participants.</li> <li>• “Drivers do not necessarily expect to see road workers.”</li> <li>• “There was no obvious ‘overall’ impact of different types [colours] of PPE on detection distance.”</li> <li>• “White may be the most appropriate vehicle colour at night, and orange PPE against white vehicles may be easiest to see.”</li> <li>• Subjective ratings of visibility of PPE/background colour combinations suggested that individuals with colour deficient vision did not behave differently from individuals with normal colour vision.</li> </ul>
<p><b>Themes:</b> conspicuity, PPE, detection distances</p>
<p><b>Comments:</b> This work seeks to establish ‘attention conspicuity’ rather than ‘search conspicuity’. In the former case subjects are not instructed to look out for pedestrians as it is argued that this better reflects real world driving scenarios. Instead, subjects comment when something grabs their attention – i.e. a worker in high visibility PPE. The results are largely subjective but nevertheless indicate two important potential behaviours – that roadworkers over-estimate their conspicuity; and that drivers do not expect to see them. The net effect is reduced reaction times and distances.</p>

<b>Title: Variable speed limits through roadworks</b>
<b>Author / organisation:</b> J. Uff (unpublished) <b>Date:</b> September 2010 <b>Format:</b> pdf <b>Link:</b> - <b>Free / priced:</b> -
<b>Objectives:</b> “To identify technology and procedures that can be used to minimise the disruption experienced by road users, due to roadworks, whilst maintaining safety.”
<b>Methodology:</b> The report conducted a literature review, proposed appropriate strategies and identified technology requirements. Modelling and on-road trials followed.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• Variable speed limits can realise significant safety and traffic flow benefits. They can potentially be applied to UK roadworks, providing adequate space is available.</li> <li>• Technology is a key enabler; for example ‘smart signs’ and the quick moveable barrier facilitate dynamic management.</li> <li>• Stepped speed limits on the approach to works were modelled and trialled and were seen to increase headway through the roadworks.</li> </ul>
<b>Themes:</b> variable speed limit, dynamic management
<b>Comments:</b> An unpublished report giving holistic consideration to the issues of safety and flow at roadworks. Particular focus on tackling the issue of ‘phantom’ roadworks.

<b>Title: Review of advisory speed limits (draft project report, unpublished)</b>
<b>Author / organisation:</b> R. Wood, N. Hilton-Ablewhite, B. Smith, N. Kinnear and I. Rillie (TRL) <b>Date:</b> June 2010 <b>Format:</b> pdf <b>Link:</b> n/a <b>Free / priced:</b> -
<b>Objectives:</b> To understand the origin, usage, observed effectiveness and self-reported responses to advisory speed limits.
<b>Methodology:</b> A literature review was followed by a study of the Highways Agency’s MIDAS and Halogen systems which record vehicle speed. A survey of 190 drivers gathered data on self-reported responses.
<b>Key Findings:</b> Advisory speed limits “promote a small reduction in speed that is carried through the displayed limit; however, vehicle speeds remain far in excess of the displayed limit.” Self-reported responses revealed a disparity with speed data; drivers reported that they slowed significantly. A majority of drivers “do not correctly understand the meaning of an advisory speed signal”.
<b>Themes:</b> speed, advisory speed limits, compliance
<b>Comments:</b> Although not focussed on roadworks, this unpublished report shows how an oft-used tool for protecting road works actually results in poor driver compliance.

<b>Title:</b> Road restraint systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers. [BS-EN 1317-2:2010]
<b>Author / organisation:</b> British Standards Institution
<b>Date:</b> 2010
<b>Format:</b> pdf
<b>Link:</b> <a href="http://shop.bsigroup.com/ProductDetail/?pid=000000000030099528">http://shop.bsigroup.com/ProductDetail/?pid=000000000030099528</a>
<b>Free / priced:</b> £136.00
<b>Objectives:</b> -
<b>Methodology:</b> -
<b>Key Findings:</b> -
<b>Themes:</b> -
<b>Comments:</b> British Standard.

<b>Title:</b> Improving safety in high-speed work zones: A super 70 study
<b>Author / organisation:</b> A. Tarko, M. Islam and J. Thomaz (Joint Transportation Research Programme)
<b>Date:</b> September 2009
<b>Format:</b> pdf
<b>Link:</b> <a href="http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2678&amp;context=jtrp">http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2678&amp;context=jtrp</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> To establish whether the reduction in RTIs during works on the I70 in March to November 2007 was the result of reduced traffic volume, or the result of novel countermeasures.
<b>Methodology:</b> The study applied econometric models to consider spatial differences in the risk of RTIs on roads in and around the work zone. A before and after study was also carried out.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• The single most successful countermeasure was re-routing goods vehicles (over 13 tons) on to alternative interstate routes.</li> <li>• Police enforcement, reduced speed and other traffic management strategies was the next most successful.</li> <li>• Widening shoulders has been indicated as an additional means of improving safety by reducing the number and severity of work zone RTIs.</li> <li>• The study could not find evidence that moveable barriers provided any direct safety benefits.</li> <li>• Not only was safety improved on the I70 during works, but safety on other affected interstates also improved.</li> </ul>
<b>Themes:</b> road works safety, good vehicles
<b>Comments:</b> Although works were only in place for a short time, this study shows good results. Diversion of goods vehicles is a novel solution which in this instance proved to be surprisingly effective. Due to the methods of study, it does not appear possible to disaggregate the effects of enforcement, speed limits and "other traffic management".

<p><b>Title:</b> Variable speed limit signs: effects on speed and speed variation in work zones</p>
<p><b>Author / organisation:</b> T. McMurtry, M. Saito, M. Riffkin, S. Heath (Utah Department of Transportation)  <b>Date:</b> August 2008  <b>Format:</b> pdf  <b>Link:</b>  <a href="http://www.workzonesafety.org/files/documents/database_documents/Publication9947.pdf">http://www.workzonesafety.org/files/documents/database_documents/Publication9947.pdf</a></p>
<p><b>Free / priced:</b> Free</p>
<p><b>Objectives:</b> To evaluate the effectiveness of Variable Speed Limit (VSL) signs on driver behaviour.</p>
<p><b>Methodology:</b> Two VSL signs were placed on a six mile work zone on the westbound I80 in Utah (non-works speed limit of 75mph). Five speed detectors were placed to measure speed upstream and downstream of the VSL signs. Vehicle speeds were monitored for three months.  Static signs all posted a 65mph limit. The trial used VSL signs in two conditions – 65mph 24 hours a day in place of static signs; and 65mph at night and 55mph during the day (i.e. when road workers were present).</p>
<p><b>Key Findings:</b></p> <ul style="list-style-type: none"> <li>• Both static and VSL 65mph signs at the works entry achieved the necessary speed reductions. Difference in speeds between the two sign types was not statistically significant at the 95 per cent confidence interval.</li> <li>• The VSL 65mph sign did reduce speed variances near entry to the construction area, although variations further downstream were similar for both sign types.</li> <li>• The daytime 55mph VSL sign further reduced speeds through the work zone; however average vehicle speeds did remain statistically higher than the posted 55mph limit. At three of the four downstream locations fewer than 30 per cent of drivers complied with the 55mph limit.</li> <li>• Overall, VSL signs tended to significantly reduce the standard deviation of vehicle speeds during the trial.</li> </ul>
<p><b>Themes:</b> variable speed limit, compliance, variation</p>
<p><b>Comments:</b> The results do not show conclusively that VSL signs achieved the desired effects, although the trial used only two signs (more frequent repeaters would be expected in the UK) and the site was on a constant down slope which would have increased vehicle speeds.  Tendencies for VSL signs to reduce variance in vehicle speed does have positive safety implications.</p>

<b>Title: Safety camera technology at roadworks – Final report [Unpublished]</b>
<b>Author / organisation:</b> M. Brackstone (Scott Wilson Ltd) <b>Date:</b> April 2008 <b>Format:</b> pdf <b>Link:</b> <a href="http://tna.europarchive.org/20120703124527/http://www.highways.gov.uk/knowledge_compendium/publications/CCA16DB06EBB4A05987BB03CCDA1F76E.aspx">http://tna.europarchive.org/20120703124527/http://www.highways.gov.uk/knowledge_compendium/publications/CCA16DB06EBB4A05987BB03CCDA1F76E.aspx</a>
<b>Free / priced:</b> -
<b>Objectives:</b> To research speed enforcement systems at roadworks and specifically to compare Spot Speed (SS) to Time Over Distance (TOD) enforcement.
<b>Methodology:</b> <ul style="list-style-type: none"> <li>• A literature review preceded development of indicators of effectiveness: Flow, Spacing, Speed; ‘Surfing’; Lane Changing; Incidents.</li> <li>• A questionnaire study collated the views of stakeholders responsible for planning and managing roadworks.</li> <li>• Driver behaviour was studied by use of an instrumented vehicle in drive through trials at roadworks on the M4 (spot speed) and M1 (time over distance). Two groups of 23 subjects took part in each trial.</li> <li>• Data was also taken from a previous project which used inductive loops to monitor traffic flow in a time over distance site on the M5.</li> </ul>
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• Roadworks stakeholders view TOD systems most favourably. However easier deployment of SS systems helps them to retain support.</li> <li>• “TOD systems may cause traffic to become more uniform with slightly smaller headways”.</li> <li>• ‘Surfing’ occurs with both systems, though to a far greater extent and magnitude under SS enforcement.</li> <li>• “Far sharper and earlier speed reductions may be taking place at SS enforced roadworks.”</li> <li>• “Driver glance patterns at TOD enforced roadworks can differ substantially from the norm (evidence of both greater and less distraction has been found).”</li> </ul>
<b>Themes:</b> enforcement systems, compliance, surfing
<b>Comments:</b> A broad study offering comparison of two systems. Potential short-coming in that the same subjects did not drive under both conditions (i.e. one group of 23 drove in the SS field trial and a separate group of 23 drove in the TOD trial).

<p><b>Title:</b> Improved driver comprehension of traffic management signing</p> <p><b>Author / organisation:</b> S. Jamson (Institute for Transport Studies)</p> <p><b>Date:</b> March 2008</p> <p><b>Format:</b> pdf</p> <p><b>Link:</b> <a href="http://www.its.leeds.ac.uk/itsresearch/facilities/uolds/cr_idc.php">http://www.its.leeds.ac.uk/itsresearch/facilities/uolds/cr_idc.php</a></p> <p><b>Free / priced:</b> -</p>
<p><b>Objectives:</b> To identify which roadwork scenarios have the most severe implications for both driver and roadworker safety; and to identify the types of signage in these scenarios that can cause confusion or anxiety.</p>
<p><b>Methodology:</b></p> <ul style="list-style-type: none"> <li>• A literature review was carried out.</li> <li>• A laboratory based stimuli (tachistoscope) trial was carried out on 40 subjects.</li> <li>• Driver focus groups were consulted.</li> <li>• Driving simulator experiments were carried out on 34 subjects, incorporating behavioural, emotional and physiological measures.</li> </ul>
<p><b>Key Findings:</b></p> <ul style="list-style-type: none"> <li>• Drivers showed good comprehension of signs relating to lane drops. Focus groups established a range of behaviour from early to last minute merging, with each group believing that the other was behaving erroneously. This behaviour was largely played out in the driving simulator. Insertion of a new 'merge in turn' sign saw drivers change lanes earlier, although the difference was not statistically significant.</li> <li>• Drivers showed good comprehension of signs relating to narrow lanes. Although drivers exhibited anxiety related to passing HGVs, they typically appreciated that keeping lanes open maintained throughput.</li> <li>• Drivers showed some confusion relating to contraflow signs, however comprehension improved when confirmatory information was added (e.g. 'use hard shoulder'). Additional confirmatory information on signs in the simulator trial did not influence timing of the lane change manoeuvre. Contraflows are associated with the emotion 'cognition', indicating a high driver workload.</li> <li>• Focus groups reported significant frustration with roadworks with no one apparently working. Drivers reported lost confidence in advanced signing and simulator trials revealed more aggressive driving and shorter headways having experienced 'ghost' road works.</li> </ul>
<p><b>Themes:</b> signs, comprehension, simulator trials</p>
<p><b>Comments:</b> A credible recent study on driver understanding and emotional response to roadworks.</p>

<b>Title: The development and use of a web based traffic manager</b>
<b>Author / organisation:</b> P. Boulton and P. Owlett
<b>Date:</b> 2008
<b>Format:</b> pdf
<a href="http://ieeexplore.ieee.org/xpl/login.jsp?tp=&amp;arnumber=4562190&amp;url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F4550748%2F4562143%2F04562190.pdf%3Farnumber%3D4562190">http://ieeexplore.ieee.org/xpl/login.jsp?tp=&amp;arnumber=4562190&amp;url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F4550748%2F4562143%2F04562190.pdf%3Farnumber%3D4562190</a>
<b>Free / priced:</b> £31.00
<b>Objectives:</b> To develop traffic management software to make best use of a Quick Moveable Barrier (QMB) and improve traffic flow at roadworks.
<b>Methodology:</b> The paper is typically concerned with software development, but does report successful use of the QMB on UK roadworks sites.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• QMB feasibility is proved by daily use on 11.8km of the M25 during widening works.</li> <li>• In current application the QMB has been congestion neutral, but its use has allowed acceleration of construction programmes which reduces overall road worker risk exposure.</li> </ul>
<b>Themes:</b> QMB, congestion, works design
<b>Comments:</b> Although this paper focuses mainly on the software control system, it does offer a useful snapshot of the potential application of QMB technology at roadworks.

<b>Title: Traffic management and concrete safety barriers</b>
<b>Author / organisation:</b> A. Chequer, J. Mitchell and S. Thompson (TRL)
<b>Date:</b> August 2007
<b>Format:</b> pdf
<b>Link:</b> <a href="http://www.dft.gov.uk/ha/standards/tech_info/files/safety_barriers/PPR_278_-_Traffic_management_and_concrete_safety_barriers_.pdf">http://www.dft.gov.uk/ha/standards/tech_info/files/safety_barriers/PPR_278_-_Traffic_management_and_concrete_safety_barriers_.pdf</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> The study aimed to establish how best to manage erection of temporary traffic management in the central reserve with concrete barriers present.
<b>Methodology:</b> The study established current maintenance practices through stakeholder consultation. It reviewed existing sign mounting measures available from sign manufacturers and those used abroad.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• Traditional temporary traffic management 'A' frame signs typically cannot be used as designed when a concrete barrier is present, i.e. they tend to straddle the barrier without touching the ground and require weighing down with sandbags.</li> <li>• Provision of temporary or retro-fit brackets provide solutions for securing temporary traffic management signs. Eyelets at regular intervals are a potential alternative.</li> <li>• Vertically mounted sockets to accommodate temporary traffic management signs are possible only on wide concrete barriers which already accommodate lighting columns.</li> <li>• It is not desirable to present a 'one size fits all' solution – the most effective methods tend to be site specific.</li> </ul>
<b>Themes:</b> concrete barriers, temporary traffic management signs
<b>Comments:</b> This report identifies potential solutions for safe and rapid erection of temporary traffic management signs on / adjacent to concrete barriers. This report does not make use of physical trials, but recommends that these be carried out.

<b>Title: Roadworker's Safety Research – Phase Two</b>
<b>Author / organisation:</b> Highways Agency (HA) <b>Date:</b> July 2006 <b>Format:</b> pdf <a href="http://www.highways.gov.uk/knowledge/documents/Roadworkers_Safety_Research_Phase_two_report_final_1pdf.pdf">http://www.highways.gov.uk/knowledge/documents/Roadworkers_Safety_Research_Phase_two_report_final_1pdf.pdf</a> <b>Free / priced:</b> Free
<b>Objectives:</b> To inform the Highways Agency strategy towards improving road workers' safety, specifically by identifying higher risk drivers' perceptions of roadworks and road workers.
<b>Methodology:</b> Qualitative research through questionnaires to two selected groups: <ul style="list-style-type: none"> <li>• Higher risk drivers (those who have been banned from driving or taken a driver improvement / speed awareness course in order to avoid a ban), 617 responses analysed; and,</li> <li>• Improvement professionals (those who train or rehabilitate driving offenders), 31 responses analysed.</li> </ul> Initial interviews with a small number from each group were carried out in order to inform questionnaire design.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• Different initiatives to improve safety will meet with differing successes depending on driver age and behaviour.</li> <li>• "In general, a combination of education, information and enforcement initiatives would appear to be likely to have the most effect.</li> <li>• The use of VMS (factual and to the point), variable speed limits, and displaying the speed of vehicles when entering roadworks, are expected to be successful for most driving behaviours.</li> <li>• Motorway driving tests and educating drivers about the importance of driving safely at roadworks are also expected to be successful for most driving behaviours and particularly for hesitant drivers."</li> <li>• Improvement professionals believed enforcement initiatives would be successful, in particular average speed checks and a police presence.</li> </ul>
<b>Themes:</b> attitudes, high risk drivers, improvement professionals
<b>Comments:</b> Qualitative only, but this study outlines some underlying beliefs and behaviours which are linked to safety of driver behaviour at road works.

<b>Title: Exploring the effectiveness of variable speed limit controls on highway work-zone operations</b>
<b>Author / organisation:</b> P. Lin, K. Kang and G. Chang <b>Date:</b> Intelligent Transportation Systems, 8:1–14, 2004 <b>Format:</b> pdf. <b>Link:</b> <a href="http://attap.umd.edu/document/Journal_of ITS.pdf">http://attap.umd.edu/document/Journal_of ITS.pdf</a> <b>Free / priced:</b> Free
<b>Objectives:</b> To evaluate variable speed limit algorithms with the aim to increase work zone throughputs and reduce vehicle delays.
<b>Methodology:</b> Computer traffic simulations with varying variable speed limit algorithms.
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• Variable speed limit controls result in traffic flow with substantially lower speed variances than non-controlled scenarios.</li> <li>• Reduction in speed variances may indirectly contribute to safety improvements.</li> </ul>
<b>Themes:</b> variable speed limit, algorithm, speed variance
<b>Comments:</b> Although computer simulation only, this report adds to the body of evidence that variable speed limit systems can smooth traffic flow at road works.

<b>Title: Motorway road works: effects on traffic operations</b>
<b>Author / organisation:</b> Yousif, Dr. S. (University of Salford)
<b>Date:</b> April 2002
<b>Format:</b> pdf
<b>Link:</b> <a href="http://usir.salford.ac.uk/9704/1/ht_april_2002_motorway.pdf">http://usir.salford.ac.uk/9704/1/ht_april_2002_motorway.pdf</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> To explore parameters relating to safety and capacity at actual roadwork sites.
<b>Methodology:</b> Data collection was at sites on the M6 and the M61 via roadside camcorders; data was extracted and flow and speed data based on five minute intervals.
<b>Key Findings:</b> During free flow conditions there was poor compliance with the posted mandatory 50mph limit. This trend was consistent across both open lanes and for the duration of the studied period.
<b>Themes:</b> flow, speed, compliance
<b>Comments:</b> The period of study was short (~ half a day) and results are reliant on robust data extraction techniques. Nevertheless, the study indicates that, in the absence of enforcement on this particular scheme, speed compliance levels are very poor.

<b>Title: Guidance for safer temporary traffic management</b>
<b>Author / organisation:</b> Highways Agency (HA)
<b>Date:</b> 2002
<b>Format:</b> pdf
<b>Link:</b> <a href="http://webarchive.nationalarchives.gov.uk/+http://www.highways.gov.uk/aboutus/1091.aspx">http://webarchive.nationalarchives.gov.uk/+http://www.highways.gov.uk/aboutus/1091.aspx</a>
<b>Free / priced:</b> Free
<b>Objectives:</b> To promote a safe system of work for traffic management operations.
<b>Methodology:</b> This document was put together following extensive consultation with Highways Authorities, Contractors, maintenance agents, police, health and safety practitioners and highway research specialists.
<b>Key Findings:</b> The document makes many practical recommendations for designing, implementing and managing road works, based on a simple framework of risk principles.
<b>Themes:</b> risk, safety, management
<b>Comments:</b> The approach to risk and principles are potentially valuable. However, the industry has developed in the time since this was published and the two revisions to TSM Chapter 8 are likely to supersede much of the technical content in this document.

<b>Title: Study into the causes and implications of accidents and incidents at roadworks</b>
<b>Author / organisation:</b> M. Freeman, J. Geston and G. Coe (TRL) <b>Date:</b> March 2000 <b>Format:</b> pdf <b>Link:</b> n/a <b>Free / priced:</b> -
<b>Objectives:</b> To identify factors associated with RTIs; to identify factors which affect highway capacity in the event of an RTI.
<b>Methodology:</b> <ul style="list-style-type: none"> <li>• Video recording from CCTV at three road works sites yielded data on 91 RTIs and 539 breakdowns.</li> <li>• Police personal injury RTI records were also obtained for two of the sites.</li> <li>• Recovery operator's logsheets (2611no.) were collected from major motorway works sites.</li> <li>• Data was collated, coded and analysed.</li> </ul>
<b>Key Findings:</b> <ul style="list-style-type: none"> <li>• Shunt type RTIs account for over half the RTIs in the video survey. Loss of control, driver misjudgement and lane changing were also common.</li> <li>• Common contributory factors were: driving too fast for conditions, driving too close, driving aggressively and driving without due care and attention.</li> <li>• Layout features commonly associated RTI locations included: approaches to lane closures, diverging lanes, entry slips and contra-flows.</li> </ul>
<b>Themes:</b> characteristics, road works, casualties
<b>Comments:</b> Although dated, this study gives characteristics of incidents at roadworks derived from a large pool of data.

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