Transport Research Laboratory

Speed Compliance in Overnight Road Works

by R Wood, B Sexton, I Rillie

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CLIENT PROJECT REPORT

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Evaluation of Rapid Deployment Speed Enforcement Systems
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Executive summary

Maintenance work to keep the Highways Agency (HA) road network running is mostly carried out through short term overnight road works. Night working is successful at improving Journey Time Reliability (JTR) but can increase the risk to road worker safety due to excess speed from passing traffic, with many vehicles exceeding national and/or advisory speed limits.

Enforcement of speed limits via safety cameras is one of the most effective ways of reducing vehicle speeds and achieving speed limit compliance. Following a successful initial evaluation of the Speed Check Services (SCS) SPECS-Rapid Deployment (RD) system in 2008, one of the HA's Service Providers (Amey) proposed a trial to define the benefit and effectiveness of average speed enforcement systems at short-term overnight road works.

This trial was carried out by TRL (with support from Amey and SCS) over 92 non-consecutive days. The trial recorded speed data for 46,576 vehicles passing through short-term night road works on the M5 or M6 motorways in the West Midlands. The results from the trial show:

- With no speed control imposed (i.e. no 50mph mandatory or advisory limit):
  - Displaying just a camera warning sign reduces average speed by 1.32mph
  - Displaying a camera warning sign with a visible enforcement camera reduces average speed by 0.81mph

- With a 50mph mandatory speed limit imposed:
  - Displaying a speed limit alone will reduce speed to an average of 51.65 mph (a decrease in average speed of 4.70mph)
  - Displaying the mandatory speed limit and a camera warning sign will reduce average speed by a further 0.54mph
  - Displaying the mandatory speed limit with a camera warning sign and a visible camera reduces average speed by a further 1.08mph

- With a 50mph advisory speed limit displayed:
  - The speed limit alone will increase average speed by 0.97 mph
  - Displaying a camera warning sign alone reduces the increased speed by 2.41mph, an effective decrease in speed of 1.44mph
  - Displaying a camera warning sign and a visible camera reduces average speed by a further 0.50mph

The speed data from this trial for the control condition (i.e. no speed limit) seem atypical compared to that reported by road works industry. The effect of the speed enforcement system on driver speed was smaller than anticipated, possibly due to drivers not recognising the SPECS-RD camera as an enforcement system.

Calculation of the benefit of using average speed enforcement at short-term night road works showed a reduction in road worker injury and fatality equivalent could be achieved from the use of mandatory speed limits with or without enforcement. The casualty prevention cost for the use of mandatory speed limits only was £1.94M per year, rising to £2.37M per year when the mandatory speed limit was enforced with a visible camera and warning signs.

The most effective method for reducing vehicle speeds through the road works appeared to be use of a 50mph mandatory speed limit. Enforcement of such speed limits is necessary to promote and maintain compliant driver behaviour. This requires either use of a system such as that trialled (with the associated costs) or identification of alternative methods for speed enforcement at short-term night road works.

1 Introduction

Maintenance work to keep the Highways Agency (HA) road network running is mostly carried out through short term overnight road works. Night working is successful at reducing the impact of works upon congestion and thus improving Journey Time Reliability (JTR) but can increase the risk to road worker safety. The increase in risk to road workers primarily comes from excess speed from passing traffic, with many vehicles exceeding national and/or advisory speed limits.

In the period 2003-2007, 284 workers were injured or killed on the HA motorway network. Reducing the speed of traffic passing through short-term road works should improve road worker safety and reduce fatalities and injury for both road users and road workers. This vision been incorporated into the HA target to improve road worker safety ("*Aiming for Zero: Safety For Our Road Workers").*

Enforcement of speed limits via safety cameras is one of the most effective ways of reducing vehicle speeds and achieving speed limit compliance. Speed enforcement has historically only been used at long term road works due to the complexities of setting up enforcement equipment. However, following a successful initial evaluation of the Speed Check Services (SCS) SPECS-Rapid Deployment (RD) system in 2008, one of the HA's Service Providers (Amey) proposed a trial to define the benefit and effectiveness of average speed enforcement systems at short-term overnight road works.

This report presents the result of a trial where the speed of 46,000 vehicles was measured at 92 night road works sites in the West Midlands. These data were recorded to measure the effect of SPECS-RD, in conjunction with a number of other speed management and compliance measures such as advisory speed limits or mandatory (enforceable) speed limits plus visible enforcement cameras and enforcement camera signs.

The report presents the direct costs associated with utilising a SPECS-RD system together with the likely safety benefits from improved speed compliance in overnight road works carried out on the HA motorway network. Improved speed compliance may require enforcement and thus a number of alternative enforcement systems are examined in order to determine their viability as rapid deployment speed enforcement solutions for short-term road works operated at night.

2 SPECS – RD Trial System Description

Speed Check Services (SCS) have been providing Type Approved average speed enforcement systems in the UK since 1999. The SPECS distance-over-time systems are claimed by SCS to reduce the number of collisions, smooth traffic flow, reduce casualties and lower vehicle exhaust emissions.

SPECS systems use linked cameras to monitor a length of road. As a vehicle passes into the camera's field of vision Automatic Number Plate Recognition (ANPR) is used to generate a log of the location and time for the vehicle. Each identified vehicle encounter is logged and the time taken to traverse a known distance can be calculated. This allows vehicle speed to be calculated and identifies vehicles exceeding a defined speed threshold. Exception logs are created for non-compliant vehicles while data regarding compliant vehicles is discarded.

The SPECS-RD system is a development of the standard SPECS system designed for utilisation at short-term road works. At long-term road works, the installation of the SPECS system is usually carried out over a number of days. This installation time requirement renders a standard SPECS installation unsuitable for short-term road works, whereas SPECS-RD uses a simple configuration that can be assembled, tested and calibrated by two operatives in less than one hour.

The current configuration of SPECS-RD requires camera towers (shown in Figure 1) to be transported to site on a twin-axle trailer, towed by a 7.5 tonne commercial vehicle. The tow vehicle also carries supporting equipment such as ballast for the towers and is used to house the HA600 control cabinet used to process and store recorded data.

The SPECS-RD distance-over-time system is based on the SPECS3 system, which is Type Approved by the Home Office for speed enforcement activity.

Figure 1: SPECS-RD Camera Tower

3 Trial Design

3.1 Conditions

The study investigated three potential speed reduction approaches, with two mechanisms to improve speed compliance through road works. The approaches were:

Speed reduction approaches

- National speed limit applies (control)
- National speed limit applies, with a 50mph advisory speed limit sign
- A mandatory 50mph speed restriction

Speed compliance approaches

- No signing or visible enforcement camera (control)
- An enforcement camera warning sign (encouragement)
- An enforcement camera warning sign plus a visible enforcement camera

The study was designed to investigate which combinations of these approaches gave the optimum speed reduction.

3.2 Experimental design

In order to obtain average speeds of vehicles through the road works it was necessary to measure vehicle speeds without influencing driver speed choice using either visible speed enforcement or any device that appeared to be an enforcement camera. The use of inductive loops in the carriageway was impractical as the short-term road works could not be guaranteed to be adjacent to existing loop sites.

The system used to monitor vehicle speeds was a SCS journey time measurement system. Cameras were mounted discreetly on two lighting towers and used to record the entry and exit of vehicles to the road works. Vehicle matching was subsequently used to calculate the time to traverse the road works; knowledge of the road works length permitted calculation of vehicle average speed through the road works.

When visible enforcement cameras were required, the SPECS-RD system was deployed and the works area was lit using the lighting towers carrying the journey time measurement cameras. However, as journey time data were being recorded by the journey time measurement system the SPECS-RD system was essentially a non-functional (dummy) system with the central HA600 processing unit omitted. As a result, no enforcement was carried out during the trial, which ensured that road user behaviour remained unaffected across the duration of the trial.

Experimental conditions were designed for the trial in order to provide every possible appropriate permutation of the speed reduction approaches and speed compliance approaches. The advantage of this design was a balance between combinations of conditions employed and the day of week. Thus the potential influence of day of the week could safely be ignored when comparing conditions due to the intrinsic balance in the design. The balance also enabled a single control value to be produced for the “before” condition and for all potential interaction effects between conditions to be meaningfully compared.

The design thus simplified interpretation of any significant findings for each experimental combination of interest.

Table 1 shows the combinations required which have been labelled from A to I.

Table 1: Experimental condition combinations

	Speed reduction approach		*Speed compliance approach*	
Condition	50mph mandatory speed limit	50mph advisory speed limit	Camera warning signs	Camera warning signs and camera visible
A	N	N	N	N
B	N	N	Y	N
C	N	N	Y	Y
D	Y	N	N	N
E	Y	N	Y	N
F	Y	N	Y	Y
G	N	Y	N	N
H	N	Y	Y	N
I	N	Y	Y	Y

Experimental conditions were assigned using a balanced Latin square design across the 18 weeks of trial days required in order to obtain two replicates. In practice, due to a delay in obtaining Temporary Traffic Regulation Orders to permit the use of the 50mph mandatory speed limit, conditions D, E and F were not used in the first 5 weeks.

There was a specified requirement that no site should be used on successive nights, in order to try and avoid any regular users of the motorway stretch learning and remembering that a trial was being conducted. This learning affect could potentially have influenced their speed through the site, although the risk was small. In practice this requirement was not always met for operational reasons.

Inevitably due to external factors such as Bank Holidays, restrictions on work scheduling and adverse weather conditions the trial took longer than the minimum 18 weeks. However, as there was no systematic allocation of specific experimental conditions to specific sites or areas on the network there was no reason to consider any biases were introduced into the data.

3.3 Operational Delivery

The trial was undertaken at 92 works sites, over 34 locations within Area 9. Amey (the incumbent Managing Agent Contractor) was engaged to deliver the trial, with Speed Check Services contracted by Amey to install the monitoring and enforcement equipment and provide data to TRL.

Although the local Safety Camera Partnership was informed about the trial, no enforcement (i.e. issue of Notice of Intended Prosecution for offences committed) was carried out during the trial. It was planned to use post-trial correction of data to account for any enforcement carried out by the police; however, data from the West Midlands Police indicated there were eight specific police activities in the trial area during the

period of the trial. None of these involved enforcement and thus the influence on data was negligible.

The trial utilised a two camera journey time system to collect the speed data for vehicles passing through the road works. Installation and calibration of the data collection system was achievable in less than one hour (for reference, a typical overnight works scheme would be expected to last for approximately seven hours).

Where an enforcement system was needed (ie. conditions C, F and I), a two camera SPECS-RD system was installed at the commencement of works by a Speed Check Services engineer. The SPECS-RD speed enforcement system mobile camera tower was positioned after the taper, directly after the safety zone and within the coned off area. The SPECS-RD system required a minimum working zone of 300m therefore the second camera was placed at 300m from the first. The second camera and 7.5 tonne deployment vehicle were also placed inside the cone barrier. The SPECS-RD system was operated as a dummy system and thus did not require calibration, for reasons described previously.

4 Data Collection - Results

A total of 46,576 vehicles were observed passing through the roadwork sections used in the trial. These were observed over 92 non-consecutive days within road work sites on the M5 or M6 motorways in the West Midlands. The trial data collection period usually started around midnight and lasted for around two hours, during which time it was usual to observe and record speeds for approximately 500 vehicles.

4.1 Achieved design

The planned design was largely achieved, although the adverse weather condition in December 2009 and January 2010 did cause significant problems. Despite extending the trial timescale, the delay due to weather conditions caused the trial to cease data collection early. However, the only conditions not repeated were a condition A and a condition E on a Friday (i.e. these conditions were used once on a Friday but only once). A few conditions were replicated 3 times. This imbalance in the delivery of the design presented issues for the data analysis, as described in Section 4.6.

4.2 Vehicles observed

The numbers of vehicles (net of the duplicates) are shown in Table 2.

Table 2: Number of observed vehicles by sign/camera condition

Number of observed vehicles (net of duplicates)		50mph mandatory speed limit?		
		NO	YES	TOTAL
Camera warning sign?	NO	10423	6597	17020
	YES	19585	9869	29454
Camera warning sign plus visible enforcement camera?	NO	20805	11131	31936
	YES	9203	5335	14538
50mph advisory speed limit displayed?	NO	15315	16466	31781
	YES	14693	N/A	14693
	TOTAL	30008	16466	46474

4.3 Duplicates

The journey time system used to collect the data for the trial occasionally generated duplicate vehicle records within the data. This sometimes occurred due to a vehicle using the same stretch of motorway more than once during the sampling period, which was visible as two vehicle records stored with a significant time difference. However, if a vehicle changed lanes while in the road works this caused difficulties in matching incoming and outgoing data. The journey time system would then generate two vehicle records adjacent to each other in the database with identical time stamps. There were other, minor, glitches which also generated some genuine duplicates within the raw data.

It was observed that quite often the same vehicle was travelling on the same section of motorway more than once during the sampling period. However, by time matching vehicle registration marks it was possible to identify genuine duplicate vehicles since duplicates had the same entry time and had near identical speeds. Vehicles travelling on the same section of motorway more than once during the sampling period entered the system at quite different times and so were genuine observations; if the same driver was driving the vehicle each time, they would obviously have been aware of the works and the signing/cameras on their second pass through the road works. The effect of this prior

awareness of the works and response to signing/camera layouts was not evaluated as part of this programme; however, the data were retained so that this could be undertaken at a later date.

In total 102 true duplicate records were identified, i.e. there were 102 errors (0.2% of the data collected). The true duplicate records were not used in the analysis.

4.4 Locations

Thirty four locations (motorway links) were used as trial sites during the trial period. The links used are listed in Table 3. All links were on either the M5 or the M6 in the West Midlands, with some using the southbound and others the northbound carriageways.

Given that there were about 500 vehicles observed (about 1% of the full trial sample) on any one trial day, then sites which were used more than once are evident from the frequencies or percentage shown. Hence, for example, the M5 northbound in the vicinity of Junction 1 was used for four of the trials.

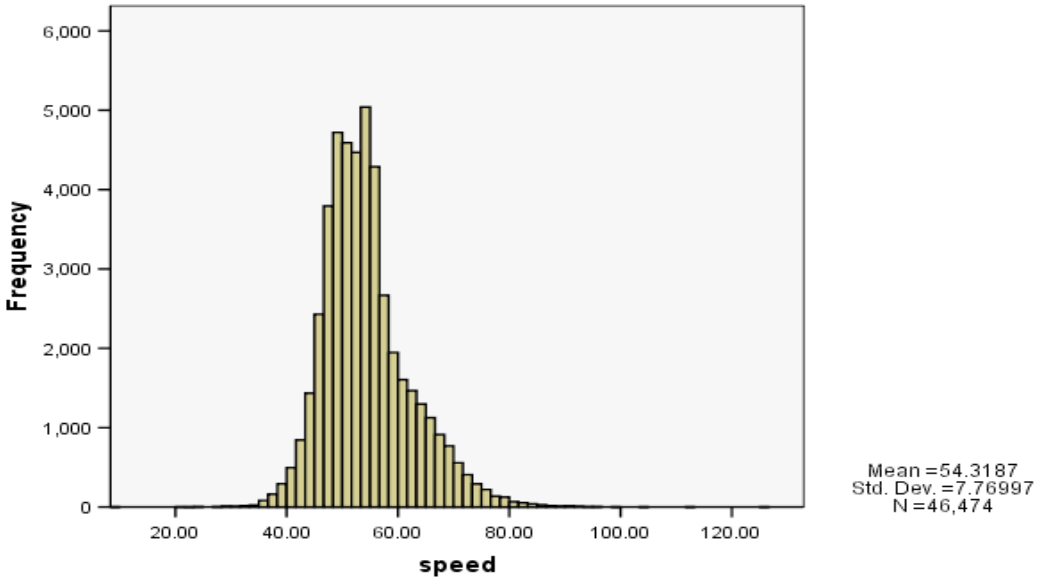
Table 3: Distribution of vehicles by site

Location	Frequency	Percent
M5 N/B J1-J2	613	1.32
M5 N/B J1	1912	4.11
M5 N/B J2-J1	1604	3.45
M5 N/B J2 - J1	321	0.69
M5 N/B J3-J2	630	1.36
M5 S/B J(M6) – J1	733	1.58
M5 S/B J1-J2	260	0.56
M5 S/B J1	2336	5.03
M5 S/B J2	360	0.77
M5 S/B J5-J6	480	1.03
M6-J1 M5 SB	661	1.42
M6 N/B &13-J14	638	1.37
M6 N/B J10-J10A	401	0.86
M6 N/B J10	577	1.24
M6 N/B J11	1335	2.87
M6 N/B J6-J7	5228	11.25
M6 N/B J6	1755	3.78
M6 N/B J7-J8	719	1.55
M6 N/B J7	8644	18.60
M6 N/B J8-J9	716	1.54
M6 S/B J10	682	1.47
M6 S/B J11-J10A	611	1.31
M6 S/B J11	459	0.99
M6 S/B J4	320	0.69
M6 S/B J4A-J4	1976	4.25
M6 S/B J4A	412	0.89
M6 S/B J6-J5	433	0.93
M6 S/B J6-J7	5973	12.85
M6 S/B J6	624	1.34
M6 S/B J7 - J6	360	0.77
M6 S/B J7	3544	7.63
M6 S/B J8-J7	570	1.23
M6 S/B J8	587	1.26
Total	46474	100.00

4.5 Distribution of speeds – all conditions

The distribution of speeds from the 46,474 vehicles observed is shown in Figure 2. The overall average speed is 54.31mph with a standard deviation of 7.77mph. The speeds range from 9.7mph to 125.4mph. Overall the distribution is approximately Gaussian although it is skewed towards the higher speeds.

Figure 2: Distribution of observed speeds



Analysis of the higher vehicle speeds (using the ACPO enforcement guideline of +10%+ 2mph as a calibration) indicated that the level of compliance with speed restrictions was generally good, as shown in Table 4:

Table 4: Distribution of speeds versus speed limit, all conditions

Speed Reduction Approach			
50mph mandatory speed limit	speed	Mean	51.65
		Standard Error of Mean	0.05
	speed over 57.0mph		14.82%
	speed over 79.0mph		0.25%
		Sample size (vehicles)	16466
50mph advisory speed limit	speed	Mean	57.32
		Standard Error of Mean	0.07
	speed over 57.0mph		34.07%
	speed over 79.0mph		0.86%
		Sample size (vehicles)	14693
National speed limit	speed	Mean	56.35
		Standard Error of Mean	0.06
	speed over 57.0mph		37.23%
	speed over 79.0mph		0.90%
		Sample size (vehicles)	15315

Speed limit compliance was good, with only small numbers of vehicles exceeding the national speed limit when advisory or no speed limits were displayed. Compliance with the 50mph mandatory speed limit was better than with either the 50mph advisory or the

national speed limit. Approximately 15% of vehicles exceeded the enforcement guideline for a 50mph mandatory speed limit; however, this still represented around 2,400 vehicles exceeding the speed limit by more than 10% + 2mph.

4.6 Results summary: all conditions

Summaries regarding data collected during all weather conditions are included below with full data and graphical representations available within Results Data.

Average vehicle speed recorded at trial sites can be classified initially by the three speed reduction approaches. The affects of these approaches are shown in Table 5:

Table 5: Speed reduction approach by measured vehicle speed

Displayed Speed	Mean (mph)	Speed Change (mph)
None	56.35	-
50mph Advisory	57.32	+0.97
50mph Mandatory	51.65	-4.70

With no speed reduction (i.e. control condition), an average vehicle speed of 56.35mph was recorded during the trial. Using a 50mph mandatory speed limit reduces speed by 4.70mph. However, the effect of displaying a 50mph advisory speed limit under the same conditions resulted in an increase of mean vehicle speed of 0.97mph.

The average speeds from all observed data under all weather conditions for each of the trial combinations are shown in Table 6.

It must be noted (as referred to in Section 4.1) that the mean values in the NO '50mph mandatory speed limit ?' column are based on different sub-sets of the data as a consequence of the slight imbalance in design that occurred due to data collection issues. This imbalance required calculation of a mean value for each control sub-set depending on which experimental condition was being examined. This was necessary to ensure that the control speed was matched to the experimental condition speed to enable a valid comparison.

As a consequence of this requirement, there are three slightly different mean values for the control sub-sets (with small intersample differences) representing three slightly different sub-samples for each of the experimental conditions.

Table 6: Average speed by trial combination (all weathers)

		50mph mandatory speed limit ?					
		NO			YES		
		Mean	Standard Error of Mean	Valid N	Mean	Standard Error of Mean	Valid N
camera warning sign?	NO	56.82	0.080	10423	51.65	0.092	6597
	YES	55.50	0.055	19585	51.11	0.059	9869
camera warning sign & camera?	NO	56.21	0.056	20805	51.85	0.065	11131
	YES	55.40	0.079	9203	50.23	0.079	5335
50mph advisory display?	NO	56.35	0.063	15315	51.33	0.051	16466
	YES	57.32	0.065	14693			

It makes sense to consider the results for when a mandatory 50mph speed limit is operating or is not operating, i.e. consider the results within 'columns' and hence the effect on the average speed of having a camera warning sign or a camera visible when a

mandatory limit is imposed etc. For example, with no 50mph mandatory limit the effect of having a camera warning sign is to reduce the average speed from 56.82mph to 55.50mph – a reduction of 1.32mph.

However, comparing the results within 'row' in Table 14 indicates the direct impact of the mandatory 50mph speed limit, so with no camera warning sign the effect of the 50mph mandatory limit is to reduce the average speed from 56.82mph to 51.65mph – a reduction of 5.17mph.

4.7 Speed reductions: summary

Thus, the speed change effects of the various measures trialled may be summarised as:

- With no speed control imposed (i.e. no 50mph mandatory or advisory limit):
    - Displaying just a camera warning sign reduces average speed by 1.32mph
    - Displaying a camera warning sign with a visible enforcement camera reduces average speed by 0.81mph, around 0.5mph less than the camera sign alone
- With a 50mph mandatory speed limit imposed:
    - Displaying a speed limit alone will reduce speed to an average of 51.65 mph (a decrease in average speed of 4.70mph)
    - Displaying the mandatory speed limit and a camera warning sign will reduce average speed by a further 0.54mph
    -
    - Displaying the mandatory speed limit with a camera warning sign and a visible camera reduces average speed by a further 1.08mph
- With a 50mph advisory speed limit displayed:
    - The speed limit alone will <u>increase</u> average speed by 0.97 mph
    - Displaying a camera warning sign alone reduces the increased speed by 2.41mph, an effective decrease in speed of 1.44mph
    - Displaying a camera warning sign and a visible camera reduces average speed by a further 0.50mph

The largest reduction in average speed is therefore associated with imposing a 50mph mandatory speed limit. The reduction in average speed varies, but in the order of approaching 5mph for all weather conditions. This reduces to an overall average of about 4mph under dry conditions.

The results suggest that if no 50mph speed restriction is imposed then there is a speed reduction of 1.3mph associated with a camera warning, a speed reduction of 0.8mph associated with a visible camera and a speed <u>increase</u> of 0.97mph associated with an advisory speed limit.

Analysing data from dry conditions found similar results to those for all weathers except that there was an increase in average speed associated with the camera being visible or not under some combinations.

The results of analysis of vehicles travelling in excess of the ACPO enforcement guidelines that would apply within a 50mph mandatory speed limit (i.e. a 57mph

guidline) shows that an advisory speed limit decreases the percentage of vehicles travelling in excess of 57mph to 34.07%, a reduction of 3.16% compared to when the national speed limit applies. When a mandatory speed restriction is in place, the percentage of vehicle travelling above 57mph drops to 14.82%, a decrease of 22.41% compared to when the national speed limit applies.

5 Value Analysis

Understanding the benefit from using SPECS-RD to improve road worker safety requires knowledge of the likely benefits to be obtained from the use of the system or an equivalent.

This section of the report provides outline benefit calculations for the SPECS-RD system, based on the data collected during the trial.

5.1 Calculation of benefits

The number of road worker casualties on motorways is shown in Table 7 for weekdays in 2003 to 2007 together with the average number per year. There were a total of 284 casualties in total during this period.

Table 7: National number of road worker casualties on motorways

Year	Fatal	Serious	Slight
2003	2	17	42
2004	1	17	43
2005	5	12	38
2006	2	21	41
2007	0	14	29
average pa	2	16.2	38.6

Note 1: Data are provided by the National Audit Office (NAO), data for 2008, 2009 currently unavailable

The use of different speed reduction measures could reduce the average speed of vehicles going through road works on motorways. Overall a speed reduction from about 55mph to about 50mph should be possible depending on what conditions are imposed. If it is assumed that this speed reduction is achieved then there should be an associated reduction in casualties. (It is appreciated that a much finer analysis could be conducted based on combinations of different options, however the assumption of 5mph does seem the most tenable outcome provided that a 50mph speed restriction can be used).

However, the relationship between average speed and casualties has not been established under this set of conditions, i.e. road works on a motorway at night. However, Nilsson (2004) developed a relationship between speed, accidents and casualties. It has been reviewed, modified and evaluated by Elvik *et al* (2004). The latter includes a meta-analysis of 98 previous studies over the period from 1966 to 2004 which provided a total of 460 estimates of the relationship between speed and safety.

The relationship model suggested by Nilsson is as follows:

$$\text{Casualties after} = \text{Casualties before} * (\text{Mean speed after}/\text{Mean speed before})^{k}$$

'Before' and 'after' refer to casualty numbers and speeds 'before' and 'after' a change in average speed. The values of 'k' (exponent for the ratio of average speeds) as reported in Elvik *et al* (2004) for different severities of casualty are given in Table 8.

Table 8: The effect on national casualties of average speed

Type of accident or casualty	Value of 'k'
Fatal casualty	4.5
Seriously injured casualty	3.0
Slightly injured casualty	1.5
All casualties	*2.7*

Source: Elvik *et al* (2004), Table 21, page 70

Table 8 indicates that the values of the exponent depend strongly on severity. Elvik *et al* (2004) conclude that the relationship between changes in speed and changes in casualties holds for all speeds in the range from 25 kph to 120 kph and that the Nilsson type model with its logical simplicity and generality makes it superior to other models. For the purposes of the evaluation being considered, the Elvik version of Nilsson's model for estimating casualty reductions has been adopted.

The absence of causation data within the road worker accident data needs to be considered, in that any calculation for reduction in casualties should reflect a link between the likely factors that contribute to the accident and the reduction in accidents. This is partly modelled by the Elvik version of the Nilsson model for road users but whether this approach is directly applicable to road worker casualties is uncertain. In the absence of clear data, the model used makes the base assumption that road worker casualties occur due to collision between road user vehicles and road workers.

Additionally, the road worker casualty figures are not disaggregated by time of day i.e. the numbers of casualties represent all road workers. However, the effect of a global speed reduction on road worker safety would have an effect for all road workers and thus has been calculated based on the data presented.

The results from the road worker casualty reduction calculation are shown in Table 9:

Table 9: Calculation of potential national road worker casualty savings - 50mph mandatory only

	Fatal	Serious	Slight
Elvik factor, k=	4.5	3	1.5
Current average speed	56.35	56.35	56.35
Reduced average speed	51.65	51.65	51.65
Savings factor	34.9%	24.9%	13.3%
Estimated casualty savings pa	0.648	3.725	4.727
2007 price, HEN1 cost	1,648,390	185,220	14,280
2010 price, (applying a 2.2% COBA growth rate)	1,759,595	197,715	15,243
Savings (£)	1,141,055	736,467	72,056

The model suggests that the speed reduction associated with displaying a 50mph mandatory speed could reduce motorway road worker casualty injuries nationally equivalent to savings (at 2010 prices) of about £1.94M per year.

However, the continued effectiveness of the mandatory speed limit will depend on driver compliance, which is known to be strongly linked to enforcement. Thus, the additional

benefit from using enforcement on a widespread basis across night-time road works was examined using the same Elvik model approach. The results from this are shown in Table 10

Table 10: Calculation of potential national road worker casualty savings – 50mph mandatory plus camera and advance warning signage

	Fatal	Serious	Slight
Elvik factor, k=	4.5	3	1.5
Current average speed	56.35	56.35	56.35
Reduced average speed	50.47	50.47	50.47
Savings factor	34.9%	24.9%	13.3%
Estimated casualty savings pa	0.782	4.561	5.881
2007 price, HEN1 cost	1,648,390	185,220	14,280
2010 price, (applying a 2.2% COBA growth rate)	1,759,595	197,715	15,243
Savings (£)	1,375,954	901,685	89,648

The estimated cost savings nationally associated with displaying a camera warning sign and a visible camera, in addition to a 50mph mandatory speed is about £2.37M per year. The additional injury and fatality reductions associated with camera usage and warning signage (compared to a 50mph mandatory limit alone) are calculated as:

Fatal: - 0.134 fatalities per year
Serious: - 0.836 casualties per year
Slight: - 1.154 casualties per year

5.2 Summary of benefits

Based upon the figures for speed reductions achieved from the interventions trialled, the estimated benefits from the use of speed limit and speed limit plus cameras have been calculated.

- If mandatory speed limits are used nationally at all road works and achieve a reduction of 5mph in driver speeds through all road works, this has the potential to reduce the calculated cost of road worker casualties
- The calculated cost of road worker casualties saved is about £1.94M per year for use of a 50mph speed limit alone

However, the effectiveness of mandatory speed limits may decrease if they are used regularly without enforcement. Thus, the effects of the 50mph mandatory speed limit plus enforcement was also calculated.

- The calculated cost of casualties saved is about £2.37M per year for use of a 50mph speed limit with visible enforcement cameras
- The figure of £2.37M is calculated upon the basis of a 5.88mph speed reduction from 56.35mph, compared to a 5mph speed reduction in the case of the 50mph mandatory speed limit alone.

6 Discussion

The results from the trial demonstrate the practicality of the SPECS-RD system, in that it can be deployed by two operatives in under one hour. This demonstrates its capability to be used for enforcement at short-term road works, but the impact of the system on driver speed choice was disappointingly small.

6.1 Influences on vehicle speeds

The greatest influence by far seen on vehicle speeds during the trial was from a 50mph mandatory speed limit. Vehicle speeds were generally of the order of 50mph without a 50mph mandatory speed limit with average speed of 55-56mph. Approximately 38% of vehicles were travelling above 57mph (=50mph+10%+2mph, ACPO enforcement guideline for a 50mph mandatory limit) when there was no speed limit displayed; this was reduced to 35% when a 50mph advisory speed limit was displayed. Less than 1% of vehicles were exceeding the speed limit of 70mph by the enforcement guideline (i.e. speeds in excess of 79mph).

With the use of a 50mph mandatory speed limit the average vehicle speed dropped by 5mph to 51mph and the number of vehicles travelling above 57mph also dropped to around 15%. However, the number of vehicles exceeding the new reduced speed limit by 10% + 2mph increased to 15% as it now included any vehicle travelling at 57mph or more.

Further evidence of the influence of mandatory speed limits was also inadvertently collected within the data on 21st August 2009. On this night, data were collected on the M42 when one of the M42 Active Traffic Management signs had been left showing a 40mph speed limit. The average recorded speed for traffic passing through the road works was 39.74mph (standard deviation 6.95mph) which was identified as highly unusual.

Following checks of the HA logs for the M42, the signal setting was discovered and as these data were clearly influenced by the 40mph mandatory limit, they were excluded from the analysis. However, the effect of these signs was significant and thus it is recommended that the use of mandatory limits at short term road works should be considered as a widespread measure to reduce speeds.

6.2 Influences of enforcement

The use of mandatory speed limits must be backed up with some form of enforcement to encourage road user compliance with the displayed speed limit. Average speed enforcement systems are the type of speed enforcement most often used at road works due to their ability to slow traffic throughout the length of the works section. Traditionally the use of average speed enforcement has been limited due to the logistics of installing the camera system masts and cabling required; a system such as SPECS-RD has the potential to overcome these issues and could enable the use of average speed enforcement at short-term road works.

The use of SPECS-RD did not achieve a large speed reduction when compared to the use of 50mph mandatory speed limits alone. This is unusual as the effect of average speed enforcement on driver speed choice in road works is well understood through previous work which suggests such speed enforcement does have a significant effect. However, in this trial the percentage of “offending” drivers (defined as those exceeding the speed limit by 10% + 2mph) was halved through the use of the mandatory speed limit sign alone; adding the speed enforcement warning signs and a visible enforcement camera did not achieve a large additional reduction in average speed.

The “before” speeds of traffic observed at the road works were surprisingly low. This could be a function of the general use of average speed enforcement at road works

associated with the fiscal stimulus programme, which engrained the requirement to travel through road works at 50mph into the driver behavioural model. This is potentially encouraging as it confirms that enforcement has a persistent effect, but without the presence of ongoing enforcement it is very likely that mean vehicle speeds would increase through all road works. This would degrade the effectiveness of 50mph mandatory speed limits, reducing the safety benefit to road workers and road users.

The small speed change observed may also be due to public unfamiliarity with the SPECS-RD system; a significant element within the enforcement by average speed cameras is the yellow over-carriageway mast system used by Speed Check Services to mount the cameras used at longer-term road works. The SPECS-RD mast was dissimilar to these masts and may not have been recognised by drivers as an enforcement system, despite the advance warning signing indicating enforcement would be carried out.

A second possibility for the low levels of effect seen from the SPECS-RD system in encouraging compliance was the location of the enforcement system in the road works. This may have compounded the previous issue of poor familiarity by causing road users to view the enforcement cameras as a part of the road works equipment. Such an effect would cause no association between the cameras and enforcement system and hence no association between lack of compliance and likely penalty or consequence.

In both cases, it is recommended that the use of any average speed enforcement (or speed enforcement of any type) at road works is backed up by a driver information programme or publicity campaign to reinforce the message that enforcement is being carried out. This should include information that would enable the road user to recognise an enforcement system and thus build an association between the presence of enforcement equipment and probable consequence.

6.3 Benefits from enforcement

As discussed in Section 6.2 above, achieving a speed drop of just 5mph may be unrepresentative as the vehicle speeds measured through the road works during the trial may be atypical of the wider picture across the network. Vehicles speeding through road works are commonly reported by road maintenance contractors, thus the traffic speed of around 50mph in the control data reported is unusual. It may be beneficial to investigate this and determine whether larger effective speed reductions may be achieved by use of 50mph mandatory speed limits that are enforced, as this will in turn increase the cost benefit associated with casualty reduction. For example, if vehicle speeds without enforcement were of the order of 60mph and the speed with enforcement and signage continues at the current level observed, the national benefit would increase by approximately 27%.

In such a case, the speed reduction used in the benefit calculation could be much greater, thus potentially increasing the safety benefit to road users and road workers. A similar calculation to the Elvik/Nilsson model for road workers could be carried out for road users, demonstrating the benefit from reduced speed through road works. This would provide supporting evidence for the widespread use of reduced speed limits at all road works, together with its enforcement to ensure driver compliance. As there are of the order of several hundred short-term road works sites on the HA network every night, such a change (assuming compliance) could significantly reduce road user and road worker casualty risk.

6.4 Road worker safety

If the widespread use of mandatory speed limits is to be adopted at short-term night road works, there is a need to ensure that their use is backed up by a consequence of non-compliance. This can only realistically be achieved via enforcement and the use of some form of enforcement system.

The decision to implement widespread use of any enforcement system at short-term overnight road works (whether SPECS-RD or other systems) will generate a benefit. However, enforcement is potentially expensive, if effective it will not be cost neutral and it is essential that speed enforcement is not treated as a revenue generation mechanism. It is therefore likely that carrying out enforcement to encourage compliance with reduced speed limits in short-term road works will incur a cost to the HA. However, the decision to use 50mph mandatory speed limits at all road works and enforce these, even if only in the short term to achieve driver behavioural change, is completely consistent with the HA vision to improve road worker safety, as contained in the vision of "*Aiming for Zero: Safety For Our Road Workers"*.

Reducing speed within road works will improve road worker safety, as the benefit calculations demonstrate. This is a key part of the HA's forward plan to deliver a safe road network and be an exemplar in safety, which again fits with the HA vision as set out in the Road Worker Safety Strategy and the associated Action Plan for 2009-11.

One potential mechanism to reduce the cost and improve the effectiveness of rapidly deployable speed enforcement systems could be their use at medium-term road works where the cost and time taken to install conventional enforcement renders it uneconomic or impractical. If a SPECS-RD system were used across medium-term road works, the installation costs would be spread across a longer period of time. This would reduce the per-day enforcement cost, making average speed enforcement accessible to the scheme designers of shorter schemes where conventional average speed enforcement is not cost-effective. This has the potential to make significant contributions to road worker and road user safety by reinforcing compliance with mandatory speed limits in road works.

It is therefore recommended that the use of these types of systems at medium-term road works is explored and alternative approaches are considered for speed enforcement at short-term overnight road works.

6.5 Road works speed enforcement

Reducing vehicle speeds through road works is an important part of improving both road user and road worker safety. For the road user it reduces the likelihood of loss-of-control type accidents and for the road worker it reduces the risk of being struck by vehicles involved in accidents. The trial suggests that these speed reductions can be achieved by imposing a mandatory speed limit, but the effectiveness of these limits without some form of enforcement is likely to be temporary.

It is therefore recommended that an initial investment in enforcement will be necessary in order to educate road users that compliance with speed limits in road works is required. This will require an investment decision from the HA as the cost:benefit ratio suggests that such an action would not be cost-positive or cost-neutral. Once speed compliance has improved, the level of enforcement could potentially be reduced (with appropriate monitoring) to a "maintenance" level in order to maintain desired driver behaviours.

Average speed enforcement is effective in reducing vehicle speeds, but the robustness of any enforcement action taken against drivers is critically dependent on the evidence trail for installation, set-up and calibration of the system. This has traditionally been carried out by the engineers from the speed enforcement service provider, but this has a not inconsiderable cost associated with provision of this service. This would potentially be impractical and uneconomic for widespread use of systems such as SPECS-RD; however, if road workers could be trained and certified as competent to set up the system, this would have significant cost and time savings for the HA. It is suggested that this business model be explored with average speed enforcement service providers to determine whether the widespread use of such systems can be made practicable and affordable.

If the use of mandatory speed limits is to be considered at short-term overnight road works (as in the trial), a further requirement would be the enabling of blanket temporary traffic regulation orders to permit both use of reduced speed limits and enforcement. Enforcement at night would also need consideration, as there would be significant benefits from the use of peripatetic enforcement that could cover a number of road works sites per night, much as is done by mobile safety camera vans during the daytime. However, there are some safety issues that would need to be considered (relating to positioning a vehicle with an occupant within the works) as well as the technology considerations of using optical enforcement equipment at night and potentially on an unlit motorway.

It is recommended that the possibility of using peripatetic enforcement that could enforce at multiple temporary road works sites in an area on one night is investigated, as this has the potential to provide a mechanism to deter motorists from exceeding the speed limit in road works for relatively little cost.

7 A Review of Rapidly Deployable Speed Enforcement Systems

In order to understand potential alternatives for enforcement at short-term night road works, a review was undertaken of rapidly deployable speed enforcement systems. This study sought to define the availability/existence of rapidly deployable speed enforcement systems of both spot-speed and distance-over-time types.

7.1 Spot-speed systems

Spot-speed systems define vehicle speeds at a single point, by means of radar (with secondary calibration marks on-road) or piezo sensors embedded in the road surface. Table 11 provides a summary of the features and capabilities of a number of spot-speed enforcement solutions and determines the applicability of such solutions to usage at short-term road works conducted at night upon the HA's road network.

Table 11: Spot-speed enforcement system capabilities

Company	Product	ANPR	Rapidly Deployable	UK Type Approved
Truvelo	Combi SMC	✓	x	✓
Gatsometer	DRCS	✓	x	✓
Sensys	RWASS	x	✓	X
Olvia	Photo Radar	✓	x	x
ATS	SC-300F	x	?	x
RedSpeed Int.	SpeedCurb	x	X	✓
RedSpeed Int.	RedSpeed	X	X	✓

Note: It has not been possible to clarify whether ATS SC-300F has rapid deployment capabilities

Four systems are Home Office Type Approved (HOTA) for usage upon the HA road network, although not any of these systems are designed for use in a rapid deployment situation. The Truvelo, RedSpeed, SpeedCurb and Gatsometer systems require sensors to be placed within the road surface to calculate vehicle speed and are therefore unsuitable for rapid deployment

Although not currently type approved for UK usage the Sensys, Road Working Area Safety System (RWASS) is the only rapidly deployable system designed specifically for use at short term road works. RWASS is a non-intrusive, rapidly deployable enforcement solution designed specifically for road works areas. Utilising a three way approach to 'work-zone' safety, the system will warn drivers, warn road workers and enforce speed violations. RWASS warns drivers of their approach speed, if it is in excess of that permitted an audible warning is provided to warn road workers of the potential hazard. If the vehicle does not respond to the warning a high resolution camera will be used for enforcement. Should the vehicle reduce its speed to that permitted then both audible and visual warnings will cease.

A fuller summary of the Sensys RWASS is included within Appendix A.

7.2 Distance-over-time / average speed systems

Table 12 summarises the features and capabilities of distance-over-time speed enforcement systems, with an emphasis upon essential requirements for utilisation at short-term road works conducted at night.

Table 12: Distance-over-time speed enforcement system capabilities

Company	Product	ANPR	Rapidly Deployable	Type Approved
ATS	Axsis POINT TO POINT	?	?	X
Multanova/Robot	TraffiSection	✓	✓	X
Red Speed International	RedFusion	✓	X	✓
Redflex	Redflex point-to-point	✓	?	X
Sensys	SCSS	✓	✓	X
Speed Check Services	SPECS RD	✓	✓	✓
Gatsometer	Point-to-point	✓	X	?

Automatic Number Plate Recognition (ANPR) capability is common to all distance-over - time systems and is an integral part of an average speed system. Distance-over-time systems utilise ANPR to log a vehicles Vehicle Registration Number (VRN). The systems require a vehicle to pass two cameras or more and for VRNs to be matched. The time taken for each vehicle to travel known distances between cameras is then classified therefore allowing vehicle speeds to be calculated.

The RedFusion multi point to multi point system manufactured by Red Speed International, gained Home Office Type Approval during December 2009. However the RedFusion system does not support short term usage due to the requirement for control cabinets to be 'rooted in concrete'. It has been indicated that a rapidly deployable version has been considered and may be produced if a viable 'business case' is presented.

Conversely the Sensys Section Control Safety System (SCSS) has the ability to be operated as a short-term enforcement solution but has not gained Type Approval at the time of writing.

The Speed Check Services SPECS-RD system has both Type Approval and the ability to be used as a short-term rapid deployment speed enforcement system.

Further information regarding SCSS, RedFusion and TraffiSection can be found within Appendix B.

8 Conclusions and Recommendations

This report presents the results from an on-road trial of using a rapidly deployable average speed enforcement system at short-term overnight road works. The key conclusions are:

1. The trial has confirmed that the system trialled (SPECS-RD) is capable of being utilised at short-term road works.

Speed reductions observed during the trial

2. The largest reduction in average speed seen during the 96 day trial (of the order of 5mph) was associated with imposing a 50mph mandatory speed restriction.
3. With no speed control imposed (i.e. no 50mph mandatory or advisory limit):
    a. Displaying just a camera warning sign reduces average speed by 1.32mph
    b. Displaying a camera warning sign with a visible enforcement camera reduces average speed by 0.81mph
4. With a 50mph mandatory speed limit imposed:
    a. Displaying a speed limit alone will reduce speed to an average of 51.65 mph (a decrease in average speed of 4.70mph)
    b. Displaying the mandatory speed limit and a camera warning sign will reduce average speed by a further 0.54mph
    c. Displaying the mandatory speed limit with a camera warning sign and a visible camera reduces average speed by a further 1.08mph
5. With a 50mph advisory speed limit displayed:
    a. The speed limit alone will increase average speed by 0.97 mph
    b. Displaying a camera warning sign alone reduces the increased speed by 2.41mph, an effective decrease in speed of 1.44mph
    c. Displaying a camera warning sign and a visible camera reduces average speed by a further 0.50mph
6. Data from dry road conditions found generally similar results to that for all weathers.
7. Vehicles travelling in excess of ACPO enforcement guidelines for 50mph shows that:
    a. with a 50mph advisory speed limit set, the percentage of vehicles travelling in excess of 57mph is 34.07%, only 3.16% lower than with no speed set.
    b. when a 50mph mandatory speed restriction is in place this figure drops to 14.82%.
8. The use of a 50mph mandatory speed limit thus has the largest effect and the use of a 50mph advisory speed limit has the smallest effect on vehicle speed
9. The use of camera warnings, visible cameras or both serves to increase the speed reduction further; the largest improvement in speed limit compliance was achieved with a speed restriction and both visible cameras and warnings.

Benefits

•

10. If mandatory speed limits are used nationally at all road works and achieve a reduction of 5mph in driver speeds through all road works, this has the potential to reduce the calculated cost of road worker casualties
11. The calculated cost of road worker casualties saved is about £1.94M per year for use of a 50mph speed limit alone
12. Where speed limits are used with a visible enforcement system and camera warning signs, the annual calculated cost of casualties saved increases to around £2.37M.

8.1 Recommendations

The following recommendations are made, based on the results of the trial:

A. Use of mandatory speed limits at short-term road works

The use of mandatory speed limits at short-term road works should be considered as a widespread measure to reduce vehicle speeds through the road works. This would require "blanket" temporary traffic regulation orders to enable their use, together with some degree of initial enforcement to improve driver speed compliance through the road works, followed up with a programme to maintain compliance (see below).

B. Publicise the use of speed enforcement at short-term road works

The use of any average speed enforcement (or speed enforcement of any type) at short-term road works needs to be supported by a driver information programme or publicity campaign to reinforce the message that enforcement is being carried out. This should include information as to why the speed limit is being imposed and enable the road user to recognise any enforcement system used.

C. Investigate the use of SPECS-RD at medium-term road works

While SPECS-RD may not be cost-effective for use at short-term night road works, it is possible these types of systems could have significant benefit at medium-term road works. It is recommended that this use is explored.

D. Investigate alternative enforcement methods for night road works

It is recommended that alternative approaches are considered for speed enforcement at short-term overnight road works in order to provide a range of "tools" to deliver speed compliance. It is suggested that the approaches should ideally concentrate on those with the capability to provide enforcement at several different road works sites in one night.

E. Consider an enforcement programme to improve road worker safety

It is suggested that an initial investment in enforcement will be necessary in order to educate road users that compliance with speed limits in road works is required. This will improve road worker safety but will require an investment policy decision from the HA as it would not be cost-positive or cost-neutral. Once speed compliance has been improved, the level of enforcement could potentially be reduced (with appropriate monitoring) to a "maintenance" level in order to maintain desired driver behaviours.

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References

Elvik R, Christensen P and Amundsen A (2004). Speed and road accidents – an evaluation of the power model TOI Report 740/2004, Institute of Transport Economics, TOI, Norway.

Nilsson G (2004). Traffic Safety Dimensions and the Power Model to Describe the Effect of Speed on Safety. Bulletin 221. Lund Institute of Technology, Department of Technology and Society, Traffic Engineering, Lund.

Appendix A Spot-speed enforcement technologies

A.1 Sensys RWASS

Although not currently type approved for UK usage the Sensys, Road Working Area Safety System (RWASS), the system is designed for use at short term road works. RWASS is a non-intrusive, rapidly deployable enforcement solution designed specifically for road works areas. Utilising a three way approach to 'work-zone' safety, RWASS warns drivers of their approach speed, if in excess of that permitted, provides an audible warning to road workers of vehicles travelling in excess of a specified speed threshold and if the vehicle does not respond to the warning a high resolution camera will be used for enforcement. Should the vehicle reduce its speed to that permitted then both audible and visual warnings will cease.

Vehicle tracking starts 150m from the deployment point with vehicles found to be exceeding the specified limit provided with a visual warning at a defined report line. A photo of the violation is taken and stored with offence data including date, time, speed, location etc embedded allowing appropriate action to be taken if required.

The high resolution camera allows number plate and/or driver identification with offence details including time, date, location, vehicle speed and limit being linked to each violation log.

The RWASS radar system measures vehicle speed 20 times per second and supports either front or front and rear simultaneous imaging of non-compliant vehicles. Video sequencing capability can also be added to support the provision of evidential data. The Road Working area Safety System can be equipped with Global Positioning System (GPS) positioning to determine the exact point at which RWASS has been deployed.

It is understood that at present RWASS is not Home Office Type Approved for UK usage.

Appendix B Distance-over-time enforcement systems

B.1 Sensys SCSS

SENSYS® Traffic AB develops, produces and markets various products for traffic informatics and traffic safety, including systems for speed and red light enforcement. The systems are based on SENSYS' unique multi-tracking radar technology that has excellent precision and ensures it meets the highest legal security standards. They are non-intrusive and therefore very cost-effective. Thousands of systems are operated in 17 countries worldwide with excellent coverage in both Scandinavia and the Middle East.

- Sensys offers a number of enforcement options including:
- Fixed speed enforcement
- Mobile speed enforcement
- Red-light enforcement
- Work zone enforcement (RWASS)
- Speed zone enforcement
- Tunnel enforcement
- Section control enforcement (SCSS)

The Sensys Section Control Safety System (SCSS) is a distance-over-time speed measurement and enforcement system providing a non-intrusive solution for longer stretches of road. SCSS can be configured to either operate a single camera for either one or two lanes. Utilising ANPR technology vehicles are identified by their VRN upon entry to the controlled section and at subsequent enforcement points. Vehicle registration data and time stamps are used to determine a vehicle's average speed.

Additional functionality can be added to an SCSS therefore providing enhanced capabilities including:

- Identification of the vehicle's driver through additional camera points
- Scheduled functionality providing enforcement only during hours specified by an operator
- Incident detection

The system can be used at short-term road works although a rapid deployment system must be provided by the operator and at present a suitable third-party solution has not been encountered. SCSS has also not currently gained Home Office Type Approval, although it is understood that this process has been initiated.

B.2 Red Speed International: RedFusion

RedFusion is RedSpeed International's newest addition to its digital traffic enforcement product line. RedFusion is a distance-over time technology designed to increase speed limit compliance. RedFusion is designed predominantly for usage over a greater distance than that of spot-speed enforcement systems such as the RedSpeed. The RedFusion enforcement distance is fully configurable allowing the number of camera enforcement points to be tailored to take into account individual road features. This therefore ensures that increased speed limit compliance applies to all road users within the analysed zone.

Lane specific cameras track a vehicle's Vehicle Registration Number (VRN) by use of Automatic Number Plate Recognition (ANPR). A vehicle passing the first camera point is identified using ANPR and subsequently identified at all other camera points, this data is analysed by a central processing point that determines the time taken to pass through a known distance. Distance and time details are used to calculate vehicle speed, although vehicles must pass through a minimum of two camera points to allow a calculation to be completed. The use of vehicle tracking ensures that vehicles are tracked regardless of any lane changes that may be made.

If a tracked vehicle is classified as exceeding the specified speed enforcement threshold a violation log will be generated and high resolution images of the target vehicle stored. Violation log data is collected by the central processing system and encrypted to both ensure evidence integrity and total confidentiality.

The RedFusion system was granted Type Approval for use on the UK motorway network in December 2009 and is a direct competitor for the SPECS average speed camera system used both at long-term road works and at fixed sites.

The system is not currently suitable for a short-term, rapid deployment due to the requirement for the control cabinet to be 'fixed in concrete', although RedSpeed International have expressed interest in developing such a capability.

B.3 TraffiSection

Robot, the visual systems arm of the Jenoptik group produces a number of speed compliance and enforcement technologies, including fixed point and mobile speed measurement, red light and toll monitoring systems. The TraffiSection average speed check system is a distance-over-time technology designed to increase vehicle speed limit compliance over longer stretches of road.

In a similar manner to both SPECS and RedFusion, TraffiSection uses Automatic Number Plate Recognition to identify vehicles, in this case such capability is provided by integrated OCR software. Vehicle images are collected at the first 'check section' and then at subsequent camera points. The use of ANPR ensures that vehicles are matched by VRN at each point and these lane specific cameras with infrared flash capability log the exact time a vehicle enters and exits an enforcement zone. These timings are compared to a predefined baseline which allows non-compliant vehicles to be identified.

Violation data is immediately transferred to a 'central road section station' to be stored whilst cached data relating to those vehicles remaining below the specified speed threshold is immediately removed.

TraffiSection has the ability to monitor any number of lanes through use of multiple cameras. Robot also states that TraffiSection can be used in mobile or fixed situations, although minimal details regarding 'mobile' short-term installation are available. It is also understood that TraffiSection has at the time of writing not yet gained Home Office Type Approval.

Appendix C Results Data

C.1 Distribution of speeds – filtered

The distribution of speeds indicates that there are a few drivers who drive either very slowly or excessively fast through the road works. If those vehicles with speeds less than 30mph or greater than 80mph are excluded (i.e. about 0.6% of the data), the average speed across all vehicles decreases from 54.32mph to 54.17mph, a decrease of 0.15mph.

Table 13: Average speeds of all and filtered data (30mph to 80mph) by condition

Data	50mph speed restriction?	50mph advisory?	No camera visible or warning	No camera visible but a warning	Camera visible and a warning
All speeds	No	No	56.35	56.25	56.38
		Yes	57.32	54.91	54.41
	Yes	No	51.65	52.15	50.23
Filtered speed (30mph to 80mph)	No	No	56.04	56.05	56.29
		Yes	57.03	54.82	54.23
	Yes	No	51.59	52.09	50.22

The average speeds by conditions used are shown in Table 13, and indicate that filtering the speeds to only include 30mph to 80mph vehicles does reduce the average by a small amount. However, the differences are small and are fairly consistent so in net terms will not change the effect size associated with any condition significantly.

The analysis in the main part of this report has included all speeds.

C.2 Average speeds – all conditions

The average speeds from observed data under all weather conditions for each of the trial combinations is shown in Table 14.

Table 14: Average speed by trial combination (all weathers)

		50mph mandatory speed restriction ?					
		NO			YES		
		Mean	Standard Error of Mean	Valid N	Mean	Standard Error of Mean	Valid N
camera warning sign?	NO	56.82	0.080	10423	51.65	0.092	6597
	YES	55.50	0.055	19585	51.11	0.059	9869
camera visible?	NO	56.21	0.056	20805	51.85	0.065	11131
	YES	55.40	0.079	9203	50.23	0.079	5335
50mph advisory display?	NO	56.32	0.063	15315	51.33	0.051	16466
	YES	55.58	0.065	14693			

It makes sense to consider the results for when a mandatory 50mph speed limit is operating or is not operating, i.e. consider the results within 'columns' of Table 14 and hence the effect on the average speed of having a camera warning sign or a camera visible when a mandatory limit is imposed etc. For example, with no 50mph mandatory

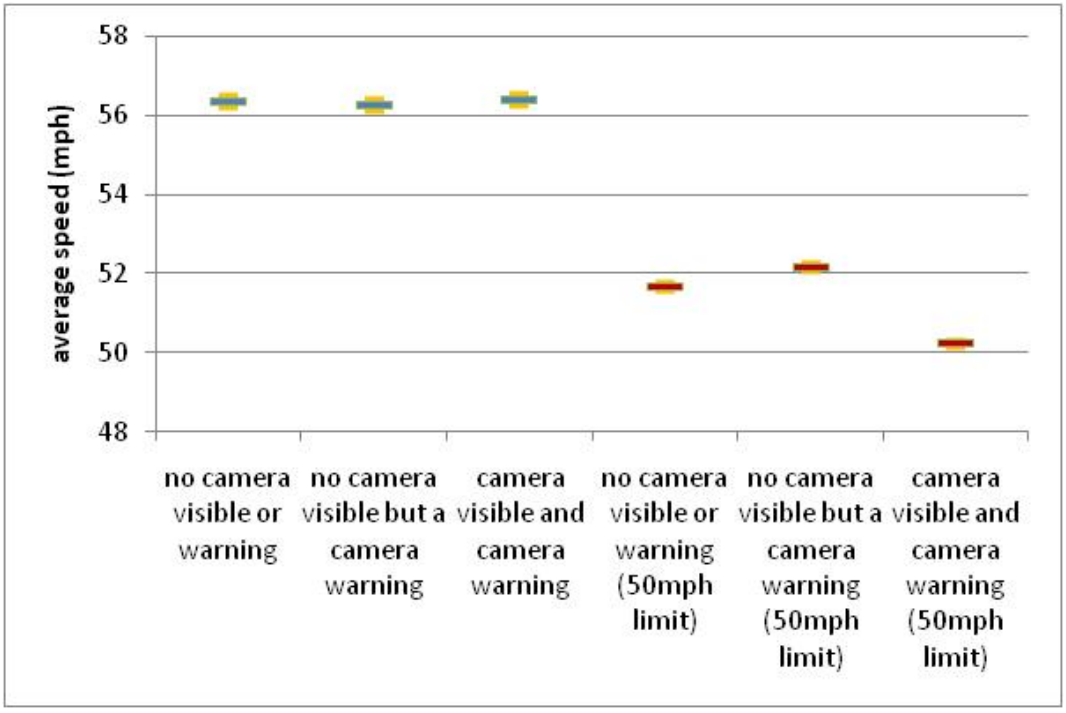
limit the effect of having a camera warning sign is to reduce the average speed from 56.82mph to 55.50mph – a reduction of 1.32mph.

However, comparing the results within 'row' in Table 14 indicates the direct impact of the mandatory 50mph speed limit, so with no camera warning sign the effect of the 50mph mandatory limit is to reduce the average speed from 56.82mph to 51.65mph – a reduction of 5.17mph.

C.2.1 Average speed reductions due to 50mph mandatory restriction

Figure 3 shows the average speed for different camera visibility options when there is no advisory speed limit set and there is either a mandatory speed restriction or not. The effect of the 50mph speed restriction under each of the camera options is between 4.7mph and 6.1mph. The differences are statistically significant[1].

Figure 3: Average speeds and different camera options, no advisory limit set (with 95% confidence interval)

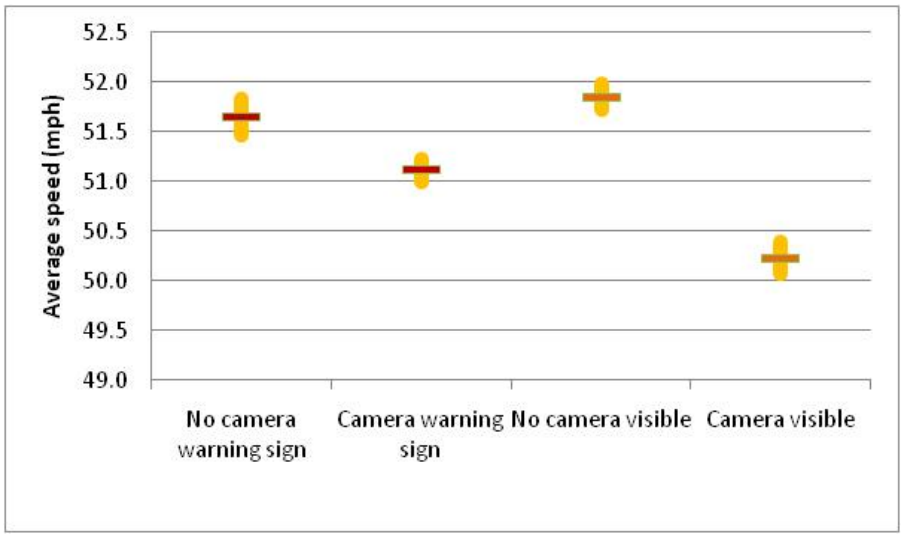


[1] The standard error associated with average speeds is generally less than 0.1mph, hence it is likely that average speeds which differ by more than 0.2mph will be statistically significant, i.e. there is less than a 0.05 probability that a 0.2mph difference is zero. However, it is suggested that this size difference is too small to be meaningful in road safety terms.

C.2.2 Average speeds within a 50mph speed restriction

Figure 4 shows the average speed (and 95% confidence interval) for different camera visibility conditions when a 50mph restriction was operating. It illustrates the effect of having a camera warning sign (i.e. about 0.5mph) or of having a visible camera (i.e. about 1.7mph).

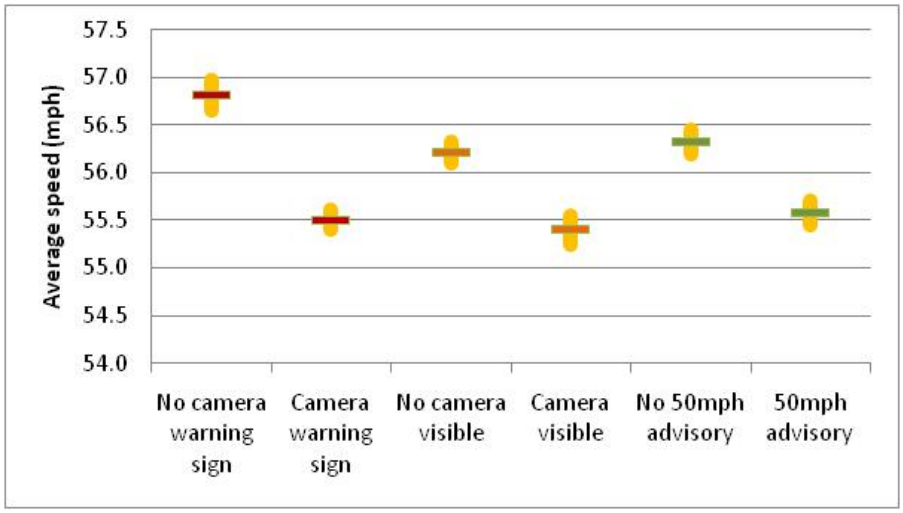
Figure 4: Average speeds and different camera options with 50mph mandatory speed restriction (with 95% confidence interval)



C.2.3 Average speeds effects without a 50mph speed restriction

Figure 5 shows the average speed (and 95% confidence interval) for different camera visibility conditions and an advisory speed limit when there is no 50mph restriction operating. It illustrates the effect of having a camera warning sign (i.e. reduction of about 1.3mph), of having a visible camera (i.e. reduction of about 0.8mph) and of having an advisory speed limit (i.e. reduction of about 0.7mph).

Figure 5: Average speeds and different camera options with no 50mph speed restriction (with 95% confidence interval)



C.3 Sample in dry conditions

The average speeds from observed data under dry weather conditions for each of the trial combinations is shown in Table 15.

Table 15: Average speed by trial combination (dry conditions)

		50mph mandatory speed restriction ?					
		NO			YES		
		Mean	Standard Error of Mean	Valid N	Mean	Standard Error of Mean	Valid N
camera warning sign?	NO	56.59	0.093	7821	52.89	0.118	3748
	YES	55.90	0.068	13038	51.23	0.067	7748
camera visible?	NO	56.04	0.064	15901	52.49	0.072	8229
	YES	56.55	0.108	4958	49.97	0.099	3267
50mph advisory display?	NO	56.10	0.078	10470	51.77	0.060	11496
	YES	56.21	0.078	10389			

The effect of camera warnings, camera visibility within and across 50mph speed limit setting can be obtained by comparing columns or rows within Table 15. For example, the average effect of a camera warning sign when there is no speed restriction is to reduce the average speed from 56.59mph to 55.90mph, a reduction of 0.69mph – which is small but statistically significant. The effect of having a 50mph restriction compared to having no 50mph restriction, both with no camera warning sign, is to reduce the average speed from 56.59mph to 52.89mph, a reduction of 3.7mph.

It is perhaps surprising that there is an increase in average speed when there is no 50mph restriction and a camera is made visible, albeit the increase is only 0.52mph. If there is a 50mph restriction the presence of a camera results in a decrease in average speed of 2.52mph, i.e. there is an interaction between the speed restriction and camera visibility.

There also appears to be an increase of 0.11mph when an advisory speed limit is introduced (though this difference is not statistically significant.

The data were analysed using an analysis of variance (ANOVA) which took into account the day of week as well as indicator values for the trial conditions set. The ANOVA found statistically significant effects associated with the day of the week and attributable to different conditions. The day of week average speeds are shown in Figure 6.

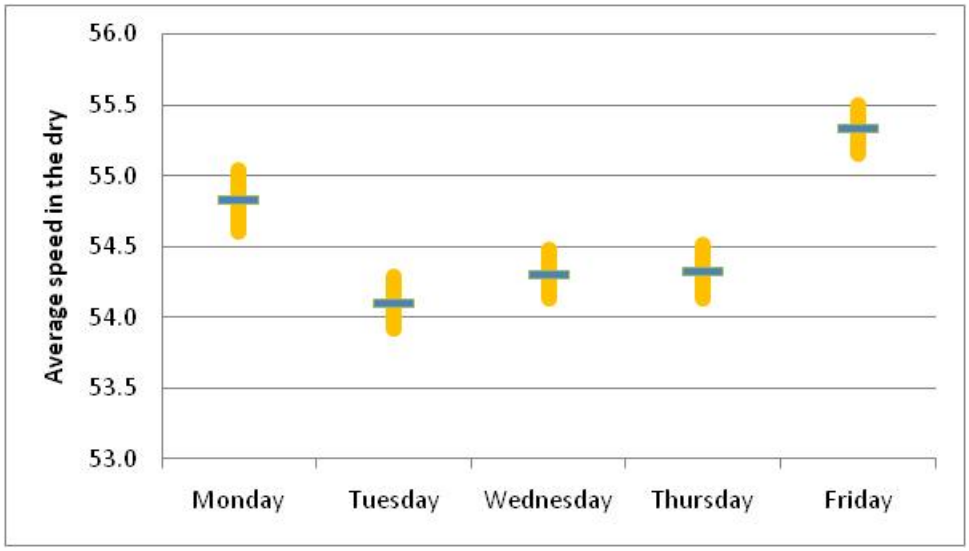
It was found to be useful to code the warning and visible presence of a camera into a single variable. Table 16 shows the average speed values, and which combinations of conditions were used.

Table 16 Average speeds in dry conditions by camera warning and visibility

		No camera visible or warning		No camera visible but a camera warning		Camera visible and camera warning	
		Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean
Speed restriction of 50mph?	NO	56.59	0.093	55.50	0.088	56.55	0.108
	YES	52.89	0.118	52.15	0.087	49.97	0.099
camera warning sign?	NO	55.39	0.075	.	.	.	.
	YES	.	.	54.30	0.066	53.94	0.084
camera visible?	NO	55.39	0.075	54.30	0.066	.	.
	YES	.	.	.	.	53.94	0.084
50mph advisory display?	NO	54.31	0.087	54.05	0.078	52.78	0.101
	YES	57.57	0.138	54.95	0.121	55.94	0.141

Figure 6 shows the average speed by day of week in dry conditions (with 95% CI). It indicates that Friday and Monday have slightly higher speeds and that Tuesday, Wednesday and Thursday are very similar.

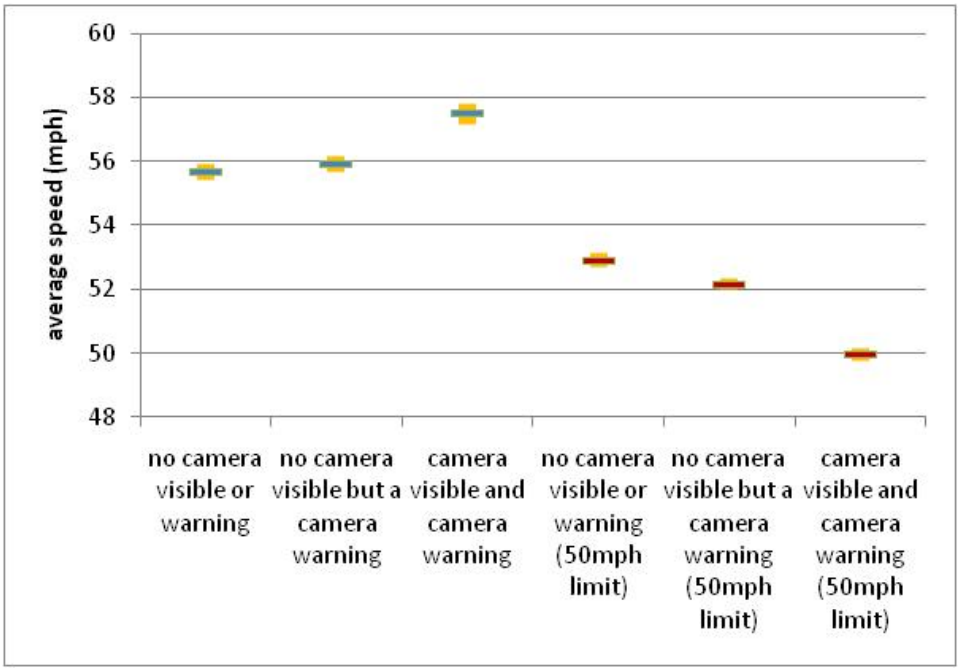
Figure 6: Average speed by day of week (dry conditions)



C.3.1 Average speed reductions due to 50mph mandatory restriction

Figure 7 shows the average speed for different camera visibility options when there is no advisory speed limit set and there is either a mandatory speed restriction or not. The effect of the 50mph speed restriction under each of the camera options is between 2.7mph and 7.5mph. The differences are statistically significant and similar to the findings when looking at all the data regardless of weather conditions.

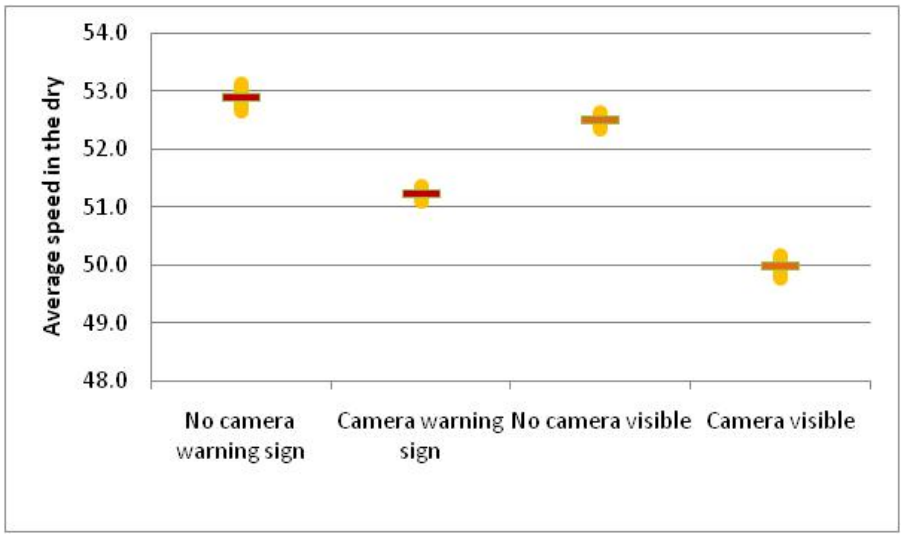
Figure 7: Average speeds and different camera options, no advisory limit set (with 95% confidence interval)



C.3.2 Average speed effects within a 50mph speed restriction

Figure 8 shows the average speed (and 95% confidence interval) for different camera visibility conditions when a 50mph restriction was operating. It illustrates the effect of having a camera warning sign (i.e. about 1.7mph) or of having a visible camera (i.e. about 2.5mph).

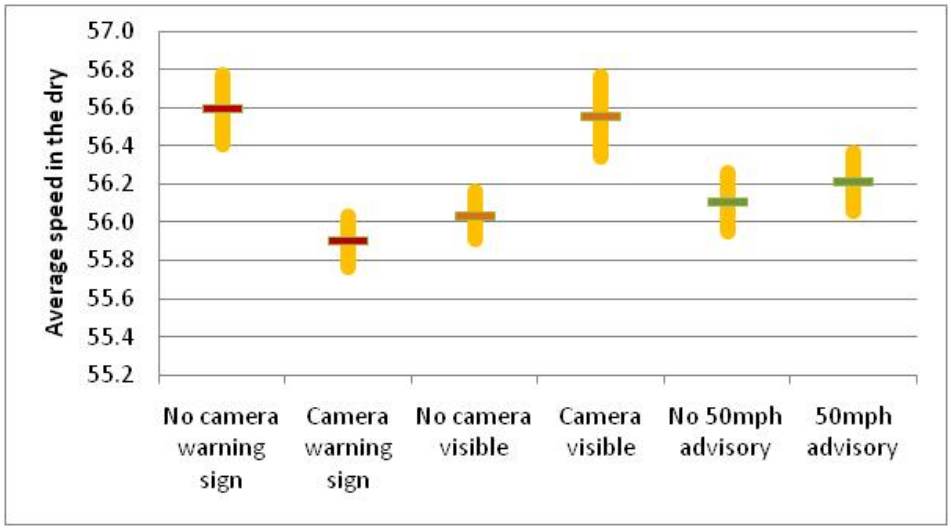
Figure 8: Average speeds and different camera options, 50mph mandatory speed restriction (with 95% confidence interval)



C.3.3 Average speeds effects without a 50mph speed restriction

Figure 9 shows the average speed (and 95% confidence interval) for different camera visibility conditions and an advisory speed limit when there is no 50mph restriction operating. It illustrates the effect of having a camera warning sign (i.e. reduction of about 0.7mph), of having a visible camera (i.e. increase of about 0.5mph) and of having an advisory speed limit (i.e. non-significant increase of about 0.1mph).

Figure 9: Average speeds and different camera options with no 50mph speed restriction (with 95% confidence interval)



It is surprising that having a visible camera in dry conditions when there is no speed restriction should result in an increase in average speed of 0.5mph. This suggests that perhaps the trial results are less balanced when only dry days are being analysed. Table 17 shows details of average speeds for this combination. It shows that the increase in average speed when a camera is visible occurs when there is a camera sign (of about 1mph), and when there is no advisory speed limit (of about 1.7mph).

Table 17 Average speeds, dry conditions with no 50mph restriction

		camera visible?					
		NO			YES		
		Mean	Standard Error of Mean	Valid N	Mean	Standard Error of Mean	Valid N
camera warning sign?	NO	56.59	0.093	7821	.	.	
	YES	55.50	0.088	8080	56.55	0.108	4958
50mph advisory display?	NO	55.79	0.088	8528	57.49	0.165	1942
	YES	56.32	0.094	7373	55.94	0.141	3016
Table Total		56.04	0.064	15901	56.55	0.108	4958

C.4 Vehicles exceeding ACPO guidelines

Table 18 , details the number of vehicles travelling in excess of the Association of Chief Police Officers (ACPO) guidelines for speed enforcement. Such guidelines specify a threshold 10% + 2mph above the limit, therefore with a 50mph limit the threshold is 57mph and at 70mph the threshold is 79mph.

With a 50mph restriction 14.82% of vehicles were found to be travelling in excess of 57mph but with a 50mph advisory the figure increases to 34.07%. With no speed set 37.23% of vehicles were found to be travelling in excess of 57mph.

Table 18: Vehicles exceeding ACPO guideline speeds

50mph restriction	Speed	Mean	51.33
		Standard Error of Mean	0.05
	speed over 57.0mph		14.82%
	speed over 79.0mph		0.25%
		Valid N	16466
50mph advisory	speed	Mean	55.58
		Standard Error of Mean	0.07
	speed over 57.0mph		34.07%
	speed over 79.0mph		0.86%
		Valid N	14693
No speed set	speed	Mean	56.32
		Standard Error of Mean	0.06
	speed over 57.0mph		37.23%
	speed over 79.0mph		0.90%
		Valid N	15315