An assessment of traffic calming for trunk roads using the TRL driving simulator

Prepared for Safety Standards and Research (Traffic, Safety and Environment Division), Highways Agency

M C Taylor, L F Crinson and R E Osborn

TRL Report TRL539

First Published 2002
ISSN 0968-4107

This report has been produced by TRL Limited, under/as part of a contract placed by the Highways Agency. Any views expressed in it are not necessarily those of the Agency.

CONTENTS

Executive Summary

It is now well established that there is a strong relationship between vehicle speeds and road accidents. To deal with competing demands for funding, Highway Authorities are increasingly seeking more cost-effective means of reducing vehicle speeds. Measures which involve only signing and marking, which successfully encourage drivers to slow down rather than physically forcing them to do so, are needed, particularly on more major roads. Although many such measures are now in use, there is a need for better guidance to provide greater consistency and to encourage good practice.

This report describes a project in which the TRL driving simulator was used to examine the effectiveness of a range of signing and marking measures designed specifically for application on trunk roads. The work was commissioned by the Highways Agency's Safety Standards and Research Directorate (Traffic, Safety and Environment Division) and follows on from a pilot study previously undertaken for the (now) Department for Transport, Local Government and the Regions (DTLR). The objective was to evaluate new and existing traffic calming measures in different trunk road situations, comparing one measure with another. Combinations of measures used together were also investigated and the responses of drivers with different characteristics were examined.

The speed-reducing effects of measures were studied in the following situations:

- at bends and isolated developments on rural single carriageway roads;
- at village gateways and within villages;
- at rural roundabouts and urban T-junctions;
- on rural single carriageway and urban dual carriageway link sections.

The measures comprised both established and innovative examples, in particular enhanced signing, the use of coloured road surfacing and other road markings, and including 'perceptual' measures designed to make the situation appear more dangerous to drivers than it actually is.

Members of the public drove 'test routes' representing a journey, about 30 miles long, on rural and urban road types. During the journey they encountered a number of these signing and marking measures in different situations, including 'control' sites where no measures were applied. Speeds were recorded continuously. The measures were evaluated by comparing the speeds which drivers chose at the sites with the measures with the speed they chose in the control situation.

Since the trial took place in a driving simulator, in artificial conditions, the magnitude of the speed reductions achieved should be considered only as indicative. The *relative* effectiveness of different measures in the same situation is, however, likely to be reliable. The results suggest a number of measures that have the potential to reduce speeds in different situations on trunk roads. The following were the main conclusions:

- The most visual measures that alert drivers well in advance to hazards where there is an accident problem are likely to be the most effective at improving safety. Specific examples are:
  - a large chevron sign (4 chevrons) on a yellow backing board at bends;
  - a series of buff bands on the road – importantly, incorporating a SLOW marking (tested here at an isolated development);
  - narrowing using longitudinal red surface strips with hatching (isolated development);
  - coloured transverse strips, resembling cobbles (an innovative measure tested at village gateways);
  - speed camera with camera symbols marked on the carriageway in advance (tested here on an urban dual carriageway).
- Countdown signs, when used in combination with other measures at a village gateway, appear to strongly influence the resulting speed reductions on the village approach, but repeated measures in the village are still required to reduce speeds there. The spacing of repeated marking measures is less critical than that of repeated physical measures.
- The potential of the presence of bus/cycle lanes to reduce speeds is likely to be limited on trunk roads because of the need for the other road lanes to remain sufficiently wide to accommodate heavy goods traffic.
- Other continuous measures with visual impact which reduce the marked lane width on both sides appear to be effective at reducing speeds over several kilometres on link sections of roads.
- There are indications that different measures in different situations affect different groups of drivers in different ways. Measures which were effective in reducing the speed of the fastest drivers were identified; these will be likely to produce the greatest safety benefits.

The results will complement knowledge obtained from the direct application of signing and marking measures on the public road and are being incorporated in Highways Agency guidance concerning traffic calming on trunk roads. The measures have the potential to reduce accidents through a combination of reduced speeds and increased driver awareness. Further examination of the effectiveness of the more successful measures across a wider range of situations is recommended – in particular, with different road widths, road environments and varying levels of traffic flow.

1 Introduction

1.1 Background

It is now well established that there is a strong relationship between vehicle speeds and road accidents (Taylor *et al.*, 2000; 2002). Over many years, TRL has investigated on the public road and on the TRL Test Track, the effectiveness of traffic calming measures designed to reduce vehicle speeds. The findings have related particularly to physical measures such as road humps. They have been reported extensively and have been incorporated by the Department for Transport, Local Government and the Regions (DTLR) in Traffic Advisory Leaflets giving advice to practitioners on best practice.

The costs involved in mounting trials, particularly on the public road limits the knowledge that can be gleaned in this way. Once a scheme has been designed and implemented, only minor modifications are generally feasible and it is not cost-effective to establish what might have happened if alternative configurations had been adopted. In addition, Highway Authorities are reluctant to apply measures that are not tried and tested because of the possibility of adverse local reaction.

To deal with competing demands for funding, Highway Authorities are increasingly seeking more cost-effective means of reducing vehicle speeds. Measures which involve only signing and marking, which successfully *encourage* drivers to slow down rather than physically forcing them to do so, are needed. Such measures are also important for more major roads, which carry higher traffic flows and speeds, where physical measures are often inappropriate. A number of these measures have already been introduced on major roads, but with the exception of those in villages (Wheeler and Taylor, 1999) their effectiveness has not been widely reported. There is a need for better guidance to provide greater consistency and encourage good practice.

This report describes a project in which the TRL driving simulator was used to examine the effectiveness of a range of signing and marking measures designed specifically for application on trunk roads. The work was commissioned by the Highways Agency’s Safety Standards and Research Directorate (Traffic, Safety and Environment Division) and follows on from a pilot study previously undertaken for (the now) DTLR (Lockwood, 1997).

The pilot study established that the TRL simulator was an effective tool for determining the *relative* impact of different measures on vehicle speeds. This was achieved by comparison between observations on the public road and results from a simulator trial in which the same features were modelled. It served to demonstrate that the tool provides a sufficiently realistic driving environment to replicate real-life behaviour for the purpose of distinguishing between the effect of different measures (particularly different types of signing and marking) on speed. Details of the pilot trial are summarised in Appendix A.

1.2 Objectives

The pilot study examined only a limited number of measures. The aim of the present project was to expand this range of measures and the locations in which they might be applied. The results are being incorporated in guidance concerning traffic calming on trunk roads.

The specific objectives were:

- to evaluate new and existing traffic calming measures in different trunk road situations, comparing one measure with another and with combinations of measures used together;
- to establish the effect of the measures on the behaviour of drivers with different characteristics;
- to look at the effect of measures which might benefit public transport and/or vulnerable road users.

Trunk road environments are varied, including different junction types, different road widths, layouts and speed limits, and urban and rural environments. Therefore, various signing and marking features were tried in a number of different trunk road situations. The trial took place in two phases as follows:

Phase 1 examined the effects of features at village gateways, and at bends and isolated developments on rural roads.

Phase 2 examined the effects of features on rural single carriageway and urban dual carriageway links, at rural roundabouts and urban T-junctions, and also the spacing of features within villages.

1.3 Report structure

Section 2 of the report describes the experimental design and analysis procedures. Section 3 indicates the effectiveness of the different traffic calming features, in terms of how they influenced average speeds. Section 4 considers differences in behaviour between drivers of different ages and sexes, and between drivers with different speed characteristics. The results of the study are summarised and discussed in Section 5, and key conclusions drawn in Section 6.

2 Experimental design and analysis

2.1 Benefits of simulator trials

Simulator trials have several advantages over public road trials:

- novel measures can be assessed safely and cheaply;
- a larger number of measures and variants can be tested much more quickly and cheaply;
- a range of combinations of measures can easily be tested;
- the conditions are controlled (i.e. comparison of the effectiveness of measures is not hampered by variations in other factors, as happens in public road trials).

2.2 The TRL driving simulator

The TRL driving simulator consists of a room, within which is a real car with screens in front of it, on either side of it, and behind. Images projected on these screens provide a driver in the car with forward and side vision, over 210 degrees, and also in the rear-view mirror. The images are generated by computer and respond to the steering and pedals of the car. Simulated noise is provided, and the car is given a limited amount of motion. The speed of the car and many other variables can be recorded continuously. The variables recorded in this study are described in Section 2.6.

2.3 The test routes

In the remainder of this report, 'traffic calming' should be understood to mean signing and marking measures. The traffic calming measures were assessed by inviting subjects (all members of the public) to drive simulated routes and examining how they responded. Each test drive, as seen by a subject, consisted of a journey along a route, during the course of which they encountered a number of sites (villages, junctions etc – see Section 2.4) with traffic calming, separated by lengths of untreated road. This was so that the simulation would feel like a single drive along a rural road, passing through villages or towns, rather than like a series of isolated tests. 'Control' sites, that is sites without any traffic calming, were used within the routes to assess behaviour at equivalent sites where there was no calming present. Each type of site appeared several times in a route (once for each of the traffic calming features tested at that type of site, plus once for use as a control). Thus the number of appearances varied depending on how many traffic calming features were to be tried.

Four test routes were used in each phase of the trial, so that some subjects encountered the features (but not the sites) in a different order from others. This was to minimise any possible effects resulting from the order in which features were presented. In each phase, the routes differed only in the order in which the traffic calming features were applied; apart from the calming, the routes were identical.

The test routes had to enable a subject to pass through all the features in a reasonably realistic drive that was not excessively long. A number of criteria were taken into account based on previous experience of this type of trial (Lockwood, 1997) – for example: sites were an adequate distance apart so as not to be influenced by the previous site, but this distance varied to avoid monotony; the routes were designed so that drivers did not consecutively encounter a large number of sites with calming by including more uncalmed sites than were needed to act as controls.

Each subject passed 50 oncoming vehicles during their drive, including heavy goods vehicles, to give the impression of a trunk road. These were arranged in such a way that a particular vehicle would be passed at approximately the same point on the road by every subject. The subjects did not encounter any vehicles in the same direction as themselves, to ensure that they were free to choose their own speed.

2.4 The sites and the features tested

The type of site and the traffic calming measures tested at each are described below. Appendix B contains the simulated images, including some of the control sites.

Rural single carriageway road (60 miles/h speed limit) - bend:

1 One large chevron sign (large enough to contain four chevrons), on a yellow backing board.

2 Four small chevron signs (each containing one chevron), each on a yellow backing board.

3 Coloured bend warning sign on the road surface.

4 Buff lane, starting on the approach (alongside the warning sign) and continuing half way round the bend.

The two configurations of chevron sign were for comparison with each other. The latter two features were innovative.

Rural single carriageway road (60 miles/h) - isolated development (petrol station):

5 Three buff bands on the approach, with a SLOW marking on the middle band.

6 Longitudinal red strips along the centre and edge of the road, with hatching.

Each of these features was provided on both approaches to the petrol station (thus, each subject saw one on their own side of the road as they approached the petrol station, and another on the opposite side of the road after they had passed the station). Both measures were intended to highlight the garage entrance by acting as alerting devices.

Rural single carriageway road (60 miles/h) – village gateway (40miles/h):

7 3-D 'wedges' along the centre of the road; these were actually painted flat on the road, but intended to look as though they projected out of it. Nine wedges were provided, just in advance of the village entrance.

8 Transverse strips of what appeared to be cobbles (but were actually a pattern marked on the road). The strips were always applied across the full width of the road, but decreased in length closer to the village. (These were to simulate a marking pattern, not a surface texture, on the public road.)

9 Four rows of white triangles, arranged in a triangular chequer board pattern in the running lane.

These were all innovative measures designed to act as alerting devices by influencing drivers' perceptions and making the situation appear more dangerous than it actually was. The cobbles pattern was intended to be less environmentally intrusive than other, brighter coloured, markings.

More established measures were also tested singly and in combination, as follows. This was in an attempt to investigate whether features were less effective when used with other traffic calming features already present.

10 ***A:*** An enlarged village nameplate, plus visual narrowing created using white lines and hatching.

11 ***B:*** Buff bands on the approach to the village.

12 ***C:*** A '40' roundel on the road surface at the village entrance.

13 ***ABC:*** The three features above, used in combination.

14 ***ABCD:*** The 'ABC' combination, plus count down '40' signs placed 300, 200 and 100 yards before the village entrance.

15 ***E:*** A '40' roundel on a red surface, plus yellow backing boards around the speed limit sign and village nameplate.

16 ***AE:*** A combination of the features used in 'A' and in 'E'.

Rural single carriageway – within village (40 miles/h):

17 SLOW marking on a buff band every 80m throughout the length of the village.

18 SLOW marking on a buff band every 130m throughout the length of the village.

19 SLOW marking on a buff band every 200m throughout the length of the village.

20 Pelican crossing (always showing green).

The first three of these were included to investigate the effect of different spacing between measures.

Rural single carriageway (60miles/h) – roundabout approach:

21 Standard 'countdown' signs – a sequence of three signs at 100 yard intervals (DTLR recommendation).

22 Three buff bands, with a SLOW marking on the middle band.

Both measures were intended to reduce speeds on the approach to the roundabout.

Rural single carriageway (60 miles/h) – link section:

The following were trialled over a distance of 3100m (and compared to a control situation of standard edge lining and centre marking):

23 Hatched area along the centre of the road.

24 Hatched, red surfaced area along the sides of the road.

25 Hatched, red surfaced area along both the centre and sides of the road.

Urban single carriageway (40 miles/h) - T-junction:

Three measures were trialled at urban T-junction locations:

26 Build-out incorporating a sheltered parking area.

27 Green bus lane on the left of the road.

28 Green bus lane on the right of the road.

The first measure was intended to slow vehicle speeds, while also providing sheltered parking for cars beyond the junction. The latter two measures were trialled to determine if the reduction in road width caused by the introduction of a bus lane reduced vehicle speeds, and to see whether the effect differed according to whether the bus lane was immediately adjacent or opposite.

Urban dual carriageway (40 miles/h) – link section:

Two measures were trialled over a distance of 2200m:

29 A series of speed camera symbols marked on the road at 200m intervals, with a single speed camera part way along (no speed camera signing).

30 Mandatory green cycle lane.

The first of these was an 'enhanced' speed camera measure. The second was trialled to determine if the reduction in road width caused by the introduction of the cycle lane reduced vehicle speeds (which would in turn be likely to benefit cyclists' safety).

2.5 The subjects

64 subjects took part in each phase of the trial, all of whom had driven the simulator previously, but who had not taken part in the previous pilot trial (Lockwood, 1997). Each set of 64 subjects comprised four groups - younger males, younger females, older males, and older females - with 16 subjects in each. Here 'younger' means 17-29 years and 'older' means 40-60 years. In each phase of the trial, 4 subjects from each group drove each of the four test routes.

Immediately before their trial, each subject was given a brief preliminary drive on the simulator, to re-familiarise them with its handling. They were asked to drive during the trial as they would normally do on the public road.

2.6 Data and analysis

Data are recorded 60 times a second in the TRL driving simulator. The data were used to determine the time and the driven speed for each subject at 10m intervals along the route.

The following describes the method of analysis. The speed at which each subject passed a pre-defined point at a site with a traffic calming feature was measured and the speed at which the *same subject* passed the same point at the 'control' site (the same site without traffic calming) was subtracted. This difference gave an indication of the speed reduction brought about by the traffic calming. The average of this difference across all subjects was used as an estimate of how much the traffic calming feature affected the speed of a typical driver. The statistical robustness and consistency of this result were determined by examining how much the speed reduction varied from one driver to the next (ie. by determining its standard error) and testing whether the result could have occurred by chance or was a statistically significant effect. Unless otherwise stated, a result is deemed statistically significant if it is significant at at least the 5% level.

For measures that might be described as 'spot' measures (ie. those that would be intended to have an effect on speeds particularly at a certain position) the speed differences with respect to the control refer to specific points.

For the features through villages (17-19) and those on links (23-25; 29-30), there is no well-defined position for determining the effect and so results for these 'continuous' features are presented:

i for the point at which the greatest speed reduction occurred, and ii as an average reduction over the entire distance of the measure.

For (ii) the results are indicative only; it was not considered realistic to attempt to determine an associated statistical significance for this parameter.

For both the ‘spot’ features and the ‘continuous’ features, speed profile plots of average speed through the site and of average speed relative to the control have been thoroughly examined; some examples are included in Sections 3 and 4.

3 Results

The results of the trials are summarised in Table 1 (‘spot’ measures) and in Table 2 (‘continuous’ measures).

3.1 Features at bends

Table 1 shows that both types of chevron sign (features 1 and 2) generated a statistically significant reduction in speed. For the other two features (3 and 4), the speed changes were minimal. Of the two chevron designs, the single large sign gave a larger speed reduction than the four small signs. This occurred on all four of the test routes, and the overall difference was statistically significant.

Figure 1 shows how the average speed relative to the control site varied as subjects approached and passed through the bend; 0 on the horizontal axis indicates the start of the bend. From this it is evident that, no matter where on the bend the speeds were measured, the single large chevron had an effect as large as, or larger than, any of the other features. When inspecting this graph, it should be borne in mind that the standard error (of ‘speed relative to control’) was about 0.7miles/h, and so little weight should be given to small differences between the profiles.

3.2 Features at an isolated development

Table 1 shows that statistically significant speed reductions were produced by both the features (5 and 6) tested at the petrol station. At the point where these speed measurements were made, 50m before the first entrance to the petrol station, the buff bands with SLOW marking (feature 5) gave a statistically significantly larger change than the red strips feature (feature 6). Both measures

Table 1 Summary of speed changes for ‘spot’ measures

Trial location *Point of speed measurement*	*Mean speed at control (miles/h)*	*Measure*	*Mean speed change relative to control (miles/h)*
Bend			
Start of bend	56.4	One large chevron sign	-4.8**
		Four small chevron signs	-2.5**
		Buff lane	0.8
		Bend warning sign on road	0.4
Isolated development (petrol station)			
50m before first turn-in	55.4	Buff bands	-6.0**
		Narrowing with red strips	-4.4**
Innovative measures at village gateways			
At the gateway	44.2	Cobbles	-3.0**
		3-D road marking	-2.5
		Triangles	-1.9
Combinations of measures at village gateways			
At the gateway	42.1	A	-0.1
		B	-0.2
		C	-0.1
		ABC	-0.3
		ABCD	-4.7**
		E	-0.1
		AE	-1.2
Within village			
At the pelican	39.9	Pelican crossing	-2.7
Roundabout			
30m before roundabout	20.0	Countdown signs	-0.4
		3 buff bands plus 'slow' marking	-1.0
Urban T-junction			
At the T-junction	41.0	Build-out with car parking	-1.2
		Bus lane: left	-1.7
		Bus lane: right	-1.2

*** result significant at least at the 5% level*

Table 2 Summary of speed changes for 'continuous' measures

Trial location / *Measure*	*Mean speed at control*[1] *(miles/h)*	*Greatest mean speed change relative to control* — *Position*	*Value (miles/h)*	*Mean speed change over entire distance of measure (miles/h)*
Rural single carriageway				
Centre hatching	60.6	360m beyond the start of hatching	-2.8**	-1.6
Hatching on red surface at sides	60.6	380m beyond start the of hatching	-3.0	-1.6
Hatching on red surface at centre and sides	60.6	340m beyond the start of hatching	-5.6**	-3.6
Urban dual carriageway				
Speed camera with markings	45.8	1270m beyond the first marking	-6.2**	-2.9
Cycle lane	46.1	20m beyond the start of cycle lane	-3.0**	-0.4
Village				
Buff bands: 80m spacing	41.3	120m beyond the village entrance	-2.3**	-1.3
Buff bands: 130m spacing	40.7	210m beyond the village entrance	-1.4	-0.9
Buff bands: 200m spacing	41.2	140m beyond the village entrance	-2.3**	-1.5

*** result significant at least at the 5% level*
[1]at position of greatest change in mean speed

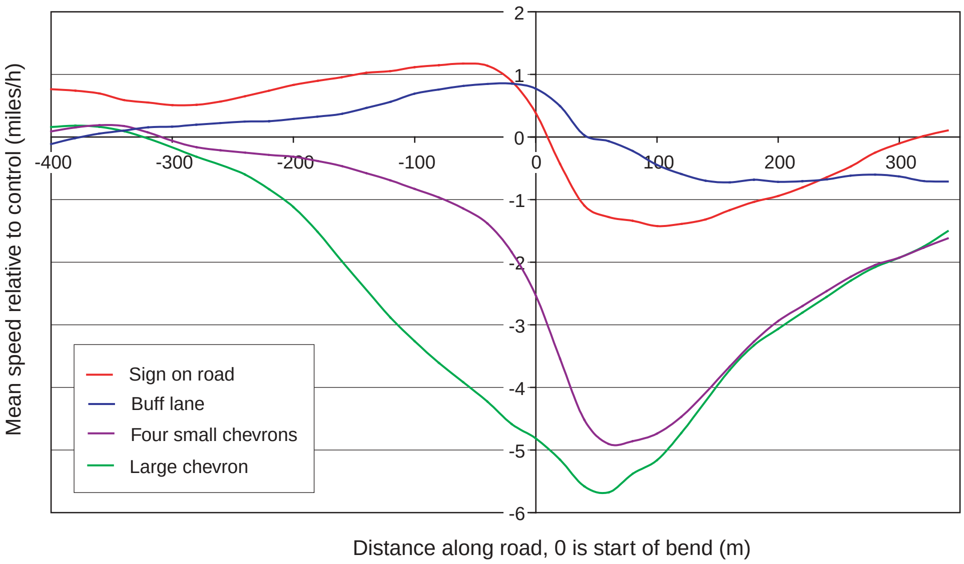

Figure 1 Rural road – bend. Relative mean speed profile averaged over all drivers

reduced speeds relative to the control, from 200m in advance of the petrol station. The reduction with the buff bands was the greater from 200m before the station to about 100m beyond it.

3.3 Features at village gateways

3.3.1 Innovative measures

Of the three measures tested, the 'cobbles' (feature 8) produced the most consistent and, on average, largest speed change at the village entrance (defined as the start of the village speed limit). The effects of the other two measures varied greatly from one test route to the next, and hence the average effect was rather uncertain. The speed profiles showed that the effects of these features were greatest near the village gateway and did not persist for more than about 100m into the village.

3.3.2 Combinations of established features at village entrances

Only one of the features numbered 10-16 produced a statistically significant reduction in average speed (measured at the village entrance); this was feature 14, coded ABCD. This differed from feature 13 (coded ABC) only in that countdown signs had been added, and the substantial effects of these signs are evident from this comparison. Speed profiles indicated that the effects of the countdown signs were greatest in advance of the village, where the signs were located (average speeds were typically 5–10 miles/h lower than in all the situations without countdown signs over this stretch), but reduced to about 2miles/h about 100m into the village.

The individual measures used in isolation in this part of the experiment (features 10, 11, 12, 15) unfortunately did not produce statistically significant reductions in average speed. It therefore did not prove possible to establish how the effect of measures used in combination was related to the effect of these measures used in isolation.

3.4 Features within villages

All three of the buff band features (17-19) produced a statistically significant reduction in average speed at a point 150m into the village. However, by about 400m into the village none of the reductions were more than 0.5miles/h. The spacing of the SLOW/buff bands had no clear effect; indeed at some points in the village the greatest speed reductions occurred where the spacing was widest (200m from one band to the next). It had been suspected that, especially with 200m spacing, drivers might speed up and then slow down between each band, giving rise to an uneven speed profile, but there was no evidence for this. Even when the results were investigated for individual drivers, there was no indication of an acceleration/deceleration effect other than for one or two drivers.

The pelican crossing (feature 20) produced the greatest speed reduction (a statistically significant 4.4miles/h) about 60m prior to the crossing itself. Drivers probably then accelerated on recognising the crossing showing its green light, and the absence of pedestrians, so that the mean speed reduction at the crossing itself was rather less (2.7miles/h).

3.5 Rural single carriageway - roundabout

As already seen in Section 3.3.2, countdown signs produced a substantial additional reduction in speed on the approach to a village, when supplementing other gateway features. The results also show that countdown signs were effective at reducing speeds at a roundabout (feature 21). The average speed was reduced by a statistically significant 3miles/h relative to the control about 240m before the roundabout. However, by the measurement point 30m from the roundabout, there was no significant effect. Although drivers may not travel any slower close to the roundabout with the signs than without, they have clearly been ‘alerted’ to the presence of the roundabout much sooner.

The SLOW/buff bands feature produced a substantial speed reduction when used at the entrance to a petrol station (Section 3.2). At the roundabout (feature 22), it produced the greatest reduction in average speed (1.5miles/h) 150m prior to the roundabout. A reduction of almost 1mile/h was achieved at a point 30m from the roundabout; neither change was statistically significant.

3.6 Rural single carriageway - link section

Figure 2 shows the average speed of all drivers through the length of the rural single carriageway link section, relative to the average speed on the control section (without measures), for each of the three features (23-25). The greatest effect on speed occurred when hatched, red surfaced areas were used on both the sides and in the centre of the road (feature 25). This produced a (statistically significant) maximum speed reduction of 5.6miles/h (relative to the control) 340m into the section. The effect diminished as drivers continued along the section of road. However, near the end of the feature there was still a statistically significant speed reduction of 2.9miles/h relative to the control.

All three measures generated the greatest mean speed reductions relative to the control between 300 and 400m into the hatching.

The speed profiles are best described in three sections: the first 500m of the hatching; the middle (500m to 2950m); and 2950m to the end of the measure. In the first section drivers quickly reduced speed relative to the control. After reaching a maximum speed reduction, speeds increased gradually despite the continued presence of the feature. With the end of the measure in sight (2950m) drivers then accelerated relative to the control. This was less apparent with the hatching in the centre and

Figure 2 Rural single carriageway – link section. Relative mean speed proviles averaged over all drivers

at the sides where the effect was fairly stable (about 2.8miles/h reduction relative to the control) after 1500m.

By applying ‘best fit’ lines to the relative speed profiles for the middle of the three sections, an estimate was made of how far the effect of each of the three features would be likely to have persisted if the measure had been applied over a longer distance. The result suggested that the hatching with red surfacing along the sides of the roads only (feature 24) produced an effect that would be expected to last for about 3km, whereas for the other two features (23 and 25), both of which had hatching in the centre of the road, the effect would be expected to last for about 6km.

3.7 Urban single carriageway - T-junction

None of the three features tested (26-28) produced a statistically significant reduction in average speed at the junction itself. The bus lane on the left hand side (feature 27) produced the greatest (but not significant) reduction in speed relative to the control site, of 2.3miles/h 80m prior to the junction.

The bus lane on the left hand side of the road (ie. in the same direction as the driven vehicle) appeared to have more effect than the equivalent bus lane on the right hand side of the road (feature 28), despite the remaining running lane width being the same in both cases.

The build-out with sheltered parking (feature 26) produced a modest (non-signficant) reduction in speed, relative to the control (1.4miles/h maximum) in the vicinity of the junction.

It is interesting to note that, in the absence of any of the features, drivers were slowing slightly as they passed through (but not in advance of) the junction.

3.8 Urban dual carriageway - link section

Feature 29 comprised speed camera symbols on the road every 200m along the 2km stretch of urban dual carriageway road, with a camera itself just over halfway along it. Near the start of the 2km stretch, the markings produced a statistically significant reduction in mean speed of 4.4miles/h relative to the control. For some distance after this the average speed was 41miles/h (1mile/h above the limit) - Figure 3. Speed dropped further to reach a minimum of –6.3miles/h relative to the control site at 1270m from the start - 50m downstream of the speed camera (again statistically significant). After this, the average speed rose considerably, to within 2miles/h of the speed at the camera-less site - despite the camera symbols continuing for a further 800m. This suggests that subjects believed, based on their experience on public roads, that they would not encounter a second speed camera on this stretch of road.

In Section 4.3 these results are discussed in more detail in relation to the age and sex of the subjects.

The green cycle lane (feature 30) produced a statistically significant 3miles/h reduction in speed relative to the control at its start, but this effect wore off rapidly after about 200m. For most of its 2200m length the effect of the cycle lane was close to zero.

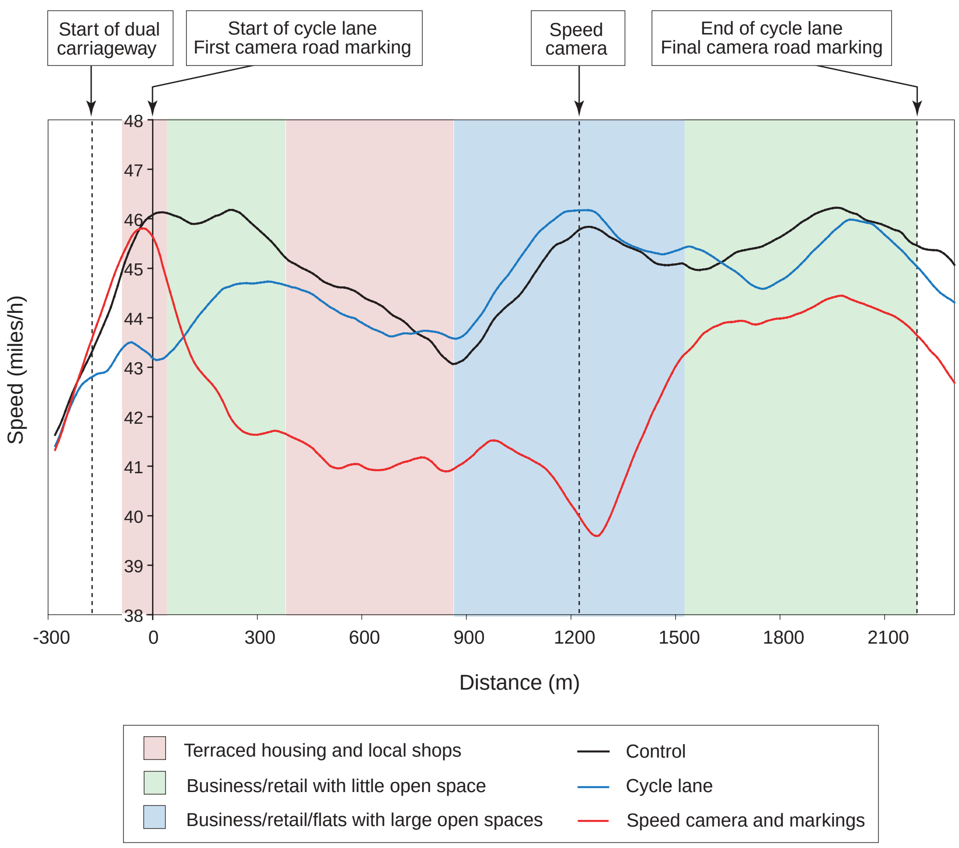

Figure 3 Urban dual carriageway – link section. Mean speed profiles of all drivers

It was interesting that even on the urban dual carriageway with no traffic calming features, average speed varied along the 2km length of the road, with most drivers slowing down between 0 and 800m and then increasing their speed again between 800 and 1200m (Figure 3). The speed profile shows the location of different land uses along the dual carriageway section; these are illustrated in Appendix B (Figures B8 (a) and (b)). Along almost half of the dual carriageway section the buildings were set well back (Figure B8 (a)). However, at the point where speeds were lowest (about 800m from the start of the section, Figure 3) there were houses quite close to the edge of the road (Figure B8 (b)). The presence of housing next to the road appears to have lowered speeds by about 2miles/h.

It is also interesting to note that drivers consistently accelerated by several miles per hour as they entered the dual carriageway section from a single carriageway, even though the speed limit was unchanged.

4 Responses of different groups of drivers

4.1 Responses of different age/sex groups

As explained in Section 2.5, there were four groups of subjects (younger males, younger females, older males, older females) in the trials. Analyses of the speed data were undertaken to investigate any differences in behaviour or responses to the measures between these groups. The most important results are now summarised.

The younger male drivers tended always to be the fastest group. Cruising speeds at a sample of randomly selected points on the rural single carriageway sections of road in the Phase 2 route varied from 51miles/h for the older female group to (a statistically significantly greater) 61miles/h for the younger male group. The older male and younger female groups averaged 59miles/h.

A similar effect is evident in Figure 4, which shows the average speed profiles by group at feature 29 (urban dual carriageway with speed camera). Here the younger males were about 5miles/h faster than the older females in advance of the camera and about 8miles/h faster beyond it.

Figure 4 also shows that the rate at which the younger males accelerated after passing the camera was much greater than for the other groups. The younger males' average speed 400m after passing the speed camera reverted to the same speed as they entered the dual carriageway section. The other drivers returned to a speed which was 1-2 miles/h lower than that at which they entered the dual carriageway section.

In the Phase 1 route, all groups of drivers slowed when entering a 'control' village (speed limit reduction and village nameplate, but no other measures). However, for the younger drivers, a higher proportion (40%) of this speed reduction typically occurred *after* passing the speed limit signs than for the older drivers (15%). Younger males in particular braked later than older males.

Based on the Phase 1 results, it appeared that the measures that were effective at reducing speeds affected the different groups of drivers differently. However, the relationship was not a simple one, being dependent on the type of site, and could not be established rigorously with the limited number of subjects in each age/sex group.

4.2 Responses by drivers' speed choice

Since increased accident frequency is particularly associated with the speeds of the fastest drivers (Taylor *et al.*, 2000), measures that influence the speed of these drivers are likely to be the most successful in reducing accidents.

A methodology was developed to divide the 64 drivers from each phase of the trial into three groups: fast drivers,

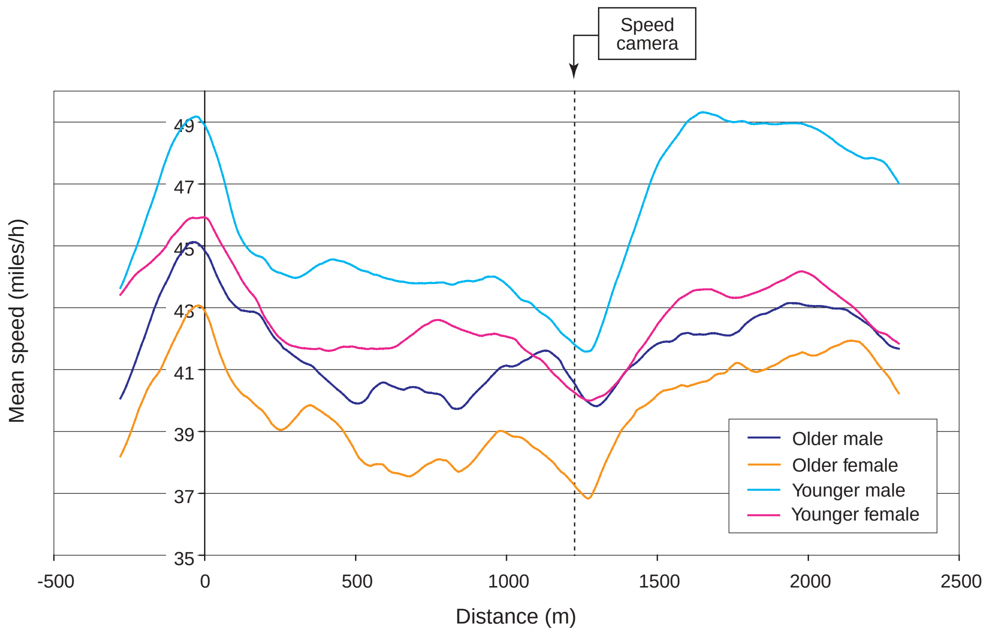

Figure 4 Urban dual carriageway with speed camera (feature 29): means speed by age and sex

medium drivers and slow drivers. The 85th percentile speed of each driver along a section of road without traffic calming measures was calculated, based on their speed at 10m intervals. In Phase 2, drivers were grouped separately by their speeds on a rural (60miles/h limit) and on an urban (40miles/h limit) section as there was evidence to suggest that the faster drivers in each case were not necessarily the same. (In Phase 1 all of the route was rural). Table 3 shows the resulting speeds for the groups, formed by ranking the 85th percentile speeds in each case.

Table 3 85th percentile speeds (miles/h) by speed group

Group	*Phase 1*	*Phase 2 - rural*	*Phase 2 - urban*
Fast (16 drivers)	67	72	57
Medium (32 drivers)	61	63	46
Slow (16 drivers)	53	54	41
All	61	63	47

For each of the features trialled, the average speeds and average speeds relative to the control were calculated for each of the 3 (appropriate) groups of drivers and compared between groups. The results are summarised in Table 4.

In Table 4, the measures have been grouped broadly into 4 types:

- *instruction* (those with an instruction to slow down and/ or an indication of a speed limit);
- *perceptual* (those highlighting a hazardous location in a way designed to alert or convey an illusion);
- *warning* (those comprising more standard signs and/or markings);
- *other* (specific facilities).

For all measures, the *greatest mean speed reduction relative to the control* for each of the three groups is shown. (Note that the location of the maximum speed change may be different for the three groups). For measures where it is appropriate to consider speed changes at a particular point, the *mean speed change relative to control* is also given for the three groups of drivers (fast, medium and slow) at a given point (P - defined in the table). Speed reductions at specific points are not compared for the 'continuous' measures. The shaded cells indicate a statistically significant result.

Based on the results given earlier in this report (Tables 1 and 2) Table 4 shows which measures significantly reduced the average speed across all drivers. It also shows which measures were especially effective at reducing the speeds of the fastest drivers.

The table shows that there were a number of measures where speeds of the fastest drivers were reduced by an amount that was both of practical and statistical significance. Those measures where there is a large overall mean speed reduction *and* where the fastest drivers are most affected would be expected to be the ones which would lead to the greatest accident reductions (Taylor at al, 2000).

Figure 5 shows schematically how this is achieved. Assume that with no measures present, the profile of speeds of drivers at a particular point is Normal in shape, as in Figure 5(a), with a mean speed shown by the vertical line. Figure 5(b) shows the resulting distribution if a measure is introduced which reduces the speed of all the drivers equally, giving the lower mean speed shown by the dotted vertical line. In Figure 5(c), the effect of the measure is to reduce the mean speed by the same amount as in (b), but this has been achieved by the fastest drivers being most affected, so that the 'top end' of the distribution is much curtailed.

From Table 4, particularly effective features of those tested (ie. effective for the fastest drivers *and* effective overall) are therefore likely to be:

Bend

Large single chevron sign (feature1).

Isolated development

Buff bands with 'SLOW' marking (5)
Narrowing using longitudinal red strips with hatching (6).

Village gateway

Countdown signs with other gateway measures (14)
Cobbles (8).

Rural single carriageway

Hatching in the centre of the road (23)
Hatching on a red surface at the side and centre of the road (25).

Urban Dual Carriageway

Speed camera with markings (29).

Some measures were fairly effective at reducing the speeds of the 16 fastest drivers, even though the overall mean speed reductions of all 64 drivers (Section 3) proved to be less encouraging. It is possible that these measures will still be effective in reducing accidents. These measures are:

Village gateway

3-D 'wedge' marking (feature 7).

Roundabout

Countdown signs (21).

Rural single carriageway

Hatching on a red surface at the sides of the road (24).

The results also showed that the fastest and medium speed drivers appeared to be affected more by *perceptual* style signing and marking measures than the slow drivers. This suggests that although the overall speed reduction across all types of driver may be greater for some of the *instruction* and *warning* signing and marking measures, the accident reduction potential of perceptual measures should not be overlooked.

Table 4 Summary of results

Type *Site*	*Measure*	*Overall good result*	*Effective at reducing speeds of fastest drivers*	*Point of speed measurement (P)*	*Mean speed change relative to control (miles/h) at point P*			*Greatest mean speed reduction relative to control (miles/h)*		
					Fast	*Medium*	*Slow*	*Fast*	*Medium*	*Slow*
Instruction										
Isolated development	3 buff bands and SLOW	★	✓	50m before entrance	-5.9	-6.0	-4.7	-7.0	-6.1	-4.8
Roundabout	3 buff bands and SLOW			30m before roundabout	-1.4	0.0	-2.4	-1.9	-1.6	-1.5
Village gateway	40 Roundel			At the gateway	-0.1	-0.2	0.4	-1.2	-0.3	-1.8
Within village	Buff bands and SLOW at 80m			*				-2.5	-2.8	-2.6
	Buff bands and SLOW at 130m			*				-1.2	-2.4	-2.6
	Buff bands and SLOW at 200m			*				-3.8	-2.8	-3.1
Perceptual										
Bend	Buff lane			Start of bend	0.3	1.4	0.0	-1.6	-0.3	-2.8
Isolated development	Longitudinal red strips/hatching	★	✓	50m before entrance	-5.7	-4.2	-1.2	-8.0	-4.5	-3.1
Rural single carriageway	Hatching in the centre of the road	★	✓	*				-5.7	-3.4	-0.6
	Hatching on red at the sides		✓	*				-3.6	-3.6	-2.3
	Hatching on red at the centre and the sides	★	✓	*				-4.9	-7.1	-5.2
Village gateway	3-D road marking		✓	At the gateway	-3.3	-2.6	-1.4	-3.3	-2.6	-1.4
	White triangles			At the gateway	-1.1	-2.3	-1.8	-1.1	-2.3	-1.8
	Cobbles	★	✓	At the gateway	-3.2	-3.7	-1.5	-3.2	-3.7	-1.5
	Narrowing			At the gateway	2.6	2.7	0.0	-0.3	-0.3	-1.0
	Buff bands			At the gateway	0.3	-0.7	0.4	-1.6	-0.8	-0.6
Warning										
Bend	Large chevron sign	★	✓	Start of bend	-6.9	-4.5	-3.7	-7.3	-5.3	-4.9
	4 small chevron signs	★		Start of bend	-2.6	-2.3	-3.0	-4.9	-5.0	-5.1
	Bend warning sign on road			Start of bend	-0.1	0.9	-0.2	-2.8	-1.8	-2.3
Roundabout	Countdown signs		✓	30m before roundabout	-0.3	-0.4	-0.7	-4.8	-2.6	-3.0
Village gateway	Countdown signs with other gateway measures	★	✓	At the gateway	-6.6	3.9	-4.4	-10.9	-9.6	-9.1
Urban dual carriageway	Speed camera and markings	★	✓	*				-11.3	-5.8	-1.8
Other										
Urban dual carriageway	Cycle lane			*				-3.9	-3.4	-2.1
Urban T-junction	Bus lane on left			At the T-junction	-1.9	-1.4	-1.8	-2.1	-2.5	-2.8
	Bus lane on right			At the T-junction	-0.6	-1.6	-1.5	-2.1	-1.6	-1.5
	Build-out with parking			At the T-junction	0.5	-1.9	-1.1	n/a	-2.4	-1.2
Within village	Pelican crossing	★		At the pelican crossing	-2.5	-2.3	-3.7	-3.7	-4.0	-6.1

▒ *Statistically significant at least at the 5% level*

★ *Measures which are effective at reducing speeds of all drivers*

✓ *Measures which are effective at reducing speeds of fastest drivers*

* *For these measures it is not meaningful to compare the speed reductions at one point*

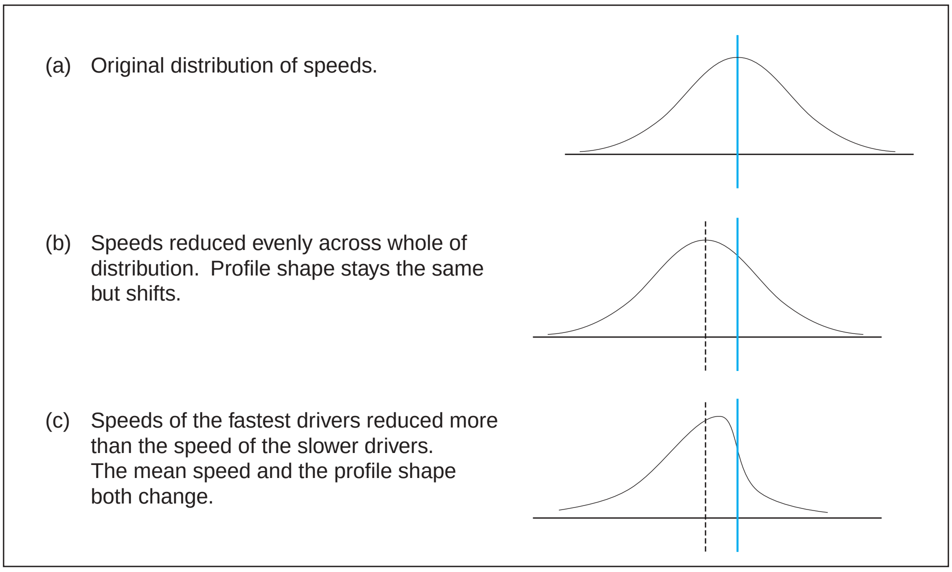

Figure 5 Speed profiles (schematic representation)

5 Summary and discussion

5.1 Effect of the measures on speeds

The traffic calming measures most effective overall at reducing speeds (ie. speed reductions statistically significant at least at the 5% level for all drivers together) were:

	Mean speed reduction (miles/h)
At bends:	
Large single chevron sign on a yellow backing board	4.8[1]
Four small chevron signs on yellow backing boards	2.5[1]
At isolated developments:	
Buff bands with SLOW marking	6.0
Longitudinal red strips/hatching along the edges and the centre of the road	4.4
At village gateways:	
Painted ‘cobbles’ – an innovative village gateway measure	3.0
Countdown signs – in combination with an enlarged nameplate, narrowing, roundel, buff bands.	4.7
Within villages:	
Buff bands with SLOW marking (80 – 200m spacing)	Up to 2.3[2]
Pelican crossing	4.4
On rural single carriageway links:	
Hatching in the centre of the road	2.8[3]
Hatching/red surfacing in the centre and at the sides of the road	5.6[3]
On urban dual carriageway links:	
Speed camera with markings	6.2[3]

[1] *At start of bend; larger reductions on bend.*

[2] *Largest reduction at any point; average reductions over length of continuous measures were only about 1mile/h.*

[3] *Largest reduction at any point; average reductions over length of continuous measures were smaller.*

Bends

Both of the sign features trialled at the bend gave statistically significant reductions in speed while neither of the road marking features did. The large, single chevron sign was more effective at reducing speeds than the four single signs, both on the approach to the bend and through the bend itself; this may be due to the large single sign being more clearly visible from a greater distance or perhaps because the single sign may suggest a more severe bend. The single sign also particularly affected the faster drivers.

Isolated developments

Both of the measures at the petrol station were effective, reducing speeds on the approach to and past the development. They also affected the faster drivers well. The three buff bands were more effective than the longitudinal red surfacing but the difference was least marked for the fastest drivers.

The similar measures using buff bands on the bend, and a much larger number of bands at the village gateway were, however, not effective. The difference is most probably because one of the buff bands at the isolated development carried a ‘SLOW’ marking, whereas the others did not. However, it is also possible that the type of site had an effect.

Villages (gateways and in-village)

Of the innovative measures trialled at village gateways, only the cobbles produced a statistically significant speed reduction. The effect of the 3-D wedges varied greatly from one test route to the next, so the reduction in speed is uncertain; however, the faster drivers were particularly affected at this feature.

The trial using combinations of more established measures at village gateways showed countdown signs to be particularly effective in association with an enlarged nameplate, narrowing, roundel and buff bands. Large reductions in speed have been obtained on the public road at village gateways with countdown signs (eg. Wheeler *et al.*, 1997) and the result here suggests that their presence is particularly important when speed reductions are generated by compound measures which include them. Countdown signs not supported by significant signing/marking at the gateway itself have not been found to be effective (Barker and Helliar-Symons, 1997).

The effects of traffic calming features at the village gateways did not persist more than about 100m into the village. This broadly agrees with the results of trials on the public road (Wheeler *et al.*, 1994), although the simulator results give added emphasis to just how short the distance is. Measures need to be spaced at frequent intervals to achieve speed reductions in the village itself. The trial here using buff bands spaced at intervals varying from 80m to 200m suggested that, within this range, the speed reduction achieved was insensitive to the spacing, but was only about 1mile/h. On the public road, the spacing of physical measures (road humps, cushions and chicanes) has a large effect (eg. Webster and Layfield, 1996) – a result replicated for road humps in a previous simulator trial (Lockwood, 1997). The limited effect of the spacing of the buff bands is likely to be because these are not physical measures; therefore drivers were not forced to slow down at each band, but *chose* to adopt a constant speed.

The pelican crossing reduced speeds in advance of it. Once past the potential hazard drivers quickly returned to their previous speed.

The narrowing at the village entrance (feature 10) was not effective at reducing mean speeds. However, a similar stretch of narrowing, enhanced by red coloured surfacing at the isolated development did reduce speeds well. This difference may be attributed to the presence of the coloured surfacing, or it may be that subjects were more responsive to calming at the petrol station, a situation where it is less likely that they have encountered measures on the public road.

Rural single carriageway links

All the measures trialled on the rural single carriageway were successful at reducing speeds, particularly of the faster drivers. The hatching on a red background in the centre and at the sides reduced speeds more than either the centre hatching alone or the hatching on a red background at the sides. The effect for all three measures was greatest near the start of the section and then gradually reduced; it appeared that if the markings had been applied over a longer distance, the speed reduction would have persisted furthest (about 6km) with the two arrangements incorporating centre hatching. This is possibly because the remaining marked available lane width was 0.5m less in the presence of centre hatching.

Urban dual carriageway links

The speed camera with associated markings was very effective at reducing speeds as far as the site of the speed camera, especially for the faster drivers. However, the effect was more limited beyond, a result which supports evidence from the public road (Winnett, 1995); the fastest drivers in particular reverted quickly to their original speed. The cycle lane, which has the primary purpose of segregating cyclists from vehicles, reduced speeds at its start, but again, the effect did not persist. The remaining marked available lane width was 3.3m, which may be sufficient for car drivers not to feel too constrained.

Junctions

The measures at the urban single carriageway T-junction all gave reductions in average speed, but none was statistically significant relative to the control site. Again, this is likely to be because the remaining road width was sufficient in all cases (at least 3.5m compared to 5m in the control) for car drivers not to feel constrained.

This and the cycle lane result above suggest that on trunk roads, where sufficient road space must remain to accommodate heavy goods traffic, the introduction of designated lanes for other traffic will have only minimal impact on vehicle speeds.

On the approach to roundabouts, countdown signs reduced speeds well in advance of the junction and particularly affected the faster drivers. The buff bands were rather less effective, but the small effect which did occur was again greatest well in advance of the junction. Like transverse yellow bar lines, which are in widespread use on the approach to roundabouts on the public road, these measures may act largely as ‘alerting’ devices and can still produce good accident benefits without any appreciable effect on speed in the vicinity of the junction.

Overall, measures which slowed drivers the most tended to be those with the most visual impact. It appeared that measures which involved a narrowing of the marked lane width were more effective if they were on both sides of the lane rather than just one (for similar remaining lane width). Interestingly, the faster drivers appeared to be the most affected by the perceptual measures.

5.2 Effect of the measures on safety

In terms of absolute levels of speed reductions achieved, the results obtained here must be considered only as *indicative* of those that might occur on the public road where many other factors will influence the effect. The impact on safety of speed reductions brought about by traffic calming measures in the situations examined here is not well known – however, reduced speed is in general associated with fewer accidents.

On good quality, rural, single carriageway roads, a 1mile/h reduction in mean speed can be expected to reduce injury accidents typically by about 4-5% (Taylor *et al.*, 2002). The hatching on a red background in the centre and at the sides tested here might therefore be expected, for example, to reduce accidents by of the order of 15%, over the distance for which speeds are reduced (potentially several kilometres). The speed reductions achieved by measures at isolated developments, together with the resulting increased driver awareness, would be expected to lead to improved safety at sites with an accident problem.

For village treatments, injury accident reductions of about 4% per mile/h reduction in mean speed have been shown (Taylor and Wheeler, 2000).

Taylor *et al.* (2000) does not specifically address roads with mean speeds in the region of 40miles/h (the speeds typically occurring here on the urban roads), but it can be inferred that a 1mile/h reduction in speed at this level might reduce injury accidents by about 1-2 %. This suggests that the urban measures tested here might reduce accidents by the order of 5%.

Reductions in vehicle speeds can be expected to have particularly beneficial effects on the risk to vulnerable road users (ie. pedestrians and cyclists) because of the reduced speed differentials. In villages, reductions in the speed of motorised vehicles might improve the freedom of local residents by encouraging pedestrian and cyclist activity. It has been found, for example, that more cycling occurs in areas where the casualty rate amongst cyclists is lower (Waldman, 1977).

Where roads are wide enough, the presence of bus/cycle lanes is beneficial for buses/cyclists in terms of capacity and safety respectively. The indications here are that the speed of other road users may also be reduced but only by a very small amount; it is possible that this could provide some limited additional safety benefit to all road users, especially cyclists.

5.3 Other results

In keeping with observed behaviour on the public road, the younger male subjects drove the fastest in the simulator. They also appeared to respond to measures later and then to brake harder.

It appeared that different measures affected the behaviour of drivers of different age/sex differently but there was insufficient data here to establish exactly how.

The proximity of the buildings in the urban dual carriageway section had an effect on the speed of drivers. Where buildings were close to the road and included terraced housing and shops, subjects slowed down by about 2miles/h, but on approaching an industrial park area with large open areas, they tended to speed up again. This confirms that general environmental features can be as important in influencing driver speeds as engineering measures specifically designed to do so.

The use of colour in the measures investigated here follows broad national guidance (DMRB, 1999). Although it was not an objective of this experiment to directly compare the effects of different coloured surface markings, in most cases, red was used to indicate areas outside the main running lanes and buff was used in the running lanes on the approach to a change in road layout. The red surfaces were generally effective *when used in this way;* the buff markings were generally only effective when enhanced with a ‘SLOW’ marking.

6 Conclusions

Since the trial took place in a driving simulator, in artificial conditions, the magnitude of the speed reductions achieved should be considered only as indicative. The *relative* effectiveness of different measures in the same situation is, however, likely to be reliable. The results suggest a number of measures that have the potential to reduce speeds in a range of situations on trunk roads:

- The most visual measures that alert drivers well in advance to hazards where there is an accident problem are likely to be the most effective at improving safety. Specific examples are:
  - a large chevron sign (4 chevrons) on a yellow backing board at a bend;
  - a series of buff bands on the road – importantly, incorporating a SLOW marking (tested here at an isolated development);
  - narrowing using longitudinal red surface strips with hatching (isolated development);
  - coloured transverse strips, resembling cobbles (an innovative measure potentially applicable at village gateways, providing it can be applied cost effectively);
  - speed camera with camera symbols marked on the carriageway in advance (tested here on an urban dual carriageway).
- Countdown signs, when used in combination with other measures at a village gateway, appear to strongly influence the resulting speed reductions on the village approach, but repeated measures in the village are still required to reduce speeds there. The spacing of repeated marking measures is less critical than that of repeated physical measures.
- The potential of the presence of bus/cycle lanes to reduce speeds is likely to be limited on trunk roads because of the need for the other road lanes to remain sufficiently wide to accommodate heavy goods traffic.
- Other continuous measures with visual impact which reduce the marked lane width on both sides appear to be effective at reducing speeds over several kilometres on link sections of roads.
- There are indications that different measures in different situations affect different groups of drivers in different ways. Measures which were effective in reducing the speed of the fastest drivers were identified; these will be likely to produce the greatest safety benefits.

The results will complement knowledge obtained from the direct application of signing and marking measures on the public road. The measures have the potential to reduce accidents through a combination of reduced speeds and increased driver awareness. Further examination of the effectiveness of the more successful measures across a wider range of situations is recommended – in particular, with different road widths, road environments and varying levels of traffic flow.

7 Acknowledgements

The work described in this report forms part of the programme of research undertaken by TRL for the Highways Agency. The authors are grateful to David Hasen for his guidance throughout.

8 References

Barker J and Helliar-Symons R D (1997). *Countdown signs and roundel markings trials*. TRL Report TRL201. Crowthorne: TRL Limited.

Design Manual for Roads and Bridges (1999). *Coloured surfacing of road layouts.* Volume 6 Section 3 Part 4. TA 81/99.

Lockwood C R (1997). *Using the TRL driving simulator to evaluate traffic calming measures*. TRL Report TRL245. Crowthorne: TRL Limited.

Taylor M C and Wheeler A H (2000). *Accident reductions resulting from village traffic calming schemes*. European Transport Conference, Cambridge, September 2000, Proceedings of Seminar J.

Taylor M C, Lynam D A and Baruya A (2000). *The effects of drivers' speed on the frequency of road accidents.* TRL Report TRL421. Crowthorne: TRL Limited.

Taylor M C, Baruya A and Kennedy J V (2002). *The relationship between speed and accidents on rural single-carriageway roads*. TRL Report TRL511. Crowthorne: TRL Limited.

Waldman J A (1977). *Cycling in towns: a quantitative investigation*. LTR1 working paper 3. London: Department of Transport.

Webster D C and Layfield R E (1996). *Traffic calming – road hump schemes using 75mm humps*. Project Report PR186. Crowthorne: TRL Limited.

Wheeler A H and Taylor M C (1999). *Traffic calming in villages on major roads: Final Report*. TRL Report TRL385. Crowthorne: TRL Limited.

Wheeler A, Taylor M and Barker J (1994). *Speed reduction in 24 villages: details from the VISP study*. Project Report PR85. Crowthorne: TRL Limited.

Wheeler A H, Abbott P G, Godfrey N S, Lawrence D J and Phillips S M (1997). *Traffic calming on major roads: the A49 trunk road at Craven Arms, Shropshire*. TRL Report TRL212. Crowthorne: TRL Limited.

Winnett M A (1995). *Management of speeds through camera enforcement*. Presented at TRAFFEX, April.

Appendix A: Summary of the pilot trial

The pilot trial examined whether the TRL driving simulator could be considered a useful tool to evaluate traffic calming features, by comparing results from trials on public roads with results from equivalent simulated situations (Lockwood, 1997).

Three villages which already had signing/marking measures at the gateways, and where the effects on speeds of these measures was known, were used in the trial. At one of these (Craven Arms in Shropshire), very large reductions in speed had been observed on the public road. At the second site (Hermitage in Berkshire) the observed speed reductions were small. The third site (South Warnborough in Hampshire) had produced speed reductions that were greater than had been expected. The measures included enhanced speed limit signs, coloured road surfacing, and innovative markings. The approach and one entrance to each of these villages were modelled on the simulator. The trial involved 64 subjects driving a route which included versions of each of the three villages, with and without the traffic calming measures present.

In Table A1 the speed changes observed in the simulator are shown as the difference between the speed driven with no traffic calming features present (representing the Before situation) and that driven with the features in place (the After situation), averaged over all subjects. The corresponding changes observed on the public road are shown for comparison. The simulator successfully distinguished the very effective scheme at Craven Arms from the less effective scheme at Hermitage. Average speeds measured on public roads are always subject to some uncertainty and, given this, there are no real discrepancies between the simulated and the real speed reductions.

Table A1 Comparison of speed changes on the public road and in the simulator

	Change in average speed (miles/h)	
	Public road	*Simulator*
Traffic calming at Craven Arms	-8.5	-8.5
Traffic calming at Hermitage	-0.7	-3.4
Traffic calming at South Warnborough:		
" at the entrance	-5	-4.3
" at ‘Site 2’	-3	-3.4
" at the pinch point	-7	-3.9

Most subjects rated the scenery and calming measures ‘Good’ or ‘Adequate’ in realism. [It should be noted that between this pilot trial and the trial discussed in the main report here, the graphics in the TRL driving simulator underwent significant enhancement.]

It was concluded that the effects of signing/marking measures could be broadly reproduced in the simulator. This, and drivers’ opinions, indicated that the quality of the images generated were sufficiently good for this kind of application. It was considered that simulator trials would be valuable in supplementing the results of road trials - in particular for comparing the effects of a wider range of measures. The simulator also offered additional data not easily obtainable from conventional road trials (for example, speeds at a large number of points). In addition it could help by sifting out ineffective measures prior to road trials.

Appendix B: Simulated images

1 Large chevron sign

2 Four small chevron signs

3 Bend warning sign on road

4 Buff lane on approach to bend

Figure B1 Rural single carriageway road – bend

5 Buff bands and SLOW at isolated development

6 Longitudinal red strips at isolated development

Figure B2 Rural single carriageway road – isolated development (petrol station)

7 3-D wedges at village gateway

8 Cobbles at village gateway

9 White triangles at village gateway

Control village gateway

10 A (see section 2.4)

11 B (see section 2.4)

12 C (see section 2.4)

13 ABC (see section 2.4)

Figure B3 Rural single carriageway road – village gateway *(continued over)*

14 ABCD (see section 2.4)

15 E (see section 2.4)

16 AE (see section 2.4)

Figure B3 *(Continued)* Rural single carriageway road – village gateway

17-19 SLOW markings and buff bands

20 Pelican crossing

Figure B4 Rural single carriageway road – within village

21 Countdown signs

22 Buff bands and SLOW

Figure B5 Rural single carriageway road – roundabout approach

Control rural single carriageway

23 Hatched area along the centre of the road

24 Hatched red surfaced area along the sides of the road

25 Hatched red surfaced area along the centre and sides of the road

Figure B6 Rural single carriageway road – link section

26 Build-out incorporating a sheltered parking area

27 (a) Green bus lane on the left (start)

27 (b) Green bus lane on left (at junction)

28 Green bus lane on right

Figure B7 Urban single carriageway road – T-junction

29 Speed camera symbols with speed camera

30 Mandatory green cycle lane

(a) Buildings set well back from the road

(b) Buildings very close to the road

Figure B8 Urban dual carriageway road – link section

Abstract

The report describes a project undertaken by TRL for the Highways Agency and designed to establish the speed-reducing performance of different traffic calming features appropriate to trunk road situations. Trials were carried out on the TRL driving simulator. Members of the public drove ‘test routes’ representing a journey, about 30 miles long, during which they encountered a number of features in different road environments.

The measures comprised: established and innovative signing/marking measures at village gateways, at isolated developments and bends on rural roads, and for junctions and link sections on rural and urban roads.

The relative effectiveness of the measures was established in each situation in terms of the observed reduction in speed, compared to an equivalent situation without measures. The results are being incorporated in Highways Agency guidance concerning traffic calming on trunk roads.

Related publications

TRL511 *The relationship between speed and accidents on rural single-carriageway roads* by M C Taylor, A Baruya and J V Kennedy. 2002 (price £25, code AX)

TRL421 *The effects of drivers’ speed on the frequency of road accidents* by M C Taylor, D A Lynam and A Baruya. 2000 (price £35, code H)

TRL385 *Traffic calming in villages on major roads: final report* by A H Wheeler and M C Taylor. 1999 (price £35, code H)

TRL245 *Using the TRL driving simulator to evaluate traffic calming measures* by C R Lockwood. 1997 (price £35, code H)

TRL212 *Traffic calming on major roads: the A49 trunk road at Craven Arms, Shropshire* by A H Wheeler, P G Abbott, N S Godfrey, D J Lawrence and S M Phillips. 1996 (price £50, code L)

TRL201 *Count-down signs and roundel markings trials* by J Barker and R D Helliar-Symons. 1997 (price £35, code J)

Prices current at June 2002

For further details of these and all other TRL publications, telephone Publication Sales on 01344 770783, or visit TRL on the Internet at www.trl.co.uk.