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TRAFFIC CALMING ON MAJOR ROADS: THE A49 TRUNK ROAD AT CRAVEN ARMS, SHROPSHIRE

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Project: **Traffic Calming On Major Roads (UG48)**

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CONTENTS

EXECUTIVE SUMMARY

A traffic calming scheme has been introduced on the A49 trunk road at Craven Arms in Shropshire. This forms part of a research project to assess the effectiveness of traffic calming measures at reducing the speed of traffic in villages and small communities on major roads.

The work follows on from the VIllage SPeed Control Working Group (VISP) study of traffic calming in villages. In this earlier study, a range of techniques was assessed, from gateway signing only, through measures both at the gateway and within the village (mainly signing and/or contrasting road surface treatments), to physical restrictions such as pinch points. The success of many of these schemes in reducing speeds was limited, especially those schemes lacking physical measures or any measures in the village itself.

Changes to legislation, together with special authorisation procedures, now enable local authorities to install a wide range of measures at localities which include, for example, villages on trunk and other major roads which carry high traffic flows. The aim of the current study is to assess the effectiveness of more comprehensive schemes intended to increase the likelihood of reducing 85th percentile speeds at least to the speed limit in the village, for example by the inclusion of physical measures. The assessment of other innovative techniques, and the study of the environmental effects of traffic calming measures will also be included.

The schemes that have been selected for study are in villages on routes with over 8000 vehicles per day and with heavy goods vehicles forming at least 10 per cent of the total. Initially, two sites have been chosen, one of which is Craven Arms, the subject of this report. The other is at Thorney on the A47 trunk road in Cambridgeshire, and is the subject of a separate report.

The scheme at Craven Arms was completed in May 1995 and a variety of measures was installed on the approaches and within the village. On each main road approach, 'count-down' signs and 'dragon teeth' markings were installed in advance of gateway features. The gateways comprise 30mph speed limit signing mounted above large village name-plates each side of the carriageway, together with an area of bright red surfacing with white edge markings and a painted '30' roundel.

In the village, the red patches and associated markings at the gateways were repeated at intervals in the outskirts of the village, and mini-roundabouts were installed at 4 junctions around the centre of the village. In the centre, a number of speed cushions, also coloured red, were installed between the mini-roundabouts. Centre hatching on a red background and pedestrian refuges completed the scheme, which had a high visual impact overall.

In addition to vehicle speeds and flows, the monitoring of journey times, traffic noise and ground vibration was undertaken, together with a survey of public opinions.

Mean and 85th percentile speeds fell by 8-9mph at the gateways, and reductions in the village ranged from 3-6mph in the outer parts of the village, to over 10mph (to below the speed limit) in the village centre, where the mini-roundabouts and speed cushions were installed. On average, vehicles took about half-a-minute longer to pass through the village.

Noise levels were measured at various sites adjacent to, and between, the speed cushions, at one of the gateways and at a site within the village away from any physical calming measures. The reductions in speed at the traffic calming measures resulted in reductions in maximum noise levels for both light and heavy vehicles. Generally the noise emission levels from vehicles travelling over the cushions were similar to the emission levels from vehicles travelling between the cushions when normalised for speed. However, noise emissions from heavy vehicles were higher at one cushion site near the exit from a mini-roundabout. Daytime traffic noise levels fell by 2 to 3 dB(A). Nighttime traffic noise levels were generally unchanged.

Measurements of ground-borne vibration induced by passing traffic were taken at a dwelling close to a pair of speed cushions, an example of a 'worst case' location. After the scheme was introduced, there was an increase in the peak levels of ground-borne vibration in the building structure near ground level. However, these levels were still well below the mean threshold level for human perception.

Public reaction to the scheme was rather unfavourable; two-thirds of residents who took part in the survey would have preferred a bypass. The mini-roundabouts were particularly disliked, mainly because main road drivers did not give way to traffic turning from their right. About half of residents perceived an increase in noise, though few blamed specific measures for this. A similar proportion thought speeds had not been reduced enough, in spite of the encouraging reductions in speed measured. On the other hand, over half of residents thought it was safer for pedestrians after implementation, and two-thirds thought the count-down signing and gateway features were useful.

The traffic calming scheme on the A49 at Craven Arms has been successful, in part of the village, in meeting the objective of reducing 85th percentile speeds to the 30mph speed limit, but rather less successful in terms of public acceptability. Detailed design changes might alleviate some of the problems mentioned by the residents. However, their reactions to the scheme highlight the dilemma for the traffic

calming engineer who is attempting to reduce accidents by measures that influence vehicle speed without causing unwanted safety and environmental side effects. The measures that are the most effective are generally the ones that have the most behavioural and environmental impact and are likely to be the most unpopular.

With regard to the impact of the traffic calming measures on vehicle noise and ground vibration, there is a discrepancy between the measured changes and the perceptions of residents which will be investigated in future studies.

Further speed measurements will be made at Craven Arms to assess the longer term impact of the scheme. The overall effect on injury accidents will be assessed when sufficient time has elapsed for a more comprehensive accident analysis to be carried out. The results of these surveys will be presented in an overall report of schemes included within this project.

TRAFFIC CALMING ON MAJOR ROADS: THE A49 TRUNK ROAD AT CRAVEN ARMS, SHROPSHIRE

ABSTRACT

Changes to legislation, together with special authorization procedures, now enable local authorities to install a wide range of traffic calming measures at localities including villages on trunk and other major roads. In 1994, research began on the effectiveness of these measures on busy roads with a significant proportion of heavy goods vehicles. Craven Arms, on the A49 trunk road in Shropshire, was one of two sites to be chosen initially for the study. The measures include gateways on each approach, with speed cushions, mini-roundabouts, painted 30mph roundels on patches of red surface at intervals, refuges and centre hatching on a red background in the village itself. 'Before' and 'after' measurements of speeds, journey times, traffic noise and ground vibration were carried out, followed by a public opinion survey. The results are presented in this report. Although speed reductions were substantial, many residents expressed reservations about the scheme.

1. INTRODUCTION

A traffic calming scheme has been introduced on the A49 trunk road at Craven Arms in Shropshire as part of a research project to assess the effectiveness of traffic calming measures at reducing the speed of traffic in villages and small communities on major roads.

The work follows on from previous studies of traffic calming in villages. In 1991 the Secretary of State for Transport announced a joint study, between the County Surveyors' Society, the DOT, and the Scottish and Welsh Offices, of ways to reduce speeds in villages. The VIllage SPeed Control Working Group (VISP) was established to undertake the study by investigating the costs, benefits and effectiveness of suitable speed reducing measures. TRL was commissioned by the DOT's Driver Information and Traffic Management (DITM) Division to provide the research input to VISP, under project UG25.

In the VISP study, villages distributed across Great Britain on a range of road types with different traffic levels, were selected for 'before' and 'after' monitoring of speeds and traffic flows. Measures ranged from gateway signing only, through measures both at the gateway and within the village (mainly signing and/or contrasting road surface treatments), to physical restrictions such as pinch points. The initial results, together with conclusions and recommendations, were published as an overview by the Working Group (County Surveyors' Society/Department of Transport, 1994), and in detail by TRL (Wheeler, Taylor and Barker, 1994). Long-term results, with an examination of injury accident occurrence, were included in Wheeler and Taylor (1995). Further sites in Devon and Gloucestershire, outside the VISP project, were also studied (Wheeler, Taylor and Payne, 1993).

These studies showed that measures could be installed which reduce vehicle speeds but that any reductions obtained are short lived if measures are modest (*e.g.* simple gateway signing/marking) or not repeated within the village. The speed reductions broadly mirrored the hierarchy of schemes; gateways comprising striking visual measures or physical measures produced greater benefits, further enhanced (10mph reduction or more in 85th percentile speed) when accompanied by repeated physical measures in the village. Measures such as these seem more likely to reduce 85th percentile speeds to the relevant speed limit.

Changes to legislation, together with special authorization procedures, now enable local authorities to install a wide range of measures at localities which include, for example, villages on trunk and other major roads which carry high traffic flows. In 1994, a new project was started to study the effectiveness of traffic calming measures in villages on busy routes (*e.g.* villages on routes with over 8000 vehicles per day and heavy vehicles forming at least 10 per cent of the total). The aim of this project is to study more comprehensive schemes intended to increase the likelihood of reducing 85th percentile speeds at least to the speed limit in the village, for example by the inclusion of physical measures. It is also intended to study other innovative techniques on these routes. Extensive monitoring at selected schemes is to be carried out: not only to assess the effect of schemes on speeds and traffic flows, but also to study the effect, particularly of physical measures, on traffic noise and ground vibration. Some opinion surveys will also be conducted.

Two schemes have initially been chosen for this study, of which one is Craven Arms, the subject of this report. The other is at Thorney on the A47 trunk road in Cambridgeshire, and is the subject of a separate report.

2. VILLAGE LOCATION AND CHARACTERISTICS

Craven Arms lies 10km northwest of Ludlow; the location of the village is shown in Fig 1. The A49 trunk road forms part of a route linking North West England with South Wales through the Welsh Marches. The population of Craven Arms was 1900 in 1991. Before traffic calming

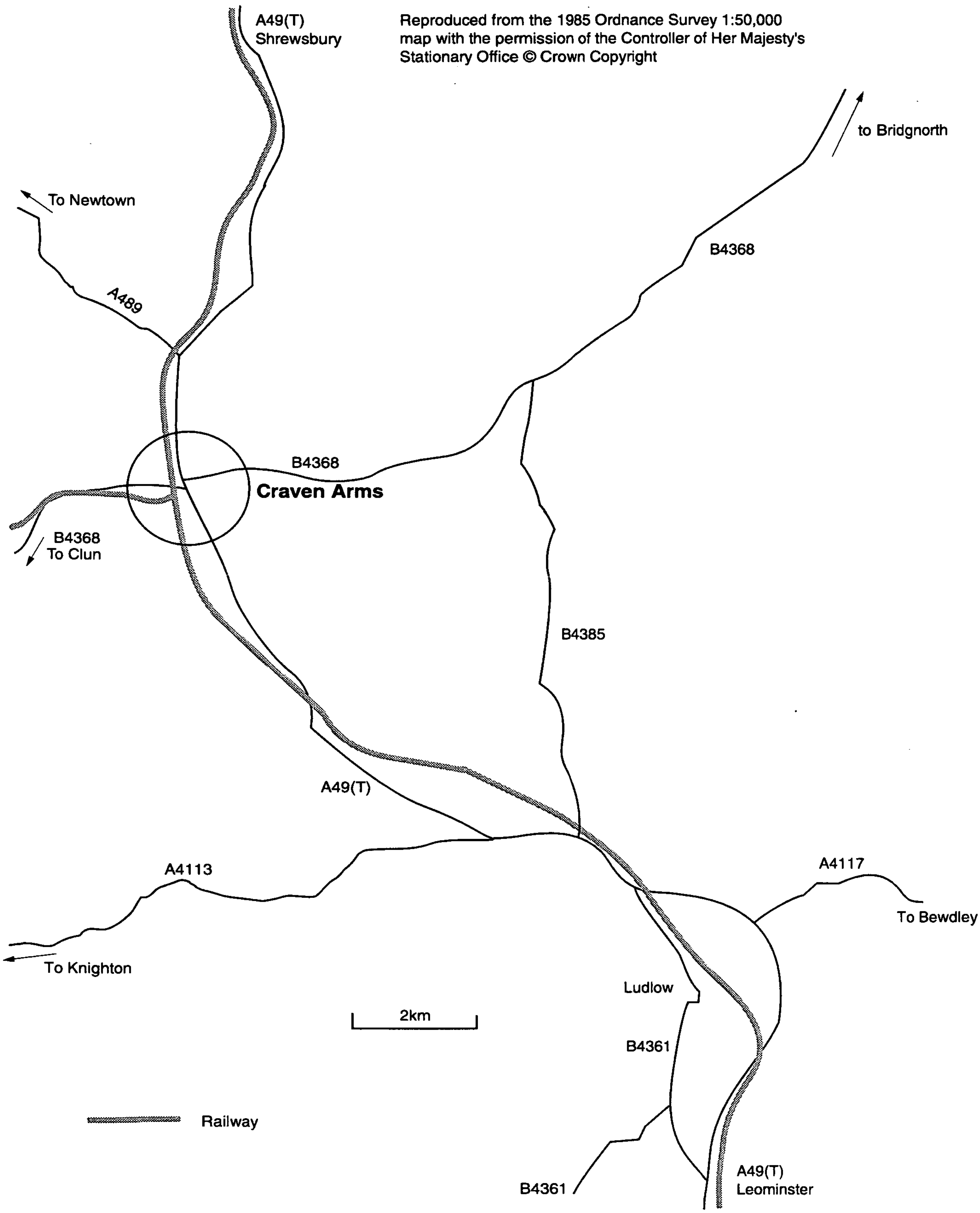

Fig. 1 Location plan for Craven Arms

measures were installed, there was a two-way mean traffic flow on the A49 through the village of about 9000 vehicles per day, of which 15% were heavy goods vehicles.

The A49 in the vicinity of Craven Arms is a two-lane single carriageway running north to south, and is subject to the national 60mph speed limit outside the village. Within the village, the current speed limit is 30mph, reduced from 40mph before scheme installation; the length of the speed limit, which coincides with the built-up area, is unaltered at 1160m.

Fig 2 shows six photographs of the A49 through Craven Arms taken prior to scheme installation. The southern approach to the village has a predominantly open aspect. It is at first undulating with a gently curved alignment, then the road straightens and runs with a downhill approach to the start of the village speed limit. In the centre section of the village, it has a curved alignment, and then the road straightens again as the northern exit to the village is approached. The northern approach is tree-lined giving it a less open aspect, and is very gently curved, straightening as the village speed limit is approached. Apart from the southern approach, the road is level throughout.

Through most of its length, the main road is built-up on both sides, but there is an open aspect with frontages mostly well away from the carriageway edge. There is a mixture of residential and commercial development, with a shopping centre including a supermarket in the centre of the village. The major junctions with the main road are in the village centre -the B4368 Clun Road and B4368 Corvedale Road. Elsewhere, there are several other junctions with residential roads, together with accesses to car parks, filling stations, the commercial premises and a livestock market. Street lighting is provided within the built-up area.

The carriageway width (unchanged on scheme installation) is mostly 7.3m, with a minimum width of 6.5m (about 170m inside the southern end of the speed limit) and exceeding 10m between the two junctions with the B4368.

As a result of an accident study carried out by Shropshire County Council, Craven Arms was found to have the highest number of accidents per year in Shropshire of any village on the A49 south of Shrewsbury (it is the largest settlement on this stretch of road). The first move was to reduce the speed limit through the village from 40mph to 30mph, though it was realised that this alone would have little effect without introducing other speed reducing measures. A bypass had been proposed as long ago as 1937, and in the Highways Agency's Roads Review announced in 1992, Craven Arms was included as a long term candidate for a bypass. There are difficulties, however, associated with this, as there is a railway on one side of the village and attractive countryside on the other. A traffic calming scheme was thus proposed as an interim solution.

3. THE MEASURES

Scheme installation took 8 weeks and was completed on 25 May 1995 at a contract cost of £80,000. It was intended to achieve a target 85th percentile speed of 30mph through the village. An earlier scheme proposal, retaining the original 40mph speed limit, comprised prominent signing and red surface treatment at the gateways, with 40mph roundels painted on areas of red surfacing repeated at intervals through the village. The residents, however, wanted a scheme which would allow a 30mph speed limit to be introduced; this led to additional measures being proposed. The locations of the measures relative to the village layout are shown in Fig 3, and an overall plan of the main road showing the measures in more detail is given at Fig 4. The measures comprise the following:

- gateway treatment at both ends of the village featuring prominent signing, additional markings and red surface treatment, with speed limit 'countdown' signs on the inbound approach to each gateway;
- areas of red surface treatment at regular intervals through the village, featuring painted '30' roundels;
- mini-roundabouts and speed cushions in the village centre;
- pedestrian refuges at intervals through the village;
- centre hatching on a red background through most of the village.

The countdown signs, the painted '30' roundels and the speed cushions required special authorisation from the DOT.

3.1 THE GATEWAYS

The measures associated with the gateways were installed in advance of, and at the start of, the 30mph speed limit. In the order encountered by *inbound* traffic, the measures comprise:

- countdown signs on the approach to the 30mph speed limit (Figs 5-7);
- a length of double broken white line, with red infill, just after the second countdown sign (Fig 8);
- 'dragon teeth' markings immediately in advance of the area of red surface treatment at the gateway (Figs 9 and 10);
- the red surfacing with a painted '30' roundel and edge markings, together with sign assemblies (30mph speed limit signing and village nameplates) erected on both sides of the carriageway (Figs 11 and 12).

(a) southern approach (cf Fig 8)

(b) site of the south gateway (cf Fig 9)

(c) site of mini-roundabout at junction with B4368 Clun Road in village centre (cf Fig 15)

(d) site of speed cushions and mini-roundabout at junction with B4368 Corvedale Road in village centre (cf Fig 16)

(e) in the north of the village, where centre hatching was laid (cf Fig 24)

(f) site of the north gateway (cf Fig 12)

Fig 2. Craven Arms before scheme installation

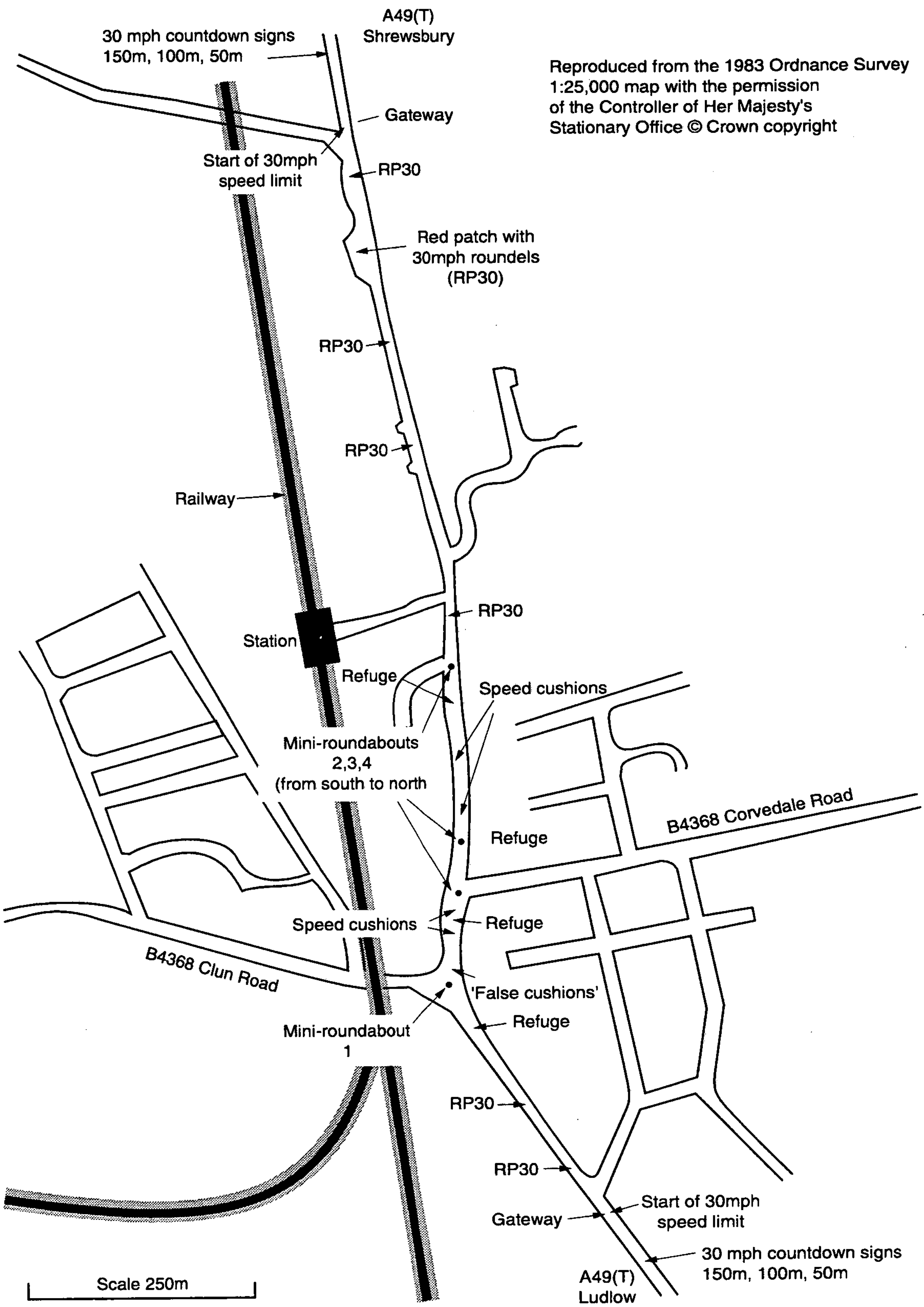

Fig. 3 Location plan of the measures

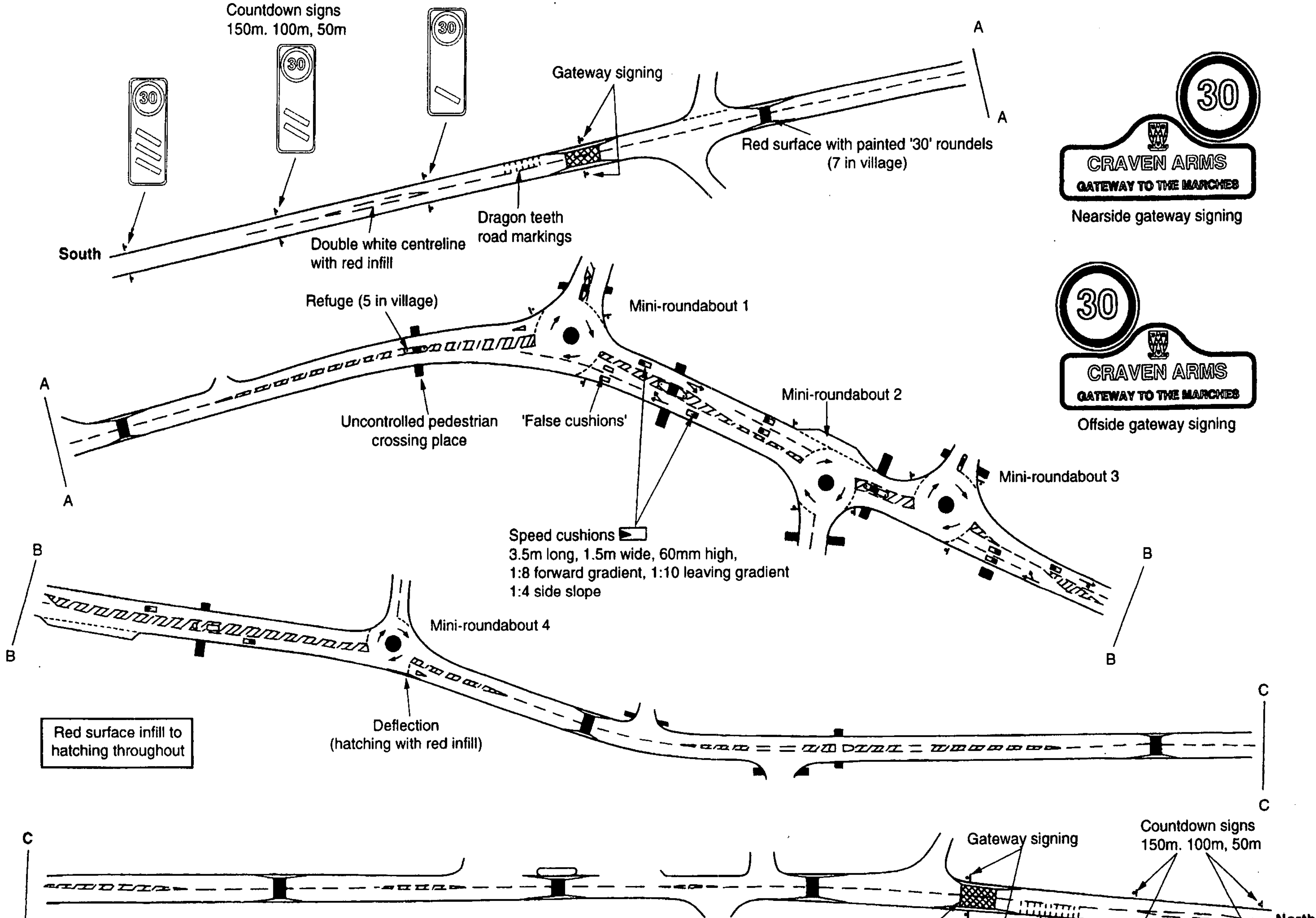

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Fig 4. The measures

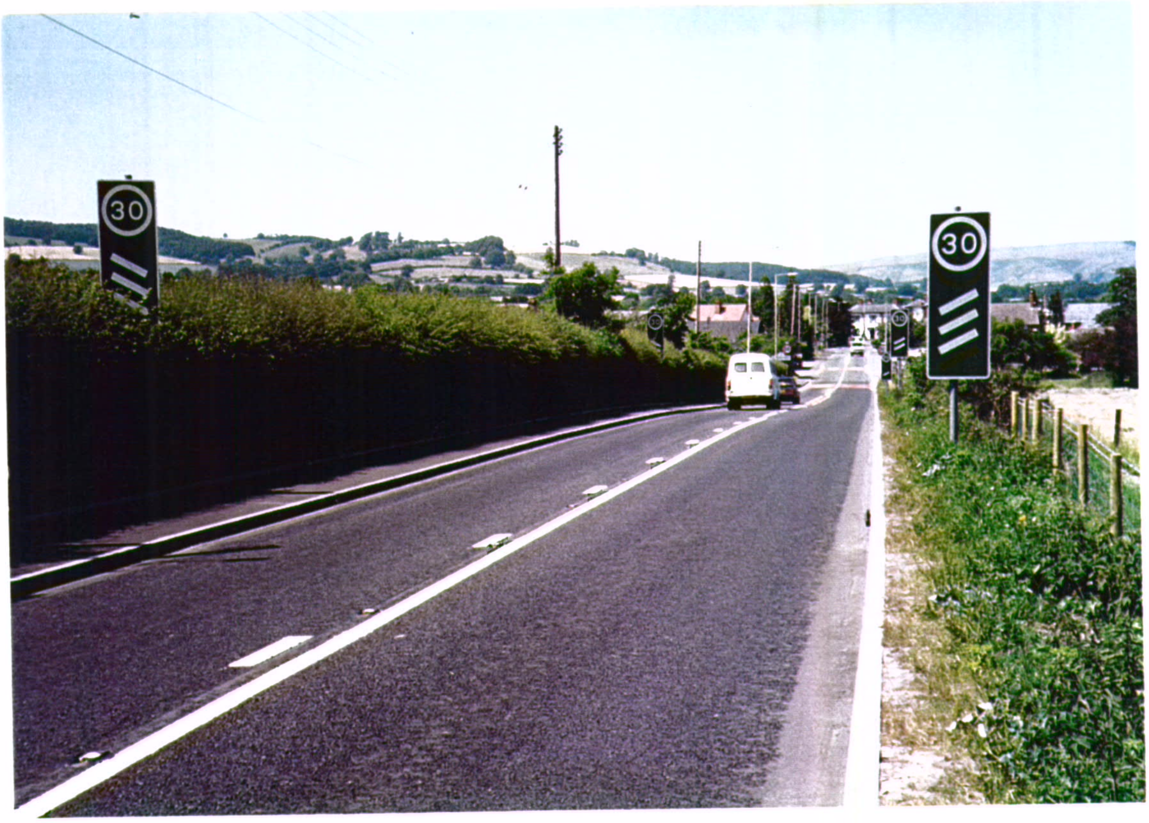


Fig 5. Countdown signs to the start of the 30mph speed limit at the south gateway (the pair illustrated are 150m from this speed limit)

Fig 6. The approach to the north gateway

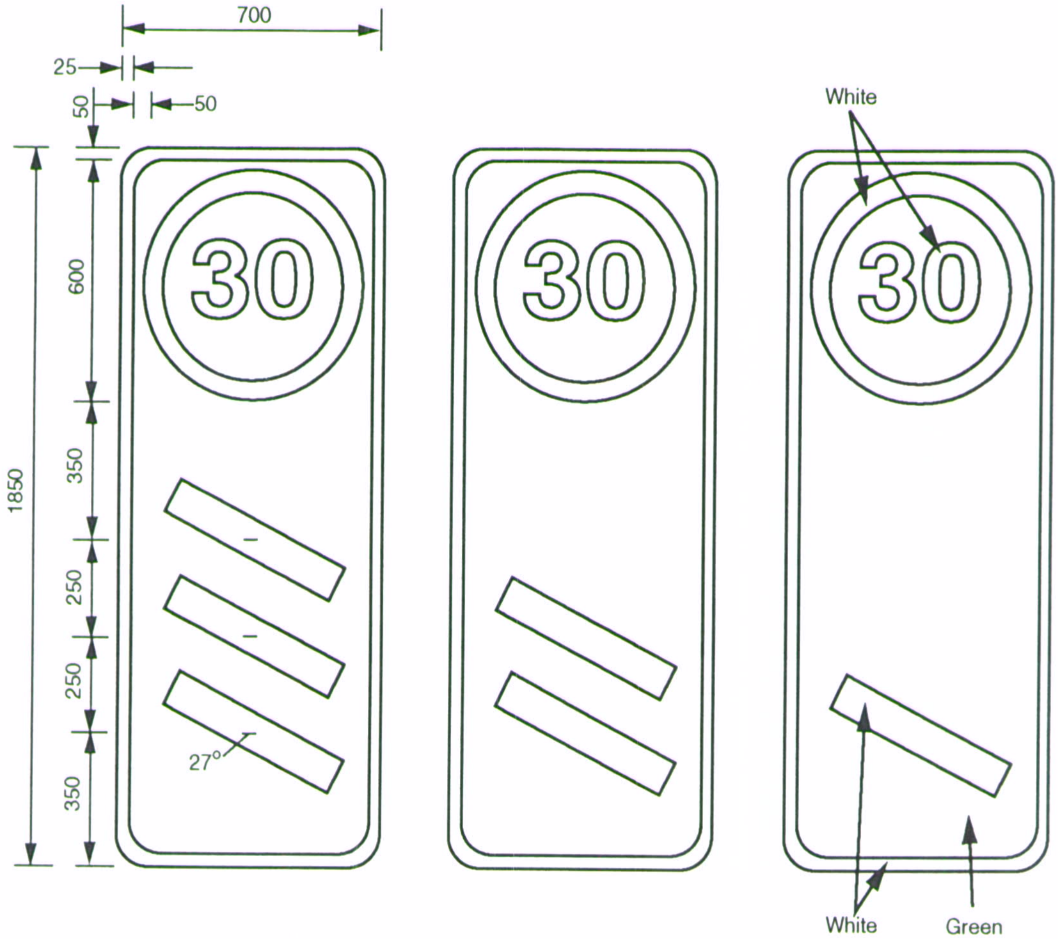


Fig. 7 Details of countdown signs
(all dimensions in mm)

Fig 8. Red-infilled double centreline terminating 50m from the start of the 30mph speed limit at the south gateway - the 'dragon teeth' markings can be seen in the distance immediately in advance of the red surfacing at the gateway

Fig 9. 'Dragon teeth' markings at the south gateway

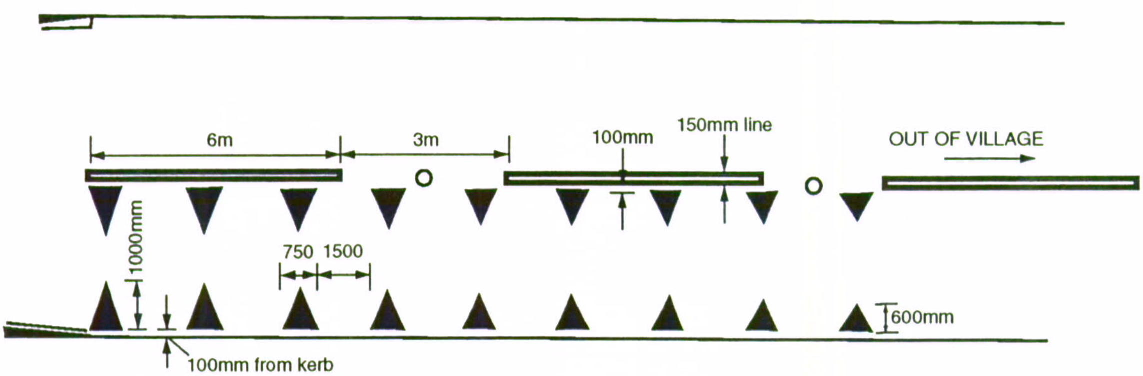


Fig. 10 Detail of 'dragon teeth' markings

Countdown signs have a long-established use on the approach to motorway off-slip roads and on dual-carriageway approaches to roundabouts. At Craven Arms, the signs provide an advance warning of the 30mph speed limit. Instead of their normal spacing of 300m, 200m and 100m on the nearside of the carriageway, they are installed at Craven Arms on *both* sides of the carriageway at 150m, 100m and 50m from the start of the 30mph speed limit. They respectively show three, two and one white diagonal marking(s) below a white speed limit roundel, all on a green background. The roundels are 600mm in diameter, on sign boards 1850mm high and 700mm wide; these and other dimensions are shown in Fig 7. Countdown signs to speed limits with the 100m spacing have been trialled elsewhere but had black symbols on a white background. The green background for the signs at Craven Arms reflect their use on a primary route.

The double broken white centreline just after the second pair of countdown signs comprises 2 parallel lines 150mm wide and 300mm apart, with red infill. This feature extends for 35m and ends in a tapering solid white line at the village end. At this point, white 'dragon teeth' markings (which required special authorisation by the DOT) are encountered; these extend to the start of the edge marking at the gateway itself, and are designed to convey a 'pinch' effect. These markings were first used in the VISP study, at Crimond, on the A952 trunk road in the Grampian Region of Scotland (County Surveyors' Society/Department of Transport, 1994; Department of Transport, 1994a; Wheeler,

Fig 11. *Textureflex* surface treatment at the south gateway and associated markings and signing; the first repeated red patch with 30mph roundels can be seen in the distance

Fig 12. North gateway

Taylor and Barker, 1994; Wheeler and Taylor, 1995). The triangular markings are based on those used on road humps, and their dimensions range from 600-1000mm wide, and 750mm long at the base. Nine pairs (each laid apex to apex) were installed 1500mm apart longitudinally (Fig 10). Going towards the village, the lateral distance between the apexes of each pair of triangles reduces from about 2000mm to 1000mm for the inner pair, to achieve the 'pinch' effect. Fig 8 shows how they appear from further away.

The red surfacing at the gateway (Figs 11 and 12) is 12m long and 6.5m wide, within a carriageway width of 7.3m; it has a white thermoplastic border 150mm wide on all sides, to further increase its visual impact. This surface treatment terminates at the gateway signing. The '30' roundel painted on the red background is 7.6m long and 1.475m wide in the inbound lane (Fig 13); this roundel provides extra emphasis to the start of the 30mph speed limit. On both sides of the carriageway, solid white edge markings extend 8m either side of the red surfacing. These markings are intended to visually narrow the carriageway - their width increases from 150mm at the ends to 300mm where they meet the leading and trailing edges of the red surfacing.

Textureflex was chosen for the red surfacing at the gateways (*e.g.* in Fig 11), the repeated red patches through the village (see Section 3.2 below), and as a background to the hatching. The orange-red colour used at Craven Arms has a high visual impact, and is fade-resistant by virtue of the natural colour of the aggregate. *Textureflex* consists of a blend of red chippings with a pigmented rosin-ester thermoplastic binder. These ingredients are pre-blended and bagged as a dry material for transhipment to site, where the mixture is heated and spread on the surface as a screed, typically 5mm thick with a texture depth of 1.5mm. The minimum skidding resistance of the material, measured with a pendulum skid tester, is 65. The aggregate has a minimum polished stone value of 62, with an aggregate abrasion value of 9. At Craven Arms, glass beads were incorporated into the mix to a proportion of 10% to give reflectivity at night.

Each sign assembly (Figs 4, 11-13) comprises an illuminated '30' roundel, of 750mm diameter, mounted above a village nameplate identical to that used prior to scheme installation. The nameplate has the legend CRAVEN ARMS, GATEWAY TO THE MARCHES in black lettering of 'x'-heights 125mm/75mm (Fig 13). The Shropshire county shield is positioned above the village name. The nameplate is of maximum height 750mm and width 1750mm. An illuminated derestriction plate is mounted on the back of the speed limit roundel.

3.2 REPEATED RED PATCHES WITH 30MPH ROUNDELS

The red surfacing and tapered edge markings of the gateways are repeated at 7 locations within the village except in the centre (Figs 3 and 4). There are 2 repeated red patches between the south gateway and the first mini-roundabout and 5 between the northernmost mini-roundabout and the north gateway. For inbound traffic, the first repeated red patch is 53m and 45m inside the south and north gateways respectively; their spacing then varies between 75m and 180m. They are of the same dimensions as at the main gateways except that the red surfacing extends for 8m instead of 12m (Figs 13 and 14). This surfacing again has a 150mm wide white border all round. Each feature has a painted '30' roundel 4.3m long and 1.475m wide in each lane; these were provided to encourage speeds to be kept down in advance of the features in the centre of the village.

3.3 MINI-ROUNDABOUTS

The mini-roundabouts were also installed to encourage speeds within the 30mph speed limit. No kerb works were necessary for their installation. Travelling northbound, they were installed at the following locations (see Fig 3):

1. at the junction with the B4368 Clun Road (Fig 15);
2. at the junction with the B4368 Corvedale Road (Fig 16);
3. at the access to the Craven Arms Centre car park (Fig 17);
4. at the junction with White Meadow Close, an access to a recent housing development (Fig 18).

The distances between the mini-roundabouts in the northbound direction were 91m, 40m and 178m. The first three mini-roundabouts have one two-lane approach to cater for traffic turning right off the main road. Blue mini-roundabout signing and roundabout 'give way' markings are provided at the intermediate mini-roundabouts ((2) and (3)), but at the first mini-roundabout to be encountered in both directions ((1) and (4)), the blue mini-roundabout sign is supplemented by a 'give way' sign and marking (Fig 15).

Each mini-roundabout has a flat painted central island 4m in diameter; the islands were deliberately flat to lessen the effect of body rattle from commercial vehicles. The islands are offset, providing deflection for northbound traffic at mini-roundabouts (1), (3) and (4) and for southbound traffic at mini-roundabout (2). On the immediate southbound approach to mini-roundabout (4), deflection is provided on the nearside by an area of hatching on a red background (length 20m, maximum width 1m) to reduce entry speeds (Fig 18).

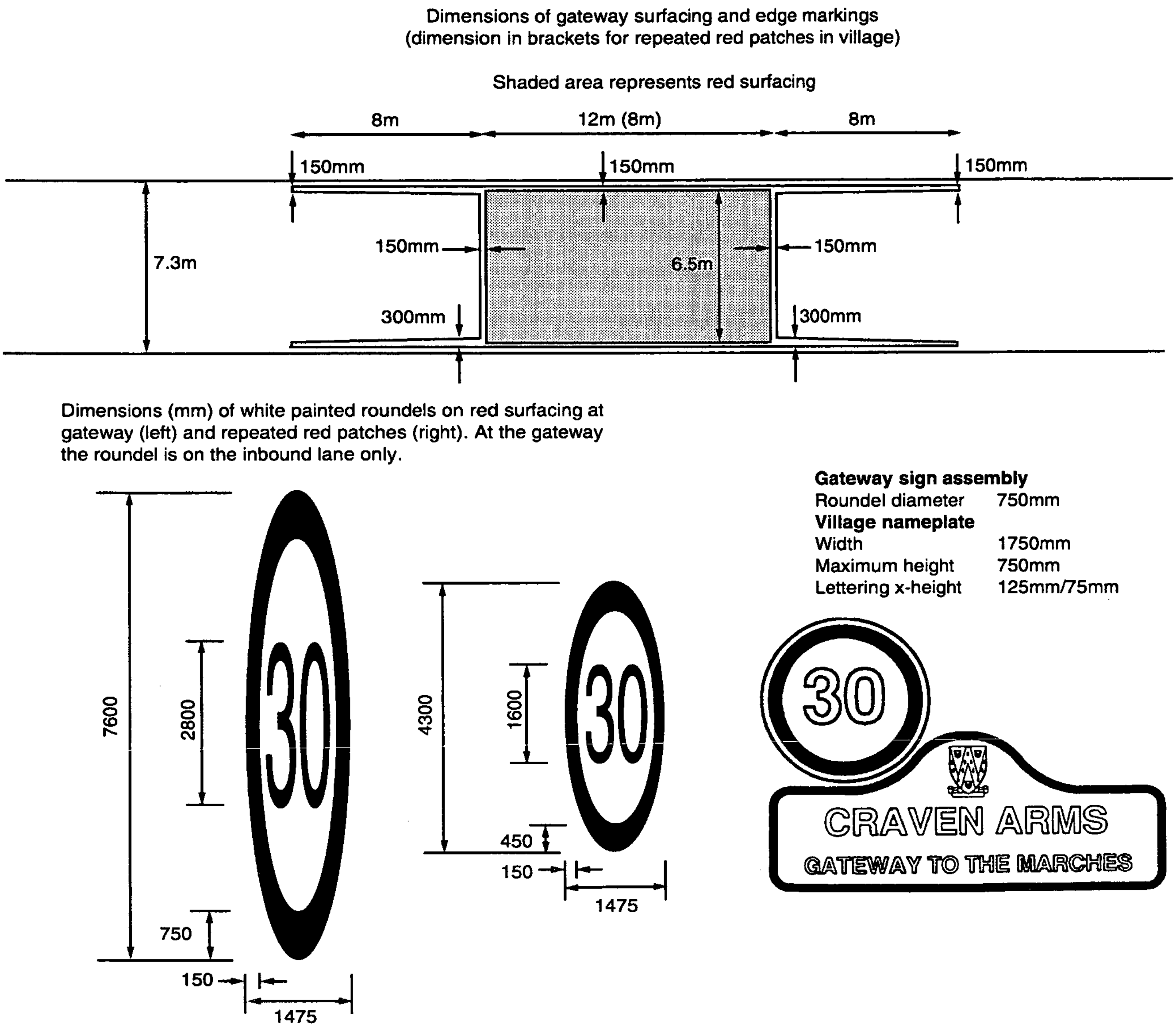


Fig. 13 Detail of gateway sign assemblies, together with the surface treatment and associated markings both at the gateways and repeated red patches in the village

3.4 SPEED CUSHIONS

The mini-roundabouts provide the necessary speed reducing measures required in advance of road humps in accordance with the Highways (Road Humps) Regulations (1990). The installation of speed cushions at Craven Arms, their first application on a trunk road, needed special authorisation from the DOT as the regulations did not permit humps on this class of road (Department of Transport, 1993). Standard road humps are unsuitable because of the relatively large proportion of HGVs, and the noise which could arise when these vehicles pass over the humps.

The cushions were installed between the more widely spaced mini-roundabouts in the following positions (see Fig 4):

northbound:

- between mini-roundabout (1) and a pedestrian refuge;
- 40m further on, two abreast, one in each lane of the two-lane approach to mini-roundabout (2) (Fig 16);
- two cushions 55m apart between mini-roundabouts (3) and (4), the second in advance of a pedestrian refuge;

southbound:

- between mini-roundabouts (4) and (3) - one on the approach to the pedestrian refuge mentioned above (Fig 19) and 110m further on, two abreast, one in each lane of the two-lane approach to mini-roundabout (3);
- one midway between mini-roundabouts (2) and (1).

Fig 14. Repeated red patch with 30mph roundels north of the village centre (looking north)

Fig 15. Mini-roundabout at the junction with the B4368 Clun Road, showing 'give way' signing and markings in addition to 'mini-roundabout' sign (looking north)

Fig 16. Speed cushions on the approach to the mini-roundabout at the junction with B4368 Corvedale Road, outside the supermarket in the village centre (looking north)

Fig 17. Mini-roundabout and pedestrian refuge outside the supermarket in the village centre, looking north (the refuge existed prior to scheme installation)

Fig 18. The northernmost mini-roundabout at the junction with White Meadow Close, showing nearside hatched deflection for oncoming traffic (looking north)

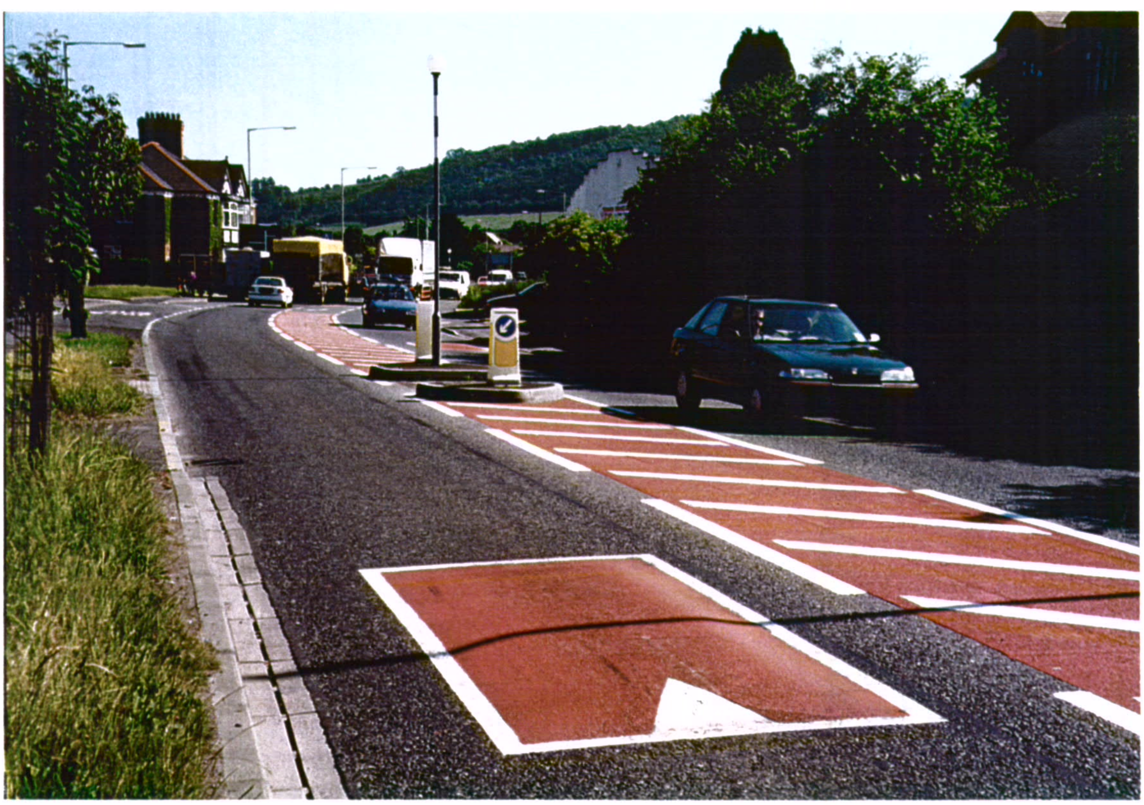


Fig 19. Speed cushion, pedestrian refuge and centre hatching just north of village centre (looking south); another cushion is just visible beyond refuge in opposite lane

The cushions are surfaced in red *Textureflex* material, are bordered by thermoplastic white screed 100mm wide, and have a white triangle in the same material on the leading slope. They are 3.5m long, 1.5m wide and 60mm high, and have a 1:8 forward gradient, 1:10 leaving gradient and a 1:4 side slope (Fig 20). These dimensions were chosen to minimise any physical effect on large vehicles, and so reduce the likelihood of increased vehicle noise occurring. Fig 21 shows a cushion being crossed by a car and an HGV. The design of the cushions is in accordance with generally agreed parameters, and reflects the latest findings of the current research into these devices (Department of Transport, 1994b; Layfield, 1994; Abbott *et al*, 1995b).

On the southbound 2-lane approach to mini-roundabout (1), a pair of 'false' cushions, one in each lane, was installed just in advance of the 'give way' markings (Fig 22). They are of identical horizontal dimensions and colour to the other cushions, but are flat. They were intended to convey the appearance of conventional cushions to encourage drivers to reduce their speed and perhaps reduce any reluctance to give way at the mini-roundabout which has no deflection in this direction. The decision to use 'false' cushions came late in the planning and implementation of the scheme and their effect on traffic behaviour was not specifically monitored.

3.5 PEDESTRIAN REFUGES AND CENTRE HATCHING

Three pedestrian refuges were installed in the following positions, shown in Fig 4 (travelling northbound):

1. between the second repeated red patch (see Section 3.2) and mini-roundabout (1);

2. between mini-roundabouts (3) and (4);

3. between the first and second repeated red patch after mini-roundabout (4).

Two more refuges, between mini-roundabouts (1) and (2) and between (2) and (3), existed prior to scheme installation. Each of the five installations consists of a pair of bollarded islands, one with a beacon.

The new refuges, one of which is shown in Fig 23, have a maximum width of 1.8m, providing a minimum lane width of 3.25m. Beige tactile paving was installed on the footway opposite each refuge and between each refuge island comprising the pair. The pre-existing refuges have a maximum width of about 2m and 3m.

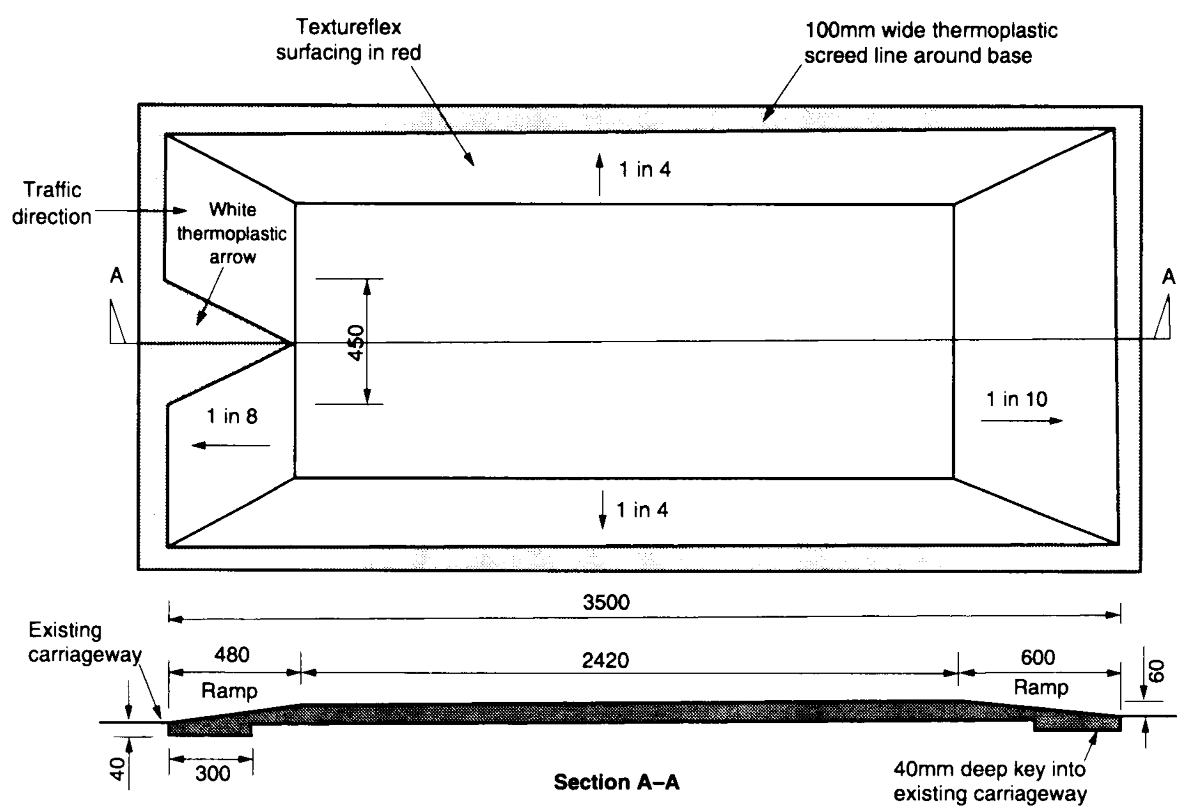


Fig 20. Detail of speed cushion installed in Craven Arms (all dimensions in mm)

Fig 21. One of a pair of speed cushions on the northbound approach to the mini-roundabout junction with B4368 Corvedale Road, outside the supermarket (looking north)

Fig 22. 'False speed cushions' (which are flat) on southbound approach to mini -roundabout junction with B4368 Clun Road, looking north (the refuge in the background existed prior to scheme installation)

Fig 23. Pedestrian refuge and associated tactile paving on the footway and between the islands in the northern part of the village (looking south); the sign on the left gives advance warning of a requirement to give way at the White Meadow Close mini-roundabout

The centre hatching with the red infill extends between the refuges, the repeated red patches and mini-roundabouts, and is intended to provide some horizontal deflection and improved driver discipline. A typical stretch of this hatching is shown in Fig 24. In the centre of the village, between the repeated red patches nearest to the first and last mini-roundabouts, the hatching is almost unbroken and is of greater width (up to 3m or 4m). Elsewhere, shorter, narrower stretches were laid.

4. SCHEME MONITORING

Monitoring of the scheme's effectiveness was carried out through 'before' and 'after' observations of the following:

1. traffic flows;
2. vehicle speeds;
3. vehicle journey times through the village;
4. traffic noise;
5. ground vibration.

A survey of public opinions on the scheme was also carried out after time had been allowed for residents to get accustomed to the measures. Accident data and information on emergency services' reactions were also obtained.

The data collection procedures and results are described in the following sub-sections.

4.1 TRAFFIC FLOWS

4.1.1 Data collection

Traffic flows were recorded before, and three weeks after, scheme installation on both approaches and at one position within the village.

On the village approaches, unclassified flows were recorded in each direction at the gateway sites. The flows were measured over a one week period with automatic data loggers (which also recorded speeds) using loop detectors.

On one day before and after scheme installation, a manual classified 12 hour count in each direction was carried out at a position (shown in Fig 25) between the village centre and

Fig 24. Centre hatching with red *Textureflex* infill in north of village (looking north); a repeated red patch is just visible in the distance

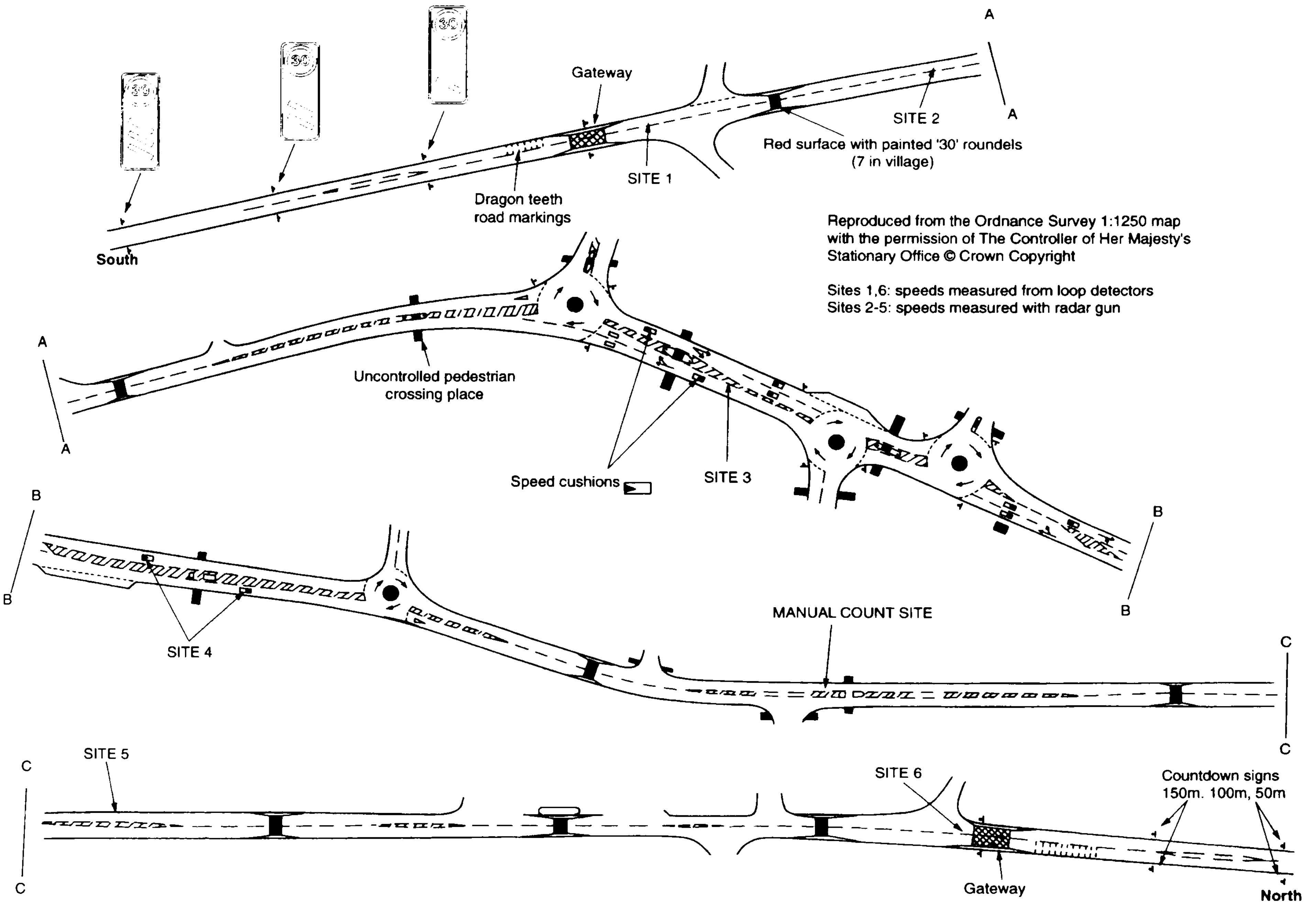


Fig 25. Positions for speed monitoring and manual traffic count

the north gateway between 0700 and 1900; the vehicle classifications were:

- cars;
- light goods vehicles;
- heavy goods vehicles (>1.5 tonne, 2+ axles, vans with twin-rear wheels);
- fire appliances;
- ambulances;
- minibuses;
- buses/coaches;
- pedal cycles;
- motorcycles.

This classification enabled the identification of the number of vehicles for which road humps in general have been a sensitive issue, for example emergency vehicles, buses and two-wheelers.

The dates of the counts were as follows:

Before scheme installation

automatic count:	15-21 November 1994;
manual classified count:	17 November 1994.

After scheme installation

automatic count:	15-21 July 1995;
manual classified count:	18 July 1995.

4.1.2 Results

At the south gateway, the mean two-way traffic flow over 7 days increased from 8100 vehicles/day in November 1994 to 9900 vehicles/day in July 1995, a change of 22%. At the north gateway, the corresponding two-way flows were 9200 and 11,000, an increase of 19% (Table 1). The largest changes occurred at the weekend, when 'before'/'after' increases exceeded 30%, though 'after' two-way flows were still slightly below those during weekdays. Friday was the busiest day of the week, when the 'after' two-way flow approached 12,000 at the south gateway and exceeded 13,000 at the north gateway. The two-way traffic flow on a Friday increased by up to 24% compared to 15% during Monday-Thursday. All of these changes were probably due to seasonal fluctuation between the November and July monitoring periods. The national increase in the mean daily two-way flow over 7 days between the same months on non built-up major roads is about 20%, based on data collected for the National Road Traffic Survey over the period 1990-1994 (Department of Transport, 1995a).

The difference in flow between gateways is likely to be due to traffic movements to and from the B4368 and other points within Craven Arms.

The 12 hour manual two-way counts classified by vehicle type are shown in Table 2. These counts were in fact higher than the automatic counts at the gateways for the same periods. Possibly vehicles not passing the gateways were being counted, for example, those making journeys between points within Craven Arms or to/from the B4368.

Light vehicles include cars, light goods vehicles (LGVs), motorcycles, ambulances and minibuses; heavy vehicles are HGVs, buses and fire appliances. The proportions of light and heavy vehicles were respectively 83.5% and 16.1% in the 'before' period and 85.0% and 14.5% in the 'after' period. Although this appears to represent a small

TABLE 1

'Before' and 'after' two-way traffic flows at gateway sites (all vehicles)

Location and period	24 hour flow Before 11.94	24 hour flow After 7.95	Change
South gateway			
7 day	8113	9869	+22%
weekday	8621	10083	+17%
weekend	6845	9335	+36%
Monday-Thursday	8394	9657	+15%
Friday	9530	11788	+24%
North gateway			
7 day	9238	11001	+19%
weekday	9717	11212	+15%
weekend	8038	10475	+30%
Monday-Thursday	9400	10680	+14%
Friday	10988	13340	+21%

TABLE 2

Flow composition (12 hour manual count to north of Craven Arms centre)

	Before (17.11.94)		After (18.7.95)	
	Two-way	Percentage	Two-way	Percentage
Pedal cycles	43	0.4	55	0.5
Motorcycles	35	0.3	65	0.6
Cars	6927	69.2	7268	69.9
LGVs	1331	13.3	1462	14.1
HGVs	1563	15.6	1435	13.8
Buses	47	0.5	74	0.7
Fire appliances	0	0.0	0	0.0
Ambulances	17	0.2	12	0.1
Minibuses	46	0.5	27	0.3
Totals	10009	100	10398	100

decrease in the proportion of heavy vehicle traffic since the scheme was implemented, this change is likely to be due to seasonal fluctuations in the numbers of light and heavy vehicles. National statistics show that there are fewer light vehicles relative to heavy vehicles in November, the month of the 'before' count, than in July (Department of Transport, 1995a).

Emergency vehicles, two-wheelers and buses (specifically counted because speed cushions were included in the scheme) made up only about 2% of vehicles during both monitoring periods.

It would seem therefore that the traffic calming scheme has not substantially affected the overall flow of traffic through Craven Arms, or the number of HGVs.

4.2 VEHICLE SPEEDS

4.2.1 Data collection

Speed monitoring (both directions) was carried out at 6 positions (Fig 25) - just inside each gateway (by automatic speed measurement) and at 4 positions in the village (using radar guns). 'After' monitoring began about 3 weeks after scheme implementation.

The monitoring positions were:

southern approach: just inside the gateway, *i.e.* just inside the 30mph speed limit (site 1);

within village: midway between the first and second repeated red patch, 105m inside the southern gateway (site 2);

between the mini-roundabouts at the junctions with the B4368; *northbound:* midway between a single and a pair† of speed cushions; *southbound:* in advance of a single speed cushion (site 3);

at the speed cushions south of the mini-roundabout at the junction with White Meadows Close (site 4);

midway between the third and fourth repeated red patches, 270m inside the northern gateway (site 5).

northern approach: just inside the gateway, *i.e.* just inside the 30mph speed limit (site 6).

† as there is a straight-ahead lane and a right-turning lane (in advance of the mini-roundabout at the junction with the B4368 Corvedale Road) at this point, only the speeds of vehicles going ahead were recorded.

The radar speed monitoring was carried out as far as possible in off-peak periods for free-flowing vehicles. At each position, the speeds of 100 light vehicles and 100 HGVs were collected on *three* successive Tuesdays and Wednesdays respectively during the 'before' period. This method ensured that the data would be more robust by allowing for week to week variability. During the 'after' period, the same procedure was followed, except that monitoring was carried out on *two* successive Tuesdays and Wednesdays.

The monitoring dates were as follows:

Before scheme installation

Gateways (sites 1 and 6):	15-21 November 1994 (all vehicles);
Within village (sites 2-5):	15, 22, 29 November 1994* (light vehicles);
	16, 23, 30 November 1994 (HGVs).

*12 December 1994 instead of 29 November at site 2.

After scheme installation

Gateways (sites 1 and 6):	15-21 July 1995 (all vehicles);
Within village (sites 2-5):	27 June and 4 July 1995 (light vehicles, sites 3 and 4 only);
	12 and 19 September 1995 (light vehicles, sites 2 and 5 only);
	28 June and 5 July 1995 (HGVs, sites 2-5).

The weather was fair on all monitoring days except on 12 December 1994, when it was wet, though this appeared to have a negligible effect on speeds. As a precaution, 'after' monitoring was repeated at sites 2 and 5 in September 1995 because of a larger than expected difference (5mph) between the means of the first and second samples collected at site 5 in July. (Monitoring was repeated at site 2 as a check.)

At the gateways, 7 complete days of data were collected. Speeds of all vehicles (unclassified by type) in each direction were recorded. From these data, mean and 85th percentile speeds were calculated for the following:

seven days;
Monday to Friday;
Saturday and Sunday;
daytime (0700-1900);
nighttime (1900-0700).

4.2.2 Results

4.2.2.1 Speed changes on the village approaches

Table 3 shows 'before' and 'after' mean and 85th percentile speeds just inside the gateway for inbound and outbound traffic. These speeds are shown for 7 day, weekday and weekend periods, together with speeds for daytime (0700-1900) and nighttime (1900-0700) periods over 7 days.

At both gateways before scheme installation, the mean and 85th percentile speeds in both directions were in the range 40-42mph and 48-49mph respectively.

Every 'before'/'after' change in mean speed shown in Table 3 was statistically significant at at least the 0.1% level (using the two tailed t-test). The overall (7 day) mean speed of inbound traffic was reduced by about 8.5mph at both gateways. The mean speed of outbound traffic fell by almost as much - within 2mph of the reduction for inbound traffic. 'Before' mean speeds and 'before'/'after' changes were up to 2mph higher at the weekend than on weekdays; weekend speed reductions for inbound traffic exceeded 9mph, with the result that weekend 'after' speeds were similar to those during weekdays (33-34mph). Inbound nighttime (1900-0700) mean speeds were up to 5mph higher (45mph) than daytime (0700-1900) speeds during the 'before' period, but they still fell by 8-9mph, suggesting that the gateways were at least as effective at night as during the day. Outbound mean speeds in all categories fell slightly less than inbound speeds, but the majority of the reductions were still at least 6mph.

At both gateways, inbound 85th percentile speeds over the 7 day period fell by at least 9mph. Again, the 85th percentile speed of outbound traffic decreased by nearly as much, by 9mph and 7.5mph at the north and south gateways respectively. 'Before' speeds and speed changes were again up to 2mph higher at the weekend than on weekdays; weekend reductions were 10mph for inbound traffic, so that weekday and weekend 85th percentile speeds after scheme installation were similar to each other (39-40mph). As with inbound mean speeds, nighttime 85th percentile speeds were up to 5mph higher (53mph) than daytime speeds during the 'before' period, but again, reductions of 8-9mph were achieved. Outbound speeds in all categories fell slightly less than inbound speeds, but reductions still exceeded 7mph.

4.2.2.2 Speed changes within the village

Table 4 shows the 'before' and 'after' mean and 85th percentile speeds within the village for light vehicles and HGVs in each direction. These speeds were calculated for the 3 'before' and the 2 'after' samples of 100 combined.

Speeds were reduced at all four monitoring positions, and every change in mean speed was statistically significant at at least the 0.1% level (using the two tailed t-test).

At site 2, between the first and second repeated red patch inside the south gateway, mean speed reductions tended to be the smallest of those achieved at the monitoring positions within the village. The mean speed of light vehicles decreased by 3-5mph. There appeared to be a greater effect

TABLE 3

Craven Arms: speeds at the gateways (mph)

Location and direction	Mean speed Before	Mean speed After	Mean speed Change	85th percentile speed Before	85th percentile speed After	85th percentile speed Change	Number of observations Before	Number of observations After
South gateway (site 1)								
Northbound/inbound								
7 days	41.6	33.1	- 8.5	49.4	40.4	- 9.0	28299	34292
weekdays	41.2	33.0	- 7.8	49.1	40.3	- 8.8	21495	25050
weekend	42.8	33.3	- 9.5	50.4	40.5	- 9.9	6804	9242
daytime[1]	40.9	32.2	- 8.7	48.7	39.0	- 9.7	23845	28201
nighttime[2]	44.9	37.1	- 7.8	53.1	45.2	- 7.9	4454	6091
Southbound/outbound								
7 days	40.4	34.0	- 6.4	47.8	40.3	- 7.5	28495	34792
weekdays	39.8	33.9	- 5.9	47.2	40.2	- 7.0	21609	25365
weekend	42.1	34.3	- 5.8	49.3	40.5	- 8.8	6886	9427
daytime[1]	40.1	33.6	- 6.5	47.4	39.5	- 7.9	24156	28790
nighttime[2]	42.0	36.1	- 5.9	50.5	43.4	- 7.1	4337	6002
North gateway (site 6)								
Southbound/inbound								
7 days	41.0	32.6	- 8.4	48.5	38.9	- 9.6	32539	38858
weekdays	40.3	32.2	- 8.1	47.8	38.6	- 9.2	24417	28163
weekend	43.3	33.6	- 9.7	50.1	39.7	-10.4	8122	10695
daytime[1]	40.2	31.7	- 8.5	47.5	37.8	- 9.7	27422	31915
nighttime[2]	45.5	36.3	- 9.2	52.8	43.2	- 9.6	5115	6943
Northbound/outbound								
7 days	42.0	34.4	- 7.6	48.3	39.4	- 8.9	32094	38160
weekdays	41.6	34.4	- 7.2	47.8	39.4	- 8.4	24140	27896
weekend	43.3	34.5	- 8.8	49.6	39.5	-10.1	7954	10264
daytime[1]	41.4	33.7	- 7.7	47.5	38.4	- 9.1	27126	31552
nighttime[2]	45.3	37.6	- 7.7	52.2	43.7	- 8.5	4966	6608

Notes: [1]daytime: 07h-19h; [2]nighttime: 19h-07h.
All changes in mean speed statistically significant at at least the 0.1% level

on HGVs, which were travelling at similar speeds to light vehicles in the 'before' period, their mean speeds falling by over 6mph.

The reductions in 85th percentile speeds at site 2 were similar to those for mean speeds. As with mean speeds, the 'before' 85th percentile speeds of light and heavy vehicles were similar to each other, at about 40mph. Reductions for light vehicles were again 3-5mph, and those for HGVs were about 7mph.

At site 3, between the speed cushions between the mini-roundabouts at the junctions with the B4368, the 'before' mean speeds of light vehicles and HGVs were both fairly low at about 28mph. At this location, 'before' mean speeds were probably constrained by the proximity of a bend at the junction with the B4368 Clun Road (see Fig 25). Notwithstanding this, the largest reductions in the village were achieved at this location, to below 20mph. The mean speeds of light vehicles fell by 9-10mph and those of HGVs fell by 11-12mph.

The 85th percentile speeds of light vehicles and HGVs at site 3 fell by 10-11mph and 12mph respectively, from 32-33mph during the 'before' period.

The speed reductions at site 3 might have been greater still if the central islands of the mini-roundabouts had been domed, so that vehicles would deflect around them instead of having a tendency to overrun them.

At site 4, at the most northerly speed cushions (where speeds of vehicles crossing the cushions were recorded), there were reductions of 7-8mph and 6-8mph respectively

TABLE 4

Craven Arms: speeds in the village (mph)

Location and direction	Mean speed Before	After	Change	85th percentile speed Before	After	Change
Site 2 (between repeated red patches in south of village)						
Northbound (light)	35.0	30.2	- 4.8	39.7	34.9	- 4.8
Southbound (light)	36.1	32.9	- 3.2	40.7	37.6	- 3.1
Northbound (heavy)	35.5	28.9	- 6.6	39.6	32.2	- 7.4
Southbound (heavy)	35.6	29.1	- 6.5	39.8	33.1	- 6.7
Site 3 (between speed cushions and mini-roundabouts outside supermarket)						
Northbound (light)	27.5	18.5	- 9.0	32.5	22.3	-10.2
Southbound (light)	28.5	18.7	- 9.8	33.3	22.3	-11.0
Northbound (heavy)	27.6	16.0	-11.6	32.0	19.5	-12.5
Southbound (heavy)	28.2	17.3	-10.9	32.4	20.6	-11.8
Site 4 (on the most northerly speed cushion)						
Northbound (light)	33.5	26.3	- 7.2	38.0	30.3	- 7.3
Southbound (light)	34.3	26.0	- 8.3	39.5	30.0	- 9.5
Northbound (heavy)	31.8	23.8	- 8.0	36.3	27.2	- 9.1
Southbound (heavy)	30.9	24.9	- 6.0	35.0	28.4	- 6.6
Site 5 (between repeated red patches in north of village)						
Northbound (light)	38.8	33.1	- 5.7	43.7	37.9	- 5.8
Southbound (light)	38.2	33.5	- 4.7	42.7	38.1	- 4.6
Northbound (heavy)	36.9	29.0	- 7.9	40.3	33.6	- 6.7
Southbound (heavy)	36.6	28.9	- 7.7	40.3	33.4	- 6.9

Number of observations at each site: 'before': 300; 'after': 200 (see text)
All changes in mean speed statistically significant at at least the 0.1% level

in the mean speed of light vehicles and HGVs, from 31-34mph. The mean crossing speeds were down to 26mph and 24-25mph respectively.

Eighty-fifth percentile speeds at site 4 fell by 7-9mph for both light vehicles and HGVs from 38-39mph and 35-36mph respectively. The 85th percentile crossing speeds on the cushions at this location were thus reduced to 30mph for light vehicles and 27-28mph for HGVs.

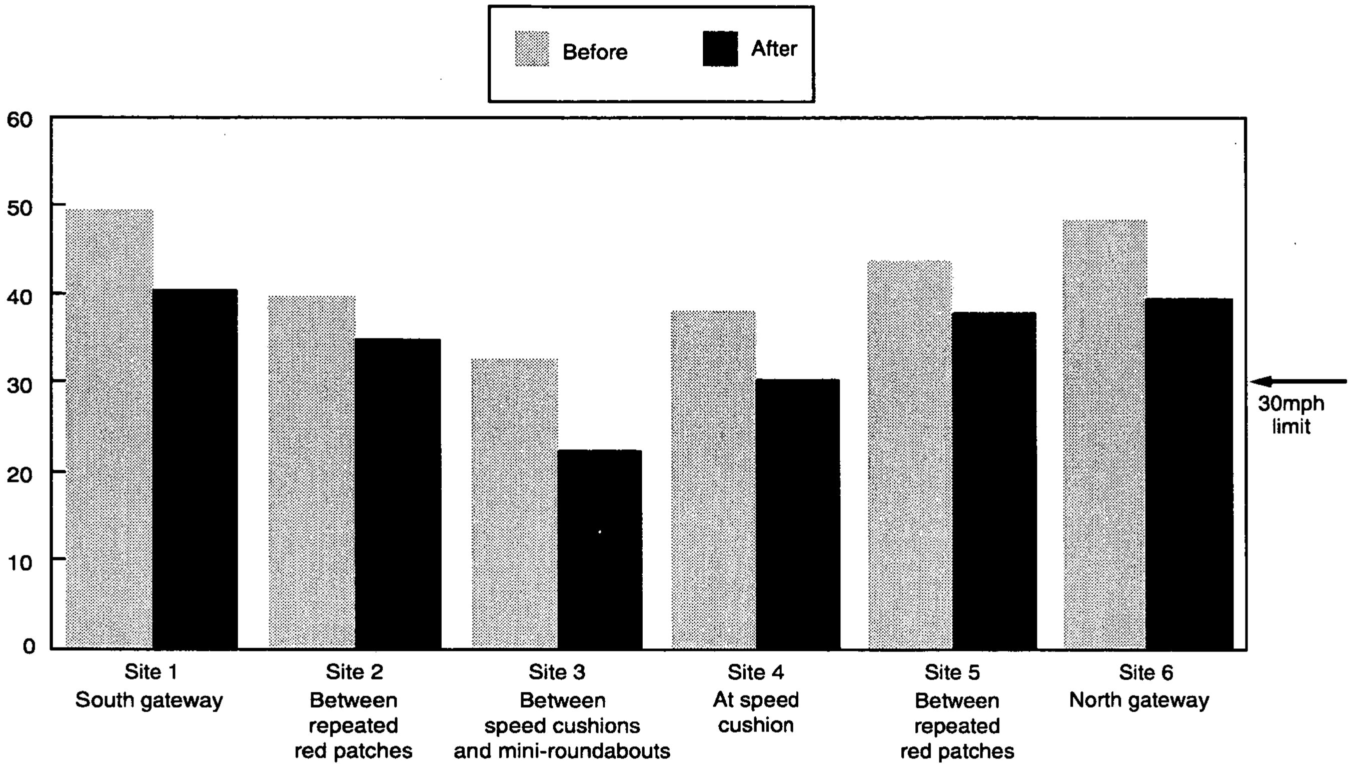
At site 5, between the third and fourth repeated red patch from the north gateway, and roughly midway between this gateway and the most northerly mini-roundabout, reductions in mean speed were 5-6mph for light vehicles and 8mph for HGVs, from 37-39mph. Therefore, the effect on HGVs was greater than for light vehicles, as at site 2.

The reductions in 85th percentile speeds at site 5 were similar to those for the mean speeds, at 5-6mph (from 43-44mph) for light vehicles and 7mph (from 40mph) for HGVs. Therefore, the effect on the 85th percentile speeds of HGVs was again greater than for light vehicles, as at site 2.

4.2.2.3 Speed profile through the village

Fig 26 shows graphically the 85th percentile speed changes in each direction of travel at all 6 monitoring positions, and shows that changes were similar in each direction. It should be noted that the 85th percentile speeds at sites 1 and 6 and those at sites 2-5 are not directly comparable, because of the collection of data at sites 1 and 6 by automatic data logger for *all* vehicles, and elsewhere by radar gun for *light vehicles only.*

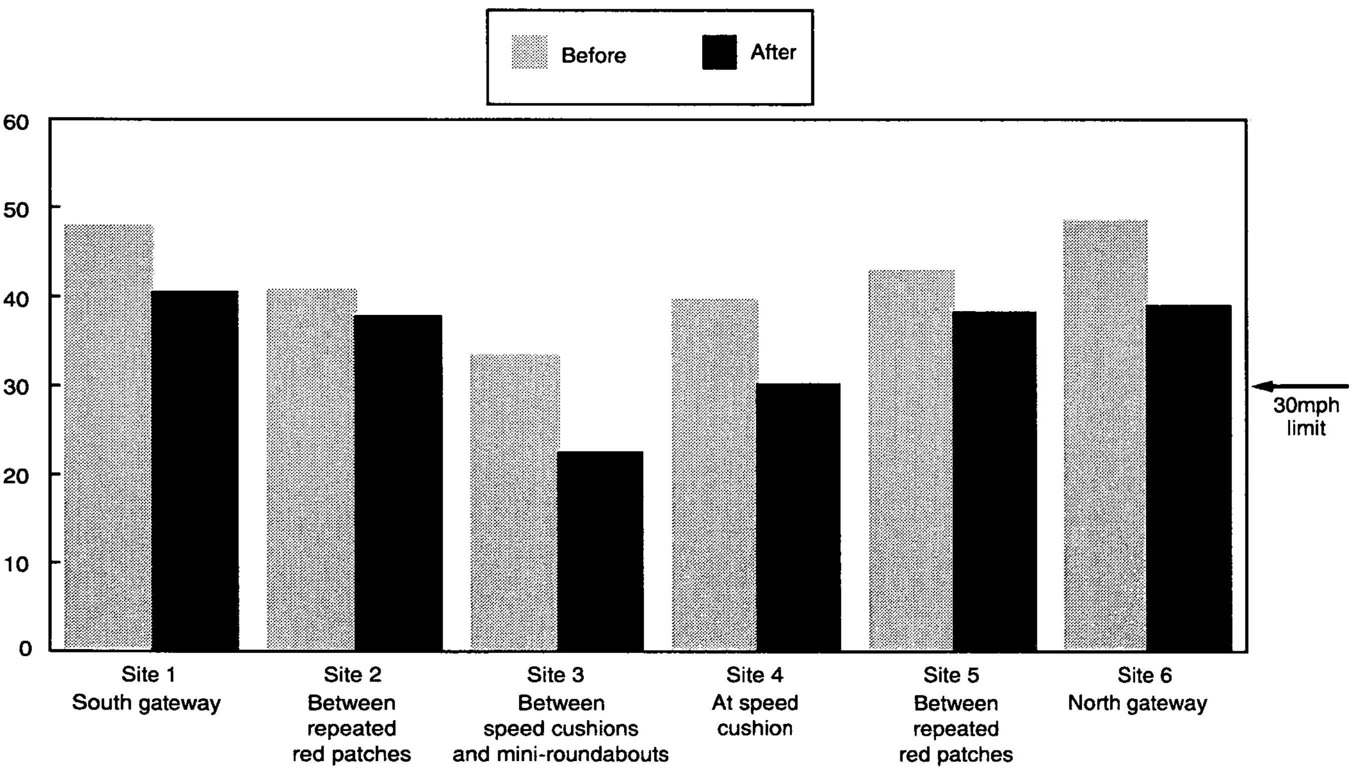
Fig 26 demonstrates that overall, with reductions of up to 12mph, the target 85th percentile speed of 30mph or below was achieved at the two monitoring positions near the centre of Craven Arms (*i.e.* sites 3 and 4 between the first and last mini-roundabouts). At the monitoring positions nearer to the gateways (sites 2 and 5), however, a further reduction of 5-8mph for light vehicles and 2-4mph for HGVs would be required, in addition to the existing reductions, to achieve this.



*7-day speeds of ALL vehicles at Sites 1 and 6; radar speeds of light vehicles only at Sites 2 to 5

Fig 26(a) Northbound speeds* through Craven Arms

85th percentile speed (mph)



*7-day speeds of ALL vehicles at Sites 1 and 6; radar speeds of light vehicles only at Sites 2 to 5

Fig 26(b) Southbound speeds* through Craven Arms

85th percentile speed (mph)

4.3 VEHICLE JOURNEY TIMES THROUGH THE VILLAGE

4.3.1 DATA COLLECTION

An overall effect of the measures on traffic can be assessed by calculating vehicle journey times through the length of the village. At each end of the village speed limit, the number plates of vehicles travelling in each direction were recorded on video, before and after scheme installation. Four cameras were used, two for each direction of travel. The cameras were positioned as discreetly as possible. Dates of filming and the periods analysed are shown below:

'before': Thursday 24 November 1994;

'after': Thursday 6 July 1995.

Northbound: 0800-0900, 1000-1100, 1200-1300, 1400-1500.

Southbound: 0900-1000, 1100-1200, 1300-1400, 1500-1600.

The video tapes were scanned such that data files were compiled containing the following information:

- camera position number;
- class of vehicle (light or heavy);
- registration number;
- time of day vehicle passed camera (hours, minutes, seconds).

From this information, it was possible to match the registration numbers of those vehicles which passed both ends of the speed limit and thus calculate their journey times. To avoid the inclusion of vehicles which might have parked or stopped in circumstances other than being within the traffic stream, those taking more than 5 minutes to pass through the village were excluded.

4.3.2 Results

For each direction, the times taken to travel between the ends of the speed limit (distance 1160m) in Craven Arms are summarised in Table 5 and presented graphically in Figs 27 and 28. The bar charts present the percentage of vehicles taking less than 60sec, between 60sec and 180sec in 10sec increments, and more than 180sec (but less than 300sec).

Before scheme installation, the mean journey time through the village was nearly 1min 25sec in each direction. Afterwards, the mean journey time increased by 31sec northbound and 24sec southbound, an increase of about one third. The changes were statistically significant at the 0.1% level.

The bar charts show a pronounced shift towards the longer journey time ranges during the 'after' period, and a flatter distribution. Whereas nearly 70% of the sample of vehicles in both directions took 70-90sec during the 'before' period, in the 'after' period about 85% of vehicles took 90-130sec. The proportion taking 70-90sec fell to 4% northbound and 13% southbound.

4.4 VEHICLE AND TRAFFIC NOISE

4.4.1 Background

The introduction of speed reducing measures may influence traffic noise levels in a number of ways. The most important factors governing overall traffic noise are traffic volume, speed, composition and driver behaviour/mode of operation (Abbott *et al*, 1995a). Where traffic volume and composition remain largely unchanged after traffic calming (as in the case of Craven Arms after taking into account seasonal variations), the influence of changes in vehicle speed and/or driver behaviour becomes critical.

Driver behaviour has been recognised as an important factor in traffic noise generation within traffic calming schemes. Drivers approaching speed reducing measures may apply the vehicle brakes excessively, inducing brake squeal or increased noise from air brakes on heavy goods vehicles. In addition, engine speed has an important effect on noise emissions. When a driver approaches and traverses a speed reducing measure s/he may reduce the vehicle speed and then accelerate away. This operation will often involve a change of gear and consequently produce an increase in engine speed. Some drivers may also continue to travel in a lower gear between the measures, which

TABLE 5

Mean journey times between the ends of the village speed limit

Direction	Time (seconds) and sample sizes: Before	After	Change	Standard deviation (seconds): Before	After
Northbound	83.7 (647)	114.5 (746)	+30.8 (+37%)	28.90	24.45
Southbound	83.1 (681)	107.1 (899)	+24.0 (+29%)	33.28	25.15

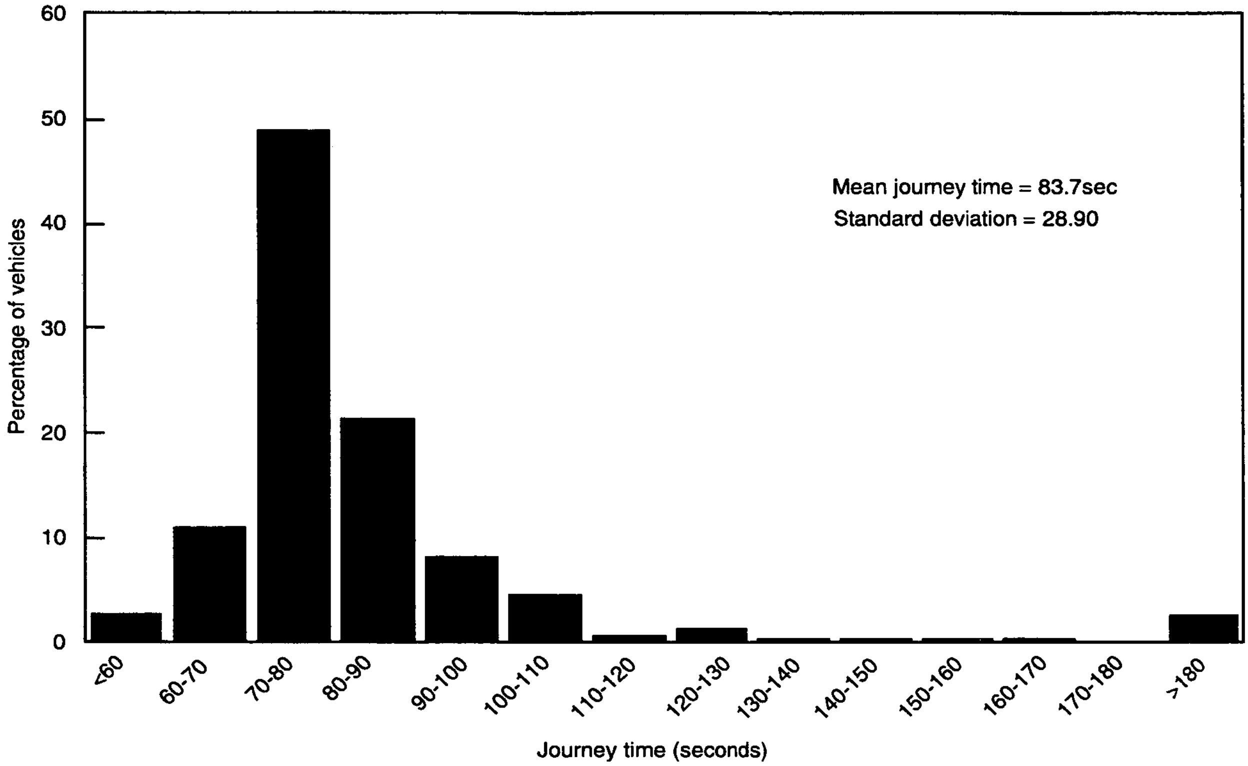


Fig 27(a) A49(T) Craven Arms - Journey times between gateway sites Northbound, Before

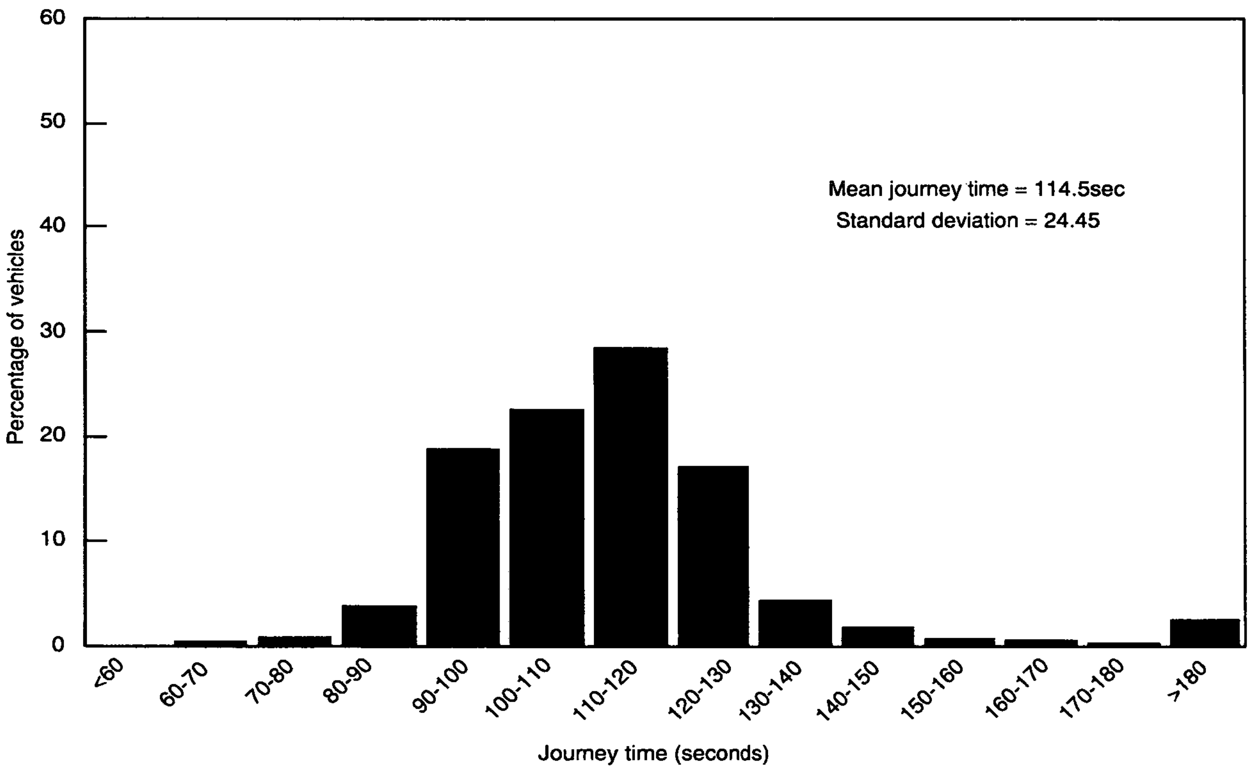


Fig 27(b) A49(T) Craven Arms - Journey times between gateway sites Northbound, After

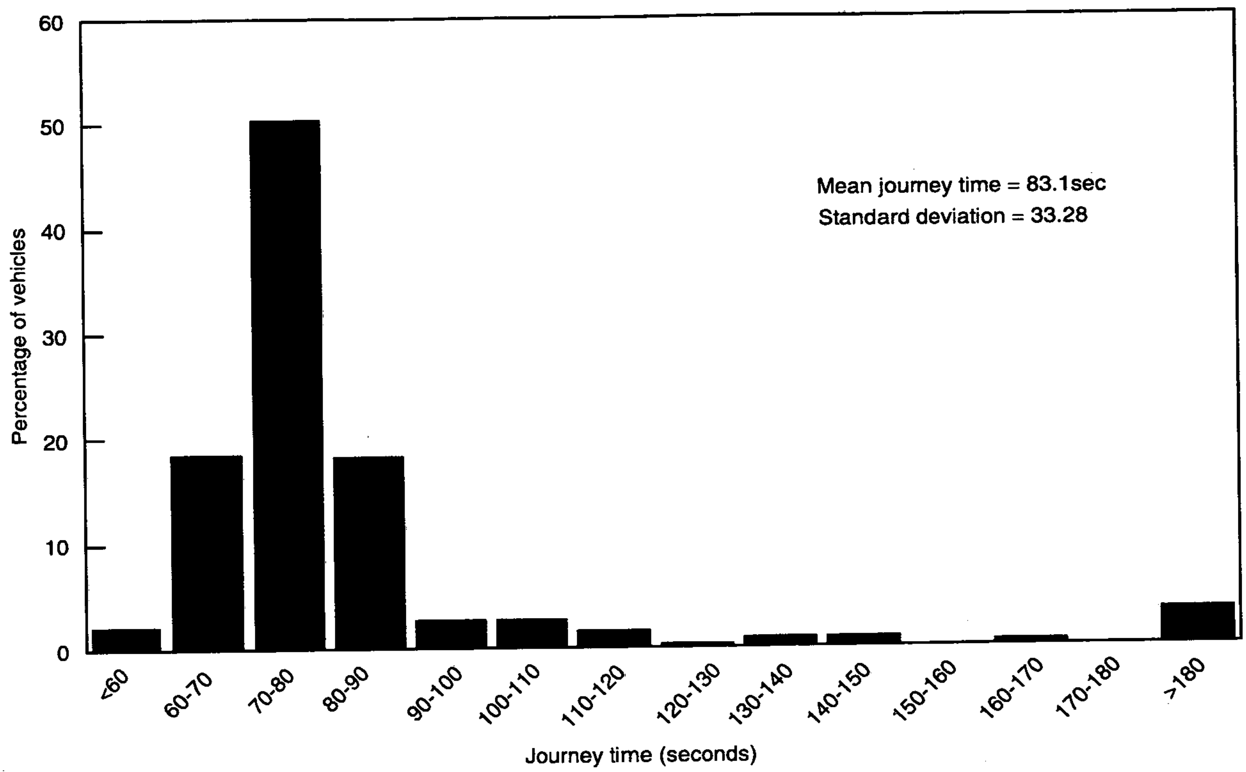


Fig 28(a) A49(T) Craven Arms - Journey times between gateway sites Southbound, Before

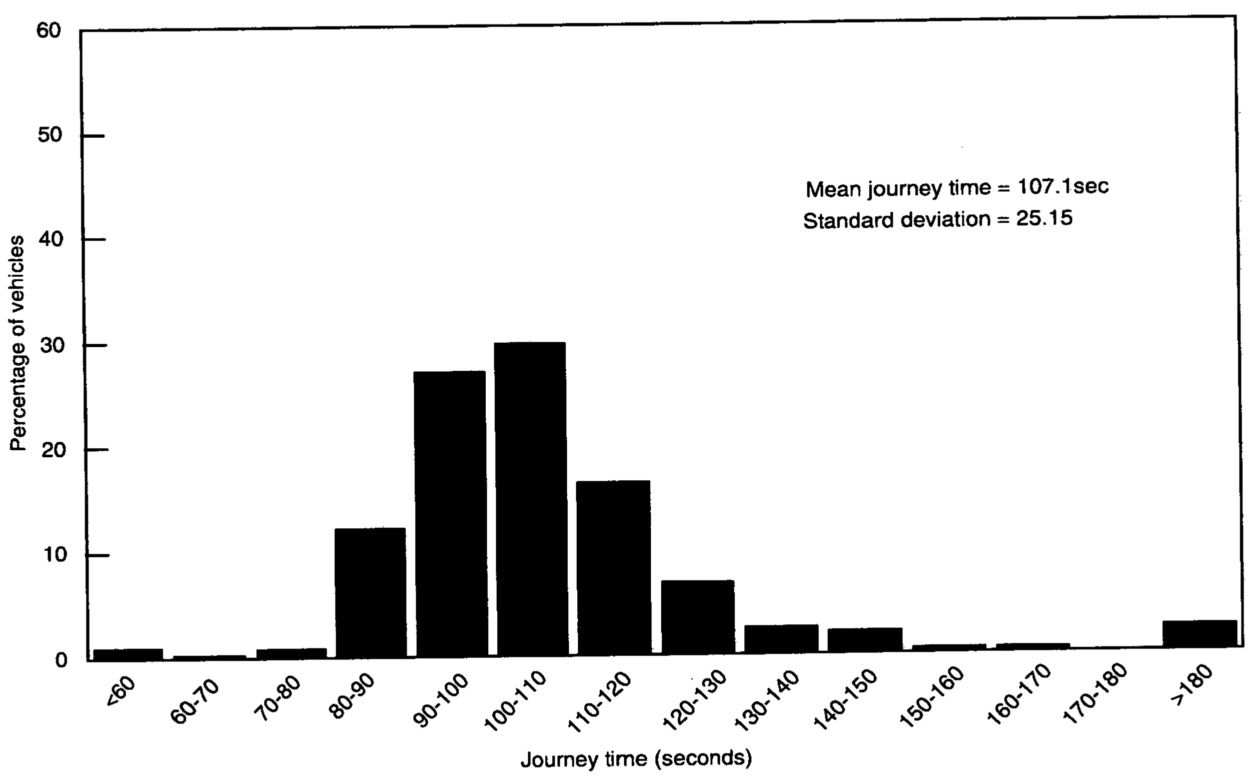


Fig 28(b) A49(T) Craven Arms - Journey times between gateway sites Southbound, After

would result in a higher noise level for a given road speed. Alternatively, drivers may accelerate hard between the measures, thus increasing engine noise.

It is important, therefore, that the design of the speed control measure is optimised so that average vehicle speeds are reduced whilst maintaining a fairly constant speed profile along the road scheme. Fluctuations in noise emissions (a possible cause of annoyance to residents) from vehicles travelling along the road scheme are then minimised.

An additional source of noise can result directly from the design of the speed reducing measure used. The noise produced by heavy vehicles rattling and banging when passing over road humps is a subject of public concern. Speed cushions (as opposed to road humps) are designed to reduce this effect by allowing large vehicles to pass unimpeded with their wheels straddling the raised area. However, the line of travel of large vehicles will be affected by the geometry of the road and interaction with other road users. Vehicles parked near cushions and/or road layout may prevent large trucks from straddling the cushions correctly.

For light vehicles, reductions in vehicle speed should give an overall decrease in traffic noise levels. Previous surveys (Abbott *et al*, 1995b), undertaken to assess the change in both vehicle and overall traffic noise levels after the installation of humps and cushions, showed that maximum vehicle noise levels were significantly reduced after the installation of these measures, as were overall traffic noise levels. However, these surveys were carried out in residential areas where the traffic composition was nearly all light vehicles.

More recent work at TRL has shown that the noise from some commercial vehicles travelling over humps and cushions may be significantly higher than when travelling at higher speeds typical for level road conditions (Abbott *et al*, 1995c). The noise levels were found to be dependent on vehicle type, the design of the cushion or hump and on the relative change in vehicle speeds. Based on this work, it was predicted that, for traffic travelling over certain cushion and hump designs (particularly wide cushions and flat-top humps), sites where heavy vehicles form more than about 5 per cent of the traffic stream may result in increased, rather than reduced, noise levels compared with noise levels prior to installing the speed control measure. However, the speed cushions used at Craven Arms were narrow (width 1.5m) and results from track trials (Abbott *et al*, 1995c) indicated that there should be little change in traffic noise following the introduction of this profile of cushions even for traffic flows with up to 25 per cent heavy vehicles.

The main aim of the noise monitoring before and after the installation of traffic calming measures in Craven Arms was to assess the overall change in the noise exposure to residents. Noise measurements were taken to quantify the change in the noise climate after the introduction of the scheme at a number of different sites, including sites adjacent to the speed cushions and the mini-roundabouts. The location of the noise measurements is given in Table 6 and is shown on a plan of the village in Fig 29.

Vehicle noise measurements were carried out to monitor the variability of noise throughout the scheme, and to identify areas or measures that may signify a noise nuisance. Traffic noise measurements were used to assess the noise exposure outside residential properties, which has

TABLE 6

Noise monitoring before and after scheme installation

Site Label	Location	Feature	Measurement type Before[1]	After[1]
A	North gateway	Gateway	*	Vehicle noise
B	4 Shrewsbury Road[2]	Cushion before mini-roundabout	Traffic & vehicle noise	Traffic & vehicle noise
C	Craven Arms Hotel	Between cushions	Vehicle noise	Vehicle noise
D	24 Shrewsbury Road	Isolated cushion	-	Vehicle noise
E	Craven Arms Hotel	Cushion after mini-roundabout	-	Vehicle noise
F	76 Shrewsbury Road	No cushion	Traffic noise	Traffic noise

*'Before' survey planned but not completed due to poor weather conditions

[1] Survey dates: 'before' 15-16 February 1995, 'after' 20 July 1995.

[2] The name given to the A49 through Craven Arms

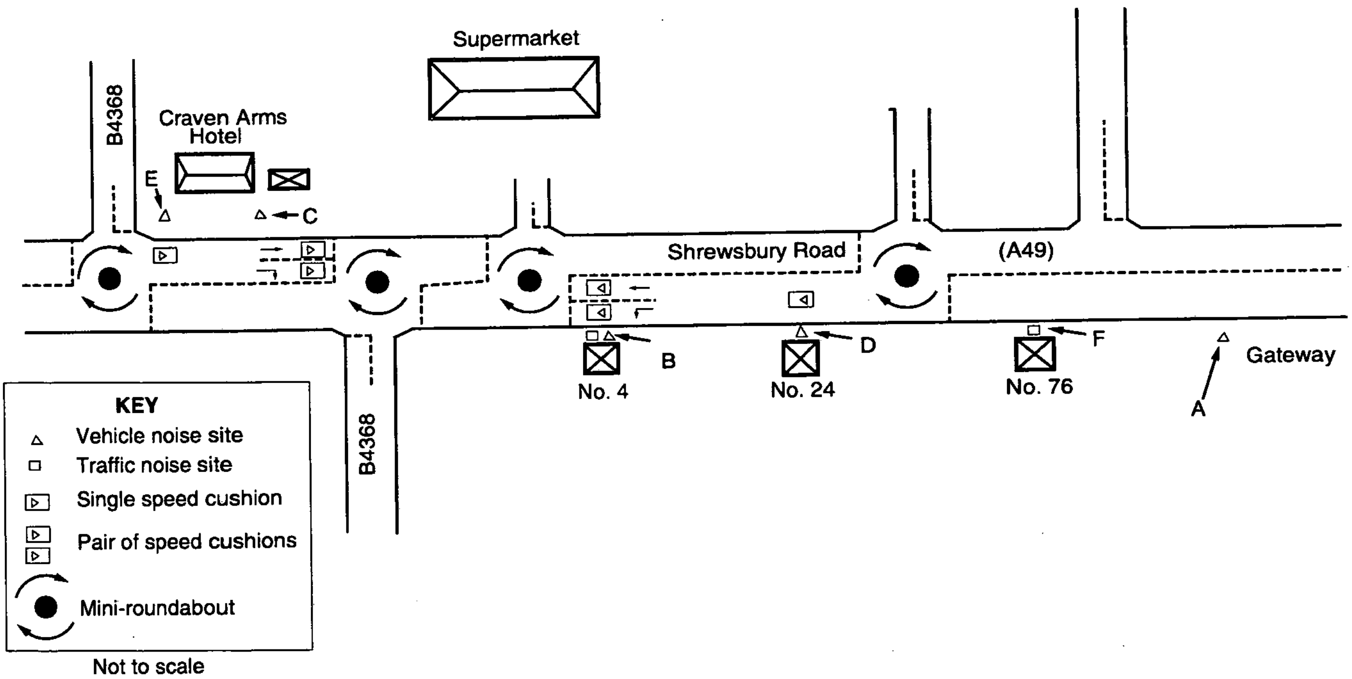


Fig 29. Location of traffic and vehicle noise measurement sites, Craven Arms

generally been shown to correlate directly with people's disturbance from road traffic noise experienced in their homes (Baughan and Huddart, 1993). The site location, measurement methods and results of the vehicle and traffic noise surveys are fully described in Sections 4.4.2 and 4.4.3.

4.4.2 Vehicle noise measurements

4.4.2.1 Location of measurement sites

Vehicle noise measurements were initially planned for three sites (A, B and C) before and after the installation of the traffic calming scheme. The three sites were chosen to survey the noise at the north gateway, alongside a cushion and at a location midway between two cushions (see Table 6 and Fig 29). The north gateway site (site A) was located alongside the inbound lane carrying traffic into the village. However, the 'before' survey was not completed at this site due to poor weather conditions. Site B was adjacent to the site of a cushion at the entry to a mini-roundabout, and near to where traffic noise measurement were carried out. The measurement microphone at site C was located in the car park of the Craven Arms Hotel, alongside the road midway between two cushions 36m apart.

In the 'after' survey it was decided that further vehicle noise measurements should be conducted to investigate the difference between cushions in different locations. The original cushion site (site B) was located immediately before a mini-roundabout. Two additional sites (D and E) were chosen to assess the performance of cushions in alternative road layouts. Site D was situated adjacent to a residential property and was chosen to represent an isolated cushion where no other road layout features, such as mini-roundabouts, would affect vehicle speed. Site E was located at the southern end of the village, directly before the Craven Arms Hotel. This site was chosen to represent a cushion immediately after a mini-roundabout.

4.4.2.2 Measurement method

The Statistical Pass-by (SPB) method was used to measure vehicle noise before and after the installation of traffic calming measures. A full description of the methodology for the SPB technique and the positioning of the microphones at the survey sites in Craven Arms can be found in Appendix A. The equipment used for vehicle noise measurement at each of the sites is shown schematically in Fig A.1 in the Appendix.

4.4.2.3 Changes in vehicle noise

In the analysis of vehicle noise, the relation between vehicle speed and noise was examined for each survey at each site. The two categories of vehicle, 'light' and 'heavy', were separated for analysis. The maximum noise levels for each vehicle event were linearly regressed against the logarithm of the vehicle speed. For example, the regression lines and data points for the 'before' and 'after' measurements at site B are shown for light and heavy vehicles in Figs30 and 31, respectively. Summary regression statistics for all of the measurements are shown in Appendix B and the speed/level functions are shown in Figs 32 and 33 for light and heavy vehicles respectively. The speed/noise level functions determined were used to calculate the average maximum noise level for a typical vehicle, in each category, travelling at the mean speed, measured during the noise survey, for the particular site.

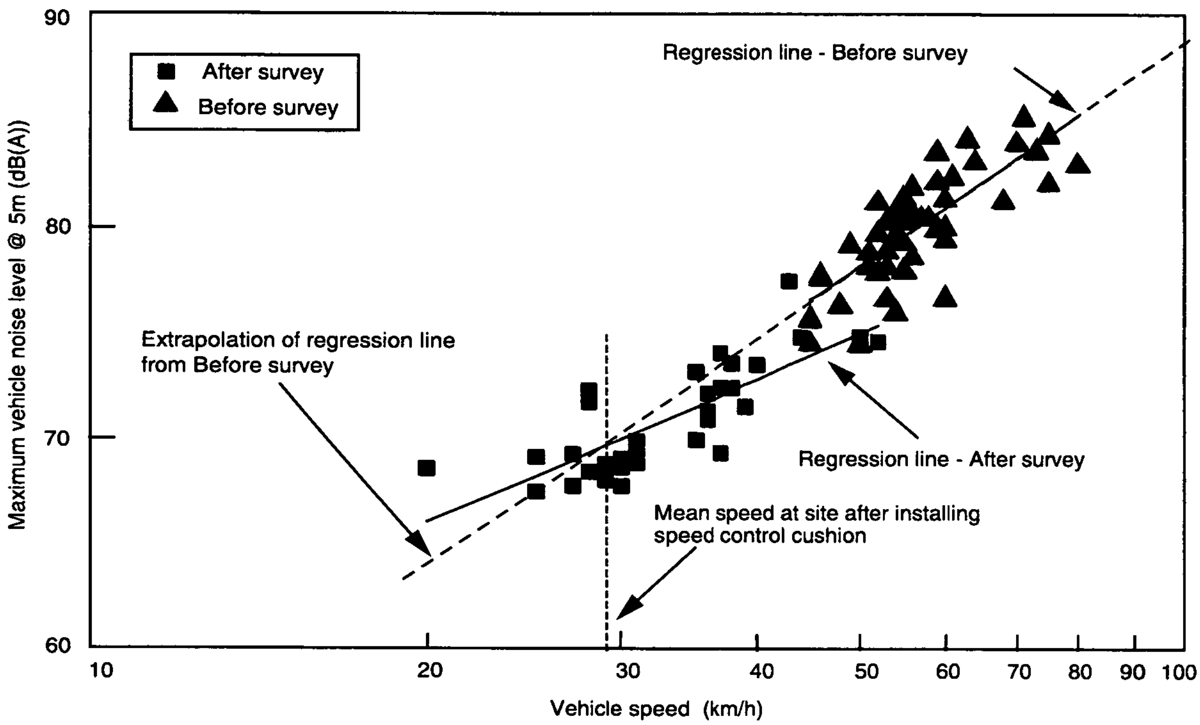


Fig. 30 Comparison of light vehicle noise levels and speed before and after installing speed control cushion at Site B
(measured at 5m from the centre of the lane)

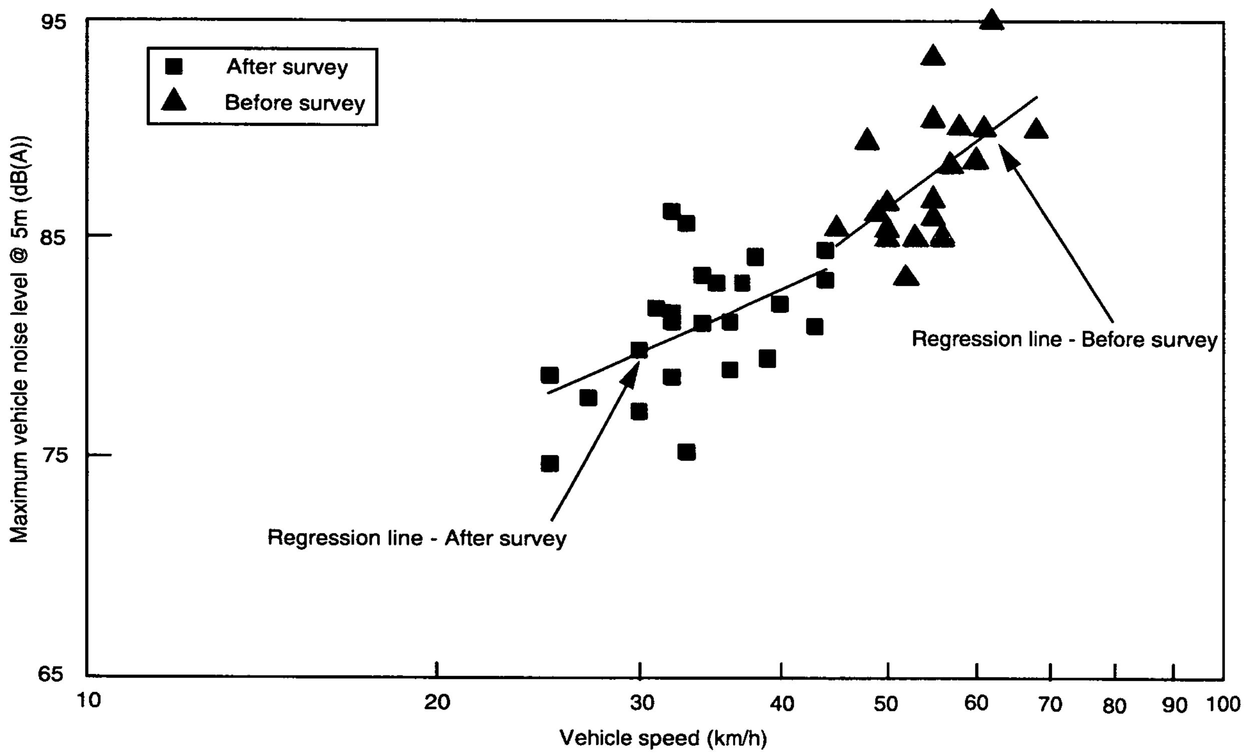


Fig. 31 Comparison of heavy vehicle noise levels and speed before and after installing speed control cushion at Site B
(measured at 5m from the centre of the lane)

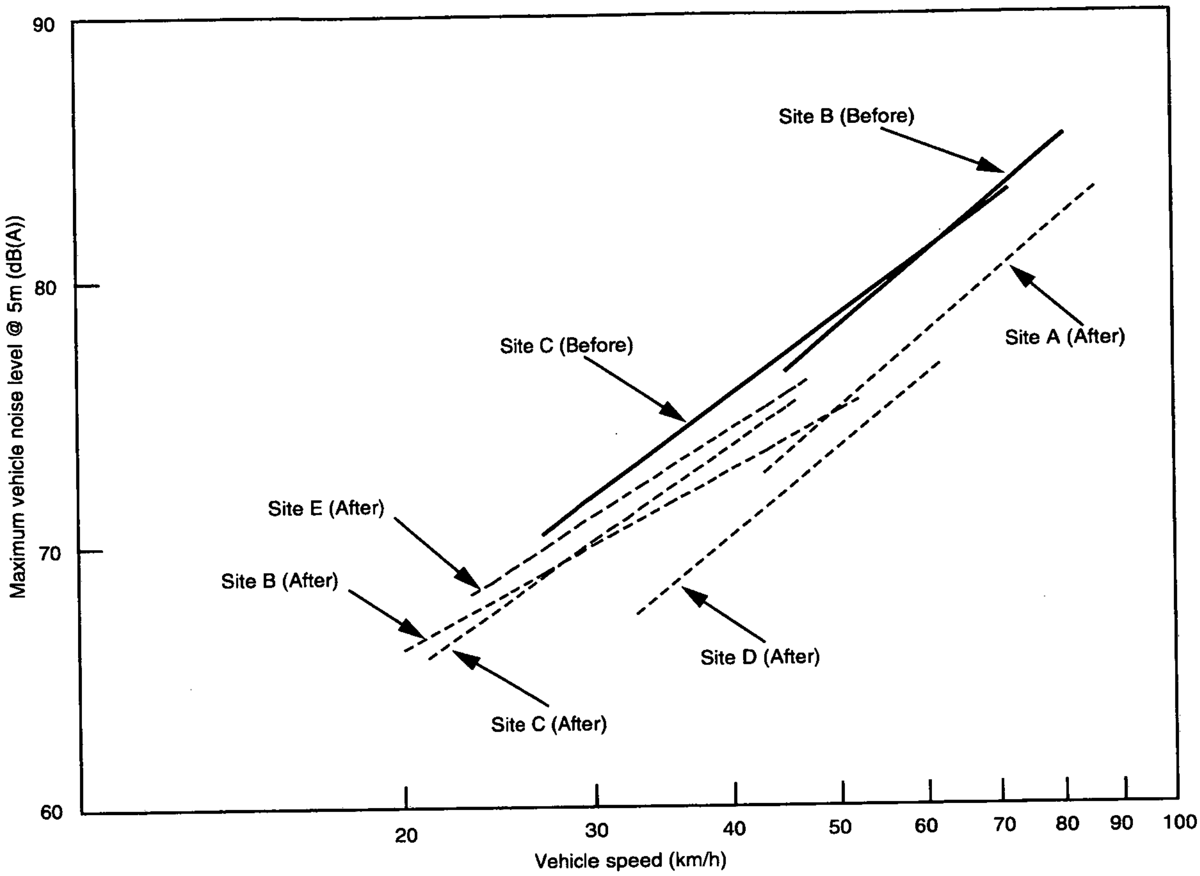


Fig. 32 Regression lines for light vehicle noise level and speed from Before and After surveys

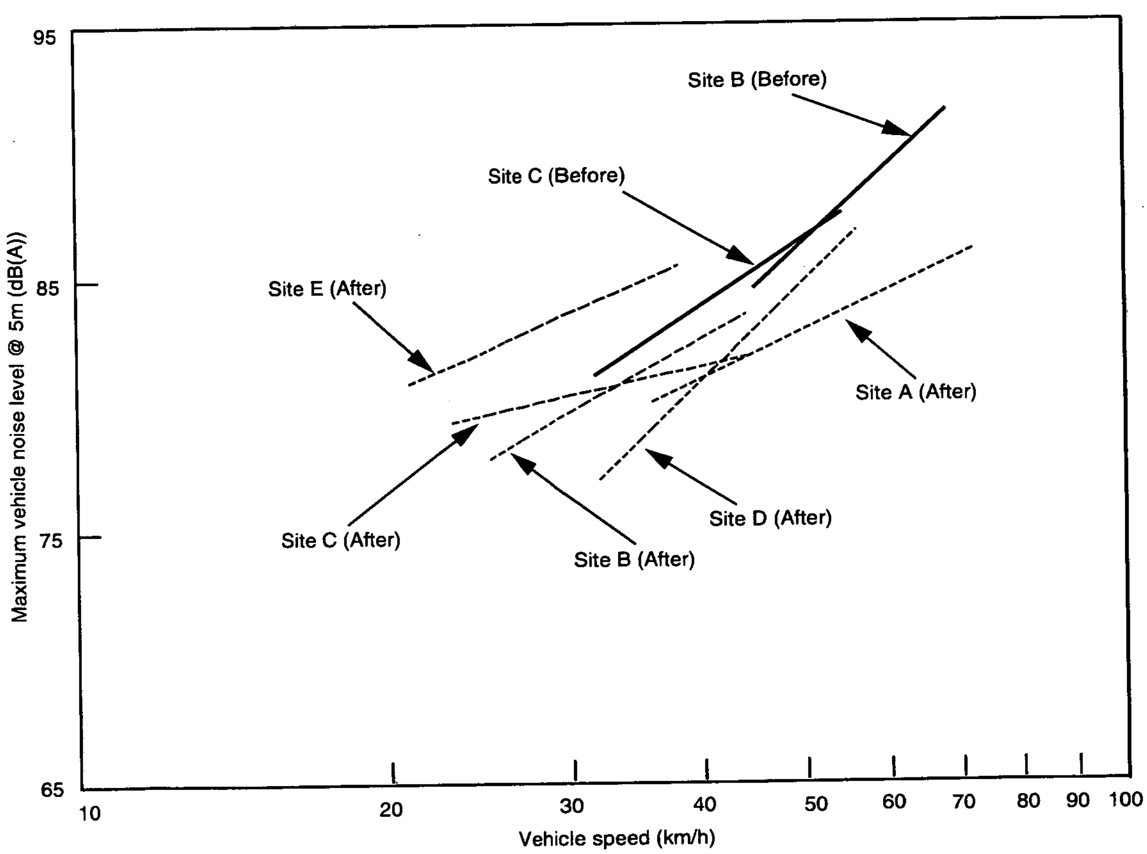


Fig. 33 Regression lines for heavy vehicle noise level and speed from Before and After surveys

At sites B and C, the 'before' to 'after' change in the maximum noise levels at the average speed for each category of vehicle were determined. The results of the noise monitoring for the two vehicle classes are discussed below.

(a) Light vehicles

The average maximum light vehicle noise levels at the mean site speed for both before and after the installation of the traffic calming measures are shown in Table 7. At both sites B and C the maximum noise levels were substantially reduced after the installation of speed reducing measures. At site B (alongside a cushion prior to a roundabout) the maximum noise at the mean speed was reduced by over 9 dB(A) and at site C (between cushions), the maximum noise at the mean speed was reduced by about 7 dB(A).

The regression lines calculated for the 'before' and 'after' surveys at site B, shown in Fig 30, were found to be statistically significantly different from each other. However, an extrapolation of the 'before' regression line to the mean 'after' speed (approximately 29 km/h), showed a difference in vehicle noise levels of less than 1 dB(A) between the before and after regression estimates at this speed. The same analysis was carried out for the 'before' and 'after' measurements at site C with similar results. It therefore can be generally concluded that at these sites the average 'before'/'after' change in light vehicle noise levels were due to reductions in vehicle speed.

Fig 32 shows the 'before' speed/noise level functions for sites B and C, and the 'after' functions for sites A, B, C, D, and E. The speed/noise level functions for sites B, C and E were similar, demonstrating that for these sites, light vehicles travelling at a given speed will produce broadly comparable noise levels. Site D and to some extent site A, located at an isolated cushion and the north gateway respectively, were different in this respect. Noise levels from light vehicles at these sites were lower and may have been affected by site conditions which were not apparent at sites B, C and E. For example, at site D, the microphone was located adjacent to a section of grass verge. This may have provided extra attenuation compared with the other sites where the intervening ground between the microphone and the road was generally concrete or other hard reflecting surface. Site A was fairly open compared with the other sites and therefore reflection effects from facades would have been reduced leading to marginally lower noise levels.

Although the 'before' survey did not include the north gateway site, site A, it is estimated that, based upon the 'before' and 'after' mean speed of all vehicles at the north gateway given in Table 3, i.e. 41-42mph (66-68 km/h) and 33-34mph (53-55 km/h) respectively, and the 'after' speed/noise level relationship, maximum noise levels for light vehicles have been reduced by about 4 dB(A).

(b) Heavy vehicles

The maximum noise levels for heavy vehicles before and after scheme installation are shown in Table 8 at the mean speeds measured for each site. The speed/noise level functions for each of the sites are shown in Fig 33 and the regression statistics are given in Appendix B. At both sites B and C the maximum vehicle noise levels were reduced after the installation of speed reducing measures.

At site B there was a reduction in maximum noise levels for heavy vehicles of about 8dB(A) between the 'before' and 'after' surveys at the corresponding mean vehicle speeds.

TABLE 7

'Before' and 'after' light vehicle noise levels

Site	Before		After		Change in	
	Mean site speed[1] km/h	Maximum vehicle noise level at mean speed dB(A)	Mean site speed[1] km/h	Maximum vehicle noise level at mean speed dB(A)	Mean speed[1] km/h	Maximum noise level dB(A)
North gateway						
A	-	-	49.8	76.9	-	-
Cushion sites						
B	53.2	79.1	28.9	69.6	-24.3	-9.5
D	-	-	42.2	71.0	-	-
E	-	-	29.2	70.8	-	-
Between cushions						
C	45.1	77.2	29.9	70.1	-15.2	-7.1

[1] Mean speed measured during noise level surveys

TABLE 8

'Before' and 'after' heavy vehicle noise levels

Site	Before		After		Change in	
	Mean site speed[1] km/h	Maximum vehicle noise level at mean speed dB(A)	Mean site speed[1] km/h	Maximum vehicle noise level at mean speed dB(A)	Mean speed[1] km/h	Maximum noise level dB(A)
North gateway						
A	-	-	44.5	81.9	-	-
Cushion sites						
B	55.1	88.0	30.3	79.7	-24.8	-8.3
D	-	-	39.3	80.6	-	-
E	-	-	26.3	82.6	-	-
Between cushions						
C	44.9	85.3	26.9	79.9	-18.0	-5.4

[1] Mean speed measured during noise level surveys

The variability of heavy vehicle noise levels is much greater than found in surveys of light vehicles. It can be seen in Fig 31 that, for a given speed, noise differences of up to 10dB(A) can be observed both in the 'before' and 'after' surveys. It is, therefore, not surprising that there was no statistically significant difference between the regression lines for the 'before' and 'after' surveys. It can be concluded therefore that at this site, the average change in heavy vehicle noise levels were due to reductions in vehicle speed.

At site C there was a reduction in maximum noise levels for heavy vehicles of about 5dB(A) between the 'before' and 'after' surveys at the corresponding mean vehicle speeds. The reduction in heavy vehicle noise levels at this site was less than that found at site B, largely because the drop in mean speed was less. However, comparing the absolute noise levels in the 'after' survey at site C with the corresponding value found at site B showed that heavy vehicle noise levels at site C were similar.

At site D, the maximum noise levels for heavy vehicles in the 'after' survey were about 2 to 3 dB(A) lower than the corresponding values found at the other cushion sites (sites B and C), after differences in speed are taken into account. These differences in noise levels could partially be explained by the variation in type of ground surface between the sites as discussed earlier for light vehicles.

At site E the 'after' speed/noise level function (Fig 33) shows that compared with site B, noise levels were about 3 dB(A) higher after normalising the noise levels to the same mean vehicle speed (i.e. 28km/h). The cushion at site E was positioned close to the exit of a mini-roundabout. Although vehicles selected for measurement at this site had all crossed the mini-roundabout unimpeded (i.e. they had not accelerated from rest at the far side give-way line) it is nevertheless possible that the higher noise levels recorded at this site compared with at site B were affected by the presence of the mini-roundabout positioned immediately before the site.

Again, as with light vehicles, the 'before' survey did not include the north gateway site, site A. However, it is estimated that based upon a mean speed for all vehicles in the 'before' survey at the north gateway given in Table 3 (64 km/h, 40 mph) and the 'after' speed/ noise level relationship, the maximum noise levels for heavy vehicles have been reduced by about 3 dB(A).

In summary, the results suggest that generally the noise emission levels from heavy vehicles travelling over the speed cushions were similar to the emission levels from vehicles travelling between the cushions when normalised for speed. However, at sites where the presence of other features, such as mini-roundabouts, exist in proximity to, and prior to, the site, then noise emission levels may be higher than at similar sites where the cushions are more isolated.

4.4.3 Traffic noise measurements

4.4.3.1 Location of measurement sites

Traffic noise measurement sites were selected to represent a variety of traffic calming features, whilst satisfying the practical and acoustical requirements of the measurement method. The traffic noise measurements were conducted over a period of 24 hours at sites adjacent to residential properties. The majority of the residential properties along the main road through the village (A49) are fairly modern two-storey, semi-detached houses, with a front garden and driveway. There are a smaller number of older, more substantial semi-detached properties towards the southern end of the village. The locations of the survey sites were selected to ensure that the microphone was not screened from the traffic by large walls or hedges. Although the survey sites were near to a railway, it is unlikely that the noise levels from passing trains were sufficiently high or frequent enough to have influenced the daytime traffic noise levels. The security of the monitoring equipment and the effects of other noise influences were considered before final site selection.

Traffic noise surveys were carried out at two sites in different parts of the village before and after the installation of the traffic calming scheme (see Table 6 and Fig 29).

The first, at site B (adjacent to the vehicle noise survey site), was located at a two storey semi-detached house (4 Shrewsbury Road) near the southern end of the village, and was adjacent to a speed cushion in the 'after' survey. The measurement microphone for the traffic noise assessment was positioned in the front garden, 1 metre from the most exposed facade of the property. The microphone height was 4.0 metres above road level and 6.4 metres (horizontally) to edge of kerb.

The second traffic noise site, site F, was situated in the northern part of the village outside a semi-detached residential property (76 Shrewsbury Road). The site was located some distance from any of the traffic calming features or mini-roundabouts, and was chosen to determine the effect of overall speed change in a predominantly residential zone. The measurement microphone for the traffic noise assessment was positioned in the front garden, 1 metre from the most exposed facade of the property. The microphone height was 4.0 metres above road level and 9.5 metres (horizontally) to edge of kerb.

4.4.3.2 Measurement method

Previous surveys have shown that disturbance from traffic noise in the home is correlated with the noise index $L_{A10,18h}$dB (Morton-Williams, Hedges and Fernando, 1978). The index is derived from noise levels measured in an 18 hour period from 0600 to midnight outside residential properties. For each of the one-hour periods, the level exceeded for 10 per cent of the time is calculated from the cumulative distribution of the sampled noise levels to give the noise index $L_{A10,1h}$. The arithmetic average of the 18 individual $L_{A10,1h}$ values is then calculated to give the $L_{A10,18h}$. This method is currently used in the UK for assessing the impact of traffic noise from new and altered road schemes (Department of Transport and Welsh Office, 1988) and for the determination of entitlement to statutory sound insulation of dwellings as described in the Noise Insulation (Amended) Regulations (House of Commons, 1988). Nighttime noise levels can also be calculated over the 6 hour period from midnight to 0600 and are termed the $L_{A10,6h}$.

At each of the traffic noise measurement sites an environmental sound level meter was installed (see Table 6). The equipment was configured to calculate a variety of noise level indices (including the $L_{A10,1h}$) in each hour. The results were stored in the internal memory of the sound level meter, and were downloaded to a laptop PC at the end of each measurement session. The equipment was installed for a minimum of 24 hours on each occasion.

4.4.3.3 Changes in traffic noise

The diurnal variation in traffic noise levels (expressed as $L_{A10,1h}$) recorded at sites B and F, both before and after the installation of traffic calming measures is shown in Fig 34. The daytime ($L_{A10,18h}$) and nighttime ($L_{A10,6h}$) levels recorded during the 'before' and 'after' surveys at sites B and F are shown in Table 9.

The measured daytime traffic noise levels, $L_{A10,18h}$, show reductions at both sites after the scheme installation. At site B, adjacent to the cushion, traffic noise fell by over 3dB(A), whilst at site F the reduction in daytime noise levels were about 2 dB(A).

The reduction in traffic noise at site B was not as large as the reduction in vehicle noise recorded at the same site during the vehicle noise survey. At this site it was estimated that heavy vehicle noise was reduced by about 8dB(A) and light vehicle noise by 9.5dB(A). It would therefore be expected that overall traffic noise would be reduced by about 8 dB(A)[1] compared with the measured reduction of 3 dB(A) assuming no change in traffic flow and composition.

Traffic surveys carried out before and after the scheme installation showed that traffic flows increased by about 20%, due to seasonal variation, with little change in vehicle composition. Although increases in traffic flow would lead to increases in traffic noise it is estimated that the increase would be less than 1 dB(A). Therefore, the discrepancy between the measured reduction in traffic noise and the estimated value based upon changes in vehicle noise levels cannot be fully explained by changes in traffic flow and composition.

It is important, however, to realise that the traffic noise recorded at site B consisted of the combined noise level from the total traffic flow travelling on both sides of the road. In the 'before' survey it can be assumed that the relationship between vehicle noise and speed for both light and heavy vehicles recorded on the southbound lane was the same for vehicles travelling on the northbound lane. However, in the 'after' survey this assumption is unlikely to be valid due to the proximity of the mini-roundabout installed as part of the scheme. It has already been shown

[1] Changes in overall traffic noise, measured using the scale L_{A10}, are influenced more by changes in noise levels from the noisiest events i.e. the noise emissions from heavy vehicles rather than from light vehicles.

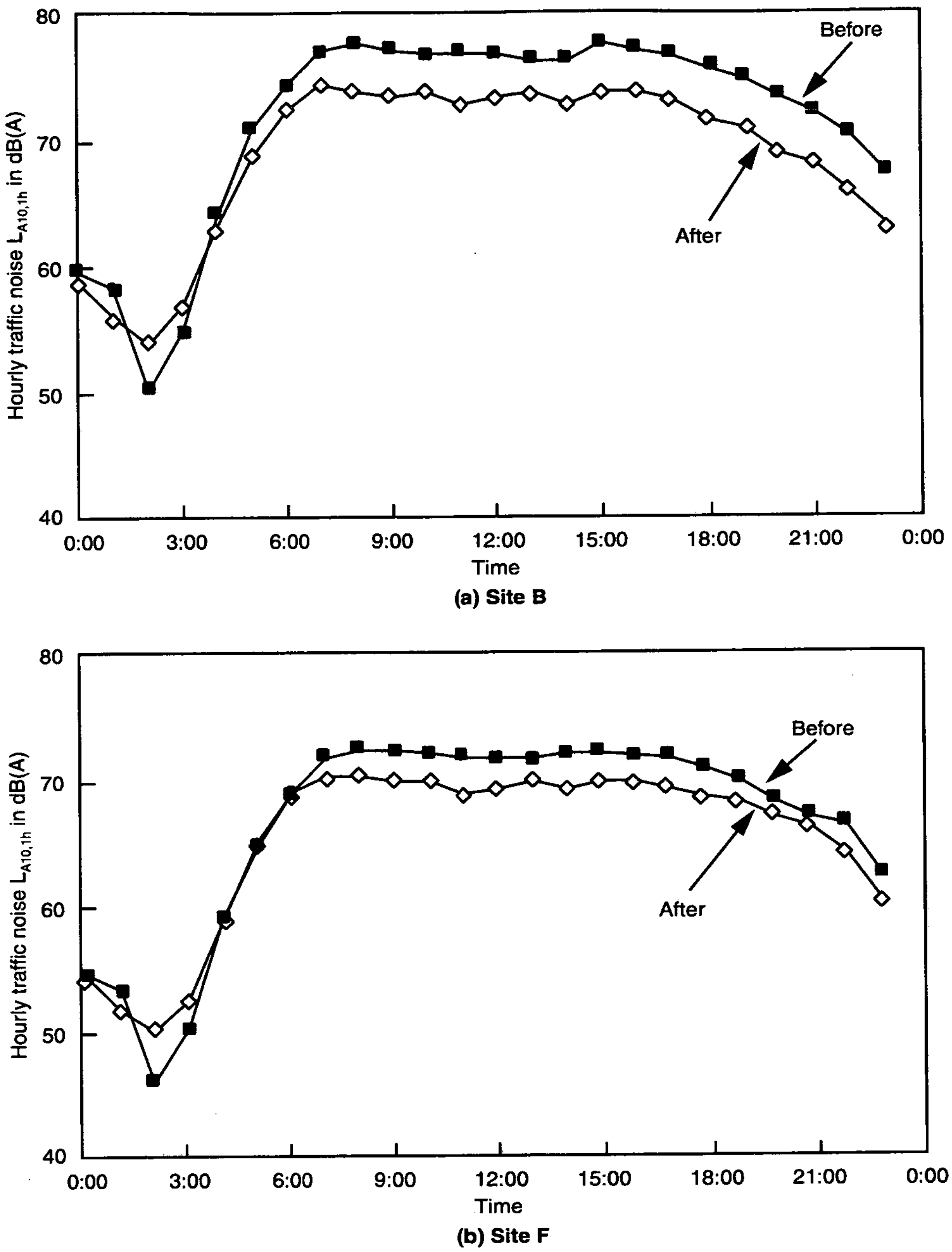


Fig. 34 Variation in hourly traffic noise levels at residential sites from Before and After surveys

TABLE 9

Traffic noise levels at 24 hour measurement sites

Site		Traffic noise levels dB(A) Before	After	Change
Daytime levels (0600-midnight, $L_{A10,18h}$)				
B	Cushion	75.4	71.8	-3.6
F	No features	74.5	72.4	-2.1
Nighttime levels (midnight-0600, $L_{A10,6h}$)				
B	Cushion	59.8	59.7	-0.1
F	No features	57.5	58.4	+0.9

that at site E, similarly positioned after a mini-roundabout as the site on the northbound lane adjacent to site B, that maximum vehicle noise levels from heavy vehicles appear to be adversely affected by the presence of the mini-roundabout. It is therefore possible that the unexpectedly small reduction in overall traffic noise recorded at site B was partly due to the influence of the mini-roundabout on driver behaviour, providing higher than expected noise levels from heavy vehicles travelling on the northbound lane.

At site F, which was positioned away from any of the speed control measures, the reduction in overall traffic noise was about 2 dB(A). It is assumed that the relationship between vehicle noise and speed at site F is similar to that measured at sites B and C and is the same for traffic on both sides of the road. If the reduction in vehicle noise levels at site F (Table 9) was due to the changes, shown in Table 4, in vehicle speed recorded at site 5 (positioned close to site F), then the reduction in overall traffic noise is estimated to be about 3 dB(A). After taking into account the small increase in traffic between the 'before' and 'after' surveys, the reduction in traffic noise at site F is estimated to be 2.2 dB(A) which is in good agreement with the measured value of 2.1 dB(A).

The nighttime traffic noise levels have not shown the same reduction as the daytime levels and have generally been unaffected by the scheme. However, where traffic flows are low, typical to the nighttime period, noise levels can be influenced by non-traffic noise sources such as bird song during the dawn chorus. Unless noise levels are carefully monitored over several nighttime periods it is difficult to draw any reliable conclusions.

4.5 GROUND-BORNE VIBRATION

It was considered important to monitor ground-borne vibration before and after the installation of speed cushions since it is known that vehicles traversing undulations in the road surface can lead to the generation of perceptible vibrations (Watts, 1990). This is the result of the dynamic loads imposed on the road surface as the wheels pass over the irregularity. Larger vehicles with stiffer suspension are responsible for the generation of the largest vibrations. Surface and body waves are generated in the underlying soil with the principal component typically in the vertical direction. Dominant frequencies are 10-12Hz which corresponds to the wheel hop frequency of an HGV's suspension. The size of the effect depends critically on the size of the undulation and the nature of the subsoil. Where there is soft ground of low shear strength then sizeable vibrations can be generated by HGVs traversing relatively modest irregularities in the road. Such vibrations can be perceptible in buildings close to the highway and result in considerable disturbance.

Ground-borne vibrations were monitored at the foundations of a house close to the point where a set of speed cushions were installed. This locality is underlain by sands and gravels. With this approach it was possible to determine the effects of the cushions at a 'worst case' location and thereby to infer the maximum likely effects along the length of the scheme.

4.5.1 Measurement method

Vibration measurements were made at 4 Shrewsbury Road on a Wednesday before and after scheme installation. The position of the speed cushions relative to the property is shown in Figs 35 and 36; in Fig 36, the front garden wall can be seen on the right in the photograph. Measurements were made using a triaxial geophone array (Fig 37) attached to

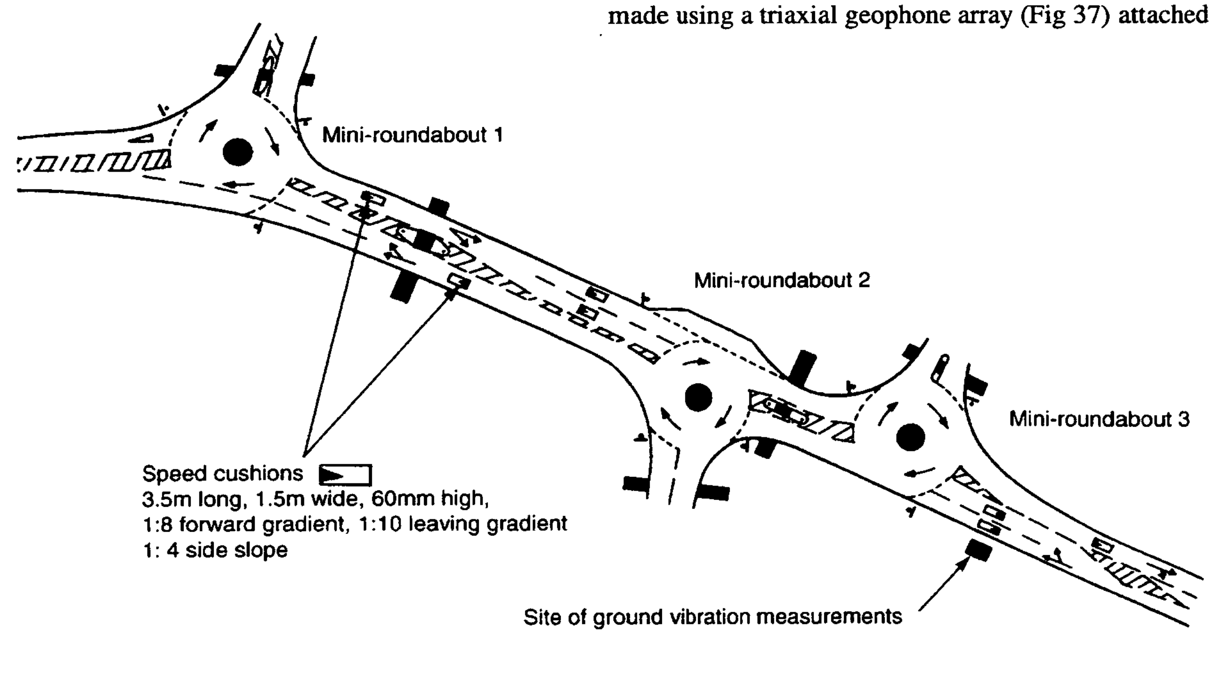


Fig 35. Location of property where ground-borne vibration measurements were made

Fig 36. Speed cushions adjacent to the property where groundborne vibration measurements were made

Fig 37. Triaxial geophone array attached to wall near ground level

the external facade of the property near ground level. The geophones produce signals directly proportional to particle velocity. The maximum amplitude of particle velocity or *peak particle velocity (PPV)* has been widely used to assess the damage potential of vibrations in buildings and has been found to be the best correlated vibration measure with case history data of damage occurrence (New, 1986). In addition to the measurement of vibrations from passing vehicles, vibration levels were also logged for non-traffic sources in order to place the level of vibration from traffic in context. For this purpose measurements were made during activities and events such as closing doors in the house, deliveries to the front door and local passenger and goods trains on a nearby railway line. For these events recordings were made when there was little or no passing traffic.

From previous work it is known that heavy vehicles produce significantly greater levels of vibration than light vehicles and in order to gauge the maximum effect of the cushions, PPVs were obtained for heavy vehicles travelling in the nearside lane. This was carried out for vehicles straddling the cushions and vehicles tracking over the cushion (not straddling).

4.5.2 Recording and analysis

Three geophones were mounted on an aluminium cube so that PPVs in 3 orthogonal (vertical, radial and transverse) directions could be measured. The array was bolted to a metal angle bracket attached securely to the brickwork with Plaster of Paris at a height of 0.3m above ground level (Fig 37). The location of the array was at the front of the house at a point closest to the nearest cushion which was at a distance of 8m.

The array was aligned so that in the horizontal plane one geophone was pointed towards the road to measure the radial component of vibration (R) while the other horizontally mounted geophone measured the transverse component (T). The third geophone measured the vertical component (V). The vibration signals were conditioned using preamplifiers and recorded on a Racal Store 7DS instrumentation tape recorder.

Subsequent analysis of the recordings was carried out using a computer system based on a CED 1401 digital interface unit. The system can simultaneously sample up to 16 channels of information and with appropriate software enabled the calculation and listing of PPVs for individual vehicles. In addition it allowed the vibration exposure in each 15 minute sample period to be evaluated for one channel. For this purpose the number of events in a 15 minute period producing vertical PPVs exceeding 0.14 mm/s were logged together with the maximum peak value in each period. The value of 0.14 mm/s was chosen since below this level complaints concerning vibration would not be expected (Watts, 1990). It should be noted that 0.3 mm/s is the mean threshold for human perception of continuous sinusoidal vertical vibration, though between 0.14 and 0.3 mm/s it is possible that vibration might be noticed as rattling objects or window panes rather than felt.

4.5.3 Results

Table 10 lists the maximum vertical PPVs recorded in each 15 minute period. It can be seen that the maximum vibrations recorded in both 'before' and 'after' periods were never greater than 0.1mm/s. Generally, peak levels were higher in the 'after' period. The maximum recorded level in the 'before' period was 0.075mm/s while in the 'after' period it was 0.096mm/s.

These vertical levels were compared with non-vehicle events in order to place the levels in context. Table 11 lists the maximum PPVs in the three axes of measurement for a wide range of events.

In Table 12 the average and maximum PPVs for heavy vehicles are given for both the 'before' and 'after' periods. It can be seen that vibration levels are approximately 50% higher on average where vehicles do not straddle the speed cushion.

4.5.4 Discussion

The results of the survey indicate that ground-borne vibration exposure is generally very low with peak levels below the level at which complaints would be expected. It is probable that the good condition of the road surface alongside the measurement site contributed to these low levels. There were no significant defects such as poorly backfilled trenches, manhole or drain covers present. The presence of the speed cushions increased vibration levels but the result-

TABLE 10

Maximum recorded vertical PPVs (mm/s) during 15 minute sample periods

Period	Hour beginning						
	1000	1100	1200	1300	1400	1500	1600
Before	-	0.032	0.031	0.031	0.038	0.075	0.038
After	0.056	0.053	0.096	0.087	0.060	0.068	0.043

TABLE 11

Maximum PPVs (mm/s) in each orthogonal direction by type of non-vehicle event

Event	Approximate distance from geophone (m)	Vertical	Radial	Transverse
Background	-	0.006	0.010	0.008
Passenger train*	115	0.019	0.014	0.021
Freight train	115	0.057	0.047	0.054
Pedestrians on path	6	0.008	0.014	0.014
Opening/closing front door	0.75	0.100	0.086	0.109
Newspaper delivery	0.5	0.026	0.026	0.080
Jumping on path	0.5	0.582	0.589	0.637

* Diesel multiple unit

TABLE 12

PPVs (mm/s) in each orthogonal direction for heavy vehicles straddling and not straddling the speed cushion

Survey	Number in sample	Vertical			Radial			Transverse		
		Mean	s.d.	Max	Mean	s.d.	Max.	Mean	s.d.	Max.
Before	12	0.028	0.007	0.045	0.028	0.005	0.038	0.034	0.007	0.043
After (straddling)	10	0.030	0.008	0.042	0.022	0.006	0.032	0.025	0.006	0.033
After (not straddling)	10	0.050	0.010	0.073	0.033	0.006	0.040	0.034	0.007	0.059

Notes s.d. = standard deviation
Max. = Maximum

ing levels were still very low. Under worst case conditions where a heavy vehicle clipped the cushion it was estimated that the level was approximately 50% higher than that produced if the vehicle straddled the cushion. The highest level recorded from passing traffic in the 'after' period was 0.096 mm/s and this can be compared with normal activities such as opening and closing the front door of the house which produced a peak level of a very similar order. A freight train passing at a distance of about 115m produced a level similar to that produced by the average heavy vehicle not straddling the cushion.

The peak levels of vibration recorded in this survey are low compared to other sites alongside main roads. For example a two-storey cottage on the A47 at Thorney was exposed to a peak vertical level of 3.5 mm/s near ground level (Watts, 1988). This is almost 35 times the maximum level due to traffic recorded in the present survey.

Watts (1990) reported that there was no firm evidence of vibration having caused significant building damage below a PPV of 10 mm/s near foundation level. This level is some two orders of magnitude (100 times) greater than the highest peak level attributable to passing vehicles recorded during the present survey. Regarding the possibility that low levels of vibration may cause structural fatigue or trigger damage, Watts concluded after extensive research that there was no evidence of such damage in a range of buildings exposed to relatively high levels of traffic vibration.

4.6 PUBLIC OPINION SURVEY

Two hundred people resident in Craven Arms were interviewed in their homes during September 1995, about 3 months after the installation of the scheme. The aim was to establish people's perceptions of the measures and their effectiveness, or otherwise, in reducing any traffic problems resulting from the main road. Only those respondents who had lived in the village prior to 1995 were eligible for interview. As many homes as possible along the main road were visited, followed by homes elsewhere until the required number of interviews had been conducted.

Section 4.6.1 presents the characteristics of respondents, and Section 4.6.2 summarises the survey results. The questionnaire is reproduced in Appendix C.

4.6.1 Sample profile (see Table 13)

TABLE 13

Classification of respondents (percentages of total)

		All respondents (200) %
Sex		
	Male	34
	Female	66
Age		
	Under 25	7
	25-39	22
	40-59	28
	60+	44
Property location		
	On main road	27
	Elsewhere	74
Children under 16		
	Yes	29
	No	71
Transportation		
	Drive a car	63
	Drive a van	7
	Drive a lorry	4
	Ride a motorcycle	2
	Ride a pedal cycle	15
	None of these	34

Thirty-four per cent of those questioned were male. Seventy-two per cent of respondents were over 40 years of age and only 7% were under 25; although care was taken in establishing the distribution of properties to be visited, this does not appear to be a very accurate reflection of the actual age distribution of the population of Craven Arms according to the 1991 Census. The age distribution derived from the Census returns was as follows:

under 16	20%
16-29	21%
30-44	19%
45-retirement age	17%
over retirement age	23%

It is possible that fewer people in the younger age groups were available for interview, also, no-one under 16 was interviewed. With a few exceptions mentioned below, however, the nature of the responses between age groups, tested using the χ^2 test, was broadly similar.

Just under 30% of the respondents had children under 16. Of those interviewed, 65% were drivers or motorcycle riders and 35% were either cyclists or had no other means of transport.

Just over a quarter (27%) of the respondents lived on the main road. Of the 53 respondents in this category, 8 were defined as living next to 'sensitive' measures - in this case the mini-roundabouts and speed cushions - which were likely to be controversial (because of their possible effect on traffic noise, for example) in their application on a busy main road.

The length of time interviewees had lived in Craven Arms was fairly evenly distributed:

0-5 years	40 (20%)
6-10	36 (18%)
11-20	38 (19%)
21-30	37 (19%)
31-50	36 (18%)
Over 50 years	13 (7%)

4.6.2 Results

Responses to each question are presented in turn. Tables show the percentage of interviewees giving each response. For simplicity, although they were computed, results classified by age, sex and whether or not the respondent was a driver have not been included in the Tables. Relevant comments have, however, been made below.

The results for questions 4-7 have also been analysed to give 'mean' responses by allocating a score to each response (see Sections 4.6.2.3 - 4.6.2.6). Scores of 1 to 5 were given as follows, where 5 was for the most positive reaction, 3 was for no opinion either way and 1 for the most negative reaction:

- Q.4 (level of satisfaction with changes made): 5 = very satisfied; 1 = very dissatisfied;

- Q.5 (effect of the changes for various groups of people): 5 = very good; 1 = very bad;

- Q.6 (usefulness of the changes made - *4 possible responses only*): 4 = very useful; 2 = of little use; 1 = causes concern;

- Q.7 (agreement with statements regarding the changes): 5 = agree a lot; 1 = disagree a lot.

Tables 17, 19, 21 and 26 show the resulting mean scores for: all respondents, those living on the main road, those living away from the main road, and for drivers and non-drivers. Respondents living on the main road are further split into those living near 'sensitive' measures (the mini-roundabouts and speed cushions mentioned above), and those living elsewhere on the main road. As only 8 respondents lived near sensitive measures, the results concerning these residents must be treated with caution.

4.6.2.1 Spontaneous recall of problems before the changes (Q.3 and Table 14)

Residents were first asked to think back to any problems caused by the road before the changes to it were made. The main problems recalled are presented in Table 14.

Respondents most frequently described how it had often been difficult and dangerous to cross the road, particularly for elderly residents or small children (37%). Interestingly, only 17% of those living on the main road mentioned this compared to 44% of those who lived elsewhere. Of all respondents, almost twice the number of women as men spoke of this difficulty (44% of females and 24% of males).

Thirty-four per cent of respondents mentioned the speed of traffic and the lack of a speed limit, in spite of the previously existing 40mph speed limit through the village. Those living on the main road were most likely to recall this issue, with forty-nine per cent of these residents mentioning the dangerous speed of traffic compared with 28% of those living elsewhere. This problem was more often mentioned by drivers (38%) than by non- drivers (25%).

Thirteen per cent of respondents said that the amount of traffic had been too great for the village. Just over one in ten residents had found it difficult to join the A49 from the side roads.

Other problems mentioned were: body rattle from HGVs encountering potholes (3%), that the road had been particularly busy at holiday times (3%); and that there had been a number of accidents (2%).

However, 23% of respondents (and 35% of non-drivers) did not think that there had been any problems before scheme installation. Four per cent of respondents went further by saying that the road had not been as bad before the changes had taken place.

4.6.2.2 Prompted recall of problems (Q.3A and Table 15)

Respondents were prompted with a number of issues concerning the main road and its traffic which could have caused problems before scheme installation. Of these, the speed of the traffic was the main worry, with 82% of respondents agreeing that it had been a problem. The danger to children (79%), to pedestrians crossing the road (76%) and, to a lesser extent, to cyclists (58%) were also endorsed as having been problems before scheme installation. Reactions to these particular issues were similar for respondents living on, or away from, the main road. More than half of respondents agreed that the amount of traffic (59%) and the number of lorries (56%) were a problem prior to scheme installation. Fewer respondents thought that dust and dirt (39%), too much noise (35%), danger to pedestrians on the footway (29%) and ground vibration (25%) had been a problem. Compared to residents living elsewhere, those living on the main road more frequently agreed that traffic noise/vibration, dust/dirt, smoke/fumes,

TABLE 14

Spontaneous recall of problems before the changes *(Main comments only)*

	All respondents %	Respondents on main road %	Respondents living elsewhere %
Number in sample	*200*	*53*	*147*
Dangerous/difficult to cross the road/took a long time/ especially for children/old people/needed a crossing	37	17	44
Speed of traffic dangerous/no speed limit	34	49	28
Amount of traffic too great for village	13	15	12
Couldn't get out on to A49/main road by car/ from side roads/no one had to give way	11	4	13

TABLE 15

Prompted recall of problems

	All respondents %	Respondents on main road %	Respondents elsewhere %
Number in sample	*200*	*53*	*147*
Amount of traffic	y=59, n=40	y=62, n=38	y=57, n=40
Speed of traffic	y=82, n=18	y=81, n=17	y=82, n=18
Number of lorries	y=56, n=41	y=64, n=32	y=52, n=44
Dangerous for motorists	y=40, n=52	y=40, n=53	y=39, n=51
Dangerous for cyclists	y=58, n=29	y=64, n=26	y=53, n=30
Dangerous/difficult for pedestrians to cross the road	y=76, n=25	y=83, n=17	y=73, n=27
Dangerous for pedestrians using the footway	y=29, n=69	y=40, n=58	y=24, n=73
Dangerous for children	y=79, n=16	y=83, n=13	y=78, n=17
Too much noise	y=35, n=56	y=49, n=45	y=29, n=60
Ground vibration	y=25, n=59	y=57, n=40	y=14, n=66
Dust and dirt	y=39, n=53	y=58, n=43	y=31, n=59
Smoke and fumes	y=42, n=53	y=55, n=43	y=37, n=56

and danger to pedestrians on the footway had been problems. This was especially the case with vibration, for which 57% of residents on the main road agreed that it had been a problem, compared with 14% of residents living elsewhere.

4.6.2.3 Level of satisfaction with the changes (Q.4 and Tables 16 and 17)

Respondents were asked about their overall level of satisfaction with the scheme. Over half of all respondents (54%) expressed dissatisfaction, with 30% being fairly dissatisfied and 24% being very dissatisfied. The reaction was similar whether the residents lived on, or away from, the main road. Allowing for those who had no opinion either way, only 39% of respondents were satisfied with the scheme. The under 40 age groups were most likely to be dissatisfied with the scheme (61%), but the over 60s (the largest age group interviewed) were more equally divided in their views.

Table 17 shows the mean scores for the overall level of satisfaction with the scheme for various categories of respondent. A mean score of 2.66 (slightly on the negative side of "no opinion either way") was recorded. The lowest mean score was 2.38 for residents living near sensitive measures. The scores for the other categories of respondents did not exceed 2.70.

4.6.2.4 Effect of the changes on certain groups of people (Q.5 and Tables 18 and 19)

The interviewees were asked how they thought the changes had affected different groups of people: 45%, 37%, 35%, and 26% of respondents thought the scheme had been quite good or very good for pedestrians, schoolchildren, elderly people and drivers respectively. On the other hand, 38%, 39%, 54% and 53% respectively thought the scheme had been quite bad or very bad for these groups. Only 9% of those questioned thought the scheme was quite good or very good for residents on the main road and 36% thought the scheme was quite bad or very bad. The under 40 age groups were more likely to say, by a statistically significant margin, that the measures were bad for drivers (under 40: 65%; 60 and over: 41%) and cyclists (under 40: 47%; 60 and over: 29%).

The mean scores for the effect of the changes on different groups of people are shown in Table 19 for various categories of respondent. These ranged from 3.00 ("no effect") on pedestrians to 2.34 (just above "quite bad") on residents living on the main road. It is interesting that the scheme was not seen as having better than "no effect" on any single group of people. For every single grouping, the drivers' mean scores were higher than those given by non-drivers.

TABLE 16

Level of satisfaction with the changes made

	All respondents %	Respondents on main road %	Respondents elsewhere %
Number in sample	*200*	*53*	*147*
Very satisfied	6	4	6
Fairly satisfied	33	30	32
No opinion either way	9	11	7
Fairly dissatisfied	30	26	31
Very dissatisfied	24	28	22
Don't know	-	-	-

TABLE 17

Level of satisfaction with the changes made: mean scores

Respondents *(with number in sample)* Total	On main road	Near sensitive measures	Away from sensitive measures	Elsewhere	Drivers	Non-drivers
200	*53*	*8*	*45*	*147*	*129*	*71*
5 = very satisfied, 4 = fairly satisfied, 3 = no opinion either way, 2 = fairly dissatisfied, 1 = very dissatisfied						
2.66	2.55	2.38	2.58	2.70	2.73	2.54

4.6.2.5 Usefulness of the changes made (Q.6, Q.6A, Tables 20 and 21)

Respondents were asked to assess how useful specific measures were. The most positive reaction was given to the countdown signs on the approaches to the gateways; 68% of respondents thought they were fairly or very useful. Sixty-six per cent felt the same way about the red surface and associated markings at the gateways, and 65% thought that the pedestrian crossing places with the refuges were beneficial. On the other hand, 21% of residents (32% of those living on the main road) felt that the latter were a cause for concern.

Table 21 shows the mean scores for the perceived usefulness of the changes, for various categories of respondent. The majority of these scores were clustered between the "fairly useful" or "of little use" ratings, none reaching the "very useful" category. The highest score of 3.14 was for drivers' views of the usefulness of the countdown signs. The countdown signs also received the highest rating by all respondents, followed by the red surfacing and 30mph roundel at the gateway (2.94) and the repeated red patches (2.82). The mini-roundabouts consistently had the lowest rating, ranging from 1.25 for those living near 'sensitive' measures, through 1.47 for all respondents, to 1.65 for non-drivers. The speed cushions had the next lowest score: 2.28 for all respondents, 2.30 for drivers, but 1.88 for residents living close to 'sensitive' measures.

The measures which caused the most concern were the mini-roundabouts, the pedestrian refuges and the speed cushions. The mini-roundabouts were the most controversial, with two-thirds of respondents, notably drivers (77%), respondents with children (78%), males (81%) and those in the middle age groups (at least 80%), expressing concern about them. A further 14% thought that they were of little use. Table 22 shows the main concerns expressed. The main worry (expressed by 61% of the 133 respondents who were concerned about them) was over who had priority: 24% said that no-one knew how to use the roundabouts; 23% said that drivers crossed straight over them without slowing down or taking any notice of them; and 14% were concerned about drivers not giving way or misinterpreting other drivers' actions. Eleven per cent of respondents mentioned that the roundabouts were difficult to see, and 10% each that there were too many of them and that visibility was poor. The latter was thought to be because the give way markings on the minor arms were too far back.

TABLE 18

Effect of the changes on certain groups of people

	Very good %	Quite good %	No effect %	Quite bad %	Very bad %	Don't know %
All respondents (200)						
Pedestrians	9	36	16	23	15	3
Drivers	4	22	9	29	24	13
Schoolchildren	8	28	16	17	22	11
Cyclists	1	10	26	18	19	27
Old people	6	29	8	23	31	4
Shopkeepers	1	10	38	8	12	32
Residents on main road	-	9	26	16	20	30
Respondents living on main road (53)						
Pedestrians	13	36	13	17	19	3
Drivers	4	17	9	28	28	13
Schoolchildren	13	26	11	19	19	11
Cyclists	-	13	21	21	26	19
Old people	4	26	9	25	32	4
Shopkeepers	-	9	36	11	21	23
Residents on main road	-	17	38	13	28	4
Respondents living elsewhere (147)						
Pedestrians	7	35	17	24	14	3
Drivers	4	24	9	29	22	12
Schoolchildren	5	28	17	16	23	11
Cyclists	1	9	28	16	16	30
Old people	7	30	7	22	31	3
Shopkeepers	1	10	39	7	9	35
Residents on main road	-	5	22	17	27	2

About one in five respondents was concerned about the pedestrian refuges, rising to about one third of those living on the main road. Of the 41 respondents expressing concern, 9 (22%) suggested that a proper pedestrian crossing was needed outside the supermarket, and 6 (15%) said that the refuges were too narrow for those with pushchairs or in wheelchairs (Table 23). Traffic not stopping for pedestrians was a worry for 4 (10%) of these respondents.

Over half of respondents had reservations about the speed cushions; 45% felt that these were of little use and 14% were concerned about them. Humps right across the road were preferred or they were generally thought not to be a good idea. The comments are shown in Table 24.

Although few respondents were concerned about the other measures, over a third said that the tooth markings at the gateway (37%) and the hatching on the red background (41%) were of little use. A larger proportion of respondents living on the main road had reservations about these measures, for example, 55% about the hatching.

Concerns about the other measures were as follows:

Countdown signs	"Signs should be more prominent".
Tooth markings	"The effects are wearing off already"; "rumble strips would have been better."
Red surfacing/markings at gateway	"Green markings preferable/as in France"; "an eyesore."
Repeated red patches	"Green markings preferable/as in France"; "silly idea/cannot see the point/just a joke"; "drivers mistake them for pedestrian crossings and keep stopping".

TABLE 19

Effect of the changes on certain groups of people: mean scores

Respondents *(with number in sample)* Total	On main road	Near sensitive measures	Away from sensitive measures	Elsewhere	Drivers	Non-drivers
200	*53*	*8*	*45*	*147*	*129*	*71*
5 = very good, 4 = quite good, 3 = no effect, 2 = quite bad, 1 = very bad						
Pedestrians 3.00	3.08	2.88	3.11	2.97	3.13	2.76
Drivers 2.47	2.30	2.86	2.21	2.53	2.52	2.33
Schoolchildren 2.80	2.96	2.75	3.00	2.74	2.87	2.64
Cyclists 2.39	2.26	2.57	2.19	2.45	2.46	2.23
Elderly people 2.54	2.43	2.63	2.40	2.58	2.60	2.45
Shopkeepers 2.68	2.44	2.00	2.55	2.79	2.83	2.37
Residents on the main road 2.34	2.45	2.29	2.48	2.27	2.40	2.19

Hatched markings "Confusion/people think they cannot overtake there"; "people think they must not drive on them"; "an eyesore"; "cars still speed"; "white lines should be continuous to stop people crossing them/overtaking".

4.6.2.6 Agreement with statements regarding the changes (Q.7 and Tables 25 and 26)

Respondents were asked whether or not they agreed about various statements regarding the changes.

In spite of the negative reactions to parts of the scheme already described, 69% of residents concluded that the changes were necessary. Just over half of those questioned agreed that the road was now safer and easier to cross (53%).

However, the level of agreement with other statements is not so encouraging. Around three out of every four respondents agreed that a bypass would have been better (77%), slightly more so amongst drivers (81%). Three-quarters of residents (74%) also agreed that other changes would have been better, and 70% felt that the measures were frustrating for drivers.

While about three quarters of respondents agreed that the changes had reduced traffic speeds (74%), less than half thought that they had been reduced enough (49%). (The corresponding proportions for residents living on the main road were 62% and 30%.) Only 43% said that it was now safer to walk on the footway. Forty-eight per cent believed that the alterations had increased noise and 27% thought that their homes shook when a lorry went past. These percentages increased to 57% and 68% respectively for respondents living on the main road.

Not many respondents felt that the scheme had made the road safer for cyclists (16% in agreement) or motorists (27%). The under 60 age groups were more likely to disagree that the measures were safer for cyclists (under 40: 53%; 40-59: 51%; 60 and over: 28%). This difference in responses by age was statistically significant. The respondents' reservations about the scheme were reinforced by the fact that less than one in five residents (17%) agreed that the measures should be introduced in other villages.

The under 40 age groups were more likely to agree that other changes would be better (under 40: 84%; 60 and over: 60%). This difference was statistically significant. Of the 147 respondents who agreed that other changes would be better, 7% suggested fewer roundabouts and 3% suggested

TABLE 20

Usefulness of the changes made

	Very useful %	Fairly useful %	Of little use %	Causes concern %	Don't know/ no opinion %
All respondents (200)					
Countdown signs	28	40	17	4	12
Tooth markings at gateway	13	30	37	2	19
Red surface/markings at gateway	26	40	24	4	7
Repeated red patches	19	43	28	4	7
Hatching on red background	15	29	41	5	11
Mini-roundabouts	2	13	14	67	5
Pedestrian refuges	28	37	12	21	4
Speed cushions	9	22	45	14	12
Respondents on main road (53)					
Countdown signs	19	36	30	2	13
Tooth markings at gateway	8	28	43	2	19
Red surface/markings at gateway	23	32	30	2	13
Repeated red patches	19	36	30	2	13
Hatching on red background	15	11	55	4	15
Mini-roundabouts	2	11	17	62	8
Pedestrian refuges	25	30	8	32	6
Speed cushions	9	17	49	8	17
Respondents elsewhere (147)					
Countdown signs	31	41	12	4	11
Tooth markings at gateway	15	31	34	2	18
Red surface/markings at gateway	27	43	21	5	4
Repeated red patches	19	45	27	5	5
Hatching on red background	15	35	35	5	10
Mini-roundabouts	1	14	13	68	4
Pedestrian refuges	29	39	14	16	3
Speed cushions	8	23	43	16	10

a pelican or zebra crossing adjacent to the shopping centre. No other changes were suggested.

The mean scores for respondents' agreement with statements regarding the changes are shown in Table 26 for various categories of respondent. The scores for residents on the main road, especially those living near 'sensitive' measures, generally suggested a more negative reaction than other respondents to these statements.

The statement "the changes were necessary" was rated fairly consistently across all categories of respondent except those who lived near 'sensitive measures'. For the latter opinions tended slightly towards disagreement with this statement, with a score of 2.63. Otherwise, there was a mild acceptance that the changes were necessary, with scores of between "no opinion" and "agree a little"; drivers (3.78) were the most likely to agree with the statement.

On the whole, respondents had no strong feelings that the scheme made it safer or easier to cross the road, or made it safer to walk on the footway.

There was a tendency to disagree with the statements that the measures made it safer for motorists or cyclists (scoring 2.43 and 2.38 respectively for all respondents). The score for drivers regarding motorists' safety differed little from the overall score of 2.43. The drivers' scores were also similar to the overall score for the scheme making it safer for cyclists, though the opinions of residents living near sensitive measures attracted a score of only 2.00 ("disagree a little").

There was no strong agreement that the measures had reduced speeds, in spite of the fairly good speed reductions actually achieved. The ratings were between "no opinion" (3) and "agree a little" (4), ranging from 3.25 for those

TABLE 21

Usefulness of the changes made: mean scores

Respondents *(with number in sample)* Total	On main road	Near sensitive measures	Away from sensitive measures	Elsewhere	Drivers	Non-drivers
200	*53*	*8*	*45*	*147*	*129*	*71*
4 = very useful, 3 = fairly useful, 2 = of little use, 1 = causes concern						
Countdown signs						
3.05	2.83	3.00	2.79	3.12	3.14	2.80
Tooth markings						
2.66	2.51	2.57	2.50	2.72	2.70	2.56
Red surface and 30mph roundel at gateway						
2.94	2.87	2.86	2.87	2.96	3.03	2.75
Repeated red patches						
2.82	2.83	2.86	2.82	2.82	2.87	2.87
Hatched markings on red background						
2.60	2.44	2.29	2.47	2.65	2.62	2.55
Mini-roundabouts						
1.47	1.49	1.25	1.54	1.46	1.38	1.65
Pedestrian crossing places with islands						
2.74	2.50	2.25	2.55	2.82	2.75	2.71
Speed cushions						
2.28	2.34	1.88	2.44	2.27	2.30	2.24

living near 'sensitive' measures, to 3.84 for residents living away from the main road. Comments by those living on the main road averaged 3.28. There was less agreement that the measures had reduced speeds *enough*, many of the scores being slightly on the negative side of "no opinion". The scores ranged from 3.23 for respondents living away from the main road, to 2.55 for residents on the main road and 2.38 for those living near 'sensitive measures'.

There was some agreement that the measures were frustrating for drivers (4.06 for all respondents, and 4.13 for drivers themselves).

Most respondents disagreed that the measures should be introduced in other villages, the strongest opinions coming from residents near 'sensitive' measures. Their comments attracted a score of 1.63, compared with 2.06 for others on the main road and 2.23 overall. No score in this category was higher than 2.34 (non-drivers).

There was a tendency towards slight agreement that the measures increased noise in spite of the findings of the noise survey (see Section 4.4). It is possible that an isolated noise at night causing disturbance, of which there is anecdotal evidence, will bias residents' opinions to the negative side.

There was a tendency towards slight agreement with the statement that houses are shaken by lorries in spite of the fact that measurements of ground-borne vibrations show an increase to levels that are still very low and are unlikely to be perceived. However, residents' comments on vibration could have related to airborne vibration due to low frequency noise emissions from traffic rather than ground-borne vibration. Low frequency noise can cause light flexible structures such as doors and windows to vibrate; this can generate noise effects which are present as vibration. Airborne vibration was not measured in this study as it can be difficult to measure - this is carried out by attaching an accelerometer to something *that is likely* to be excited by low frequency noise. This would need to be determined beforehand by asking the occupier or waiting for the effect to occur.

TABLE 22

Particular concerns regarding the mini-roundabouts

	All respondents %	Respondents on main road %	Respondents living elsewhere %
Number in sample	*133*	*33*	*100*
"No one knows what to do when they get to them/ how to use them"	24	30	22
"Cars drive straight over/do not slow up/ take no notice/they make no difference"	23	27	21
"Not easy to see/should be raised/put in a kerb/ put something in the middle"	11	15	9
"There are too many roundabouts"	10	9	10
"Poor visibility/have to come right out before can see (on Coverdale Road/Shrewsbury Road)/ (give way) line is too far back"	10	3	12
"Lorries cannot go round them"	8	9	7
"Need signs/more warning signs/suddenly you're upon them"	8	9	7
"They are offset/not in the centre of the road"	7	9	6
"Cars do not give way/lots of near misses/accidents"	7	-	8
"Other drivers misinterpret actions/think you are turning when you are not"	7	12	5
"Silly idea/cannot see the point/just a joke"	6	-	8
"Should have humps right across the road/ you can avoid them/not high enough"	5	9	4
"Won't be able to see them in winter/snow/dark/ already obliterated by tyre marks"	3	9	1

Other comments
"Cars still speed"; "not enough room in road for them"; "too close together"; "waste of money"; "traffic does not stop for pedestrians"; "need lines painted on road"; "confusion, people think they cannot overtake there"; "unusual to have one coming off a housing estate"; "signs should be more prominent"; "pedestrians misread what drivers are doing".

On the main road, there was slightly stronger agreement that houses are shaken by lorries (score 4.00) than that there is increased noise (3.69). The opinions of residents near 'sensitive' measures attracted the highest score of 4.13 for both noise and vibration.

The scores for the statement that the measures had increased traffic fumes were between "no opinion" and "agree a little" (3.53 for all respondents).

Residents agreed fairly strongly that a bypass would have been better or that other changes would have been better. The former attracted a score of 4.23 for all respondents and the latter 4.44. There was little difference in opinion between residents living on or away from the main road.

4.6.2.7 The look of the scheme (Q.8, Q.8A, Tables 27 and 28)

Respondents were asked if they had any concerns about the look of the scheme; 60% were not concerned (Table 27).

Of the 81 people who had concerns (Table 28), 60% said that it was "very ugly", "hideous", "an eyesore" or "garish"

TABLE 23

Particular concerns regarding pedestrian crossing places with islands

	All respondents %	Respondents on main road %	Respondents living elsewhere %
Number in sample	*41*	*17*	*24*
"Need a proper pedestrian crossing/zebra crossing/ with lights/outside the supermarket"	22	41	8
"Crossings too narrow for pushchairs/wheelchairs"	15	6	21
"No-one knows what to do when you get to them/ how to use them"	10	12	8
"Traffic does not stop for pedestrians/need lines painted on the road"	10	6	13

Other comments
"Have to look in 3 different directions"; "drivers mistake them for pedestrian crossings and keep stopping"; "get stuck for ages by the side".

TABLE 24

Particular concerns about the speed cushions

	All respondents %	Respondents on main road %	Respondents living elsewhere %
Number in sample	*27*	*4*	*23*
"Should have humps right across the road/ you can avoid them/not high enough"	30	25	30
"Silly idea/cannot see the point/just a joke"	22	-	26
"Make things very noisy"	4	-	4

and 17% mentioned the brightness of the coloured surfaces. Other residents felt that there were too many distracting signs, too many mini-roundabouts and that the new measures were too confusing and out of place (all mentioned by 7% of respondents). Six per cent of residents were concerned about the red surfacing and 4% felt that too many alterations had taken place.

4.6.2.8 Awareness of the changes before they occurred (Q9, Q9A, Tables 29 and 30)

Respondents were then asked if they had heard about the changes prior to scheme installation, and 71% of respondents said that they had been forewarned. The remainder (29%) had not been aware of the new scheme until work had actually started.

Table 30 shows that for the 141 respondents who did have prior knowledge of the scheme, the most common source of information was the local newspaper (for 101 respondents). Fifty-seven respondents found out about the scheme through friends or relatives, 34 mentioned public meetings and 22 had seen public notices in the street which had informed them of the plans. Other sources included leaflets picked up in shops or at an exhibition (mentioned by 10 respondents), local TV news and exhibitions or displays (referred to by 7 respondents each). There was little difference in the pattern of responses between residents living on the main road and elsewhere.

TABLE 25

Agreement with statements regarding the changes

	Agree a lot %	Agree a little %	No opinion %	Dis--agree a little %	Dis--agree a lot %	Don't know %
All respondents (200)						
The changes were necessary	29	40	1	22	8	2
They make it safer/easier to cross road	21	32	4	23	19	2
They make it safer to walk on footway	12	31	22	24	9	5
They make it safer for motorists	8	19	6	29	28	11
They make it safer for cyclists	3	13	18	18	24	26
They have reduced speeds	30	44	2	12	12	1
They have reduced speeds enough	22	27	3	30	18	2
They are frustrating for drivers	50	20	9	8	7	8
Should be introduced in other villages	6	11	25	5	43	11
They have increased noise	28	20	22	17	6	9
House shakes when lorry goes by	20	7	26	7	8	34
They have increased traffic fumes	25	20	27	12	6	11
A bypass would have been better	68	9	3	12	7	3
Other changes would have been better	65	9	10	4	3	11
Respondents living on main road (53)						
The changes were necessary	30	38	2	15	13	2
They make it safer/easier to cross road	21	30	2	26	19	2
They make it safer to walk on footway	15	25	11	26	15	8
They make it safer for motorists	9	17	8	26	28	11
They make it safer for cyclists	4	15	15	15	25	26
They have reduced speeds	19	43	2	19	17	-
They have reduced speeds enough	17	13	-	47	23	-
They are frustrating for drivers	36	23	15	6	9	11
Should be introduced in other villages	4	9	23	8	47	9
They have increased noise	36	21	21	11	8	4
House shakes when lorry goes by	57	11	6	17	6	4
They have increased traffic fumes	25	21	28	15	8	4
A bypass would have been better	68	4	2	9	9	4
Other changes would have been better	60	11	2	-	8	19
Respondents living elsewhere (147)						
The changes were necessary	28	40	1	24	5	1
They make it safer/easier to cross road	20	33	5	22	18	2
They make it safer to walk on footway	10	33	25	22	6	3
They make it safer for motorists	7	20	5	30	28	11
They make it safer for cyclists	3	12	18	19	23	25
They have reduced speeds	34	44	2	10	10	1
They have reduced speeds enough	23	31	4	24	16	2
They are frustrating for drivers	54	19	7	8	5	6
Should be introduced in other villages	7	11	25	4	41	12
They have increased noise	24	19	22	18	5	11
House shakes when lorry goes by	6	5	33	3	8	45
They have increased traffic fumes	25	20	27	10	5	14
A bypass would have been better	67	10	3	12	5	1
Other changes would have been better	66	8	9	4	4	9

TABLE 26

Agreement with statements regarding the changes: mean scores

Respondents (with number in sample) Total	On main road	Near sensitive measures	Away from sensitive measures	Elsewhere	Drivers	Non-drivers
200	*53*	*8*	*45*	*147*	*129*	*71*
5 = agree a lot, 4 = agree a little, 3 = no opinion, 2 = disagree a little, 1 = disagree a lot						
The changes were necessary						
3.60	3.58	2.63	3.75	3.61	3.78	3.28
They make it safer/easier to cross the road						
3.13	3.08	2.50	3.18	3.15	3.16	3.09
They make it safer to walk on the footway						
3.14	2.98	2.50	3.07	3.19	3.22	2.97
They make it safer for motorists						
2.43	2.47	2.29	2.50	2.41	2.45	2.38
They make it safer for cyclists						
2.38	2.44	2.00	2.53	2.35	2.34	2.47
They have reduced speeds						
3.69	3.28	3.25	3.29	3.84	3.80	3.49
They have reduced speeds enough						
3.05	2.55	2.38	2.58	3.23	3.10	2.94
They are frustrating for drivers						
4.06	3.79	3.88	3.77	4.16	4.13	3.91
They should be introduced in other villages						
2.23	2.06	1.63	2.15	2.29	2.18	2.34
They have increased noise						
3.51	3.69	4.13	3.60	3.44	3.61	3.30
House shakes when a lorry goes by						
3.36	4.00	4.13	3.98	2.95	3.49	3.09
They have increased traffic fumes						
3.53	3.41	3.63	3.37	3.58	3.58	3.44
A bypass would have been better						
4.23	4.20	3.88	4.27	4.23	4.31	4.06
Other changes would have been better						
4.44	4.53	4.38	4.57	4.40	4.56	4.19

TABLE 27

Incidence of concerns regarding the look of the scheme

	All respondents %	Respondents on main road %	Respondents elsewhere %
Number in sample	*200*	*53*	*147*
Yes	41	36	42
No	60	64	58

TABLE 28

Particular concerns regarding the look of the scheme

	All respondents concerned %
Number in sample	*81 respondents*
"Very ugly/hideous/eyesore/garish"	60
"Colour is too bright/(appearance of) the orange (surfacing)"	17
"Too many signs/distracting"	7
"Too confusing/people don't understand it"	7
"Too many mini-roundabouts"	7
"Looks stupid/silly/we are the laughing stock of the area"	7
"Red marks on the road look awful"	6
"Too many measures have been put in"	4
"Need bigger signs warning of new road layout and mini-roundabouts"	2

Other comments were that the markings could not be seen under street lighting, there were tyre marks on the red surfacing, the "white-painted features were ugly" and that the appearance of the measures were environmentally unacceptable.

TABLE 29

Awareness of the changes before they occurred

	All respondents %	Respondents on main road %	Respondents elsewhere %
Number in sample	*200*	*53*	*147*
Yes	71	74	69
No	30	26	31

TABLE 30

How the changes were heard about

	All respondents %
Number in sample	*200*
Local papers	72
From friends/relatives	40
Public meetings	24
Public notices in the street	16
Leaflets	7
Local TV news	5
Local exhibition	5
Plan in the Post Office	3
Local councillors	2
Local radio news	2
Village newsletter	1
Plan in the supermarket	1

satisfied, 36% were dissatisfied and 30% had no opinion either way or were unsure.

4.7 REACTION FROM THE EMERGENCY SERVICES

Shropshire County Council wrote to the West Mercia Constabulary, and the County Ambulance and Fire/Rescue Services for their views of the scheme. There was a mixed reaction from these emergency services to the scheme.

The Police stated there had been no effect on their response times.

The Shropshire Ambulance Service stated that the scheme had very little effect on response times or patient comfort travelling south from the Ambulance Station, which is located between the south gateway and the first mini-roundabout (at the junction with B4368 Clun Road). Travelling north, however, the mini-roundabouts and speed cushions did have an apparent effect on response times. It was claimed (a) that drivers not knowing who gives way at the mini-roundabouts could cause delay, and (b) that the

TABLE 31

Consultation with the residents about the scheme

	All respondents %	Respondents on main road %	Respondents elsewhere %
Number in sample	*200*	*53*	*147*
Yes	27	42	21
No	41	34	51
Don't know	27	25	28

4.6.2.9 Consultation with the residents about the scheme (Q10, Q10A, Tables 31 and 32)

When asked whether the council or the Department of Transport had asked residents for their views on the plans via leaflets or public meetings, just over a quarter of respondents said they had been consulted in this way (27%). However, 47% claimed that they had not been asked for their opinion and 27%, a relatively high proportion of residents, did not know.

Almost all of the residents who were aware of the council or Department of Transport asking for opinions said that they were consulted before the changes (51 out of 53 respondents). Only one respondent claimed to have been consulted after the event.

Respondents were fairly equally divided about their level of satisfaction with the consultation (Table 32): 34% were

TABLE 32

Level of satisfaction with the consultation regarding the scheme

	All respondents aware of consultation %
Number in sample	*53*
Very satisfied	8
Fairly satisfied	26
No opinion either way	28
Fairly dissatisfied	15
Very dissatisfied	21
Don't know	2

speed cushions could cause discomfort to patients when other motorists pull over and slow down to let the ambulance by, with an increased chance that the ambulance would have to mount the cushions instead of straddling them, as they would had they taken an unobstructed line.

The Shropshire Fire and Rescue Service, whose station was also located between the south gateway and the B4386 Clun Road junction, was most concerned about the scheme, claiming increased response times. They stated that:

- the mini-roundabouts were most likely to cause delays, especially during peak hours, causing appliances to take longer to go through the village;
- appliances were delayed leaving the station because of (a) tailbacks from the mini-roundabouts at busy periods, and (b) firefighters on their way to the station (called in when required, to take an appliance out) taking longer to get through the traffic;
- confusion by other drivers over who gives way at the mini-roundabouts contributed to traffic delays.

4.8 ACCIDENTS

There were 23 reported injury accidents on the A49 within the built-up area (*ie* within the 40mph speed limit) of Craven Arms in the 5 years prior to the introduction of the traffic calming measures. Seven of these accidents were reported during the last 3 years of this period. Five out of the 23 accidents involved serious injury. Following scheme implementation, no injury accidents were reported in the 5 month period that data were available at the time of writing. The 'after' period is quite short; the changes are not statistically significant and more time will be needed for a more comprehensive accident analysis to be carried out.

The 23 accidents occurring in the 'before' period can be classified as follows:

nose-to-tail (on main road)	5
nose-to-tail involving a vehicle waiting to turnright off the main road	3
pedestrian	6
vehicle shunted into oncoming vehicle	2
head-on collision (through loss of control)	2
collision with oncoming right turner	2
pedal cyclist	2
vehicle waiting to emerge on to main road hit from behind	1

Seven accidents involved intended or executed turning manoeuvres by vehicles leaving the main road. In one of these, the right-turning vehicle was not hit, but the vehicle stopping behind it was struck from behind.

5. SUMMARY AND CONCLUSIONS

A traffic calming scheme was implemented in June 1995 at Craven Arms, on the A49 trunk road in Shropshire. The A49 trunk road forms part of a route linking North West England with South Wales. Before the traffic calming measures were introduced, there was a two-way mean traffic flow through Craven Arms of about 9000 vehicles per day, of which about one-sixth were heavy goods vehicles. The built-up area of the village extends for over 1km and the current speed limit is 30mph, reduced from 40mph before scheme installation. The carriageway width (unchanged on scheme installation) is mostly 7.3m, with a minimum width of 6.5m and a maximum width of 10m. A total of 23 injury accidents were reported within the village speed limit during the 5 years prior to scheme installation.

The scheme comprised a variety of measures installed on the approaches and within the village. On each main road approach, countdown signs and 'dragon teeth' markings were installed in advance of gateway features. The latter comprised 30mph speed limit signing mounted above large village nameplates each side of the carriageway, together with an area of bright red surfacing with white edge markings and a painted '30' roundel.

In the village, the red patches and associated markings at the gateways were repeated at intervals, and mini-roundabouts were installed at 4 junctions. In the centre of the village, a number of speed cushions, also coloured red, were installed between the mini-roundabouts. Centre hatching on a red background and pedestrian refuges completed the scheme, which had a high visual impact overall.

'Before' and 'after' monitoring comprised measurements of vehicle speeds and flows, journey times through the village, traffic noise and ground vibration. A public opinion survey was conducted about 3 months after scheme installation. The results are summarised below and conclusions drawn. Further longer term measurements of vehicle speeds and flow will be made in July 1996, 12 months after the initial speed and flow measurements.

5.1 TRAFFIC FLOWS

'Before' and 'after' total vehicle counts were carried out at the gateway sites in November 1994 and June/July 1995, using data loggers connected to inductive loop detectors. A 12 hour manual classified count was carried out in the village in November 1994 and July 1995.

At the gateway sites, the mean 24 hour two-way traffic flow over 7 days increased by about 20%, to nearly 10,000 vehicles/day at the south gateway and to 11,000 at the north gateway in the 'after' period. This increase is almost certainly due to seasonal variation, and is in accordance with the national increase in the mean daily two-way flow over 7 days between November and July on non built-up major roads. Weekday flows increased by about 16% and weekend flows increased by more than 30%.

The manual classified count showed that the proportion of HGVs was 16% during the 'before' period and 14% during the 'after' period. This is approximately in accordance with national statistics for non built-up major roads, which show fewer light vehicles relative to HGVs in November than in July. Two-wheelers, ambulances, fire appliances and mini-buses, for which vertical deflections such as road humps and speed cushions have been a sensitive issue in schemes generally, comprised 2% of the total flow during both counts.

It would therefore seem that, with no practical alternative route available, the traffic calming scheme has not measurably affected the overall flow of traffic through Craven Arms, or the number of HGVs.

5.2 VEHICLE SPEEDS AND JOURNEY TIMES

The majority of the 'before' and 'after' speed monitoring was carried out in November 1994 and June/July 1995. The monitoring positions were at the gateway sites and at 4 sites within the village: 2 were between repeated red patches, one on a speed cushion and one between speed cushions. At the gateway sites, data were collected by data logger, while elsewhere radar speed readings of free-flowing vehicles were taken.

Mean and 85th percentile speeds fell by 8-9mph at the gateways, and reductions in the village ranged from 3-6mph between repeated red patches, to over 10mph on the stretch with the mini-roundabouts and speed cushions in the village centre. Within the village, 85th percentile speeds were reduced to the new speed limit or below (*ie* 20-28mph for HGVs and 22-30mph for light vehicles) at sites with mini roundabouts and speed cushions, but at the repeated red patches the 85th percentile speeds were still up to 8mph above the speed limit. The 85th percentile speeds at the village gateways were still up to 10 mph above the speed limit.

It is not known which of the measures employed on the approach to, and at, the gateways contributed most to the reduction in speeds. Approaching the gateways, the count-down signs arguably have more visual impact than the tooth markings which are inconspicuous until they are encountered. Once through the gateways, lower speeds than before scheme installation were maintained on the approach to the centre of the village. Here, the close spacing of the mini-roundabouts and the speed cushions afforded little opportunity for drivers to increase speed between these features.

Journey times through the village (between each end of the village speed limit) were calculated by matching registration numbers on video taken at the gateway sites over an 8 hour period. The times at which the vehicles passed each gateway site were subtracted to obtain the journey time. The mean journey time increased by about half-a-minute after the scheme was introduced, an increase of about one-third.

5.3 NOISE MEASUREMENTS

5.3.1 Vehicle noise

Maximum vehicle noise levels were substantially reduced after the speed reducing measures were installed. At a site located alongside a speed control cushion (site B), vehicle noise levels were reduced by about 9 dB(A) for light vehicles and 8 dB(A) for heavy vehicles. Similarly, for a site located mid-way between the cushions (site C) light vehicle noise was reduced by about 7 dB(A) and heavy vehicle noise by about 5 dB(A). The reductions in vehicle noise level were due to reductions in vehicle speed.

At the north gateway site (site A), it was estimated that maximum noise levels for light and heavy vehicles may have been reduced by about 4 and 3 dB(A), respectively. The lower reductions in noise levels recorded at this site compared with other sites are due to the smaller reduction in vehicle speeds.

At the site with cushions (site B), the 'before' and 'after' relationships between noise level and speed were similar. This indicates that, after allowance for the lower speed over the cushions, the presence of the 1500mm wide cushions had little, if any, effect on maximum vehicle noise levels for both light and heavy vehicles.

Heavy vehicle noise levels recorded at site B (alongside a cushion) were about 3 dB(A) lower than corresponding noise levels recorded at the other cushion site (site E), after normalising for speed. The reason for this variation in noise levels was thought to be due to the influence of a mini-roundabout situated in close proximity and prior to site E. It is therefore possible that residents living alongside the A49 close to mini-roundabouts may find the variations in heavy vehicle noise levels intrusive; further investigations would be required to confirm this.

5.3.2 Traffic noise

Daytime traffic noise levels, $L_{A10,18h}$ (0600 to midnight), measured adjacent to a cushion on the approach to a mini-roundabout (site B) fell by over 3dB(A). It can be concluded, therefore, that the use of speed cushions did not contribute to an increase in noise, and that cushions of similar design could be used in similar circumstances elsewhere with some confidence.

Reductions in traffic noise levels at this site were not as large as expected, based on the reduction in vehicle noise levels that were recorded from vehicles travelling in the southbound lane at the same site during the vehicle noise surveys. It was concluded that the influence of the mini-roundabout on driver behaviour was giving higher than expected noise levels from heavy vehicles in the north-bound lane travelling away from the roundabout. Although overall traffic noise levels were reduced at this site it is possible that the variability in noise levels from heavy vehicles might be intrusive to residents living alongside this section of the A49.

At a site positioned away from any speed control measures (site F), the reduction in overall traffic noise, $L_{A10,18h}$ dB, was about 2 dB(A). After taking into account the small increase in traffic in the 'after' survey and the change in vehicle speeds, the estimated reduction in traffic noise, determined from the reduction in vehicle noise levels between the 'before' and 'after' surveys, was 2.2 dB(A) and found to be in good agreement with the measured value of 2.1 dB(A).

At the north gateway (site A) it may be assumed from the reductions in vehicle noise estimated at this site that traffic noise levels have been reduced by about 3 dB(A).

Nighttime noise levels, $L_{A10,6h}$ dB (midnight to 0600), were found to be generally unaffected by the speed control measures. However, where traffic flows are low, typical to the nighttime period, noise levels can be influenced by non-traffic noise sources such as bird song during the dawn chorus. Unless noise levels are carefully monitored over several nighttime periods it is difficult to draw any reliable conclusions from these results.

5.4 GROUND-BORNE VIBRATION

The ground-borne vibration effects of speed cushions were determined at a dwelling close to such an installation. Results from this 'worst case' location enable the maximum likely vibration effects of such cushions to be gauged for the scheme as a whole.

From the measurements made before and after installation the following conclusions can be drawn:

1. The peak levels of ground-borne vertical vibration in the building structure near ground level generated by passing traffic were higher after the scheme was introduced (range 0.04 to 0.1mm/s). However, they were still well below the mean threshold level for human perception (0.3mm/s).

2. Heavy vehicles which clipped the cushion produced vibration levels approximately 50% higher than those which did not.

3. Vibration levels generated by normal use of the building and from other non-vehicle sources were of the same order as those produced by the worst case conditions where a heavy vehicle clipped the cushion.

4. A review of other relevant research has shown that some other sites on main roads are exposed to much higher vibration levels than measured at the study site. There is also no evidence of structural damage to buildings exposed to vibration levels below approximately 10mm/s at the foundations. This vibration level is approximately 30 times the maximum peak values recorded in the present survey.

5.5 PUBLIC OPINION SURVEY

A public opinion survey, of 200 local residents, took place in September 1995, about 3 months after the introduction of the measures. About 35% of the respondents were male, 72% were 40 years old or over, 27% lived on the main road and 65% were drivers or motorcycle riders. Over two-thirds of respondents knew beforehand that measures were to be installed, and a similar proportion thought that changes were necessary.

The main problem before scheme installation was thought to be the difficulty in crossing the road (particularly for the elderly or children), aggravated by traffic exceeding the speed limit. In spite of the encouraging measured speed reductions, nearly half of respondents (or over two-thirds of those living on the main road) thought speeds had not been reduced enough after implementation. Just over half of respondents thought it was safer for pedestrians after implementation; but only 27% thought it was now safer for motorists.

When asked about their level of satisfaction with the scheme, about half (54%) of the residents expressed dissatisfaction. The reaction was similar whether the residents lived on, or away from, the main road. Allowing for those who had no opinion either way, only 39% of respondents were satisfied with the scheme.

When asked about specific measures, about two-thirds of respondents thought that the countdown signs, gateway features, repeated red patches and pedestrian refuges were useful, although one in five expressed concern about the refuges, 15% of these respondents saying that they were too narrow, and over 20% preferring a zebra or pelican crossing outside the supermarket.

The mini-roundabouts came in for particular criticism, with two-thirds of respondents expressing concern about them. Over 60% of these respondents mentioned problems that seemed to be related to who had priority, *e.g.* drivers not knowing how to use them, driving straight over them without slowing down, drivers not giving way, drivers not sure of the actions of others. Also 1 in 5 of these respondents said that they were difficult to see and that there were too many of them.

Although less concern was expressed about the speed cushions and the centre hatching on a red background, over

40% of respondents thought that these features were of little use, and 37% had similar views on the tooth markings.

Although only one resident thought that the speed cushions generated extra noise, there was mild agreement generally that the measures overall had increased traffic noise, and vibration from passing HGVs. Respondents were somewhat less than satisfied with the scheme overall, and there was fairly strong agreement that other changes or a bypass would have been better.

Responses were broadly similar between age groups, except that younger respondents (aged under 40) were more likely to (a) express dissatisfaction with the scheme, (b) think that the measures disadvantaged drivers and cyclists and (c) not favour similar measures in other villages. They were also slightly more likely to say that other changes would have been better.

5.6 REACTION FROM THE EMERGENCY SERVICES

Shropshire County Council wrote to the Police, Ambulance and Fire/Rescue Services to canvas their opinions on the scheme. The Police stated that their response times had not been affected, but the Ambulance and Fire/Rescue Services were concerned. Both services claimed that response times had been increased, especially by the mini-roundabouts, where delays were alleged to occur in peak periods. Confusion in other drivers over who had the right-of-way was mentioned as a primary cause. Ambulances being forced to mount the speed cushions, by drivers pulling over to allow them to overtake, could cause discomfort to patients.

5.7 ACCIDENTS

A total of 23 injury accidents (5 involving serious injury) were reported on the A49 within the built-up area (*ie* within the 40mph speed limit) of Craven Arms in the 5 years prior to the introduction of the traffic calming measures. Seven of these accidents were reported during the last 3 years of this period. Since scheme installation, none have been reported during the 5 month period for which data were available at the time of writing; more time is needed to draw any conclusions about the safety benefit of the scheme.

5.8 DISCUSSION

The traffic calming scheme on the A49 at Craven Arms has been successful, in part of the village, in meeting the objective of reducing 85th percentile speeds to the 30mph speed limit, but rather less successful in terms of public acceptability.

About half of the people interviewed expressed dissatisfaction with the scheme. Many people thought that vehicle speeds had not been reduced enough, but their main concerns were about the measures that were most effective in reducing speeds to levels at or below the 30mph limit (mini roundabouts and, to a lesser extent, the speed cushions). Detailed design changes might alleviate some of the problems mentioned by the residents. However, their reactions to the scheme highlight the dilemma for the traffic calming engineer who is attempting to reduce accidents by measures that influence vehicle speed without causing unwanted safety and environmental side effects. The measures that are the most effective are generally the ones that have the most behavioural and environmental impact and are likely to be the most unpopular.

With regard to the impact of the traffic calming measures on vehicle noise and ground vibration, there is a discrepancy between the measured changes and the perceptions of residents. The noise measurements generally show a decrease or no change and the ground-borne vibrations show an increase to levels that are still very low and unlikely to be perceived. However, the responses from the residents suggest that noise has increased and that vibrations from lorries are noticeable in the home. This discrepancy could be caused by a number of factors associated with perception and measurement of noise and vibration:

1. Location of measurements. Due to cost considerations, noise and vibration measurements were made at a limited number of sites, while the residents survey included people living throughout the village. However, the measurement sites were chosen to reflect likely 'worst case' locations.

2. Questionnaire design. For cost reasons, the questionnaire was fairly brief and the responses were made to specific questions about levels of vibration and increased noise. It may be that the residents were influenced by the way in which the questions were put. A more detailed survey would be needed to resolve this point.

3. Although overall traffic noise levels were reduced at the two sites measured, it is possible that residents living alongside the A49 close to mini-roundabouts might have found the variations in heavy vehicle noise levels intrusive.

4. Isolated noise events, particularly at night, might have had greater impact on people's perception of changes in noise nuisance than the measured changes in the levels of traffic noise. In the longer term, further research is planned to investigate this issue.

5. The perception of increased vibration in houses at Craven Arms may be associated with airborne vibration due to low frequency noise (caused by noise emissions from vehicle engines and exhausts) rather than ground-borne vibration. Further analysis of the noise data is currently being undertaken to establish whether low frequency noise levels have increased since the traffic calming scheme was introduced.

6. People's perception of increased noise and vibration may be influenced by concerns about other aspects of the scheme. A more detailed questionnaire would help to resolve this point.

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APPENDIX A: NOISE MEASUREMENTS: THE STATISTICAL PASS-BY METHOD

The Statistical Pass-by Method was initially developed at TRL for road surface noise surveys (Franklin, Harland and Nelson, 1979). The technique is used by researchers in many other countries and has become an internationally accepted method for measuring the influence of road surfaces on vehicle and traffic noise levels (International Standards Organisation, 1995).

The method requires the simultaneous measurement of the maximum noise level and speed of individual vehicles in the traffic stream. A typical measurement site layout is shown in Fig A.1. The traffic population is categorised into 'light' vehicles, which include all cars and vans with an unladen weight less than 1.5 tonnes, and 'heavy' vehicles. Under normal conditions, approximately 50 vehicles from each category are selected for measurement.

From this data set, a regression of noise against the logarithm of vehicle speed is performed for both vehicle groups. The general relation between the maximum sound level ($L_{A,max}$) and the speed of a passing vehicle has been shown to take the form (Harland, 1974):

$$L_{A,max} = a + b \, log_{10} V \qquad (1)$$

where V = speed of the vehicle (km/h)

a = the constant term

b = the slope of the regression line

The regression lines calculated are then used to determine the noise levels at suitable reference speeds. These levels are used to compare the sites studied. This method has been found to give results for surface noise surveys which are repeatable to within 1.0dB(A) when using the vehicle sample size indicated.

All noise measurements should be taken when the road is dry and during light wind conditions, i.e. wind speeds less than 10 m/s. To further minimise the effects of any turbulence due to wind, all measurements should be conducted with a microphone fitted with a standard foam windshield. The microphone system and recording level are calibrated both prior to, and following, each measurement session using a precision 1 kHz tone calibrator. The maximum and minimum air temperatures during each of the monitoring sessions are also recorded.

In the analysis, the acoustic data are combined with the vehicle speed and classification data. The maximum noise levels for each vehicle event are regressed against the

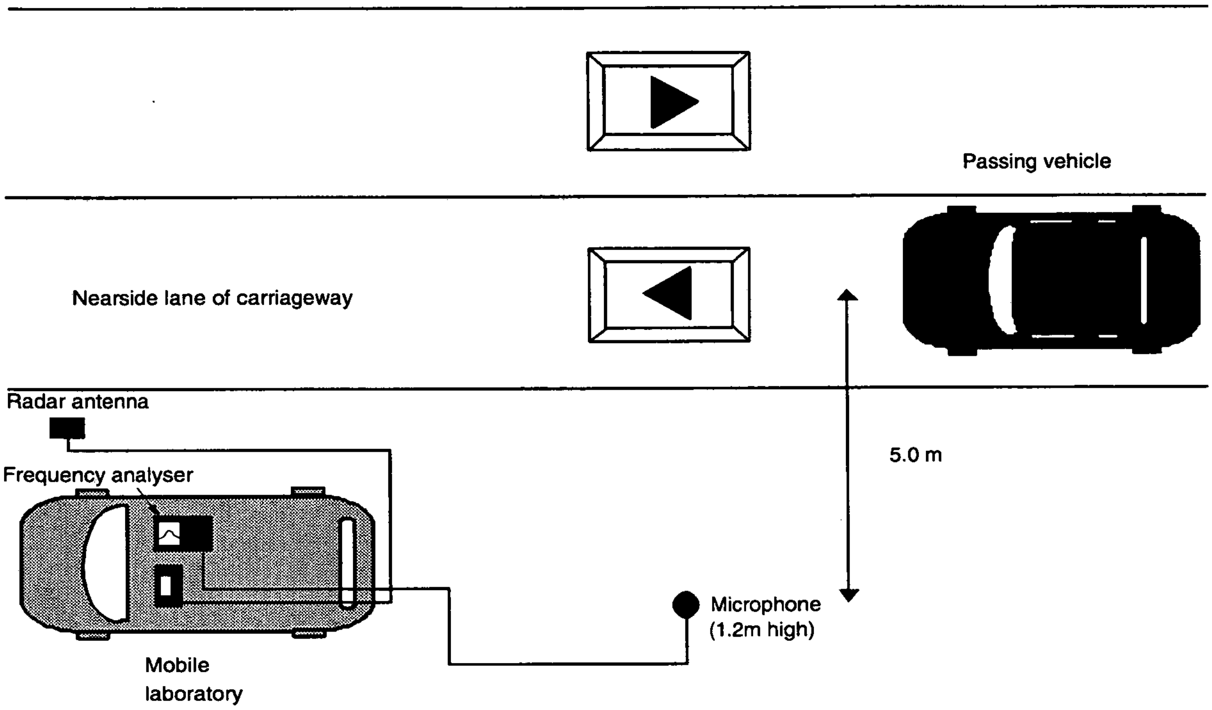

Fig A.1. Site layout for vehicle noise measurements

logarithm of the vehicle speed using the general relation given in Equation 1.

At the sites in Craven Arms, the measurement microphone was positioned 5m from the centre of the lane (or cushion) and 1.2m above the level of the road surface. Due to physical site restrictions, the microphone was placed nearer to the traffic stream than would normally be required for surveys on high speed roads. However, this alteration to the procedure did not affect the accuracy of the method, as the vehicle speeds were slow enough to prevent wind buffeting around the microphone. The microphone was connected to a noise analyzer configured to record the noise level at the moment when the A-weighted sound level reached a maximum during each selected individual vehicle pass-by. The vehicles chosen for measurement were judged to be sufficiently separated from the traffic stream so that their maximum noise characteristics were not influenced by the noise from other vehicles. Only vehicles which were wholly within the test lane were measured.

Vehicle speeds were measured using portable radar equipment. The antenna was positioned to be as unobtrusive as possible, in order to reduce the likelihood of affecting driver behaviour. The speed of each selected vehicle was recorded as it passed the microphone position, along with the vehicle classification. Table A.1 lists the site details and microphone positions for each of the vehicle noise surveys.

TABLE A.1

Microphone positions for vehicle noise measurements

Site	Feature	Microphone distance to edge of kerb (m)	Microphone distance to centre of lane/cushion (m)	Microphone height above road level (m)
A	North gateway	3.2	5.0	1.2
B	Cushion	3.5	5.0	1.2
C	Between cushions	3.0	5.0	1.2
D	Isolated cushion	3.5	5.0	1.2
E	Cushion	3.0	5.0	1.2

APPENDIX B: REGRESSION ANALYSIS OF VEHICLE NOISE AND SPEED

TABLE B.1

Regression analysis of vehicle noise and speed for light vehicles

Site	Regression analysis statistics[1] Constant (a)	Slope (b)	Correlation (r^2)	Standard deviation dB(A)
Before				
B	18.84	34.91	0.62	1.65
C	27.08	30.28	0.66	1.64
After				
A	14.76	35.48	0.83	1.19
B	36.83	22.45	0.62	1.60
C	28.23	28.38	0.65	1.51
D	15.96	33.88	0.79	1.17
E	32.77	25.95	0.54	1.83

[1]Regression analysis of maximum noise level, $L_{A,max}$ dB(A) and the logarithm of vehicle speed, V km/h, takes the form :

$$L_{A,max} = a + b\, log_{10} V \text{ dB(A)}$$

where	constant	=	the constant term a
	slope	=	the slope of the regression line b
	correlation	=	the correlation coefficient, r^2
and	standard deviation	=	residual standard deviation

TABLE B.2

Regression analysis of vehicle noise and speed for heavy vehicles

Site	Regression analysis statistics Constant (a)	Slope (b)	Correlation (r^2)	Standard deviation dB(A)
Before				
B	21.87	37.97	0.28	2.66
C	44.54	24.68	0.19	2.43
After				
A	49.97	19.39	0.25	2.53
B	45.58	23.09	0.27	2.61
C	67.09	8.97	0.07	2.33
D	16.56	40.17	0.45	2.72
E	57.12	17.93	0.11	3.19

APPENDIX C

Questionnaire number ☐ ☐ ☐ ☐ (6), card 1 (7-10)

Date ☐ ☐ ☐ ☐ ☐ ☐ (11-16)

TRAFFIC CALMING ON MAJOR ROADS THROUGH VILLAGES: QUESTIONNAIRE

Village: **CRAVEN ARMS (A49T, Shropshire)**

Good morning/afternoon/evening. My name is ____________________ and I work for the Transport Research Laboratory. We are carrying out a survey for the Department of Transport about people's opinions of traffic passing through the village.

Q.1 How long have you lived in this village? — ROUTE

WRITE IN: ________ years ________ months (17-20)

IF NOT RESIDENT IN THE VILLAGE BEFORE 1995 DO NOT CONTINUE WITH THE INTERVIEW — Q.2

Q.2 Recently some changes were made on the main road to slow traffic going through through the village. Are you aware of this?
RING CODE NUMBER

	CODE (21)	ROUTE
Yes	1	Q.3
No	2	Discontinue interview

Q.3 Thinking back <u>before</u> these changes were made, did the main road through the village and its traffic cause any problem in the village?
PROBE FULLY AND WRITE IN BELOW

(22-23)

(24-25)

(26-27)

Q.3A So, could I just check to see whether any of the following things were a problem before the changes were made
SHOW CARD 'A' AND READ OUT. RING *YES (1), NO (2) OR DON'T KNOW (9)* FOR EACH

	Yes	No	Don't know
Amount of traffic (28)	1	2	9
Speed of traffic (29)	1	2	9
Number of lorries (30)	1	2	9
Dangerous for motorists (31)	1	2	9
Dangerous for cyclists (32)	1	2	9
Dangerous/difficult for pedestrians to cross the road (33)	1	2	9
Dangerous for pedestrians using the footway (34)	1	2	9
Dangerous for children (35)	1	2	9
Too much noise (36)	1	2	9
Ground vibration (37)	1	2	9
Dust and dirt (38)	1	2	9
Smoke and fumes (39)	1	2	9

ROUTE: Q.4

Q.4 Now I would like to ask you about how the changes have affected things. How satisfied are you overall with the changes that have been made in the village?
SHOW CARD 'B' AND READ OUT

	CODE (40)	ROUTE
Very satisfied	1	
Fairly satisfied	2	
No opinion either way	3	
Fairly dissatisfied	4	
Very dissatisfied	5	
Don't know	9	Q.5

Q.5 Can you tell me, for the following groups of people, whether the changes have been a good thing, a bad thing, or have had no effect? **SHOW CARD 'C1'**

READ OUT ITEMS BELOW AND SHOW CARD 'C2'

	Very good	Quite good	No effect	Quite bad	Very bad	Don't know
Pedestrians (41)	1	2	3	4	5	9
Drivers (42)	1	2	3	4	5	9
Schoolchildren (43)	1	2	3	4	5	9
Cyclists (44)	1	2	3	4	5	9
Old people (45)	1	2	3	4	5	9
Shopkeepers (46)	1	2	3	4	5	9
Residents on the main road (47)	1	2	3	4	5	9

ROUTE: Q.6

Q.6 How useful do you consider each of the changes that have been made in the village?
SHOW CARD 'D' AND PHOTOS

ITEM NUMBER		Very useful	Fairly useful	Of little use	Causes concern	Don't know/ no opinion
(1)	Signs on the approaches to the village (48)	1	2	3	4	9
(2)	Tooth markings on the road just before the speed limit (49)	1	2	3	4	9
(3)	Red surface with 30mph marking on village approach (50)	1	2	3	4	9
(4)	Patches of red surface with 30mph markings at intervals (51)	1	2	3	4	9
(5)	Hatched markings on red background (52)	1	2	3	4	9
(6)	Mini-roundabouts (53)	1	2	3	4	9
(7)	Pedestrian crossing places with islands (54)	1	2	3	4	9
(8)	Narrow humps (55)	1	2	3	4	9

ROUTE:

For each item ringed '4' in Q.6, ask Q.6A
If none, go to Q.7

Q.6A What is your particular concern about the.....?
READ OUT FIRST ITEM RINGED '4' IN Q.6 AND WRITE IN ITEM NUMBER IN BOX PROVIDED
PROBE FULLY AND WRITE IN ANSWER
REPEAT FOR ALL ITEMS RINGED '4' IN Q.6, REMEMBERING TO ENTER THE ITEM NUMBER EACH TIME

ENTER ITEM NUMBER

☐ (56) (57) (58)

(59) (60)

☐ (61) (62) (63)

(64) (65)

☐ (66) (67) (68)

(69) (70)

☐ (71) (72) (73)

(74) (75)

☐ (76) (77) (78)

(79) (80)

☐ (11) CARD 2

(12) (13)

(14) (15)

☐ (16) (17) (18)

(19) (20)

☐ (21) (22) (23)

(24) (25)

Q.7 Now I am going to read out some things people have said about the changes. For each one please tell me whether you agree a little, agree a lot, disagree a little, or disagree a lot. **SHOW CARD 'E1'**

READ OUT ITEMS BELOW AND SHOW CARD 'E2'

	Agree a lot	Agree a little	No opinion	Disagree a little	Disagree a lot	D/K
The changes were necessary (26)	1	2	3	4	5	9
They make it safer/easier to cross the road (27)	1	2	3	4	5	9
They make it safer to walk on the footway (28)	1	2	3	4	5	9
They make it safer for motorists (29)	1	2	3	4	5	9
They make it safer for cyclists (30)	1	2	3	4	5	9
They have reduced speeds (31)	1	2	3	4	5	9
They have reduced speeds enough (32)	1	2	3	4	5	9
They are frustrating for drivers (33)	1	2	3	4	5	9
They should be introduced in other villages (34)	1	2	3	4	5	9
They have increased noise (35)	1	2	3	4	5	9
House shakes when a lorry goes by (36)	1	2	3	4	5	9
They have increased traffic fumes (37)	1	2	3	4	5	9
A bypass would have been better (38)	1	2	3	4	5	9
Other changes would have been better (39)	1	2	3	4	5	9

(FOR LAST ITEM) If you agree, what changes would you suggest? **WRITE IN BELOW** (40) (41)

(42) (43)

ROUTE: Q.8

Q.8 Do you have any concerns about the look of the scheme?	CODE (44)	ROUTE
Yes	1	Q.8A
No	2	Q.9

Q.8A If so, what? **PROBE FULLY AND WRITE IN BELOW**

(45) (46)

(47) (48)

(49) (50)

Q.9

Q.9 Did you hear about the changes before they occurred?	CODE (51)	ROUTE
Yes	1	Q.9A
No	2	Q.10

Q.9A If yes, how?
READ OUT ITEMS BELOW AND SHOW CARD 'F ', PLEASE RING ALL THAT APPLY

	(52)	
From friends/relatives	1	
Local papers	2	
Local TV news	3	
Local radio news	4	
Public meetings	5	
Visit from the Council	6	
Leaflets	7	
Public notices in the street	8	
Other **(WRITE IN BELOW)**	9	
	(53) (54)	Q.10

Q.10 Did the council or Department of Transport ask people, eg on a leaflet or in a public meeting, what they thought about the plans?	CODE (55)	ROUTE
Yes	1	Q.10A
No	2	Q.12
Don't know	9	Q.12
Q.10A If so, when did they do it?	(56)	
READ OUT: Before the changes	1	
After the changes	2	
Both	3	Q.11

Q.11 How satisfied were you with the consultation? Were you:	CODE (57)	ROUTE
READ OUT: Very satisfied	1	
Fairly satisfied	2	
No opinion either way	3	
Fairly dissatisfied	4	
Very dissatisfied	5	Q.12

CLASSIFICATION

Q.12

	CODE		CODE
(i) Sex **(BY OBSERVATION)**	(58)	(iv) Do you have any children under 16?	(61)
Male	1	Yes	1
Female	2	No	2
(ii) What was your age last birthday?	(59)	(v) Do you do any of the following? **(RING ALL THAT APPLY)**	(62)
Under 25	1	Drive a car	1
25-39	2	Drive a van	2
40-59	3	Drive a lorry	3
60 +	4	Ride a motorcycle	4
		Ride a pedal cycle	5
		None of these	6
(iii) Live on or off the main road? **(BY OBSERVATION)**	(60)		
On main road	1		
Elsewhere	2		

THANK YOU VERY MUCH FOR YOUR HELP

MORE INFORMATION

The Transport Research Laboratory has published the following other reports on this area of research:

PR35	The effectiveness of village 'gateways' in Devon and Gloucestershire by Allan Wheeler, Marie Taylor and Annabelle Payne (1993) Price Code F.
PR85	Speed reduction in 24 villages: details from the VISP study by Allan Wheeler, Marie Taylor and Judith Barker (1994) Price Code L.
PR85 (Annex)	Speed reduction in 24 villages: colour photographs from the VISP study by Allan Wheeler, Marie Taylor and Judith Barker (1995) Price Code F.
TRL180	Traffic calming: vehicle noise emissions alongside speed control cushions and road humps by Phil Abbott, John Tyler and Roger Layfield (1995) Price Code H.
TRL182	Traffic calming - four schemes on distributor roads by David C Webster (1995) Price Code E.

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