TRANSPORT RESEARCH LABORATORY

# Traffic calming — speed cushion schemes

## Prepared for Driver Information and Traffic Management Division, Department of the Environment, Transport and the Regions

R E Layfield and D I Parry

**TRL REPORT 312**

First Published 1998
ISSN 0968-4107


This report has been produced by the Transport Research Laboratory, under/as part of a Contract placed by the Department of the Environment, Transport and the Regions. Any views expressed are not necessarily those of the Department.

**Transport Research Foundation Group of Companies**
Transport Research Foundation (a company limited by guarantee) trading as Transport Research Laboratory. Registered in England, Number 3011746.

TRL Limited. Registered in England, Number 3142272.
Registered Offices: Old Wokingham Road, Crowthorne, Berkshire, RG45 6AU.

# CONTENTS

# Executive Summary

Speed reducing schemes in built-up areas are an important element in working towards the Department of the Environment, Transport and the Regions' casualty target of one-third reduction by the year 2000 compared with the 1981-85 level. Many of these schemes involve installing 'traffic calming' road engineering measures in residential areas to control speeds and encourage traffic onto more appropriate main roads.

The most effective forms of traffic calming measure usually involve some degree of vertical deflection. Road humps have proven to be highly effective at reducing vehicle speeds, but discomfort to drivers and passengers is increased, particularly in larger vehicles such as buses, lorries, fire engines and ambulances.

Speed cushions are designed to limit the vertical deflection of large vehicles with wide track widths by allowing these vehicles to straddle the cushions. Vertical deflection for smaller vehicles, such as cars, with smaller track widths is maintained as these vehicles are forced to ride over the cushions with at least one set of wheels.

In order to improve the advice available on cushion design and effectiveness, TRL has carried out an assessment of speed cushion schemes for Driver Information and Traffic Management Division of the Department of the Environment, Transport and the Regions. This report describes a study of 34 local highway authority traffic calming schemes using speed cushions, most of which were on roads with 30 mph speed limits and on bus routes. The study assesses the effect of cushions on vehicle speeds, traffic flows, accidents, driver behaviour and passenger discomfort, and considers public reaction to the schemes and the likely impact of cushions on vehicle generated noise and vibration.

Three main types of cushion arrangement have been installed at the sites studied: a series of single cushion layouts combined with carriageway narrowings (these only allow one-way working and are more suitable for lower flow roads); groups of cushions in pairs (these allow two way working, are suitable on higher flow roads, and can be combined with carriageway narrowings or islands); and groups of cushions three-abreast (these also allow two way working and are suitable on wider roads without requiring the construction of carriageway narrowings).

The report concludes the following:

### Speeds at cushions

Speed cushions are effective as a speed reducing measure but not quite as effective as road humps. The overall average mean and 85th percentile speeds *at* the cushions (17 and 22 mph respectively) were 2 to 7 mph higher than those measured at 75mm high flat-top humps and round-top humps.

The relationships between speed *at* the cushions, cushion dimensions, and 'before speed' were investigated, for mean and 85th percentile speeds, using multiple linear regression analysis. The variables cushion width, cushion length, on/off gradient and 'before speed' were statistically significant, with decreasing width, increasing length, shallower gradients and higher before speeds resulting in higher speeds *at* the cushions. The variables cushion length and on/off gradient were correlated with each other, with longer cushion lengths associated with shallower on/off gradients and thus their relative effects on vehicle speed cannot be precisely determined with this data set.

Narrow (1600mm) cushions may not provide sufficient speed reduction in 20 mph zones without additional measures. Mean speeds *at* 1600mm wide cushions are likely be about 19.5 mph, while 1900mm wide cushions would give mean speeds of about 15.5 mph.

Larger vehicles such as buses and heavy goods vehicles are likely to be slowed down to a lesser extent than cars, particularly at the narrower cushions. Motor-cyclists can avoid the cushions and the cushions may have little, if any, effect on their speeds. However, in high flow periods, a reduction in the speed of cars and large vehicles may also have a speed reducing effect on motor-cyclists.

### Speeds between cushions

Spacing between the cushions varied between 50m and 105m with an average of about 71m. The overall average mean and 85th percentile speeds midway *between* the cushions (22 and 26 mph respectively) were 1 to 2 mph higher than those measured between 75mm high humps spaced on average at about 85m.

The relationships between speed midway *between* the cushions, cushion dimensions, cushion spacing, and 'before speed' were also investigated, for mean and 85th percentile speeds. For simplicity, the data set was restricted to the majority of the cushions for which the height was 75mm, the on/off gradient 1:8 and the side gradient 1:4. Thus no attempt was made to include height or gradient as explanatory variables.

At a spacing of 60m metres, a mean speed of about 20.5 mph may be expected. Increasing the spacing from 60m to 100m, increases mean speed by about 4 mph.

A longer spacing between cushions leads to higher speeds between the cushions and also to a greater 'speed difference'. Speed difference is defined here as the speed midway between cushions minus the speed at the cushions. A large speed difference will usually be undesirable as it may lead to increased exhaust emissions, increased noise nuisance and increased passenger discomfort, particularly if it is associated with rapid acceleration and deceleration.

### Vehicle flows

Vehicle flows decreased on roads with speed cushions, with reductions in flow varying between 2 to 48 per cent. The overall average reduction in flow was 24 per cent, a reduction in flow similar to the overall average reduction found on roads with 75mm high humps.

### Accidents

A comprehensive before and after accident survey has not been carried out for the cushion sites included within this study but it is estimated from other studies, with similar speed reductions, that the reduction in speeds and flows is likely to produce injury accident savings of about 60 per cent.

### Passenger discomfort

On-road trials have found that passenger discomfort in large buses is likely to be low at speed cushion schemes, providing the buses straddle the cushion centrally. Bus passenger discomfort increased when the buses did not straddle the cushions and was similar to that measured when crossing 75mm high round-top and flat-top humps. Variation in cushion width did not appear to affect the discomfort rating for passengers in large buses.

Some cushion schemes have been found to be suitable for large single and double deck buses but unsatisfactory with respect to the level of passenger discomfort experienced by passengers in smaller minibuses and ambulances. The results of off-road trials in York indicated that the variations in discomfort with cushion dimensions were consistent across the different vehicles tested. Reducing cushion width to 1600mm would reduce the levels of discomfort in minibuses and ambulances but would be likely to lead to some increase in the speed of cars. The off-road trial results also indicated that, for car drivers, cushion width had a much stronger influence on acceptability than cushion spacing.

### Driver behaviour

Video observations of driver behaviour at some of the sites indicated that when the approach and exit from a cushion layout was unaffected by parking, about 55 per cent of cars and 90 per cent of buses were found to straddle the cushions centrally or approximately centrally.

In the paired cushion layouts, nearly 20 per cent of the drivers drove in the middle of the road between the cushions. In the three-abreast layouts, about 40 per cent of the drivers drove between the nearside and the middle cushions. At some cushion layouts with relatively wide central gaps between cushions, motorists have tended to drive through the gap rather than over the cushions, resulting in complaints and collisions. Gap sizes have subsequently been reduced. In general, this problem is likely to develop at sites with central gaps between cushions greater than 1200mm.

Parked vehicles can prevent cars from straddling the cushions centrally and will therefore increase the discomfort for drivers and passengers. When cushion layouts were combined with carriageway narrowings, the parked vehicles had less effect on vehicles approaching the cushions.

Most cyclists and motor-cyclists avoided the cushions and used the gaps between the cushions and the kerb. When these were obstructed by parked vehicles, cyclists and motor-cyclists generally moved to the centre of the road and avoided riding over the cushions.

### Opinions

The reaction to speed cushions from both the bus operators and the emergency services has generally been positive. Questionnaire surveys have indicated that residents are less supportive. There is some evidence to suggest that residents may see standard road humps as a preferable method of traffic calming.

### Noise

For light vehicles, maximum noise levels at cushions were directly related to speed, with lower speeds at cushion sites resulting in lower noise levels. However, the results from track trials indicate that, as the proportion of commercial vehicles in the traffic stream increases, the reduction in traffic noise, following the installation of wide cushions, deteriorates dramatically. Narrow (<1700mm) cushions have a much smaller effect on the maximum noise levels of commercial vehicles provided the vehicles straddle the cushion centrally.

### Vibration

Based on typical crossing speeds, the wide (1900mm) cushions generally gave higher ground-borne vibration levels in track trials than the narrower (<1700mm) cushions. Vibration levels increased when heavy commercial vehicles did not straddle the narrow cushions and care should be taken that cushions are placed so that they are likely to be straddled by the axles of commercial vehicles.

# 1 Introduction

Sixty-nine per cent of all casualties occur in built-up areas and of these a substantial proportion are vulnerable road users *ie* pedestrians and cyclists (Department of Transport, 1996a). Changes in speed have been shown to be related to changes in accidents with a 1 mph reduction in speed giving a 5 per cent reduction in accidents (Finch *et al*, 1994). Speed reducing schemes in built-up areas are an important element in working towards the Department of the Environment, Transport and the Regions' (DETR) casualty target of a one-third reduction by the year 2000 compared with the 1981-85 level. Many of these schemes involve installing 'traffic calming' road engineering measures in residential areas to reduce speeds and encourage traffic onto more appropriate main roads.

The most effective traffic calming measures generally involve some form of vertical deflection, usually in the form of a road hump (Webster, 1993a). Circular profile (round-top) and flat-top humps span most of the carriageway width and force all vehicles to be vertically deflected. The effect of this, in terms of passenger discomfort, is greater for large vehicles such as buses and emergency vehicles, than for cars. Road humps constructed to the maximum permitted height (100mm) have initiated comments from bus operators in terms of passenger discomfort and increased maintenance costs for vehicles; and from the emergency services about higher response times. Some of these objections can be overcome by using humps with lower heights (75mm) and shallower on/off ramp gradients (1:10 to 1:15). These can still provide large reductions in mean and 85th percentile speeds (Webster and Layfield, 1996; Department of Transport, 1996b).

### 1.1 Speed cushions

Speed cushions are alternative vertical deflection traffic calming measures which aim to cause less interference to larger vehicles such as buses and emergency vehicles. Speed cushions are raised areas positioned in the carriageway. The width, height, length, and on/off and side ramp gradients of the raised area vary between sites where these measures have been installed (see Figure 1).

Speed cushions are designed to limit vertical deflection of large vehicles with wide track widths by allowing vehicles such as buses and emergency vehicles to straddle the measures. Plate 1 shows the use of speed cushions on bus routes. Figure 2 shows that the vertical deflection for smaller vehicles such as cars with smaller track widths is maintained as these vehicles are forced to ride over the measure with at least one set of wheels.

### 1.2 Speed cushion trials

Speed cushions were initially introduced in Germany where cushions (1840mm wide - base width, 50mm high, and having 1:5 gradients) were reported to be effective at reducing vehicle speeds to approximately 20 mph, Pharaoh (1992). Work in the UK on speed cushions has been carried out through both on and off-road trials. In 1992 off-road trials were conducted in Sheffield, Strathclyde and York; the findings of the York and Strathclyde trials are published in reports by Pheby and Durkin (1992) and Strathclyde Regional Council (1993) respectively. Further off-road trials were carried out by York City Council in 1994 and 1995 with the aim of identifying cushion dimensions which might reduce passenger discomfort in vehicles such as minibuses and ambulances whilst maintaining discomfort, and hence speed reduction, for cars (see Section 7.2).

Hodge (1993) describes the results of speed cushion trials conducted for the Driver Information and Traffic Management Division, DETR, on the TRL test track. Six designs of speed cushion were assessed in order to determine designs of cushion that were more likely to create discomfort for car drivers whilst minimising the effect of the cushion on larger vehicles. The trials also took the form of a safety assessment of speed cushions whereby design features which may present a hazard to particular road users could be identified. The trials indicated that a height of 75mm, on and off ramps of 1:8 and side ramps of 1:4 would be appropriate for speed cushions. Higher

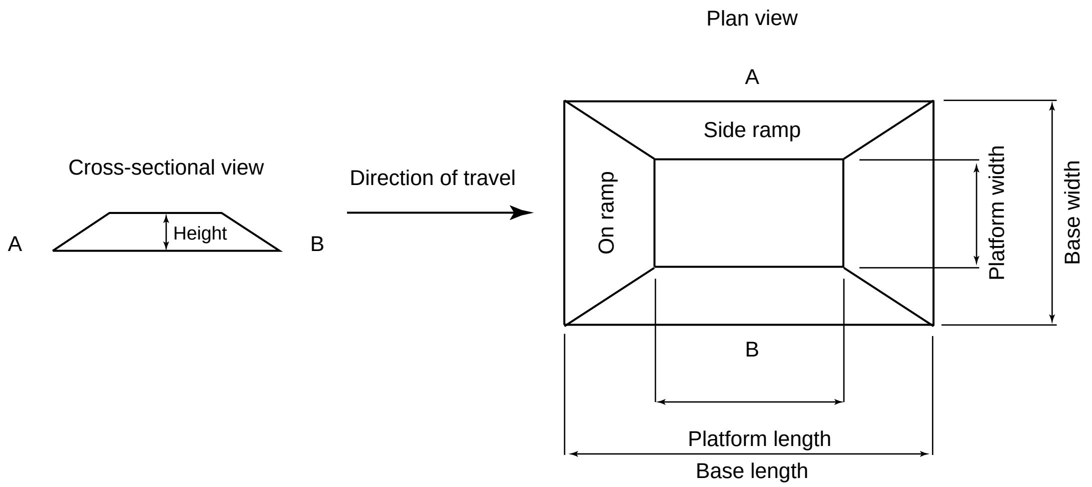



**Figure 1** Speed cushion dimensions


(a) Midibus approaching cushions — Windmill Road (site 8)
(Picture courtesy of Hertfordshire CC)

(b) Double decker bus approaching cushions — Billing Brook Road (site 25)
(Picture courtesy of Northamptonshire CC)

**Plate 1** Use of speed cushions on bus routes

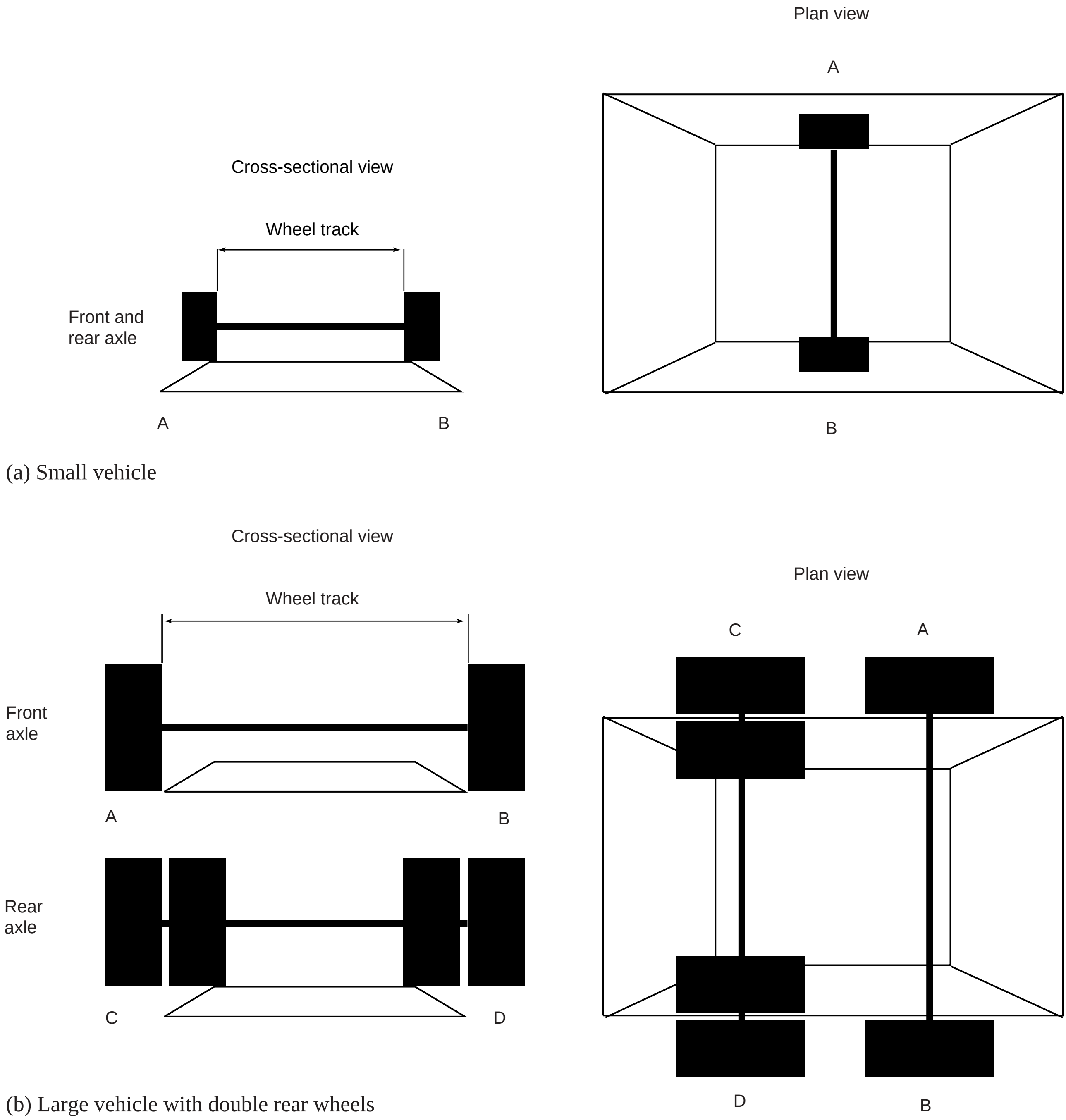



**Figure 2** Effect of speed cushions on large and small vehicles

cushions of 100mm are likely to increase the risk of grounding, on and off-ramps of less than 1:8 may produce too severe discomfort and side ramps of less than 1:4 may present dangers to two wheeled vehicles.

Following the test track trials, on-road trials of speed cushions were funded by the Driver Information and Traffic Management Division, DETR, in York and Sheffield in 1993 (Layfield *et al*, 1994). In general, narrow cushions of 1600mm width reduced the mean speeds of cars at the measure to 19 mph, with wider cushions of 1800-1900mm width reducing mean speeds to approximately 14 mph. Results were also collected in the form of: driver behaviour; passenger discomfort in cars and buses at various cushion dimensions and layouts; flow changes; residents attitudes; and the views of the emergency services and bus operators. Design advice on speed cushion schemes resulting from these trials is contained in Traffic Advisory Leaflet 4/94 (Department of Transport, 1994a).

Measurements of vehicle and traffic noise have been carried out at a number of speed cushion sites in York (Abbott *et al*, 1995a). These have been followed up by TRL track trials investigating vehicle noise and ground-borne vibration at cushions (Abbott *et al*, 1995b; Watts *et al*, 1997).

### 1.3 Regulations

Prior to the Highways (Road Humps) Regulations 1996, speed cushions were 'non-regulation road humps' and required special authorization under the Road Traffic Act 1991. Road humps (including sets of cushions) were required to be spaced between 20 to 150m apart and not further than 40m from a low speed feature such as a junction, roundabout or bend (Department of Transport, 1990).

The Highways (Road Humps) Regulations 1996 now provide local highway authorities with considerable flexibility in the design and placement of road humps. However, the regulations make local highway authorities responsible for the design and placement, so authorities will need to ensure that an adequate duty of care is exercised. The only dimensions now constrained by the regulations are maximum and minimum heights of 100mm and 25mm respectively; a minimum length of 900mm and no vertical face to exceed 6mm in height. While the 1996 regulations do not require a speed reducing feature to be located in advance of speed cushions, it is strongly recommended that such a feature is used (less than 60m away) so that the speed limit is not exceeded when a vehicle meets the first cushion. In order to prevent speeds increasing between cushions it is also recommended that cushions should be spaced between 20m and 100m apart (Department of Transport, 1996c).

### 1.4 Study method

In order to improve the advice available on the design and effectiveness of speed cushions, the Driver Information and Traffic Management Division, DETR, funded this study of speed cushion schemes on public roads in England. Where speed cushions schemes were authorized by DETR, local highway authorities were required to comply with monitoring requirements requested by TRL. Initially information was requested on speeds and flows at schemes before and after installation. Additional information such as the responses of the emergency services, bus operators and residents to speed cushions has been collected during discussions with the local authorities supplying the data.

Sections 2, 3, 4, 5 and 9 of this report are based on information collected at the cushion schemes by local highway authorities. Section 6 refers to accident information from a study of 20 mph zones. Section 7 uses passenger discomfort results from the on-road trials in York and Sheffield, and off-road trials organised by York City Council. Section 8 uses driver behaviour observations from the on-road trials in York and Sheffield, site measurements in Nottingham, and information reported by local highway authorities. Section 10 uses noise and vibration results from site measurements and TRL track trials.

## 2 Details of speed cushion schemes studied

This section gives details of the 34 local highway authority speed cushion schemes that were installed in the years 1992 to 1994. A summary of the information collected for each site is contained within Appendix A.

### 2.1 Location

The speed cushions schemes were installed within a wide variety of road environments on both residential and distributor roads, within urban and suburban areas. Table 1 displays the location, road type and width, whether the scheme forms part of a bus route, the date of scheme installation and the layout and construction of the speed cushions.

Speed cushions were installed as a part of both single-road and area-wide traffic calming schemes. The single-road schemes ranged between about 200 and 2800 metres in length. The area-wide schemes covered about 0.25 to 0.75 square km.

The cushions were installed on roads between 5 to 10 metres wide. About half of the 34 speed cushion schemes were installed on residential roads, with the other half being installed on local distributor class roads. Residential roads were regarded as those which were primarily intended to provide access to residential property with little non-residential traffic (eg see Plate 2a). Local distributor roads were those roads which provided routes to other than residential areas (*eg* see Plate 2b).

Most of the schemes were installed on roads with 30 mph speed limits but four cushion schemes formed part of 20 mph zones. These are Chaplefields (site 15), Danebury Drive (site 17), Camp Hill (site 30) and Charles Road (site 31).

Thirty of the schemes had bus services running along roads with speed cushions. The main types of buses used on the routes were a mixture of small 'midi' bus and larger single and double decker buses. Generally, where cushions had been installed on roads with no bus service, cushions rather than humps were used because the route was considered crucial to the emergency services.

**Table 1 Speed cushion sites included within this study**

| *Site No. Name*[1] | *Road type*[2] | *Road width (m)* | *Bus route*[3] | *Date of installation* | *Cushion construction* | *Cushion layout*[4] |
|---|---|---|---|---|---|---|
| ***Bedfordshire*** | | | | | | |
| 1. Coventry Rd | Resid. | 7.2 | Midi | April 94 | Rubber/asphalt | Three-abreast |
| ***Buckinghamshire*** | | | | | | |
| 2. Chairborough Rd | Resid. | 7.4 | Yes | March 94 | Rubber | Pairs with islands |
| ***Cheshire*** | | | | | | |
| 3. Ivy Road | Dist. | 6.6-8.7 | Midi | 1994 | Kerbing/asphalt | Pairs, three-abreast |
| ***Greater London*** | | | | | | |
| 4. Peterborough Rd | Resid. | 8.0 | Midi | 1994 | Asphalt | Single[5] at narrowing |
| 5. Blomfield Rd | Resid. | 8.0 | No | March 94 | Asphalt | Pairs |
| 6. Poplar Neigh'd | Dist/Res. | 6.75-7.0 | Yes | 1992 | Asphalt | Pairs, three-abreast |
| 7. Richmond Hill | Resid. | 6.3 | No | June 94 | Block paving | Single[5] at narrowing |
| ***Hertfordshire*** | | | | | | |
| 8. Windmill Rd | Resid. | 7.5 | Midi | May 94 | Block paving/asphalt | Pairs |
| ***Lancashire*** | | | | | | |
| 9. Chadderton Pk Rd | Resid. | 5.6 | Yes | March 94 | Concrete units | Pairs |
| 10. Ringmore Rd | Dist. | 7.0 | All | March 94 | Concrete in situ | Pairs |
| ***Leicestershire*** | | | | | | |
| 11. Eyres Monsell | Resid. | 5.5-7.3 | Yes | May 94 | Block paving/kerbing | Pairs, three-abreast |
| 12. Wycombe Rd | Resid. | 8.2 | Midi | May 94 | Block paving/kerbing | Three-abreast |
| ***North Yorkshire*** | | | | | | |
| 13. Eastfields Est | Resid. | 7.0-10.0 | All | July 94 | Asphalt | Single[5], pair and three-abreast |
| 14. Askham Ln | Dist. | 6.7 | All | May 94 | Asphalt | Pairs, double-pairs |
| 15. Chapelfields[1] | Resid. | 4.9 | SD, DD | Jan 94 | Asphalt | Single[5] at buildout. |
| 16. Cornlands Rd | Resid. | 6.7 | SD, DD | May 94 | Asphalt | Pairs |
| 17. Danebury Dv[1] | Resid. | 6.1-9.2 | Midi, SD | March 94 | Asphalt | Pairs, three-abreast |
| 18. Gale Ln | Dist. | 6.7-9.0 | SD, DD | Feb 94 | Asphalt | Pairs, double-pairs |
| 19. Foxwood Ln | Dist. | 7.3 | All | 1993 & 94 | Asphalt | Pairs, three-abreast. |
| 20. Kingsway West | Resid. | 4.9-6.6 | Midi | April 94 | Asphalt | Single[5] at buildout, Pairs |
| 21. Mill Ln | Dist. | 6.1 | SD | March 94 | Asphalt | Pairs |
| 22. Muncaster | Resid. | 6.2 | All | 1993 | Rubber | Pairs, double-pairs |
| 23. Skeldergate | Dist. | 6.0-8.2 | SD | April 94 | Asphalt | Pairs, three-abreast |
| 24. Tang Hall | Resid. | 6.1-7.9 | SD, DD | 1993 | Block paving/kerbing | Pairs, three-abreast |
| ***Northamptonshire*** | | | | | | |
| 25. Billing Brook Rd | Dist. | 7.3-8.6 | All | July 94 | Rubber | Pairs, three-abreast |
| ***Nottinghamshire*** | | | | | | |
| 26. Bagnall Rd | Dist. | 8.2 | Yes | January 94 | Rubber | Pairs, three-abreast |
| ***Shropshire*** | | | | | | |
| 27. Brookside Av | Dist. | 7.3 | All | April 94 | Asphalt | Pairs |
| ***South Yorkshire*** | | | | | | |
| 28. Lindsay Av | Dist. | 7.7 | All | 1993 | Concrete sections | Various |
| ***Tyne and Wear*** | | | | | | |
| 29. A183, Ocean Rd | Dist. | 7.3 | All | 1994 | Asphalt | Pairs |
| ***Warwickshire*** | | | | | | |
| 30. Camp Hill[1] | Resid. | 6.4-6.8 | All | May 94 | Asphalt | Single[5] at narrowing, Pairs |
| ***West Midlands*** | | | | | | |
| 31. Charles Rd[1] | Dist. | 9.25 | Yes | 1992 | Block paving | Double-pairs with islands |
| ***West Yorkshire*** | | | | | | |
| 32. Grosvenor Rd | Dist. | 8.3 | No | March 94 | Rubber | Pairs at buildouts |
| 33. Hollings Rd | Dist. | 8.5 | No | May 94 | Rubber | Three-abreast |
| 34. New Cross St | Dist. | 8.5 | DD | April 94 | Rubber | Pairs |

*[1]Site within 20 mph Zone.*
*[2]Resid — Residential Road, Dist — Local distributor Road*
*[3]Midi — Midibus, SD — Single decker bus, DD — Double decker bus*
*[4]Some schemes include more than one layout*
*[5]The term 'single cushion layout' refers the type of cushion layout at a particular location on a road rather than the number of cushions along a road*

(a) Residential street with three-abreast cushions of composite construction — Coventry Road (site 1)
(Picture courtesy of Bedfordshire CC)

(b) A183, local distributor road with asphalt cushions — Ocean Road (site 29)
(Picture courtesy of South Tyneside MBC)

**Plate 2** Character of speed cushion locations

## 2.2 Construction

A total of seven different methods of cushion construction were identified in the sites studied. Cushions were constructed from asphalt, moulded rubber sections, block paving (including kerbing) and concrete. In addition to these individual materials, composite cushions were constructed from asphalt and rubber sections, asphalt and kerbing and asphalt and block paving.

Asphalt cushions were installed in 16 of the sites; in many cases red asphalt was used to make cushions stand out against the road surface (Plate 2b). Because of the nature of the material, asphalt cushions are difficult to construct to exact specifications.

Moulded rubber cushions were installed in 7 of the sites; a variety of designs are available and the rubber sections are generally available in black or red (Plates 3a and 3b). The sections were fixed onto the carriageway with bolts and adhesive. The installation of sectioned rubber cushions requires little or no modification to the existing carriageway, as opposed to the other construction methods which require materials to be ‘cut in’ to the road surface.

Block paving, or block paving with sections of kerbing, was used for the construction of cushions at 5 of the sites (Plates 3c and 3d). High standards of construction are necessary when installing speed cushions from block paving as any movement by individual blocks becoming dislodged may initiate the breakup of a whole section of brickwork.

Concrete cushions were installed at 3 of the sites. Concrete cushions may be constructed from a number of preformed sections, cast as single preformed units depending on size, or cast in-situ. Colouring may be added to the mix of the concrete to distinguish it from the road surface. Pre-cast concrete units are constructed from reinforced concrete moulded to exact specifications (Plate 3e). Concrete cushions cast in-situ may present similar problems to those identified in the construction of asphalt cushions, in that, due to the nature of the material, the construction of cushions to exact specifications may be difficult.

Composite cushions were constructed at 3 of the sites. At Coventry Road (site 1), moulded rubber sections and asphalt have been used to form cushions (see Plate 2a). Rubber sections forming the ramped sides of the cushion create a central area which can be infilled with asphalt. At Ivy Road (site 3), cushions have been constructed from asphalt and kerbing. This method of construction, whereby the outer edge of the cushion platform is formed by kerbing, allows the central area to be infilled with asphalt and asphalt ramps to be formed against the kerbing. At Windmill road (site 8), cushions have been constructed with a block paved, kerb edged platform and asphalt ramps (see Plate 3f).

## 2.3 Costs

Table 2 displays information from the sample of schemes studied on the costs of cushion construction for different

**Table 2 Construction costs of speed cushions**

| *Site No. Name* | *Cushion construction* | *Cost of single cushion* | *Cushion layout*[1] | *Cost per cushion layout*[2] |
|---|---|---|---|---|
| 4. Peterborough Rd | Asphalt | - | Single at narrowing | £1000 |
| 5. Blomfield Rd | Asphalt | - | Pairs | £2000 |
| 14. Askham Ln | Asphalt | £450 | Pairs, double-pairs | £900 & £1800 |
| 15. Chapelfields | Asphalt | £210 | Single at buildout | - |
| 16. Cornlands Rd | Asphalt | £450 | Pairs | £900 |
| 17. Danebury Dv | Asphalt | £165 | Pairs, three-abreast | £330 & £495 |
| 18. Gale Ln | Asphalt | £120 | Pairs, double-pairs | £240 & £480 |
| 19. Foxwood Ln (Phase 1) | Asphalt | - | Pairs at buildout | £320 |
| 19. Foxwood Ln (Phase 2) | Asphalt | £450 | Pairs at buildout | - |
| 20. Kingsway West | Asphalt | £150 | Single at buildout, Pairs | - |
| 23. Skeldergate | Asphalt | £545 | Pairs, three-abreast | £1090 & £1635 |
| 27. Brookside Av | Asphalt | £250 | Pairs | £500 |
| 30. Camp Hill | Asphalt | £350 | Single at narrowing | £1500 |
| 30. Camp Hill | Asphalt | £350 | Pairs | £1500 |
| 22. Muncaster | Rubber | £600-950 | Pairs | £1200-£1900 |
| 26. Bagnall Rd | Rubber | £655 | Pairs (1880mm)[3] | £1305 |
| 26. Bagnall Rd | Rubber | £480 | Three-abreast (1600mm)[3] | £1434 |
| 32. Grosvenor Rd | Rubber | £695 | Pairs at buildouts | - |
| 33. Hollings Rd | Rubber | £555 | Three-abreast | £1665 |
| 34. New Cross St | Rubber | £695 | Pairs | £1390 |
| 24. Tang Hall | Block paving/kerbing | £975 | Pairs | £1950 |
| 9. Chadderton Pk Rd | Concrete units | £750 | Pairs | £1500 |
| 10. Ringmore Rd | Concrete in-situ | £250 | Pairs | £500 |
| 28. Lindsay Av | Concrete sections | £340 | Pairs at narrowing | £3980[4] |
| 1. Coventry Rd | Rubber/asphalt | - | Three-abreast | £2200 |

*[1]The term ‘single cushion layout’ refers the type of cushion layout at a particular location on a road rather than the number of cushions along a road*
*[2]May include cost of carriageway modification.*
*[3]Width of speed cushion.*
*[4]Cost of installation (2 cushions) £2,750, cost of kerb extension £550.*

(a) Moulded rubber cushions
Billing Brook Road (site 25)
(Picture courtesy of Northamptonshire CC)

(b) Moulded rubber cushions
Muncaster (site 22)
(Picture TRL)

(c) Block paved cushion
Eyres Monsell (site 11)
(Picture TRL)

(d) Block paved cushion
Tang Hall (site 24)
(Picture TRL)

(e) Pre-formed concrete cushions
Chadderton Park Road (site 9)
(Picture courtesy of Oldham MBC)

(f) Composite, block paving/asphalt
Windmill Road (site 8)
(Picture courtesy of Hertfordshire CC)

**Plate 3** Types of cushion construction materials. The costs are those at the time of installation (see Table 1 for installation dates).

Asphalt cushions ranged, per single cushion, from £120 to £545. The asphalt cushion schemes installed before mid April 1994 in York, sites 15, 17, 18, 19 (Phase 1) and 20, were generally priced at less than 50% of the cost per cushion quoted after this date. This reflects higher quotes offered by contractors for the construction of later cushion schemes due to previous difficulties encountered with construction.

Moulded rubber cushions within the sample ranged in price from £480 to £950 depending on the type and number of cushions installed. Block paving cushions installed at Tang Hall (site 24) cost £975 per cushion. Concrete cushions were constructed by either using preformed sections, or by casting the cushion in-situ. Table 2 indicates the cost of casting concrete cushions in-situ to be significantly lower than the cost of buying and installing preformed concrete units.

The costs (cushions plus installation) of the different types of cushion group layout depended on the materials used and the need for any carriageway modifications. In this sample costs varied from £1000 to £1500 for a single cushion group, £240 to £3980 for cushion pairs and £495 to £2200 for three-abreast groups.

### 2.4 Maintenance

Maintenance to cushions or cushion groups was required at several of the sites identified in this report (maintenance to cushions does not include alterations to cushion dimensions, see Section 3.2).

Two moulded rubber cushions that were installed in Byland Avenue, Muncaster (site 22), have required maintenance where bolts fixing the cushions to the carriageway surface had sheared. This was attributed to a combination of the steep on gradient of the cushions and the unusually high volume of heavy traffic using the road during the trial period. Deformation of moulded rubber cushions installed on Monkton Road, within Muncaster, has also been identified as a problem. Partial lifting of moulded rubber cushions has also been reported at some sites. Sections of several moulded rubber cushions installed at Billing Brook Road (site 25) have had to be re-fixed to the carriageway surface by the contractors who initially installed the measures. At Bagnall Road (site 26), the 1880mmm wide cushions were removed and replaced with concrete cushions with similar dimensions. The moulded rubber cushions at Chairborough Road (site 2) were removed following problems with vandalism.

Block paved cushions installed at Richmond Hill (site 7) and Eyres Monsell (site 11) have required repairs. Bricks have cracked and moved within cushions on Richmond Hill where 3 cushions had to be totally rebuilt (Richmond now use preformed concrete sections). Similarly blocks have moved becoming dislodged in cushions in Eyres Monsell. Deformation of block paved cushions at Tang Hall (site 24) has required on-going maintenance and eventual replacement of the cushions.

Preformed concrete units and sections installed at Chadderton Park Road (site 9) and Lindsay Avenue (site 28) respectively have required modification since installation. The preformed concrete units installed on Chadderton Park Road, because of their rigid nature, did not allow for the camber of the road, resulting in a higher cushion upstand relative to the road surface near to the kerb on both sides of the carriageway. In this case modification of the carriageway surface around the cushions was required to flatten the camber of the road. A number of cushions at Lindsay Avenue have cracked and/or developed a rocking motion. These failed cushions are being replaced with stronger preformed units.

There has been no reported need for maintenance at any of the asphalt cushion sites covered by this report.

## 3 Layout and dimensions

The design of speed cushion schemes is likely to be influenced by the physical situation of a site (most importantly the road width) and other factors such as the level and composition of the traffic flow, the level of on-street parking and whether the road is a bus route or emergency vehicle access route.

The speed of vehicles at, and between, the cushions will be affected by the dimensions of the cushions and the type and spacing of the cushion layout (see Section 4). The spacing between the cushions (or groups of cushions, depending on layout) for the schemes included in the study varied between 50 and 105m with an average value of about 71m. Bus operators have commented that cushion layouts should be placed at a sufficient distance from junctions to allow turning buses room to align and straddle the cushions centrally (see Section 9.1).

### 3.1 Cushion layout

Where vehicle flows are relatively high, a smooth flow of traffic along a road should be promoted by the choice of cushion layout that allows two way working and is free from obstruction by parked vehicles.

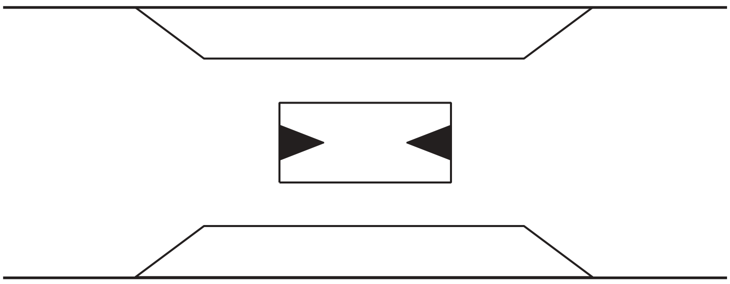
Figure 3 illustrates the main types of cushion layout found in the schemes within this study:

a a series of single cushion layouts combined with carriageway narrowings, which allow only single lane working and are more suitable for lower flow roads (Plate 4)

b groups of cushions in pairs, these allow two way working, are suitable on higher flow roads and can be combined with carriageway narrowings or islands (Plates 1, 2b, 3, 5 and 6)

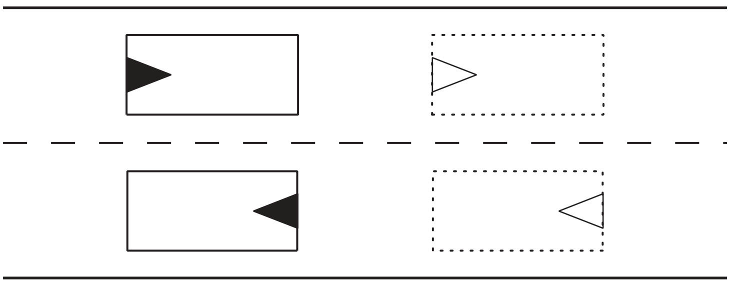
c groups of cushions three-abreast which also allow two way working and are suitable on wide roads without requiring the construction of carriageway narrowings (Plates 2a and 7).

Vehicles parked on the nearside can block a central path over a cushion. Vehicles travelling in the lane affected cannot straddle the cushion, and either have to cross the cushion off centre (with increased discomfort), or cross over the centre line and straddle the cushion in the offside lane (see Plate 5a, and Sections 8 and 9).



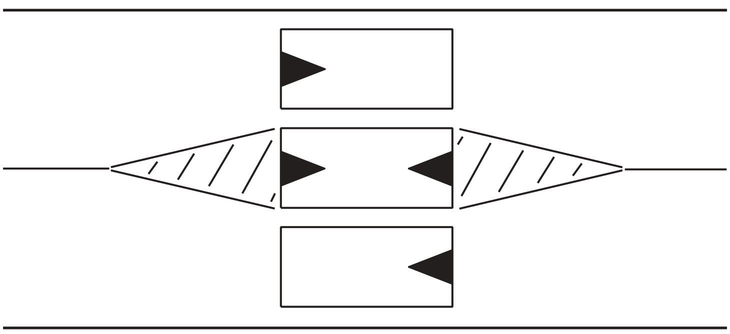
(a) Single cushion layout (single lane working)

Single cushion layouts were constructed with either a single buildout, or within a pinch point.



(b) Pair or double-pair layout

Cushion pair or double-pair layouts were sometimes combined with buildouts, pinch points or islands. At pedestrian refuges, the cushions in a cushion pair were staggered and located upstream of the refuge.



(c) Three-abreast cushion layout

At some sites, hatching was marked on the carriageway either side of the central cushion to separate the vehicle flows.

**Figure 3** Main types of speed cushion layout

(a) Single cushion layout - buildouts from both sides — Lindsay Avenue (site 28)
(Picture TRL)

(b) Single cushion layout - single buildout — Chapelfields Area (site 15)
(Picture TRL)

**Plate 4** Single cushion layouts at carriageway narrowings

(a) Cushion pair without buildouts or islands
Muncaster (site 22)
(Picture TRL)

(b) Double-pair without buildouts or islands
Muncaster (site 22)
(Picture TRL)

(c) Cushion pair within pinch point
Windmill Road (site 8)
(Picture courtesy of Hertfordshire CC)

(d) Cushion pair at single buildout
Foxwood Lane (site 19)
(Picture TRL)

(e) Cushion pair at central island
Chairborough Road (site 2)
(Picture TRL)

(f) Double-pair at refuge and pinch point
Charles Road (site 31)
(Picture TRL)

**Plate 5** Pair and double-pair cushion layouts

The installation of buildouts in association with cushions can aid the effectiveness of measures and solve some of problems presented by parked vehicles. Buildouts at pinch points produce a narrowing on both sides of the road which deter drivers from parking over the measures, thus preventing the obstruction of vehicles attempting to straddle the cushions (Plates 4a and 5c). Single buildouts may also achieve these aims and can be used to create stretches of sheltered parking (Plate 5d).

Traffic islands will prevent drivers manoeuvring centrally between cushions and may also serve to create a chicane effect with vehicles parked along the road (Plate 5e). Parking restrictions on the approach to cushions may be necessary at these locations.

The use of carriageway narrowings and central islands can create problems for cyclists who are ‘squeezed’ by motor vehicles overtaking within the narrowing (Davies *et al*, 1997). To alleviate this, cycle bypasses have been installed in some schemes (*eg* Ivy Road, site 3).

### *3.1.1 Single cushion layouts*

The term ‘single cushion layout’ refers the type of cushion layout at a particular location on a road rather than the number of cushions along a road. The single cushion layouts, within the sample of schemes studied, were all associated with horizontal deflections created by carriageway narrowings requiring single lane working over the cushion arrangement.

The dimensions of the single cushion layouts identified in this study are presented in Table B1, Appendix B. Road widths varied from 6.4 to 8.0 metres for single cushions placed within ‘pinchpoints’, buildouts of equal width from either side of the road (Plate 4a), and from 4.9 to 7.0 metres for single cushions placed next to single buildouts (Plate 4b).

All but one of the roads which included single cushion layouts were classified as residential. Lindsay Avenue (site 28), the only local distributor class road to include single cushion layouts, was a test site for on-road trials of cushions, with a total of six different cushion layouts included within the trial.

### *3.1.2 Pair and double-pair cushion layouts*

The pair and double-pair cushion layouts allow two way working and thus are more suitable for higher flow roads. Double-pair cushion layouts are simply cushion pairs placed close to create a group of 4 cushions.

Pair or double-pair cushion layouts were used at 28 of the schemes in the sample studied on both residential roads and local distributor roads. The layout and dimensions of cushion pairs or double cushion pairs are presented in Table B2, Appendix B. Five different types of paired layout have been identified depending on the presence of buildouts and islands.

Type 1: Cushion pairs or double-pairs were constructed without buildouts or islands at 19 cushion schemes, on roads of between 5.5m to 7.3m wide (Plates 5a and 5b).

Type 2: Cushion pairs within pinch points were constructed at 3 cushion schemes, on roads of 7.5m to 8.5m wide (Plate 5c).

Type 3: Cushion pairs within single buildouts, from one side of the road only, were constructed at 5 schemes, on roads of 7.3m to 8.3m wide (Plate 5d).

Type 4: Cushion pair layouts with islands and no buildouts were installed at 5 locations, on roads of 6.8m to 9.0m wide (Plate 5e).

Type 5: Sets of double cushion pairs within a pinch point with island were installed on a road 9.25m wide (Plate 5f).

Gaps between cushions and the kerb varied from 350 to 1120mm wide, with an average of about 850mm. It is recommended that cushion kerb gaps should not be less than 750mm, to allow cyclists a clear path between the cushion and kerb.

Central gaps between cushions at pair layouts without islands varied from 700 to 2100mm wide, with an average of about 1000mm. Central gaps between cushions should be greater than 750mm to allow opposing flows of traffic to straddle cushions without conflict. However, wide central gaps between cushions (greater than about 1200 mm) encourage drivers to drive centrally between cushions rather than over the measures and may give rise to conflicts between vehicles (see Plate 6 and Section 8).

About half the pair or double-pair layouts were combined with buildouts or a central island. Central gaps between cushions and islands varied from 350 to 900mm, with an average of about 700mm. Where a pair of cushions was used at a pedestrian refuge, the cushions were staggered across the refuge and located on the upstream sides of the refuge. The width of islands installed with pair or double-pair cushion layouts varied between 800mm to 2000mm, pedestrian refuges being at least 1800mm wide.

Concerns have been expressed that pedestrians might inadvertently trip over speed cushions resulting in a fall and injury. The possibility of this occurring can be reduced by using speed cushions that have a contrasting colour to the road surface and by avoiding the positioning of cushions at locations where it is likely that many pedestrians will wish to cross the road.

Care should be taken when using double-pair cushion layouts at the exit and entry sides to an uncontrolled crossing place (see Plates 5b, 5f and 6). Such layouts may not be appropriate if it is thought likely that a substantial number of pedestrians will cross outside the area between the dropped kerbs. The use of a staggered single-pair of cushions on the entry sides only of an uncontrolled crossing will halve the number of cushions at the crossing but might encourage drivers to cross the carriageway centreline to avoid the cushions, unless the layout included a pedestrian refuge. Double-pair layouts were also highlighted by some bus operators as being much too severe (see Section 9.1)

### *3.1.3 Three-abreast cushion layouts*

Three-abreast cushion layouts allow two way working and are suitable for installation on wide roads without requiring additional buildouts or islands (Plate 2a and Plate 7).

Three-abreast cushion layouts were used at 13 of the schemes in the sample studied. The dimensions of three-abreast cushion layouts are presented in Table B3, Appendix B.

**Plate 6** Vehicle manoeuvring centrally between speed cushions — Billing Brook Road (site 25)
(Picture courtesy of Northamptonshire CC)

**Plate 7** Three-abreast cushion layout — Foxwood Lane (site 19)
(Picture TRL)

Three-abreast cushion layouts were installed on the wider residential roads and local distributor roads. The road widths for three-abreast layouts were generally between 7.2 to 10.0 metres (paired cushion layouts without buildouts or islands were not constructed on roads greater than 7.3m in width). Cushion kerb gaps at three-abreast sites varied from 200 to 1000mm, with an average of about 700mm. Gaps between cushions ranged from 525 to 1025mm, with an average of 800mm.

On a heavily parked road, the presence of buildouts or islands may reduce the amount of parking space available. Three-abreast cushion layouts may be more suitable on such roads as they do not restrict parking and allow vehicles overtaking parked cars to straddle the central cushions (Plate 2a). In one scheme (Poplar Neighbourhood, site 6) smaller width cushions (1000mm) were used either side of a wider central cushion (2130mm) on heavily parked 6.8m wide roads.

#### *3.1.4 Other cushion layouts*

Cushion groupings not conforming to layouts described above have been constructed at Lindsay Avenue (site 28), and Camp Hill (site 30).

As part of the DETR on-road trials of speed cushions, Layfield *et al* (1994), a group of 3 cushions, based on a combination of a single cushion at a pinch point and a pair of cushions, was installed at Lindsay Avenue. The separate single and paired cushion elements of this group were spaced approximately 17m apart. A group of 5 cushions was also installed on Lindsay Avenue (Plate 8). This layout was based on two paired arrangements of cushions either side of a single cushion at a pinch point. In this case the cushion pairs were positioned approximately 16 to 17m either side of the single cushion, with the cushions of the paired arrangements angled toward the central cushion. These layouts were not popular with the South Yorkshire Fire and Rescue Service as they require lateral manoeuvring between cushions to properly negotiate the layouts.

At Camp Hill a speed cushion feature has been installed within a chicane arrangement of angled buildouts (Plate 9). The measure is similar to a pinch point except that the buildouts forming the pinch are angled thus creating a lateral displacement as vehicles move through the arrangement. A long, narrow cushion (5900mm long, 1000mm wide) has been installed within the chicane, orientated at the same angle as the buildouts. The function of the cushion is not to slow speeds by vertical deflection but to guide vehicles onto a path through the chicane that increases lateral deflection. If vehicles do not follow this path then they will be deflected vertically by the cushion.

### 3.2 Cushion dimensions

Recommended ranges of dimensions, based on the results of off-road trials at the TRL and on-road trials in Sheffield and York, are given in Traffic Advisory Leaflet 4/94 (Department of Transport, 1994a). This leaflet suggests the following cushion dimensions: side ramp gradients not steeper than 1:4; on/off gradients not steeper than 1:8, and with a curved on/off ramp, the average gradient not steeper than 1:5; maximum height of 80mm, a height of 75mm for cushions constructed in situ and a lower height of 65mm for narrow cushions; maximum length of 3700mm; and maximum width of 2000mm and a width of 1600mm - 1700mm for bus routes.

Most of the 34 schemes in this study had cushions within these dimensions, but some were installed before the on-road trials were completed, or were trial schemes, or were designs to suit local circumstances (eg. Camp Hill, site 30). Over 30 different combinations of speed cushion dimensions were included in this study. The dimensions of the cushions generally ranged from 1500 to 2100mm in width, 1700 to 4750mm in length and 60mm to 100mm in height. The gradient of on and off-ramps of cushions varied from 1:3.5 to 1:12, side ramp gradients varied between 1:2 to 1:5.25. The dimensions of the cushions used in each of the schemes studied are given in Appendix B.

Several designs of speed cushion have been identified which lie outside of the dimensions indicated above. Small circular cushions, 1380mm in diameter have been installed on part of Chairborough Road (site 2), along a bus route. Cushions 1380mm wide by 1880mm long were also installed along part of Chairborough Road without buses. At Camp Hill (site 30), a narrow 1000mm wide cushion was installed within a chicane, as described above. Cushions 9500mm long were also installed at Camp Hill as paired arrangements with traffic islands.

At a number of sites the speed cushions were removed or altered after installation. At Ringmore Road (site 10), the 1900mm wide cushions were regarded as too severe and replaced with 75mm high flat-top humps with shallow (1:15) ramp gradients. At Abbott Road, Poplar Neighbourhood (site 6), the cushion height was lowered from 100mm to 75mm. At Peterborough Road (site 4), the speed cushions were reduced from 2160mm to 1700mm in width after the emergency services complained that their vehicles could not straddle the wide cushions. At Brookside Avenue (site 27), cushions were increased in width from 1600mm to 1900mm in order to reduce the central gap between the cushions from 2100mm to 1500mm (see Section 8).

At several of the cushion schemes in York (sites 14, 18, 22, 23 and 24) alterations to cushion dimensions and layouts have been carried out following an off-road investigation into the public acceptability of cushion dimensions. The aim was to reduce discomfort, especially for passengers in minibuses, ambulances and small cars, and allow slightly higher speeds by reducing cushion width and height, increasing length (new dimensions 1600mm wide, 65mm high and 3500mm long), and in some cases increasing cushion spacing (see Section 4.1.1).

Marks left by vehicles grounding on humps and cushions are often visible but the local highway authorities usually attribute this to excessive speed or ill fitting exhausts. However there were a few reports from local highway authorities of vehicles grounding on cushions at the schemes included in this study. At Camp Hill (site 30), very narrow (1000mm) cushions, 65mm high, were lowered to 55mm after complaints from a resident that his Austin Metro was grounding on them.

**Plate 8** Vehicle crossing a group of 5 cushions at a pinch point — Lindsay Avenue (site 28) (Picture TRL)

**Plate 9** Long narrow angled cushion within a chicane — Camp Hill (site 30) (Picture courtesy of Warwickshire CC)

Trials at TRL (Hodge, 1993) and elsewhere, have shown that speed cushions can lead to grounding problems for some limousines, low sports cars and customised cars if the cushions are higher than 80mm or if the approach ramps are steeper than 1:8. Webster (1993b) noted that the grounding can be caused by the vehicles having low ground clearances, especially where this is combined with long wheelbases, or low front overhangs and that it was advisable not to have a cushion plateau less than 800mm long nor an overall cushion length of less than 2000mm.

Grounding was considered at off-road speed cushion trials organised by York City Council in 1994 (see Section 7.2). A sample of six large and six small cars were driven over a range of cushion profiles at typical road speeds. The results indicated that most cars with correctly fitted exhausts would not have any problem with grounding at 80mm high cushions, even when loaded with four persons. In 1995, a further trial with about 200 members of the public using their own vehicles found that some low sports cars would ground on cushions 75mm high, 1700mm wide and 2000mm long (similar dimensions to those originally used at Gale Lane, site 18). All the vehicles were able to pass over cushions 65mm high, 1600mm wide and 3500mm long.

# 4 Traffic speeds

At over half the sites, mean and 85th percentile speeds were recorded before and after the installation of the cushion schemes. The speeds were measured *at* and *between* the cushion layouts. The 'after' speeds were generally collected at least 6 weeks after the installation of schemes to allow a 'settling in' period, within which initial speed reductions may be slightly eroded. At Tang Hall, site 24, mean speeds at the cushions increased by about 2 to 3 mph during the first 4 months following cushion installation.

Almost all of the speed measurements taken at, and between, the cushions were made using hand held radar meters, with results averaged over 30-300 readings. The speeds based on the lower numbers of vehicles are likely to be less reliable. Generally speeds were measured for light vehicles (eg passenger cars and light vans) during a relatively short period of the day, so it is possible that for some sites the results can be considered a broad indication only of the mean and 85th percentile speeds at the site. At a few sites the measurements were recorded by automatic speed recording devices using pneumatic tubes or induction loops.

It is likely that the general situation, type of road, presence of parked vehicles and even geographical location will have an effect on the 'before' and also the 'after' speeds. The following results give a guide to expected average 'after' speeds but, because of differences in sites and measurement methods within the present data set, a good deal of variability is likely.

The 'before' mean speeds ranged from 21 to 35 mph with an overall average of about 30 mph; 85th percentile speeds ranged from 27 to 47 mph with an overall average of about 36 mph.

**4.1 Speeds at cushions**

The 'before' and 'after' mean and 85th percentile speeds measured at the cushions are given in Table 3. The average cushion dimensions across the different schemes were: width 1772mm, height 76mm, length 2542mm, on/off gradient 1:7.9 and side gradient 1:4.1. The results in Table 3 show that the mean and 85th percentile vehicle speeds at cushions have been reduced on average by about 13 mph. The range of mean crossing speeds was 12 to 27 mph with an overall average of 17 mph and the range of 85th percentile crossing speeds was 14 to 32 mph with an overall average of 22 mph.

The overall average mean and 85th percentile speeds at cushions (17 and 22 mph respectively) were 2 to 7 mph higher than those found by Webster and Layfield (1996) at 75mm high flat-top humps (13 and 15 mph) and 75mm high round-top humps (15 and 19 mph).

The speeds measured at the cushions are overall traffic speeds based on a mixture of vehicles, most of which will have been cars and light vans. Larger vehicles such as buses and heavy goods vehicles are likely to be slowed down to a lesser extent than cars, particularly at the narrower cushions. In the on-road trials in Sheffield and York (Layfield *et al*, 1994) it was found that before the speed cushion schemes were introduced, the mean speeds of buses were about 5 mph slower than the mean speeds of cars. After the speed cushions were installed, the mean speeds of buses at the cushions were generally similar to, or slightly faster than, the mean speeds of cars.

The results of test runs made during the trials with a fire appliance and an ambulance indicated that, due to the reduced discomfort, 'urgent' crossing speeds for fire appliances over wide and narrow cushions could be 10 to 20 mph higher than over 75mm high humps. Crossing speeds for ambulances at wide cushions would be similar to those at 75mm high humps but might be higher at narrow cushions.

Motor-cyclists can avoid cushions and the cushions will have little, if any, effect on their speeds. In high flow periods however, a reduction in the speed of cars and large vehicles may also have a speed reducing effect on motor-cyclists.

***4.1.1 Effect of cushion dimensions on traffic speed***

The size of speed cushions affects passenger discomfort and hence vehicle speed. Mean crossing speeds are likely to be affected by the magnitude of cushion dimensions such as cushion width, height, length, on-ramp gradient and side ramp gradient. Results from on-road trials of speed cushions indicated that cushion width is an important variable affecting passenger discomfort and that narrower cushions allow higher speeds.

Multiple linear regression analysis was used on the data in Table 3 to investigate the relationships between speed at the cushions, and the variables 'before' speed, cushion width, cushion height, cushion length, on/off gradient, and side gradient. The range of heights, on/off gradients and side gradients in the sample data is small, since many schemes used the recommended cushion dimensions of height

**Table 3 Before and after vehicle speeds at cushions**

| Site | *Vehicle speed (mph)* | | | | *Speed reduction (mph)* | | *Cushion dimensions (mm)* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Before* | | *After 'at'* | | | | | | | *Gradient* | |
| *No.Name* | *mean* | *85%* | *mean* | *85%* | *Mean* | *85%* | *Width* | *Height* | *Length* | *on/off* | *side* |
| 1. Coventry Rd | 23.0 | 27.1 | 15.3 | 19.8 | 7.7 | 7.3 | 1900 | 75 | 3725 | 1:8 | 1:4 |
| 5. Blomfield Rd | 30.0 | 35.5 | 20.0 | 25.7 | 10.0 | 9.8 | 1600 | 75 | 3400 | 1:8 | 1:4 |
| 6. Poplar Neigh'd (Abt. Rd) | - | 31.5 | - | 14.0 | - | 17.5 | 2130 | 100 | 4750 | 1:15[1] | 1:2 |
| 6. Poplar Neigh'd (Blr. St) | - | 27.8 | - | 16.0 | - | 11.8 | 2130 | 90-100 | 2750 | 1:3.5 | 1:2 |
| 8. Windmill Road | 31.8 | 37.9 | 17.1 | 22.0 | 14.7 | 15.9 | 1700 | 70 | 2500 | 1:10 | 1:5 |
| 9. Chadderton Pk Rd | 30.8 | 36.5 | 18.9 | 24.6 | 11.9 | 11.9 | 1500 | 75 | 1800 | 1:8 | 1:4 |
| 14. Askham Ln | 34.7 | 40.5 | 20.0 | 23.0 | 14.7 | 17.5 | 1700 | 75 | 2000 | 1:8 | 1:4 |
| 15. Chapelfields | 24.5 | - | 15.3 | - | 9.2 | - | 1750 | 75 | 2000 | 1:6 | 1:4 |
| 16. Cornlands Rd | 30.0 | 35.0 | 20.5 | 25.0 | 9.5 | 10.0 | 1700 | 75 | 2000 | 1:8 | 1:4 |
| 17. Danebury Dv | 34.1 | 40.0 | 16.7 | 23.5 | 17.4 | 16.5 | 1800 | 75 | 2000 | 1:8 | 1:4 |
| 18. Gale Ln | 32.5 | 37.0 | 17.4 | 20.7 | 15.1 | 16.3 | 1700 | 75 | 2000 | 1:8 | 1:4 |
| 19. Foxwood Ln (ph1) | 32.0 | - | 19.0 | - | 13.0 | - | 1650 | 75 | 2500 | 1:8 | 1:4 |
| 19. Foxwood Ln (ph2) | 29.8 | 33.8 | 20.6 | 27.1 | 9.2 | 6.7 | 1650 | 75 | 2500 | 1:8 | 1:4 |
| 20. Kingsway West | - | - | 16.5 | 20.8 | - | - | 1750 | 75 | 2000 | 1:8 | 1:4 |
| 20. Kingsway West | - | - | 16.1 | 21.0 | - | - | 1800 | 75 | 2000 | 1:8 | 1:4 |
| 20. Kingsway West | - | - | 19.3 | 24.0 | - | - | 1700 | 75 | 2000 | 1:8 | 1:4 |
| 21. Mill Lane | - | - | 16.2 | 22.0 | - | - | 1650 | 75 | 2500 | 1:8 | 1:4 |
| 22. Muncaster | 28.9 | - | 14.1 | - | 14.8 | - | 1900 | 75 | 1950 | 1:8 | 1:4 |
| 22. Muncaster | 28.6 | - | 13.3 | - | 15.3 | - | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 |
| 22. Muncaster | 25.9 | - | 13.5 | - | 12.4 | - | 1700 | 60 | 1700 | 1:3.5 | 1:3.5 |
| 23. Skeldergate | 21.0 | - | 14.9 | 19.0 | 6.1 | - | 1800 | 75 | 2000 | 1:8 | 1:4 |
| 24. Tang Hall | 29.9 | - | 14.0 | - | 15.9 | - | 1800 | 75 | 2500 | 1:8 | 1:4 |
| 27. Brookside Av | 35.0 | 41.8 | 26.9 | 31.8 | 8.1 | 10.0 | 1600 | 75 | 4300 | 1:12 | 1:5 |
| 27. Brookside Av | 33.8 | 41.3 | 23.0 | 27.5 | 10.8 | 13.8 | 1900 | 75 | 4300 | 1:12 | 1:5 |
| 28. Lindsay Av | 27.5 | - | 19.0 | - | 8.5 | - | 1600 | 75 | 3250 | 1:8 | 1:4 |
| 29. A183, Ocean Rd | - | 30.0 | - | 18.5 | - | 11.5 | 1750 | 75 | 3700 | 1:8 | 1:4 |
| 32. Grosvenor Rd | 26.0 | 31.0 | 12.5 | 15.5 | 13.5 | 15.5 | 1900 | 75 | 1950 | 1:8 | 1:4 |
| 33. Hollings Rd | 35.0 | 40.0 | 15.0 | 18.8 | 20.0 | 21.2 | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 |
| 34. New Cross St | 35.0 | 39.0 | 15.0 | 18.0 | 20.0 | 21.0 | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 |
| Average | 30.0 | 35.6 | 17.3 | 21.7 | 12.6 | 13.7 | 1772 | 76 | 2542[2] | 1:7.9 | 1:4.1 |

[1]*Cushion dimensions as specified. Dimensions varied on site, some on/off ramps were steeper*
[2]*Average length of cushions for available data relating to mean speeds was 2455mm and 2790mm for available data relating to 85th percentile speeds*

75mm, on/off gradient of 1:8 and side gradient of 1:4.

For *mean speed at cushions*, the variables before speed, cushion width, cushion length, and on/off gradient were statistically significant at the 1% level when individually added to the base model. Decreasing width, increasing length, and shallower on/off gradients resulted in higher speeds. However, the variables length and on/off gradient were correlated within this data set, with longer cushion lengths tending to be associated with shallower on/off gradients. The relative effects of the these two variables cannot be precisely determined with this data set as either, but not both variables, were statistically significant when included together in the model.

The best fitting relationship contained the variables mean before speed, cushion width and cushion length. All these variables were statistically significant at the 1% level.

$$V_{mn(at)} = 24.9 - 0.0134w + 0.00253l + 0.321V_{mn(bef)}$$

where $V_{mn(at)}$ = mean speed at cushions (mph)
$V_{mn(bef)}$ = mean before speed (mph)
$w$ = cushion width (mm)
$l$ = cushion length (mm)

The number of observations was 22
The standard error of the coefficients:
se($w$) = 0.0030; se($l$) = 0.00046; and se($V_{mn(bef)}$) = 0.091

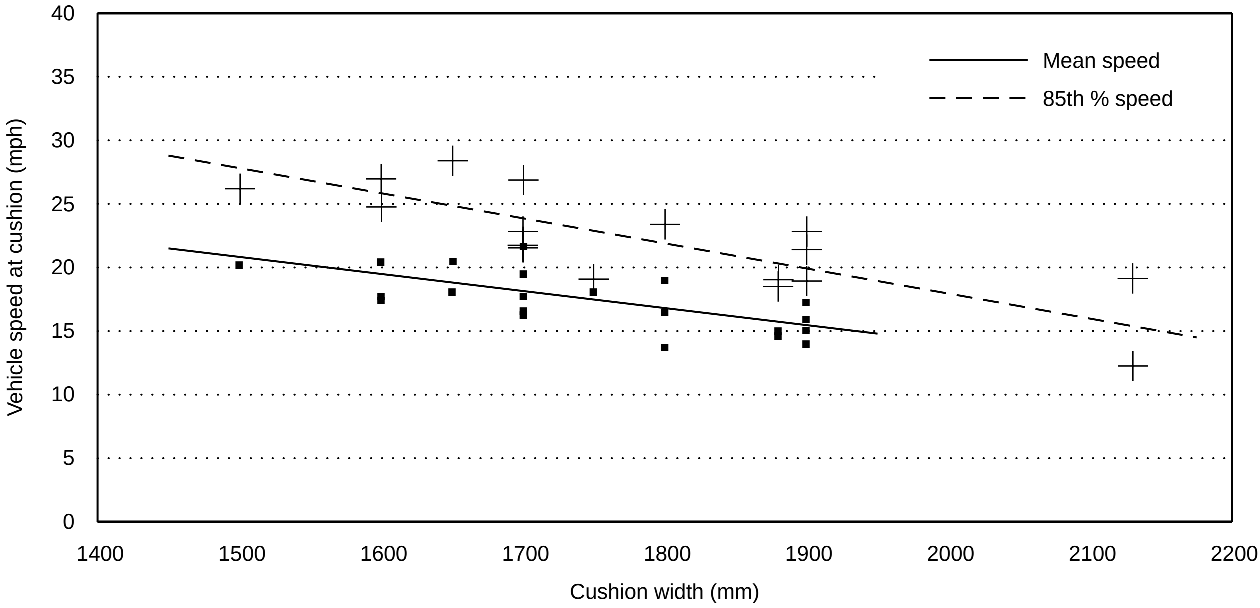
Figure 4 displays the relationship between mean vehicle speed at the cushions and cushion width, with the data values normalised to take account of differences in 'before' speed and cushion length. Figure 4 shows that, at average values of mean 'before' speed (30 mph) and cushion length (2455mm), mean speeds at 1600mm wide cushions are likely be about 19.5 mph, while 1900mm wide cushions would give mean speeds of about 15.5 mph. This represents approximately a 4 mph drop in vehicle speed for an increase in cushion width of 300mm.

For *85th percentile speed at cushions*, the best fitting relationship contained the variables 85th percentile 'before' speed, cushion width and cushion length. The variable cushion width was statistically significant at the 1% level; cushion length and 85th percentile 'before' speed were significant at the 5% level.

$$V_{85(at)} = 36.8 - 0.0185w + 0.00179l + 0.370V_{85(bef)}$$

where $V_{85(at)}$ = 85th percentile speed at cushions (mph)
$V_{85(bef)}$ = 85th percentile 'before' speed (mph)
$w$ = cushion width (mm)
$l$ = cushion length (mm)

The number of observations was 17
The standard error of the coefficients:
se($w$) = 0.0043; se($l$) = 0.00069; and se($V_{85(bef)}$) = 0.16




Speed at cushions also influenced by 'before' speed and cushion length, see text in Section 4.1.1

**Figure 4** Vehicle speeds at cushions

Figure 4 shows that, at average values of 85th percentile 'before' speed (35.6 mph) and cushion length (2790mm), 85th percentile speeds at 1600mm wide cushions are likely be about 25.5 mph, while 1900mm wide cushions would give 85th percentile speeds of about 20 mph. This represents approximately a 5.5 mph drop in vehicle speed for an increase in cushion width of 300mm.

Only one site had 1500mm wide cushions, Chadderton Park Road (site 9). Similar width cushions have been used in a trunk road traffic calming scheme at Craven Arms in Shropshire, not part of the present study, with recorded mean and 85th percentile speeds of light vehicles over the cushions of about 26 mph and 30 mph respectively (Wheeler *et al*, 1996). These results are consistent with those found here, given that the mean and 85th percentile 'before' speeds and cushion length at Craven Arms were greater than the mean values here.

The effects of changes in cushion dimensions were considered at off-road trials organised by York City Council, with TRL assisting with data collection and analysis (see Section 7.2). At these trials, passenger discomfort rating (and by implication speed reduction) decreased with narrower cushion widths. The first set of trials indicated that an increase in cushion length might reduce passenger discomfort but this was not confirmed in the second set of trials. Cushion height was found to affect discomfort at wider cushion widths.

Following these trials, alterations to cushion dimensions were carried out at several of the sites in York (Askham Lane, site 14; Gale Lane, site 18; and Tang Hall, site 24). The new cushion dimensions were: width 1600mm, height 65mm and length 3500mm. Mean speeds over cushions on Gale Lane and Askham Lane increased by about 1 mph and 3 mph respectively, following the change in cushion dimensions (cushion width reduction of 100mm, a height reduction of 10mm and an increase in length of 1500mm). Mean speeds over cushions on Tang Hall, site 24, increased by about 2 mph after a cushion width reduction of 200mm, a height reduction of 10mm and an increase in length of 1000mm.

These increases in speed were less than those predicted using the relationship above between mean speed at cushions and cushion dimensions. It may be that cushion length has less effect on vehicle speed than indicated in the relationship above and/or that once drivers have modified their driving behaviour because of the introduction of cushions, they are less sensitive to subsequent changes in the cushion dimensions.

#### *4.1.2 Effect of cushion layout on traffic speed*

Mean crossing speeds may also be affected by changes in cushion layout. On-road trials of speed cushions, suggested that mean speeds through single cushion layouts and three-abreast cushion layouts might be slightly higher than for paired cushion groups. Most of the cushion layouts included in Table 3 were pairs of cushions without carriageway narrowings or islands. There were small differences in mean speeds between these and the other paired types (mean speeds at paired cushions with carriageway narrowings or islands were 2 mph slower) but they were not statistically significant at the 5 per cent level.

### 4.2 Speeds between cushions

Spacing between the cushions (or groups of cushions, depending on layout) varied between 50m and 105m with an average of about 71m. 'Before' and 'after' speed measurements were taken midway between the cushions and the results are given in Table 4. Mean and 85th percentile speeds between the cushions were reduced by an average of about 10 mph. The overall average mean and 85th percentile speeds between the cushions (22 and 26 mph

**Table 4 Before and after vehicle speeds *between* cushions**

| *Site* | *Vehicle speed (mph)* | | | | *Speed reduction (mph)* | | *Cushion dimensions (mm)* | | | | | *Distance between cushions(m)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Before* | | *After 'between'* | | | | | | | *Gradient* | | |
| *No. Name* | *mean* | *85%* | *mean* | *85%* | *mean* | *85%* | *Width* | *Height* | *Length* | *on/off* | *side* | |
| 1. Coventry Rd | 23.0 | 27.1 | 20.6 | 24.8 | 2.4 | 2.3 | 1900 | 75 | 3725 | 1:8 | 1:4 | 54 |
| 4. Peterborough Rd | - | 37.0 | - | 24.2 | - | 12.8 | 1700 | 75 | 3400 | 1:8 | 1:4 | 64 |
| 5. Blomfield Rd | 29.7 | 35.3 | 20.4 | 24.6 | 9.3 | 10.7 | 1600 | 75 | 3400 | 1:8 | 1:4 | 65 |
| 6. Poplar Neigh'd (Abt. Rd) | - | 31.5 | - | 23.5 | - | 8.0 | 2130 | 100 | 4750 | 1:15[1] | 1:2 | 78 |
| 6. Poplar Neigh'd (Can. St) | - | 30.0 | - | 16.8 | - | 13.2 | 2130 | 90 | 2750 | 1:3.5 | 1:2 | 70 |
| 8. Windmill Rd | 31.8 | 37.9 | 21.8 | 26.9 | 10.0 | 11.0 | 1700 | 75 | 2500 | 1:10 | 1:5 | 77 |
| 9. Chadderton Pk Rd | 30.8 | 36.5 | 24.0 | 28.8 | 6.8 | 7.7 | 1500 | 75 | 1800 | 1:8 | 1:4 | 75 |
| 10. Ringmore Rd | 34.8 | 38.7 | 20.8 | 26.8 | 14.0 | 11.9 | 1900 | 80 | 2280 | 1:8 | 1:4 | 65 |
| 10. Ringmore Rd | 32.3 | 37.0 | 22.0 | 26.9 | 10.3 | 10.1 | 1900 | 80 | 2280 | 1:8 | 1:4 | 53 |
| 14. Askham Ln | 34.7 | 40.5 | 24.0 | 26.0 | 10.7 | 14.5 | 1700 | 75 | 2000 | 1:8 | 1:4 | 85 |
| 15. Chapelfields | 24.5 | 29.0 | 19.0 | 22.0 | 5.5 | 7.0 | 1750 | 75 | 2000 | 1:6 | 1:4 | 64 |
| 15. Chapelfields | 24.5 | 29.0 | 17.3 | 20.0 | 7.2 | 9.0 | 1750 | 75 | 2000 | 1:6 | 1:4 | 59 |
| 15. Chapelfields | 24.5 | 29.0 | 18.0 | 22.0 | 6.5 | 7.0 | 1750 | 75 | 2000 | 1:6 | 1:4 | 50 |
| 16. Cornlands Rd | 30.0 | 35.0 | 23.3 | 27.0 | 6.7 | 8.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 73 |
| 16. Cornlands Rd | 27.0 | 32.0 | 22.2 | 27.0 | 4.8 | 5.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 68 |
| 17. Danebury Dv | 34.1 | 40.0 | 21.5 | 26.0 | 12.6 | 14.0 | 1800 | 75 | 2000 | 1:8 | 1:4 | 77 |
| 17. Danebury Dv | 34.1 | 40.0 | 22.7 | 27.0 | 11.4 | 13.0 | 1800 | 75 | 2000 | 1:8 | 1:4 | 85 |
| 17. Danebury Dv | 34.1 | 40.0 | 22.0 | 27.0 | 12.1 | 13.0 | 1800 | 75 | 2000 | 1:8 | 1:4 | 75 |
| 17. Danebury Dv | 34.1 | 40.0 | 21.7 | 26.0 | 12.4 | 14.0 | 1800 | 75 | 2000 | 1:8 | 1:4 | 66 |
| 18. Gale Ln | 32.5 | 37.0 | 20.0 | 23.0 | 12.5 | 14.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 64 |
| 18. Gale Ln | 32.5 | 37.0 | 18.8 | 22.0 | 13.7 | 15.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 63 |
| 18. Gale Ln | 32.5 | 37.0 | 21.0 | 25.0 | 11.5 | 12.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 55 |
| 18. Gale Ln | 32.5 | 37.0 | 20.3 | 23.0 | 12.2 | 14.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 60 |
| 18. Gale Ln | 32.5 | 37.0 | 20.3 | 23.0 | 12.2 | 14.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 65 |
| 18. Gale Ln | 32.5 | 37.0 | 22.3 | 25.0 | 10.2 | 12.0 | 1700 | 75 | 2000 | 1:8 | 1:4 | 69 |
| 19. Foxwood (ph1) | 32.0 | - | 22.0 | - | 10.0 | - | 1650 | 75 | 2500 | 1:8 | 1:4 | 66 |
| 19. Foxwood Ln (ph2) | 29.5 | 33.2 | 26.5 | 32.3 | 3.0 | 0.9 | 1650 | 75 | 2500 | 1:8 | 1:4 | 92 |
| 19. Foxwood Ln (ph2) | 29.5 | 33.2 | 22.9 | 27.0 | 6.6 | 6.2 | 1650 | 75 | 2500 | 1:8 | 1:4 | 67 |
| 19. Foxwood Ln (ph2) | 29.5 | 33.2 | 21.1 | 23.5 | 8.4 | 9.7 | 1650 | 75 | 2500 | 1:8 | 1:4 | 69 |
| 19. Foxwood Ln (ph2) | 29.5 | 33.2 | 22.9 | 27.8 | 6.6 | 5.4 | 1650 | 75 | 2500 | 1:8 | 1:4 | 65 |
| 20. Kingsway West | - | - | 21.5 | 25.0 | - | - | 1750 | 75 | 2000 | 1:8 | 1:4 | 86 |
| 20. Kingsway West | - | - | 18.8 | 22.0 | - | - | 1800 | 75 | 2000 | 1:8 | 1:4 | 64 |
| 20. Kingsway West | - | - | 23.9 | 28.0 | - | - | 1700 | 75 | 2000 | 1:8 | 1:4 | 94 |
| 21. Mill Ln | - | - | 20.2 | 24.0 | - | - | 1650 | 75 | 2500 | 1:8 | 1:4 | 56 |
| 22. Muncaster | 28.6 | - | 18.2 | - | 10.4 | - | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 | 59 |
| 22. Muncaster | 29.7 | - | 20.8 | - | 8.9 | - | 1900 | 75 | 1950 | 1:8 | 1:4 | 81 |
| 22. Muncaster | 25.9 | - | 17.9 | - | 8.0 | - | 1700 | 60 | 1700 | 1:3.5 | 1:3.5 | 51 |
| 24. Tang Hall | 31.2 | - | 19.0 | - | 12.2 | - | 1800 | 75 | 2500 | 1:8 | 1:4 | 65 |
| 26. Bagnall Rd | 36.2 | 47.3 | 23.0 | 30.5 | 13.2 | 16.8 | 1600 | 75 | 1950 | 1:8 | 1:4 | 100 |
| 27. Brookside Av | 34.9 | 41.5 | 28.3 | 33.0 | 6.6 | 8.5 | 1600 | 75 | 4300 | 1:12 | 1:5 | 90 |
| 27. Brookside Av | 34.9 | 41.5 | 32.4 | 37.5 | 2.5 | 4.0 | 1600 | 75 | 4300 | 1:12 | 1:5 | 105 |
| 27. Brookside Av | 35.4 | 41.5 | 27.4 | 32.0 | 8.0 | 9.5 | 1600 | 75 | 4300 | 1:12 | 1:5 | 90 |
| 27. Brookside Av | 35.5 | 43.0 | 28.2 | 31.0 | 7.3 | 12.0 | 1600 | 75 | 4300 | 1:12 | 1:5 | 102 |
| 32. Grosvenor Rd | 26.0 | 31.0 | 18.0 | 21.0 | 8.0 | 10.0 | 1900 | 75 | 1950 | 1:8 | 1:4 | 57 |
| 33. Hollings Rd | 35.0 | 40.0 | 19.0 | 24.0 | 16.0 | 16.0 | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 | 64 |
| 33. Hollings Rd | 35.0 | 40.0 | 19.0 | 22.0 | 16.0 | 18.0 | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 | 58 |
| 34. New Cross St | 35.0 | 39.0 | 19.0 | 23.0 | 16.0 | 16.0 | 1880 | 80 | 1880 | 1:5.25 | 1:5.25 | 98 |
| Average | 31.3 | 36.5 | 21.7 | 25.7 | 9.6 | 10.7 | 1750[2] | 76 | 2440 | 1:8 | 1:4 | 71 |

[1]*Cushion dimensions as specified. Dimensions varied on site, some on/off ramps were steeper*
[2]*Average width of cushions for available data relating to mean speeds was 1720mm*

respectively) were 1 to 2 mph higher than those recorded by Webster and Layfield (1996) between 75mm high flat-top and round top humps with an average spacing of about 85m.

Multiple linear regression techniques were again used to develop relationships between the mean vehicle speed recorded mid-way between cushions and cushion spacing. For simplicity the data set was restricted to the majority of the cushions for which the height was 75mm, the on/off gradient 1:8 and the side gradient 1:4. Thus no attempt was made to include height or gradient as explanatory variables.

For *mean speed between cushions*, the variables cushion spacing and cushion width were statistically significant at the 1% and 5% levels respectively. The variables mean 'before' speed and cushion length were not significant at the 5% level when added to this model.

$V_{mn(bet)} = 26.89 + 0.096s - 0.0071w$

where $V_{mn(bet)}$ = mean speed midway between cushions (mph)

$s$ = longitudinal spacing between cushion layouts (m)

$w$ = cushion width (mm)

The number of observations was 29

The standard error of the coefficients:

se($s$) = 0.020, se($w$) = 0.0026

Figure 5 displays the relationship between vehicle speed between the cushions and cushion spacing for 75mm high cushions with on/off gradients of 1:8 and side gradients of 1:4. The data values have been normalised to take account of differences in cushion width. At a spacing of 60m metres, a mean speed of about 20.5 mph may be expected for cushions of average width (1720mm). Increasing the spacing from 60m to 100m, increases mean speed by about 4 mph.

For *85th percentile speed between cushions*, the variable cushion spacing was statistically significant at the 1% level. The variables 85th percentile 'before' speed, cushion length and cushion width were not significant at the 5% level when added to this model.

$V_{85(bet)} = 14.81 + 0.152s$

where $V_{85(bet)}$ = 85th percentile speed midway between cushions (mph)

$s$ = longitudinal spacing between cushion layouts (m)

The number of observations was 27

The standard error of the coefficient:

se($s$) = 0.030

Figure 5 shows that at a spacing of 60m metres, an 85th percentile speed of about 24 mph may be expected. Increasing the spacing from 60m to 100m, increases mean speed by about 6 mph.

#### *4.2.1 Speed difference — at and between cushions*

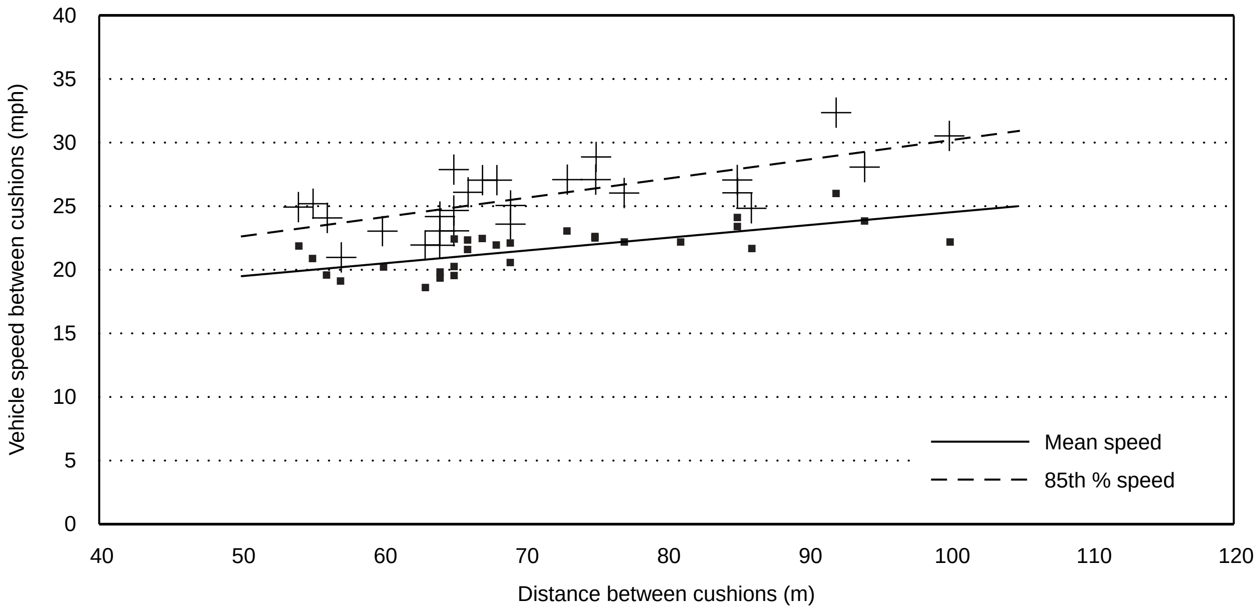
A longer spacing between cushions leads to higher speeds between the cushions and also to a greater 'speed difference'. Speed difference is defined here as the speed midway between cushions minus the speed at the cushions. A large speed difference will usually be undesirable as it may lead to increased exhaust emissions, increased noise nuisance and increased passenger discomfort, particularly if it is associated with rapid acceleration and deceleration.

For a given target 'after' speed (average of *at* and *between* speeds) of say 20 mph, a smaller speed difference can be achieved by using shorter spacing between cushions and narrower cushion widths. This is illustrated in Table 5.

**Table 5 Speed difference (at and between cushions)**

| | *Estimated 'after' mean speeds*[1] | |
|---|---|---|
| | *With 1800mm wide cushions paced at 100m (mph)* | *With 1600mm wide cushions spaced at 60m (mph)* |
| At cushions | 17 | 19 |
| Between cushions | 24 | 21 |
| Overall average | 20 | 20 |
| Speed difference | 7 | 2 |

*[1]For a 'before' speed of 30 mph, and cushions 75mm high, on/off gradient 1:8 and average length of 2455mm.*




Data set restricted to cushions 75mm high and with a 1:8 on/off gradient.
Mean speed between cushions also influenced by cushion width, see text in Section 4.2.

**Figure 5** Vehicle speed between cushions

# 5 Flows

'Before' and 'after' traffic flows were not available at many sites. Table 6 displays the change in vehicle flow recorded at cushion schemes where data were available. Vehicle flows decreased at all schemes in Table 6, with reductions in flow varying between 2 and 48 per cent. The overall average reduction in flow on roads with speed cushions was 24 per cent. This is similar to reductions in flow on roads with 75 mm high humps (flat-top 28 per cent and round-top 24 per cent), Webster and Layfield (1996).

**Table 6 Changes in traffic flow at cushion schemes**

| *Site No. Name* | *Sample period* | *Before flow* | *After flow* | *% change* |
|---|---|---|---|---|
| 3. Ivy Rd | 24h | 7219 | 5331 | -26% |
| 8. Windmill Rd | 24h | 4400 | 3200 | -27% |
| 11. Eyres Monsell,Pasley Rd | 24h | 3342 | 1748 | -48% |
| 6. Poplar Neigh'd (Abt. Rd.) | 1h flows[1] | 1435 | 1412 | - 2% |
| 6. Poplar Neigh'd (Can. St.) | 1h flows[1] | 317 | 263 | -17% |
| 6. Poplar Neigh'd (Blr. St.) | 1h flows[1] | 208 | 115 | -45% |
| 19. Foxwood Ln | 1h flows[2] | 398 | 331 | -17% |
| 22. Muncaster,Elmfield Av | 1h flows[2] | 151 | 131 | -13% |
| 22. Muncaster,Monkton Rd | 1h flows[2] | 126 | 111 | -12% |
| 22. Muncaster,Byland Rd | 1h flows[2] | 166 | 130 | -22% |
| 24. Tang Hall,Fourth Av | 1h flows[2] | 189 | 145 | -23% |
| 28. Lindsay Av | 1h flows[3] | 116 | 101 | -13% |
| 32. Grosvenor Rd | 11h (0730-1830) | 2585 | 1924 | -26% |
| 33. Hollings Rd | 11h (0730-1830) | 2768 | 2033 | -27% |
| 34. New Cross St | 11h (0730-1830) | 3779 | 2207 | -42% |

[1] *Average flow during periods 0800-0900 and 1700-1800*
[2] *Average flow during period 1400-1800.*
[3] *Average flow during periods 0800-1000 and 1600-1800.*

Details of 'before' to 'after' changes in vehicle flow were provided by the local authorities (without flow values) at a number of additional sites. The results for these sites are broadly in line with those given in Table 6. Flow readings taken on Peterborough Road (site 4) indicated little variation in flow between 'before' and 'after' monitoring periods. Flows on Hillsborough Road, Eyres Monsell (site 11) have fallen by about 20 per cent and flows on Chadderton Park Road (site 9) have fallen by about 30 per cent. On roads with calming measures in the Eastfields Estate (site 13), flows have fallen by 2 to 53 per cent (average 31 per cent reduction),

Vehicle flows on roads adjacent to a traffic calmed area may well increase if drivers try to avoid such areas. The effect of this extra traffic will be more pronounced if flows on the adjacent roads are relatively light before the traffic calming scheme is introduced. In the Eastfields Estate, vehicle flows on roads without traffic calming increased between 2 and 50 per cent (average 19 per cent).

# 6 Accidents

A comprehensive before and after accident survey has not been carried out for the cushion sites included within this study. However, changes in speed have previously been shown to be related to changes in accidents, with a 1 mph reduction in speed giving a 5 per cent reduction in accidents (Finch *et al*, 1994). This has been confirmed by TRL studies of traffic calmed roads and 20 mph zones (Webster and Mackie, 1996). The speed and flow changes at the speed cushion schemes in this study are very consistent with those from the study of 20 mph zones where injury accidents reduced by about 60 per cent. It is therefore likely that, on average, the present speed cushion schemes should reduce accidents by a similar figure.

# 7 Passenger discomfort

Bus passengers find the quality of ride is worse on traffic calmed streets and can experience difficulties when standing or moving along the bus as it negotiates a road hump. Such difficulties may be acute for elderly and infirm passengers. Considerable discomfort can also be caused for bus drivers, who may have to negotiate the humps several times each hour for several hours each day. Relatively speaking there tends to be a greater loss in ride quality for passengers in buses than for private car occupants (County Surveyors Society, 1994).

Speed cushions are designed to provide low levels of discomfort for passengers in large vehicles by minimising the vertical deflection if the vehicles straddle the cushions centrally (see Section 1.1). Passenger discomfort when crossing speed cushions was not measured as part of this study but the results available from a number of on and off-road trials are summarised in the following Sections.

### 7.1 Passenger discomfort in large buses

Measurements of passenger discomfort rating (self-reported) on a 7 point scale, varying between 'comfortable' and 'very uncomfortable', were made during the on-road speed cushion trials in York and Sheffield in 1993 at sites 19, 22, 24 and 28 (Layfield *et al*, 1994). Most of the bus routes at these sites were served by large single deck or double deck buses.

The results from these trials indicated that for passengers in large buses, which straddled the speed cushions centrally, the discomfort was low at a rating of 'comfortable' or 'slightly uncomfortable'. Bus passenger discomfort increased when the buses did not straddle the cushions and was similar to that measured when crossing 75mm high round-top and flat-top humps. Changes in cushion width did not appear to affect the discomfort rating for passengers in large buses.

For passengers in cars which straddled the cushions centrally, the discomfort was also low. Passengers gave a rating of 'comfortable' when crossing cushions with narrow (1000mm) platforms and 'slightly uncomfortable' when crossing cushions with wider (1300mm) platforms. Values of discomfort rating increased when the cars did not straddle the cushions centrally and were similar to that measured when crossing 75mm high flat-top and round top humps.

Although the values of discomfort for car passengers were generally found to be similar to those for bus passengers when both vehicles straddled the cushions centrally, differences in driver behaviour will increase the discomfort experienced by some car passengers. A high percentage of car drivers were observed to not straddle the cushions even when there were no parked cars blocking a central approach. Most buses straddled the cushions unless prevented from doing so by parked vehicles (see Section 8).

### 7.2 Passenger discomfort in smaller buses and ambulances

The cushion schemes in York were found to be suitable for large single and double deck buses but unsatisfactory with respect to the level of passenger discomfort experienced by passengers in smaller minibuses, which are characterised by a shorter wheelbase and a narrow rear wheel track.

A series of off-road speed cushion trials was carried out by York City Council at Elvington Airfield with the assistance of TRL in 1994 and 1995 in order to overcome this problem. The aim of the first two sets of trials was to identify cushion dimensions which might reduce passenger discomfort in vehicles such as minibuses and ambulances whilst maintaining discomfort (and hence speed reduction) for cars. The third set of trials aimed to determine the combination of cushion width and spacing between measures that was most acceptable to car drivers, but which also generated a significant speed reduction.

In the first two sets of trials, different vehicle types were driven over a range of cushion dimensions (cushion widths 1550m to 1700mm) at speeds between 15 mph and 30 mph. The results indicated that, as expected, passenger discomfort was higher in the minibus and ambulance than in the large single deck bus. The passenger discomfort in small cars was generally higher than in the minibus and ambulance while the passenger discomfort for large cars was generally lower.

All vehicle types except the large buses showed an increase in passenger discomfort with increasing cushion width. The passenger discomfort for the minibus and ambulance was slightly more sensitive to changes in cushion width than for cars. The first set of trials indicated that an increase in cushion length might reduce passenger discomfort, particularly for the minibus, but this was not confirmed in the second set of trials which found no consistent relationship between passenger discomfort and cushion length. Cushion height affected passenger discomfort at wider cushion widths.

In general, it was found that the variations in discomfort with cushion dimensions were consistent across the different vehicles tested. Reducing cushion width would improve the levels of discomfort in minibuses and ambulances but would be likely to lead to some increase in the speeds of cars.

In the third set of trials organised by York City Council, about 200 members of the public drove their own vehicles along a series of seven road layouts with different cushion dimensions and spacing on each layout. The road layouts were made as realistic as possible and the participants encompassed a broad cross section of the general public, including disabled drivers, and a wide variety of vehicles. Participants were invited to drive over the seven road layouts until they formed a view on the ‘acceptability’ of each layout. The scoring system went from 1 for ‘not at all acceptable’ to 7 for ‘totally acceptable’. No advice was given on driving speeds other than to imagine they were on an urban road. Speeds were measured at and between the cushions with radar guns (York City Council, 1995).

Table 7 gives details of the road layout, acceptability rating and 85th percentile speeds at and between the cushions. The 85th percentile speeds achieved in the trials were slightly lower than those achieved with similar cushions at similar spacings on the public roads.

**Table 7 Results from cushion trials organised by York City Council (June 1995)**

| *Road layout* | | | | *Acceptability rating (1 - 7)* | *85th percentile speeds* | |
|---|---|---|---|---|---|---|
| *Cushion dimensions** | | | | | | |
| *Width (mm)* | *Length (mm)* | *Height (mm)* | *Spacing (m)* | *(average score)* | *At cushion (mph)* | *Between cushion (mph)* |
| 1700 | 2000 | 75 | 60 | 2.44 | 20.6 | 22.8 |
| 1650 | 3500 | 65 | 60 | 3.01 | 21.6 | 23.9 |
| | | | 90 | 3.03 | 20.6 | 24.0 |
| | | | 120 | 3.24 | 24.7 | 27.0 |
| 1600 | 3500 | 65 | 60 | 4.23 | 22.7 | 24.4 |
| | | | 90 | 4.35 | 23.8 | 25.2 |
| | | | 120 | 4.65 | 26.9 | 29.5 |

**all cushions had an on/off ramp gradient of 1:8 and side ramp gradient of 1:4*

The results indicated that, over the range of cushion dimensions and spacings tested, the acceptability of speed cushions for car drivers was more strongly influenced by cushion width than cushion spacing.

At a cushion spacing of 60m, a decrease in cushion width of 100mm (1600mm to 1700mm) resulted in an increase of about 1.5 mph in 85th percentile speeds between the cushion and an increase of 1.8 in the acceptability rating. Increasing cushion spacing by 60m (60m to 120m) resulted in an increase of about 4 mph in 85th percentile speeds between the cushions and an increase of 0.3 in acceptability rating.

Following these trials, York City Council decided to standardise on cushions with dimensions 1600mm wide, 65mm high and 3500mm long at spacings of 60m to 90m, with closer spacing on residential roads than on mixed priority roads. Alterations to cushion dimensions and layouts were carried out at several of the existing sites (Askham Lane, site 14; Gale Lane, site 18; and Tang Hall, site 24) to reduce discomfort, especially for passengers in minibuses, ambulances and small cars.

## 8 Driver behaviour

Observations of driver behaviour have been made at several locations in the present study in order to highlight driving practices over speed cushions and to identify differences in behaviour at various cushion layouts. In general, for a given speed, the discomfort experienced when straddling the cushions is noticeably less than when not straddling (see Section 7).

In a study of on-road trials of speed cushions (Layfield *et al*, 1994), a total of approximately 5000 vehicle movements over several different cushion arrangements were recorded on video. Sites 19, 22, 24 and 28, Foxwood Lane, Muncaster, Tang Hall, and Lindsay Avenue respectively were included in this study. The main driving characteristic that was analyzed was the lateral location of the vehicle at the cushion layouts - in particular, whether drivers tended to straddle the cushions centrally (straddling) or preferred not to straddle the cushions by driving off-centre (not straddling), letting wheels on one side only ride up onto the cushions.

The results showed that, when the approach and exit from a cushion layout was unaffected by parking, about 55 per cent of cars and 90 per cent of buses were found to straddle the cushions centrally or approximately centrally. In general, cushions with narrower platform widths resulted in a higher percentage of cars straddling the cushions, whereas buses nearly always straddled cushions. There was no trend regarding the side on which cars overlapped a cushion when not straddling (ie. with one set of wheels off), except at the three-abreast cushion groups where drivers tended to take the path nearer to the centre of the road because of the proximity of the cushions to the kerb.

Parked vehicles can prevent cars from straddling the cushions centrally. The amount of parking varied between the schemes, with small numbers of parked vehicles on some roads, to almost solid parking along one side of a road in Muncaster. On Lindsay Avenue and Foxwood Lane, cushion layouts were combined with carriageway narrowings and the parked vehicles had less effect (Plates 4a and 5d). When vehicles were parked at one side of a pair of cushions, car drivers travelling in the lane affected by parked vehicles were forced to choose a central path (35 per cent) or cross to the offside of the road and drive over the off side cushion (65 per cent). Almost all the bus drivers crossed over and straddled the offside cushion (Plate 5a). When vehicles were parked on both sides of the road close to a pair of cushions, drivers had to take a central path. Most cars crossed the cushions with one wheel on, one wheel off. Buses crossed very slowly with wheels going over both cushions.

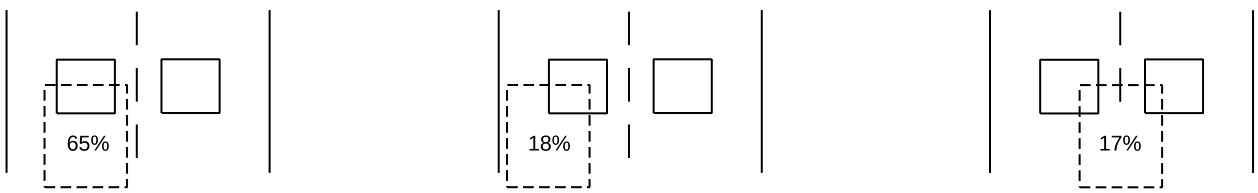
Most cyclists and motor cyclists avoided the cushions and used the gaps between the cushions and the kerb (Plate 7). When these were obstructed by parked vehicles, cyclists and motor cyclists generally moved to the centre of the road and avoided riding over the cushions.

At the single cushion layouts with single lane working there were no road markings or traffic signs giving priority to a specific direction. However, there appeared to be no conflicts over priority and traffic seemed to treat the layouts in a similar manner to an obstruction caused by closely parked vehicles. There were no incidents on the video tapes of any driver/rider behaviour resulting in sharp braking or swerving to avoid a collision at any of the cushion layouts examined.

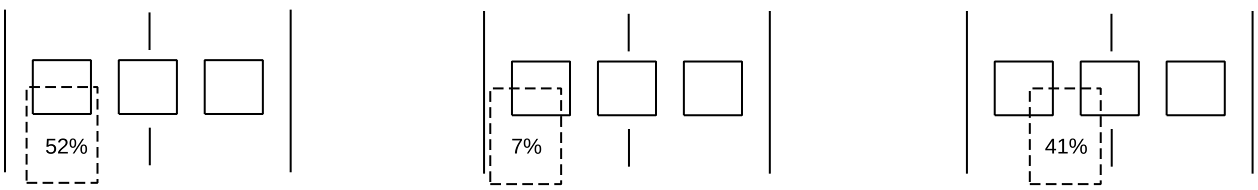
At Bagnall Road (site 26), driver behaviour of a sample of 100 vehicles at a cushion pair and at a three-abreast cushion arrangement was assessed by Nottinghamshire County Council. Figure 6 (a) and (b) display the methods of cushion negotiation for a paired cushion arrangement (1880mm wide cushions with a platform width of 1280mm and a central gap of 1000mm) and a three-abreast arrangement (1600mm wide cushions with a platform width of 1000mm and a central gap of 850mm).

It can be seen that almost half the drivers chose not to straddle cushions. In the paired arrangement 17 per cent of the drivers drove in the middle of the road between the cushions and in the three-abreast arrangement 41 percent of the drivers drove between the nearside and the middle cushions.

At cushion pair layouts with relatively wide central gaps between cushions, motorists have tended to drive through the gap rather than over the cushions. In general, this




(a) Paired arrangement of 1880mm wide cushions




(b) Three-abreast arrangement of 1600mm wide cushions

**Figure 6** Driver behaviour at site 26 (Bagnall Road) problem is likely to develop at sites with central gaps between cushions greater than 1200mm.

At Brookside Avenue (site 27), cushion pairs were initially installed with a central gap between cushions of 2100mm. This led to drivers avoiding travelling over the cushions by driving through the central gap, even though a ghost island was painted on the carriageway to indicate a ‘no go’ area. Complaints were received from residents expressing concern that the arrangement of the cushions encouraged dangerous driving.

The cushions in Brookside Avenue have since been widened from 1600mm to 1900mm thus reducing the central gap to 1500mm.

The layout of cushions on Billing Brook Road (site 25), has also been altered due to drivers taking advantage of wide central gaps between cushions (Plate 6). Central gaps of 1800mm to 2740mm were reduced to 500 to 1300mm by increasing the kerb gap at some cushion sites, and by adding an additional cushion in the centre of the road at several others, creating a three-abreast arrangement.

The analysis of driver behaviour at Bagnall Road (site 26), has shown that even with a relatively narrow central gap (1000mm), some drivers are likely to choose a central path. At site 10, Ringmore Road, with a central gap between cushions of 1000mm, two drivers were charged with driving without due care and attention after colliding as they attempted to drive centrally between cushions at the same time.

At Blomfield Road, site 5, an additional smaller cushion was placed within parking bays next to cushion pairs to deter motorists from using the parking bays to by-pass the cushion pairs.

# 9 Consultation and action on comments received

The local highway authorities were asked about reactions to the speed cushion schemes from the general public, the bus companies and the emergency services. The results of any attitude surveys were also noted.

Highway authorities should consult widely. The Highways Act 1980 requires the police to be consulted and the proposals advertised. The Highways (Road Humps) Regulations 1996 require the fire and ambulance services to be consulted, as well as organisations or groups representing people who use the road. This should certainly include bus operators, and residents. In certain instances it may also be appropriate to consult with the coastguard, haulage associations, and in rural areas, organisations representing the local farming community (Department of Transport, 1994b and 1996c).

In order to assess the success of speed cushion schemes in overcoming the objections of the emergency services and bus operators to road humps, extensive consultation was conducted with these organisations by the local highway authorities both before and after the installation of speed cushions schemes. In several areas, before the large scale introduction of these measures, speed cushions have been assessed by the emergency services and bus operators in either on or off-road trials conducted by local authorities.

Residents were consulted, often in the scheme design stage, and in several areas, residents views on the installation of speed cushions were gathered by questionnaire surveys both before and/or after traffic calming.

In general the reaction to speed cushions from both the emergency services and bus operators has been positive. Questionnaire surveys have indicated that residents are less supportive. There is some evidence to suggest that residents may see standard road humps as a preferable method of traffic calming.

## 9.1 Bus companies

The response from bus operators, where correspondence has been received concerning cushion schemes, has been very supportive of the use of speed cushions as traffic calming devices.

In particular Hertfordshire County Council report the local bus operator to be ‘extremely pleased’ with the measures installed at Windmill Road (site 8), where midibuses are in frequent use. A similar response was received by The Metropolitan Borough of Stockport for the cushions installed at Ringmore Road (site 10).

Correspondence between York City Council and the major bus operator in York has highlighted several important points, specifically that cushion layouts should be placed at a sufficient distance from junctions to allow buses room to align and straddle the measure. The bus operator also highlighted the problem of parking next to cushions forcing buses to straddle cushions on the opposite carriageway. Double-pair cushion layouts (see Section 3.1.2) were regarded as being much too severe.

At some sites in York (Askham Road, site 14, and Gale Lane, site 18), the 1700mm wide cushions were found to be suitable for large single and double deck buses but created problems of passenger discomfort for smaller minibuses. These cushions were modified following off-road trials (see Section 7.2).

In the Kingsway West area concerns were expressed with the number of measures proposed but it was accepted that the installation of speed cushions was preferable to the installation of standard road humps.

## 9.2 Emergency services

In general the reaction of the emergency services to the implementation of traffic calming schemes included within this report has also been positive. Speed cushions have generally been accepted as a favourable alternative to full width road humps. There has however been some degree of variation in responses to traffic calming, between the services and regional divisions within services. Specific points raised with the highway authorities concerned are examined below.

### *9.2.1 Ambulance service*

Comments received by The City of Bradford Metropolitan Council from The West Yorkshire Metropolitan Ambulance Service (WYMAS) indicate support for the use of speed cushions in Bradford. The 1900mm wide cushions installed on Grosvenor Road (site 32) were cited as presenting ‘no problems’ to present ambulance vehicles. The careful positioning of vehicles crossing cushions was highlighted to be of importance when crossing the measures, to minimise the effect of cushions. WYMAS state a preference for the 1900mm wide cushions with straight 1:8 on and off-ramps, as installed at Grosvenor Road (site 32). These have less severe on and off-ramps than the 1880mm wide cushions with rounded on, off and side ramps such as those installed in Bradford at Hollings Road (site 33), and New Cross Street (site 34).

Leicester City Council report that the Leicestershire Ambulance Service support the implementation of traffic calming, but prefer the installation of long flat top speed humps.

The North Yorkshire Ambulance Service support the implementation of measures by The City of York Council to reduce traffic accidents and have recommended expanding the use of speed cushions. Concerns, however, have been expressed about the installation of measures on the ‘secondary’ road network, on roads such as Askham Lane (site 14). The problem of vehicles parking next to cushion layouts preventing ambulances straddling cushions has been identified as an issue at Gale Lane (site 18). Cushions on Gale Lane were also felt to be slightly too wide (1700mm) to allow ambulances to straddle them, causing some patient discomfort. These cushions were modified following off-road trials (see Section 7.2).

#### *9.2.2 Fire service*

At Peterborough Road (site 4), the Fire Service is reported to have complained to The London Borough of Hammersmith and Fulham that the 2160mm wide cushions initially installed were too wide for their vehicles to straddle completely. The cushions on Peterborough Road have subsequently been reduced to 1700mm in width. Poplar Neighbourhood reported, however, that the London Fire and Civil Defence Authority (LFCDA) expressed support for 2130mm wide speed cushions in Poplar (site 6). LFCDA stated that speed cushions allowed them to meet attendance times.

The South Yorkshire Fire Service (SYFS) are reported to have stated a preference for single cushion layouts involving road narrowings where the effect of parked vehicles, preventing drivers straddling cushions, is eliminated or reduced. SYFS objected to the ‘eccentrically’ placed cushions in two cushion layouts installed at Lindsay Avenue (site 28), which require vehicles to manoeuvre between closely spaced cushions. The fire service were happy with the 1600mm width of the cushions installed.

The North Yorkshire Fire and Rescue Service (NYFRS) initially opposed the installation of traffic calming measures at Gale Lane (site 18), and Foxwood Lane (site 19), indicating that self enforced speed limit areas (those employing traffic calming measures) would prevent response vehicles from travelling at emergency speeds. An assessment of cushion schemes was carried out after the installation of cushions, in response to a questionnaire prepared by York City Council. It was the view of representatives of NYFRS that speed cushions of the type installed at Gale Lane would not impede the Fire Service in their response to emergency incidents. The main complaint was the problem of parking next to cushions, forcing vehicles to ride over the measures.

#### *9.2.3 Police force*

There were no objections to the installation of traffic calming measures in Bradford from the West Yorkshire Police. However, improvements in on-street lighting were suggested where obstructions to the carriageway were installed, specifically at New Cross Street (site 33), in order to aid the visibility of measures at night.

Leicester City Council report Leicestershire police to prefer the use of standard round top road humps for traffic calming.

North Yorkshire Police, through consultation with York City Council, have detailed a number of objections to the use of speed cushions in certain areas. The Police are opposed to the installation of traffic calming features involving vertical deflection such as cushions and humps on district distributor roads (*eg* site 14, Askham lane), since these measures hinder the response of Police Officers on important routes.

Concern was expressed by North Yorkshire Police that the Chapelfields (site 15) and Danebury Drive (site 17) 20 mph zones would not be self enforcing if speed cushions only are used. In both cases however, the average of *the mean speed at cushions* and *the mean of speeds between cushions*, has been reduced to less than 20 mph, demonstrating the ability of wider cushions (1750mm and 1800mm) to achieve speed reductions which comply with the requirements of a 20 mph zone.

The North Yorkshire Police have made several comments on the scheme installed at Gale Lane (site 18). It was felt that one third of the cushions should be removed as too many cushions had been installed along Gale Lane. Vehicles parking next to speed cushions were identified as hindering the straddling of cushions, encouraging drivers to cross the centre line in order to straddle the cushion in the opposing carriageway. It was also felt that cushions were not constructed to consistent dimensions, particularly in terms of height, resulting in very low vehicle speeds at certain locations, driver frustration and an increase in dangerous overtaking manoeuvres. York City Council reduced the height of any over-high cushions (over 75mm), and subsequently modified all the cushions at the site following off-road trials (see Section 7.2).

### 9.3 General public

Residents have commonly voiced support for the introduction of traffic calming measures. The level of support for cushion schemes after implementation, however, has been relatively low, with several major criticisms being levelled at cushions. Residents have generally indicated that they feel cushions to be a less effective method than road humps for reducing the speed of all vehicles.

Attitude surveys were carried out by the local highway authority *prior to the installation of traffic calming* *measures* in the Poplar Neighbourhood (site 6), and at Eastfields Estate (site 13). Residents opinions at Eastfields Estate have also been collected and forwarded by North Yorkshire County Council since the installation of speed cushions. The results of two surveys undertaken by Leicester City Council and York City Council, detailing residents attitudes to traffic calming *after the installation of schemes*, have been assessed in order to determine the response of residents to speed cushion schemes. 340 questionnaires were issued to residents in Eyres Monsell (site 11) by Leicester City Council; 41 per cent of the questionnaires were returned. The questionnaire survey conducted by York City Council included 750 face-to-face interviews with residents of areas both with and without traffic calming.

Attitude surveys conducted before the installation of schemes showed a high level of support for traffic calming measures. Eighty-two per cent of respondents in the Eastfields Estate (site 13) and 78 to 97 percent of respondents (depending on area of survey) in Poplar Neighbourhood (site 6) supported the introduction of traffic calming measures. In York, 76 per cent of those questioned agreed with the view that it was ‘very important that the City Council looked at ways to improve road safety in York’.

After the installation of speed cushions at Eyres Monsell (site 11), 46 per cent of respondents felt that the cushion scheme had been successful, with 43 per cent considering the scheme to be unsuccessful. Opinions in York were also split; 30 per cent of respondents living in traffic calmed areas were satisfied with traffic calming in their neighbourhood and 25 per cent dissatisfied. For respondents living on traffic calmed streets, however, satisfaction with traffic calming rose to 49 per cent.

Respondents in York were more critical of the different aspects of the cushions than of speed tables or speed humps. Speed cushions were also felt to be less effective at reducing vehicle speeds than road humps by residents in Eyres Monsell. Fifty-six per cent of respondents in Eyres Monsell felt road humps to be more effective than speed cushions, with 35 per cent considering their effect to be the same.

Cushions were specifically criticised by residents in Eyres Monsell and Eastfields Estate for not slowing motorcycles, lorries and buses and increasing the risk of vehicle damage. Similarly, in York, 53 per cent of car owners questioned felt cushions may cause unacceptable damage to cars. Letters of complaint received by North Yorkshire County Council concerning the Eastfields Estate scheme have also cited the problems of motorists deliberately driving down the centre of the road and parking on speed cushions to reduce the acceptability of the scheme.

Cushions also received criticisms associated with kerb-to-kerb road humps: for increasing noise and vibration levels; diverting vehicle flows to uncalmed routes; inducing high levels of discomfort for elderly passengers in cars or buses; and for being too high and too closely spaced.

The dimensions of cushions on several roads in York (Askham Lane, site 14; Gale Lane, site 18; and Tang Hall, site 24) were modified following off-road ‘public acceptability’ trials (see Section 7.2) to determine suitable cushion dimensions that would reduce discomfort for passengers in minibuses, ambulances and small cars and also eliminate any grounding problems. Opinion surveys of residents carried out in the areas affected found that about 60 per cent of respondents thought that the modified cushions were acceptable.

## 10 Noise and vibration

Concern has been expressed that speed control measures which involve vertical deflection may have an adverse effect on noise and vibration levels generated by commercial vehicles. In particular, problems may exist with vehicle body noise (*eg* body rattles, suspension noise etc) and traffic induced vibration from large vehicles passing over road humps. In several areas, residents have complained about increased noise and vibration levels after the implementation of cushion schemes.

Noise and vibration surveys at speed cushion schemes were not undertaken as part of this study. However, the results of other studies (including some at sites included within this study) are available and are summarised in Sections 10.1 and 10.2.

### 10.1 Vehicle and traffic noise

TRL has studied noise levels alongside speed control cushions at sites in York (Abbott *et al*, 1995a). The general finding of this study was that for light vehicles, maximum noise levels were directly related to speed, with lower speeds resulting in lower noise levels. There was insufficient data to carry out an analysis of the maximum noise levels of heavy vehicles at cushions, but there was an indication that the maximum noise levels of buses at the cushions were higher than between the cushions, even after adjustment for differences in speed. Overall traffic noise was substantially reduced by the installation of the cushions, both *at* and *between* cushions. At Gale Lane (site 18), day-time traffic noise levels were reduced by 4 dB(A). An overall decrease in traffic noise of this order should produce a substantial reduction in disturbance to residents caused by road traffic noise.

Following the noise measurements in York, research was undertaken on the TRL test track to measure maximum noise levels from a range of heavy vehicles passing over a selection of road humps and cushions (Abbott et al, 1995b). This study found that, compared to a level road profile, there were only small increases in maximum vehicle noise for buses crossing speed cushions. However, there were substantial increases in the maximum noise levels for large commercial vehicles crossing wide (>1700mm) cushions. The results indicated that as the proportion of commercial vehicles in the traffic stream increases, the reduction in traffic noise following installation deteriorates dramatically. Installation of wide cushions is likely to result in an increase in traffic noise of about 7dB(A) when the proportion of commercial vehicles in the traffic stream is about 10 per cent. Narrow (<1700mm) cushions have a much smaller effect on the maximum noise levels of commercial vehicles, provided the vehicles straddle the cushion centrally.

The results from these two studies have been included in Traffic Advisory Leaflet 6/96 (Department of Transport, 1996d).

Additional track trials have confirmed that noise levels generated by heavy commercial vehicles crossing road humps or cushions are dependent on vehicle loading, the type of suspension system, the hump or cushion profile and whether the vehicles straddle the cushions. In order to reduce noise nuisance, it is important, when designing cushion schemes, to ensure that the incidence of commercial vehicles not straddling the cushions is minimised.

The use of narrow (1500mm) cushions as traffic calming measures at villages on major roads has been investigated in a study of a scheme on the A49 trunk road at Craven Arms (Wheeler *et al,* 1996; Department of Transport, 1997). It was found that the reductions in speed at the traffic calming measures resulted in reductions in maximum vehicle noise levels for both light and heavy vehicles. Daytime traffic noise levels adjacent to the cushions fell by 3 dB(A) but nighttime traffic noise levels remained unchanged. However there was a discrepancy between the changes in measured noise levels and the perception of residents, interviewed in a public opinion survey, who believed that noise levels had increased. This may be due to the fact that whilst noise has been reduced, the character of the sound may have altered, causing residents to be more sensitive to it. Further investigations are being made into these issues.

### 10.2 Ground borne vibration

Traffic generated ground-borne vibrations are affected by the type and magnitude of any discontinuity in the road profile (eg a poorly maintained surface or a specific vertical deflection used as a traffic calming measure), the vehicle loading, the vehicle speed, the vehicle suspension, the distance from the vibration source and the soil type. Ground-borne vibration diminishes as it radiates from the source. The firmer the soil in the vicinity, the more localised will be the vibration effects.

At Ringmore Road (site 10), The Metropolitan Borough of Stockport commissioned a report looking at vibration levels generated by vehicles passing over cushions at one property in response to complaints from the resident. The report's findings were inconclusive. However, the 1900mm wide cushions were regarded as being too severe in terms of discomfort and were replaced with 75mm high flat-top humps with shallow (1:15) ramp gradients.

Track trials have been carried out at TRL to assess the effect which road humps and speed cushions might have in generating ground-borne vibrations when commercial vehicles are driven over them. Measurements of vibrations were made for a wide range of vehicle types crossing a selection of road humps and speed cushions at a range of speeds. The results were used to estimate the likely general levels of vibration exposure from vehicles crossing the different hump and cushion profiles (Watts et al, 1997).

Based on typical crossing speeds, the wide (1900mm) cushions generally gave higher vibration levels than the narrower (1500 - 1600mm) cushions. Vibration levels increased when vehicles did not straddle the narrow cushions and care should be taken that cushions are placed so that they are likely to be straddled by the axles of commercial vehicles.

The results from this study have been included in Traffic Advisory Leaflet 8/96, (Department of Transport, 1996e) and used to provide an initial guide to the predicted minimum distances from dwellings to avoid vibration exposure. This is of particular relevance in trying to avoid locating road humps and cushions near dwellings where, because of the soil type, complaints might arise.

Ground-borne vibrations were measured as part of the investigation into the use of narrow (1500mm) cushions as traffic calming measures on the A49 trunk road at Craven Arms (Wheeler *et al*, 1996; Department of Transport, 1997). Measurements of ground-borne vibration induced by passing traffic were taken at a dwelling 8m from a pair of speed cushions; an example of a 'worst case' location at the scheme. 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, even after the scheme was introduced, the ground-borne vibration exposure at the site was considered to be generally very low with peak levels below the level at which complaints would be expected. Vibrations generated by normal use of the building and from non traffic sources were of the same order as those produced by the worst case conditions when a heavy vehicle clipped a cushion. A public opinion survey revealed that residents felt that vibrations from lorries were noticeable in the home. However, this may have been more the result of airborne vibration (due to low frequency noise from vehicle engines and exhausts) rather than ground-borne vibration.

## 11 Summary and conclusions

Thirty-four traffic calming schemes involving the use of speed cushions have been studied to establish their effectiveness at reducing speeds and to examine their influence on traffic flows, accidents, driver behaviour and passenger discomfort.

The speed cushion schemes in the study were located on residential and distributor roads, within urban and suburban areas in England, and were introduced for both vehicle speed and accident reduction purposes. Most of the speed cushions schemes were installed on roads with 30 mph speed limits, but, at four of the sites, speed cushions were installed as part of 20 mph zones.

Different types of material were used in the construction of cushions included in this study. Cushions were constructed from asphalt, sections of moulded rubber, block paving including kerbing and concrete. The construction costs and maintenance required varied with the materials used. The asphalt cushions were relatively cheap to install and required little maintenance but presented problems in terms of construction to exact and reproducible cushion dimensions.

## 11.1 Layout and dimensions

Three main types of cushion arrangement have been installed at the sites studied: a series of single cushion layouts combined with carriageway narrowings (these only allow one-way working and are more suitable for lower flow roads); groups of cushions in pairs (these allow two way working, are suitable on higher flow roads, and can be combined with carriageway narrowings or islands); and groups of cushions three-abreast (these also allow two way working and are suitable on wider roads without requiring the construction of carriageway narrowings).

The installation of buildouts and islands in association with cushions can aid the effectiveness of the measures and solve problems presented by parked vehicles which may prevent drivers from straddling the cushions centrally. Three-abreast layouts can also be used on heavily parked roads as they allow vehicles overtaking parked cars to straddle the middle cushions. Where parking occurs over both nearside cushions, the middle cushion can act like a single one-way working cushion layout.

Concerns have been expressed that pedestrians might inadvertently trip over speed cushions resulting in a fall and injury. The possibility of this occurring can be reduced by using speed cushions that have a contrasting colour to the road surface and by avoiding the positioning of cushions at locations where it is likely that many pedestrians will wish to cross the road. Care should be taken when using double-pair cushion layouts at the exit and entry sides to an uncontrolled crossing place. Such layouts may not be appropriate if it is thought likely that a substantial number of pedestrians will cross outside the area between the dropped kerbs.

At all cushion schemes a minimum gap of 750mm should be allowed between the cushion and kerb for cyclists. In paired cushion layouts, without islands, central gaps between the cushions of between 750mm and 1200mm are recommended. Wide central gaps (greater than 1200mm) between cushions were found to encourage drivers to drive centrally between the cushions.

The size of speed cushions affects passenger discomfort and hence vehicle speed. Within the 34 schemes studied, there were over 30 different combinations of speed cushion dimensions. The dimensions of the cushions generally ranged from 1500 to 2100mm in width, 1700 to 4750mm in length and 60mm to 100mm in height. The gradient of on and off-ramps of cushions varied from 1:3.5 to 1:12, side ramp gradients varied between 1:3.5 to 1:5.25.

Recommended cushion dimensions based on off-road trials and operational experience on the public roads are: side ramp gradients not steeper than 1:4; on/off gradients not steeper than 1:8, and with a curved on/off ramp, the average gradient not steeper than 1:5; maximum height of 75mm and a lower height of 65mm for narrow cushions; and maximum width of 2000mm and a width of 1600mm - 1700mm for bus routes.

Grounding may be a problem, particularly at narrow cushions, if the cushions are over 80mm high or less than 2000mm long. The results from off-road speed cushion trials indicate that most cars with correctly fitted exhausts would not ground on 80mm high, 1600mm wide cushions, even when loaded with four persons. However, some low sports cars were found to ground on cushions 75mm high but cleared cushions 65mm high.

Speed cushions were removed or altered at some of the sites. At one site, the cushions were regarded as too severe and replaced with flat-top humps with shallow gradients. Cushion width was reduced a number of other sites to reduce discomfort for passengers in ambulances and minibuses. Cushion width was increased at one site to reduce the central gap between cushions. At two sites, cushion height was reduced due to grounding problems.

## 11.2 Traffic speeds

It is likely that the general situation, type of road, presence of parked vehicles and even geographical location will have an effect on the ‘before’ and also the ‘after’ speeds. The following results give a guide to expected average ‘after’ speeds but, because of differences in sites and measurement methods within the present data set, a good deal of variability is likely.

Speed cushions are effective as a speed reducing measure but not quite as effective as road humps. The overall average mean and 85th percentile speeds *at* the cushions (17 and 22 mph respectively) were 2 to 7 mph higher than those measured *at* 75mm high flat-top humps and round-top humps.

The relationships between speed *at* the cushions, cushion dimensions, and ‘before’ speed were investigated, for mean and 85th percentile speeds, using multiple linear regression analysis. The variables cushion width, cushion length, on/off gradient and ‘before’ speed were statistically significant, with decreasing width, increasing length, shallower gradients and higher before speeds resulting in higher speeds *at* the cushions. The variables cushion length and on/off gradient were correlated with each other, with longer cushion lengths associated with shallower on/off gradients and thus their relative effects on vehicle speed cannot be precisely determined with this data set.

Predictive relationships are provided between mean and 85th percentile speeds *at* the cushions and the variables cushion width, cushion length and ‘before’ speed.

Narrow (1600mm) cushions may not provide sufficient speed reduction in 20 mph zones without additional measures. Mean speeds *at* 1600mm wide cushions are likely be about 19.5 mph, while 1900mm cushions would give mean speeds of about 15.5 mph.

Larger vehicles such as buses and heavy goods vehicles are likely to be slowed down to a lesser extent than cars, particularly at the narrower cushions. Motor-cyclists can avoid the cushions and the cushions may have little, if any, effect on their speeds. However, in high flow periods, a reduction in the speed of cars and large vehicles may also have a speed reducing effect on motor-cyclists.

Spacing between the cushions varied between 50 and 105m with an average of about 71m. The overall average mean and 85th percentile speeds midway *between* the cushions were reduced by 10 mph (to 22 and 26 mph respectively) and were 1 to 2 mph higher than those measured between 75mm high humps spaced on average at about 85m.

The relationships between speed midway *between* the cushions, cushion dimensions, cushion spacing, and 'before speed' were also investigated, for mean and 85th percentile speeds. For simplicity the data set was restricted to the majority of the cushions for which the height was 75mm, the on/off gradient 1:8 and the side gradient 1:4. Thus no attempt was made to include height or gradient as explanatory variables.

Predictive relationships are provided between mean and 85th percentile speeds *between* the cushions and the variables cushion width, and cushion spacing.

At a spacing of 60m, a mean speed of about 20.5 mph may be expected. Increasing the spacing from 60m to 100m, increases mean speed by about 4 mph.

A longer spacing between cushions leads to higher speeds between the cushions and also to a greater 'speed difference'. Speed difference is defined here as the speed midway between cushions minus the speed at the cushions. A large speed difference will usually be undesirable as it may lead to increased exhaust emissions, increased noise nuisance and increased passenger discomfort, particularly if it is associated with rapid acceleration and deceleration.

### 11.3 Traffic flows

Vehicle flows decreased on roads with speed cushions, with reductions in flow varying between 2 to 48 per cent. The overall average reduction in flow was 24 per cent, a reduction in flow similar to the overall average reduction found on roads with 75mm high humps.

### 11.4 Accidents

A comprehensive before and after accident survey has not been carried out for the cushion sites included within this study but it is estimated from other studies that the reduction in speeds and flows is likely to produce injury accident savings of about 60 per cent.

### 11.5 Passenger discomfort

Speed cushions are designed to cause less interference than humps to large vehicles, such as buses and emergency vehicles, but still slow down small vehicles, such as cars.

On-road trials have found that passenger discomfort in large buses is likely to be low at speed cushion schemes, providing the buses straddle the cushion centrally. Bus passenger discomfort increased when the buses did not straddle the cushions and was similar to that measured when crossing 75mm high round-top and flat-top humps. Variation in cushion width did not appear to affect the discomfort rating for passengers in large buses.

Some cushion schemes have been found to be suitable for large single and double deck buses but unsatisfactory with respect to the level of passenger discomfort experienced by passengers in smaller minibuses and ambulances. The results of off-road trials in York indicated that the variations in discomfort with cushion dimensions were consistent across the different vehicles tested. Reducing cushion width to 1600mm would improve the levels of discomfort in minibuses and ambulances but would be likely to lead to some increase in the speeds of cars. The off-road trial results also indicated that, for car drivers, cushion width had a much stronger influence on acceptability than cushion spacing.

### 11.6 Driver behaviour

Video observations of driver behaviour at some of the sites indicated that when the approach and exit from a cushion layout was unaffected by parking, about 55 per cent of cars and 90 per cent of buses were found to straddle the cushions centrally or approximately centrally.

In the paired cushion layouts, nearly 20 per cent of the drivers drove in the middle of the road between the cushions. In the three-abreast layouts about 40 per cent of the drivers drove between the nearside and the middle cushions. At some cushion layouts with relatively wide central gaps between cushions, motorists have tended to drive through the gap rather than over the cushions, resulting in complaints and collisions. Gap sizes have subsequently been reduced. In general, this problem is likely to develop at sites with central gaps between cushions greater than 1200mm.

Parked vehicles can prevent cars from straddling the cushions centrally and will therefore increase the discomfort for drivers and passengers. When cushion layouts were combined with carriageway narrowings, the parked vehicles had less effect on vehicles approaching the cushions.

Most cyclists and motor cyclists avoided the cushions and used the gaps between the cushions and the kerb. When these were obstructed by parked vehicles, cyclists and motor cyclists generally moved to the centre of the road and avoided riding over the cushions.

### 11.7 Consultation action taken

**Bus operators:** The response from the bus operators has been very supportive of the use of speed cushions as traffic calming devices. Specific comments on design and layout received from bus operators related to: the placement of cushions at a sufficient distance from junctions to allow turning buses room to align and straddle the cushions; and the problem of parked vehicles next to cushions forcing buses to straddle cushions on the opposite carriageway. Narrower cushions were encouraged for use in areas served by midibuses and double cushion pair arrangements were highlighted as being much too severe.

**Ambulance services:** Responses from ambulance services varied. While some services indicated support for the use of speed cushions, others preferred humps to cushions. Specific comments on design and layout related to: vehicles parked near cushions preventing ambulances straddling, cushion width; and a preference for cushions with straight 1:8 on/off ramp gradients, rather than steeper 1:5 on/off gradients with rounded profile ramps. Concern was also expressed about the use of cushions on the 'secondary' road network.

**Fire services:** The fire services consulted have generally supported the implementation of speed cushion schemes with some services commenting that speed cushions allowed them to meet attendance times. Specific comments on design and layout included: a preference for the use of buildouts and pinch points to reduce or eliminate parking problems at cushions; an objection to cushion layouts which require lateral movement of vehicles between sets of closely spaced cushions; and a preference for narrower cushion widths of 1600mm to 1700mm.

**Police forces:** The responses from the police forces also varied, with some police forces supporting the use of speed cushions and others advocating the use of humps. Specific comments related to: vehicles parked near cushions hindering the straddling of cushions; overheight cushions producing low speeds and driver frustration; improvements needed in on-street lighting to aid visibility at traffic calming measures; and objections to the use of humps or cushions on district distributor roads.

**Residents:** The support from residents for traffic calming was generally high before the installation of schemes. Support for speed cushion schemes after implementation appears to be lower with 30 to 50 per cent of respondents being satisfied with the cushion schemes.

Residents have highlighted several main problems with speed cushion schemes relating to the high speed of motorcycles and large vehicles such as lorries and buses; damage to vehicles travelling over the cushions; parked vehicles preventing drivers straddling cushions; and drivers travelling in the centre of the road between cushions. In general residents questioned have felt that cushions are not as effective as road humps.

Cushions have received a number of criticisms which may also be associated with road humps. Residents have complained about higher levels of traffic noise and vibration; diversion of traffic onto other roads; and passenger discomfort due to the height and spacing of the cushions.

The dimensions of cushions on several roads in York were modified following off-road ‘public acceptability’ trials to determine suitable cushion dimensions that would reduce discomfort for passengers in minibuses, ambulances and small cars and also eliminate any grounding problems. Opinion surveys carried out in the areas affected found that about 60 per cent of respondents thought that the modified cushions were acceptable.

### 11.8 Noise and ground borne vibration

For light vehicles, maximum noise levels at cushions were directly related to speed, with lower speeds at cushion sites resulting in lower noise levels. However, the results from track trials indicate that, as the proportion of commercial vehicles in the traffic stream increases, the reduction in traffic noise, following the installation of wide cushions, deteriorates dramatically. Narrow (<1700mm) cushions have a much smaller effect on the maximum noise levels of commercial vehicles provided the vehicles straddle the cushion centrally.

Based on typical crossing speeds, wide (1900mm) cushions generally gave higher ground-borne vibration levels in track trials than narrower (<1700mm) cushions. Vibration levels increased when heavy commercial vehicles did not straddle the narrow cushions and care should be taken that cushions are placed so that they are likely to be straddled by the axles of commercial vehicles.

An on-road study of narrow (1500mm) cushions at a village traffic calming scheme on a trunk road has found a discrepancy between the reduction in measured noise levels and the perception of residents who indicated that noise levels had increased. This may be due to the fact that whilst noise has been reduced, the character of the sound may have altered, causing residents to be more sensitive to it. Further investigations are being made into these issues. Ground-borne vibrations were also measured at this site. After the scheme was introduced, there was an increase in the peak levels of ground-borne vibration in a building near a speed cushion. However, the ground-borne vibration exposure was considered to be generally very low; vibrations generated by normal use of the building and from non-traffic sources were of the same order as those produced by the worst case conditions when a heavy vehicle clipped a cushion.

## 12 Acknowledgements

The authors would like to thank all the staff in the local authorities who supplied information about their schemes. The authors would also like to thank Mike Durkin and Tim Pheby, York City Council, for the useful TRL/YCC collaboration in the off-road cushion trials organised by York City Council in 1994 and 1995; and David Webster, TRL, for his assistance in collecting and collating the local authority data.

## 13 References

**Abbott P G, Phillips S M and Layfield R E (1995a)**. *Vehicle and traffic noise surveys alongside speed control cushions in York*. TRL Project Report 103, Transport Research Laboratory, Crowthorne.

**Abbott P G, Tyler J and Layfield R E (1995b)**. *Traffic calming: vehicle noise emissions alongside speed control cushions and road humps*. TRL Report 180, Transport Research Laboratory, Crowthorne.

**County Surveyors Society (1994)**. *Traffic calming in practice*. County Surveyor’s Society, Landor Publishing Ltd. London.

**Davies D G, Ryley T J, Taylor S B and Halliday M E (1997)**. *Cyclists at road narrowings*. TRL Report 241 Transport Research Laboratory, Crowthorne.

**Department of Transport (1990)**. *Speed control humps*. The Department of Transport, Traffic Advisory Leaflet 2/90, Traffic Advisory Unit, London.

**Department of Transport (1994a)**. *Speed cushions*. The Department of Transport, Traffic Advisory Leaflet 4/94, Traffic Advisory Unit, London.

**Department of Transport (1994b)**. *Emergency services and traffic calming: a code of practice*. The Department of Transport, Traffic Advisory Leaflet 3/94, Traffic Advisory Unit, London.

**Department of Transport (1996a)**. *Road Accidents Great Britain: 1995 The Casualty Report*. The Department of Transport, HMSO, London.

**Department of Transport (1996b)**. *75mm high road humps*. The Department of Transport, Traffic Advisory Leaflet 2/96, Traffic Advisory Unit, London.

**Department of Transport(1996c)**. *Highways (Road Humps) Regulations 1996*. The Department of Transport, Traffic Advisory Leaflet 7/96, Traffic Advisory Unit, London.

**Department of Transport (1996d)**. *Traffic calming: traffic and vehicle noise*. The Department of Transport, Traffic Advisory Leaflet 6/96, Traffic Advisory Unit, London.

**Department of Transport (1996e)**. *Road humps and ground-borne vibrations*. The Department of Transport, Traffic Advisory Leaflet 8/96, Traffic Advisory Unit, London.

**Department of Transport (1997)**. *Traffic calming on major roads: A49, Craven arms, Shropshire*. The Department of Transport, Traffic Advisory Leaflet 2/97, Traffic Advisory Unit, London.

**Finch D J, Kompfner P, Lockwood C R and Maycock G (1994)**. *Speed, speed limits and accidents*. TRL Project Report 58, Transport Research Laboratory, Crowthorne.

**Hodge A R (1993)**. *Speed control humps - A trial at TRL*. TRL Project Report 32, Transport Research Laboratory, Crowthorne.

**Layfield R E, Hodge A R and Parry D I (1994)**. *On-road trials of speed cushions in Sheffield and York*. Project Report PR/TT/030/94, Transport Research Laboratory, Crowthorne (*Unpublished report available on direct personal application only*).

**Pharaoh T (1992)** *Case Study: Herne, Germany*. Urban Transport International, p26, March/April 1992.

**Pheby T and Durkin M (1992)** *Speed cushion trials*. Directorate of Development Services, York City Council, York.

**Strathclyde Regional Council (1993),** *Road Hump Trials*. A joint report by Strathclyde Roads and Strathclyde Passenger Transport Executive, Strathclyde Regional Council, Glasgow.

**Watts G R, Harris G J and Layfield R E (1997)**. *Traffic calming: vehicle generated ground-borne vibration alongside speed control cushions and road humps*. TRL Report 235, Transport Research Laboratory, Crowthorne.

**Webster D C (1993a)**. *Road humps for controlling vehicle speeds*. TRL Project Report 18, Transport and Road Research Laboratory, Crowthorne.

**Webster D C (1993b)**. *The grounding of vehicles on road humps*. Traffic Engineering and Control, Vol. 34 No.7/8 July/August, pp369-371.

**Webster D C and Layfield R E (1996)**. *Traffic calming — Road hump schemes using 75mm high humps*. TRL Report 186, Transport Research Laboratory, Crowthorne.

**Webster D C and Mackie A M (1996)**. *Review of traffic calming schemes in 20 mph zones*. TRL Report 215, Transport Research Laboratory, Crowthorne.

**Wheeler A H, Abbott P G, Godfrey N S, Lawrence D J and Phillips S M (1996)**. *Traffic calming on major roads: the A49 trunk road at Craven Arms, Shropshire*. TRL Report 212, Transport Research Laboratory, Crowthorne.

**York City Council (1995)**. *Traffic calming review — speed cushion trials and proposed on road changes*. Traffic and Transportation (Management) Sub-committee Report September 1995, York City Council, York.

## Appendix A: Cushion schemes site descriptions

**Bedfordshire**
**1. Coventry Road, Queens Park, Bedford.**

**Location:** Queens Park is a 30 mph speed limit, residential area of terraced and detached housing. A traffic calmed area covering 500 by 200m was installed in April 1994. The Queens Park Area has a high accident rate, with 48 injury accidents between 1989 and 1992, 29 of which involved pedestrians or cyclists.

**Layout:** The Queens Park road safety project has a total of 32 groups of three-abreast cushions, 7 raised junctions, with spacings of between 25 to 60m. Coventry Road has 5 sets of three-abreast cushions with a road width of 7.2m, each cushion group consisting of two 1600mm base width cushions and one central 1900mm base width cushion. Coventry Road is generally double parked with vehicles commonly straddling the central (1900mm) cushion.

**Construction:** Asphalt infill of moulded rubber ramps.

**Results:** The 85% speed of vehicles on Coventry Road has fallen 7.3 mph from 27.1 to 19.8 mph at the cushions, and 2.3 mph to 24.8 mph between the cushions, at a spacing of 54 metres.

**Comments:** The road is a midibus route.

**Buckinghamshire**
**2. Chairborough Road, High Wycombe.**

**Location:** Chairborough Road is a 30 mph limit residential road with calming over a length of over 1000m installed in March 1994. Off street parking is available to most residents however the road is still heavily parked. The road is used as a ‘rat run’ experiencing tidal flows of traffic. In the three year period from January 1989 to January 1992, 11 injury accidents were reported, one being a fatality.

**Layout:** The scheme was installed in two phases, the first phase was the installation of traffic islands on the 7.4m carriageway, and the marking of parking areas. The second phase involved the installation of 1380mm wide, 80mm high speed cushions either side of the islands. Cushions installed on the southbound carriageway were 1380mm long, and on the northbound carriageway 1880mm long.

**Construction:** Moulded rubber sections with rounded profile.

**Results:** Before 85% speeds of 42 mph fell to 33 mph after the installation of traffic islands as a chicane effect was produced with the parking areas. After the installation of cushions 85% speeds further fell to 31 mph in both directions.

**Comments:** The installation of the scheme was reported to be widely supported by both the emergency services and local bus operators by Buckinghamshire County Council. Removed in August 1996 due to vandalism.

**Cheshire**
**3. Ivy Road, Macclesfield. Borough of Macclesfield.**

**Location:** Ivy Road is a 30 mph speed limit residential distributer with various types of housing and a Primary School along its 800m length.

**Layout:** Three cushion arrangements were installed on Ivy Road, these being 4 cushion pairs (road width 6.6m), 2 cushion pairs with a buildout and cycle bypass (road width 7.3m), and 6 three-abreast cushion groups (road width 8.7m). All cushions were 1700mm wide, 2320mm long and 80mm high. Spacing between cushion groups ranged between 38 to 100m.

**Construction:** Asphalt infilled kerbing with asphalt ramps.

**Results:** Before 85% speeds on Ivy Road of 35.7 mph have fallen to 30.3 mph between cushion groups. Average 24h traffic flows dropped by 26% on Ivy Road from 7219 to 5331 vehicles per day.

**Comments:** The installation of the scheme was supported by the emergency services who were consulted before the scheme was constructed. The road is a route for midi type buses.

**Greater London**

**4. Peterborough Road, Hammersmith. London Borough of Hammersmith and Fulham.**

**Location:** Peterborough Road is primarily a residential road, with a Collage, recreation ground and children's playground joining onto the road. The road has a 30 mph speed limit and forms part of the Borough's Cycle route. The scheme covers 900m and was installed in April 1994.

**Layout:** Twelve single cushion groups placed within buildouts were installed on Peterborough Road. The road width is approximately 8.0m, with a 1700mm wide, 3400mm long and 75mm high cushion being installed between two 1920mm buildouts. Cushion spacings range between 54 to 94m.

**Construction:** Rolled Asphalt. The cost of installation per single cushion within a narrowing was over £1000.

**Results:** Before 85% speeds fell from 37 mph to 24.2 mph at a point mid-way along Peterborough Road, the after speed measurements being taken between cushions with a 64m separation. Flows between the before and after period have remained relatively constant.

**Comments:** The road is a midi/hopper bus route, the bus operators have been very pleased with the scheme. Cushions with a width of 2100mm were initially installed but were removed and replaced with 1700mm wide measures after complaints from the Fire Service.

**5. Blomfield Road, Maida Vale Area. City of Westminster.**

**Location:** Blomfield Road is a local residential road with a speed limit of 30 mph. Cushions were installed in March 1994 over a 430m stretch of the road.

**Layout:** A total of 7 cushion pairs were installed in Blomfield Road, subsequently an additional smaller cushion has been placed within parking bays next to these groups to prevent vehicles by-passing cushions. Blomfield Road is 8.0m wide, which includes a 2.0m parking bay. The cushion pairs consist of 1600mm wide, 3400mm long and 75mm high cushions, with spacings of 52 to 70m.

**Construction:** Asphalt, at a cost of approximately £2000 for each cushion group.

**Results:** Average 85% speeds in the before period were recorded at 35.5 mph which have fallen to 25.7 and 24.6 mph at and between the cushions respectively, indicating that a constant speed is being maintained by vehicles on the road.

**Comments:** The North London Bus Company do not run services on Blomfield Road, but have supported cushion schemes elsewhere in Maida Vale. Both the Fire service and Police force also supported the scheme prior to installation after initially objecting to the use of speed humps. Blomfield Road is a primary emergency access route to Paddington Station. The scheme is currently being reviewed.

**6. Poplar Neighbourhood, Tower Hamlets. Poplar Neighbourhood.**

**Location:** Poplar Neighbourhood is an area of high density residential and industrial use. The area experienced a very high level of 'rat running' as it lies between the two major routes into the Borough of Tower Hamlets. The area had a very bad accident record, with nearly 40% or all accidents in Tower Hamlets being within Poplar, approximately one third of the accidents within Poplar occur within residential areas. Speed cushions were installed in 1992 in the Aberfeldy and Canton Street areas on several residential roads and one distributor road (Abbott Road).

**Layout:** Four cushion layouts were used: an paired offset layout in association with islands on Abbott Road; a paired layout without islands; a paired offset layout without islands; and a three-abreast layout with narrow outer cushions for use on heavily parked roads. The cushion dimensions installed were width 2130mm (1000mm for outer cushions on three-abreast layout), length 2750 (4750mm on Abbott Road) and height 90 to 100mm, with on/off gradients of 1:3.5 (approximately 1:15 on Abbott Road) and side gradients of 1:2.

**Construction:** Asphalt

**Results:** 85% speeds of 31 to 37 mph on Abbott Road have been reduced to 14 mph at and approximately 23 mph between cushions. On Blair Street 85% speeds of 27 to 29 mph fell to 16 mph at the cushions. On Canton Street 85% speeds of 30 mph fell to 17mph between the cushions. Peak vehicle flows fell by 17% on Canton Street, 44% on Blair Street but by only 2% on Abbott Road.

**Comments:** Both the Police and Ambulance service initially objected to the use of vertical deflections in Poplar, however the Fire service indicated support for the scheme by concluding after an evaluation of the measures, that cushions were preferable to road humps. The cushions on Abbott Road have been lowered by 25mm to 75mm.

**7. Richmond Hill, Richmond Upon Thames. London Borough of Richmond Upon Thames.**

**Location:** Richmond Hill is a one way residential road and cycle route with some shops and services, little off street parking is available. The scheme was installed in June 1994 over a length of 500m, road has a 30 mph speed limit.

**Layout:** Seven cushions were installed on Richmond Hill, the measures were installed as single cushions with buildouts. The road width varies between 5.3 to 6.3m, a typical buildout being 1.8m into the road providing sheltered parking, one or two buildouts were used as required. Initially two types of cushion were installed, these being cushions with either a 1300mm or 2000mm base width, subsequently all 1300mm cushions have been increased to 2000mm. Cushion length is 3700mm and height 75mm. Cushion spacing on Richmond Hill was between 47 to 75m.

**Construction:** Block paving.

**Results:** 85% speeds on Richmond Hill have fallen by over 10 mph, both at and between the measures installed, with 20 and 19 mph being recorded at and between the measures respectively.

**Comments:** Richmond Hill is not a primary or secondary emergency service route, it is not an important bus route with only school coaches using the road. Problems have been identified with the construction of the cushions as the block paving used is prone to cracking and movement. 3 of the 7 cushions had to be completely reconstructed and Richmond now use preformed concrete sections.

**Hertfordshire**
**8. Windmill Road, Adeyfield, Hemel Hempstead.**

**Location:** Windmill Road is a residential road with a 30 mph limit, there is some, but not heavy on street parking. The scheme was installed in May 1994 over a length of approximately 800m of Windmill Road. In the five year period from 1988 to 1992 a total of 11 injury accidents occurred, 8 slight and 3 serious.

**Layout:** Twelve pairs of cushions were installed in Windmill Road, with spacings of between 33 to 117m between the measures. The carriageway is approximately 7.5m wide, this accommodates two 1700m wide cushions and two buildouts 1.0m into the road. The buildouts constructed were 3200mm long and 610mm wide forming an island next to the kerb, allowing the drainage channel to be maintained. The overall length of the cushions is 2500mm, with a height of 70mm, on, off and side ramp gradients are 1:10, 1:10 and 1:5 respectively.

**Construction:** Block paving and kerbing forming the central platform, asphalt ramps.

**Results:** A before 85% speed of 37.9 mph was reduced to 22 and 26.9 mph at and between (separation of 77m) the cushions respectively. Traffic flows on Windmill Road have reduced by 27% from approximately 4400 to 3200 vehicles per day.

**Comments:** Windmill Road is a route for midi type buses, the local bus company is reported by the County Council to be very happy with the scheme. The use of Windmill Road by emergency vehicles has fallen since to implementation of the scheme, however no complaints have been received. In some instances problems have been observed with vehicles parking close to the cushion groups thus preventing the straddling of the cushion. No grounding problems have been reported.

**Lancashire**
**9. Chadderton Park Road, Oldham. Oldham Metropolitan Borough Council.**

**Location:** Chadderton Park Road is a long straight residential road (700m) with much off street parking, the scheme was installed in March 1994. The road inclines upward from both ends reaching a low visibility brow midway, poor pedestrian visibility is also created by vehicles parked on the wide footways. There were 5 injury accidents between 1989 to 1992. The road has a 30 mph speed limit.

**Layout:** Thirteen cushion pairs were installed on Chadderton Park Road with spacings between groups of between 26 to 97m. Pairs of 1500mm wide, 1800mm long and 75mm high cushions were installed within a 5.6m wide carriageway.

**Construction:** Preformed concrete unit, approximately £1500 per pair.

**Results:** 85% speeds of 36.5 mph before the scheme was installed were reduced to 24.6 and 28.8 mph at and between (spacing 75m) the measures respectively. Vehicle flow (vehicles per day) was reduced by approximately 30% on Chadderton Park Road.

**Comments:** Cushions were used on Chadderton Park Road primarily for the benefit of the emergency services. Bus operators running midibuses in Oldham are reported by the District Council to be positive about the cushions installed. Problems were encountered with the installation of the concrete cushions as the did not fit the camber of the road.

**10. Ringmore Road, Bramhall, Stockport. Metropolitan Borough of Stockport.**

**Location:** Ringmore Road is a residential or local distributer road with a 30 mph speed limit. Ringmore Road is a heavily used rat-run between two strategic routes. Speed cushions were installed over a length of approximately 800m in March 1994, Ringmoor Road is very lightly parked.

**Layout:** Thirteen paired arrangements of cushions were installed in Ringmore Road with spacings of between 35 to 72m. Pairs of 1900mm wide, 2280mm long and 80mm high cushions were installed within a 7.0m wide carriageway.

**Construction:** Concrete cast in-situ, £500 per pair.

**Results:** Before 85% speeds of 37 to 39 mph have been reduced to approximately 27 mph between cushions.

**Comments:** Speed cushions were installed primarily due to objections to speed humps from the Fire service. The Borough council has been thanked by the local bus company operating double decker, single decker and midibuses through the area. Problems have occurred with drivers manoeuvring centrally between cushions resulting in one damage only head on collision between two vehicles. Removed in February 1997 because too severe. Replaced with flat-top humps, 75mm high, 4.5 metre long with shallow ramps (1:15 approx).

**Leicestershire**
**11. Eyres Monsell, Leicester. Leicester City Council.**

**Location:** Eyres Monsell is a residential area within which an accident problem has been identified on the distributer roads running through the area. There is a high flow of buses through the estate. On the roads targeted by traffic calming there have been 14 injury accidents in the last 3 years.

**Layout:** Cushions have been installed in paired and three-abreast arrangements. Cushions are 1600mm wide, 2200mm long and 75mm high. Cushion pairs were generally installed in a 5.5m wide carriageway, with three-abreast cushion arrangements installed within a 7.3m carriageway. Seven meter long flat top humps were also installed on bus routes in some area of Eyres Monsell.

**Construction:** Block paving, kerbing.

**Results:** 85% speeds have been reduced of Hillsborough Road from 43 mph to 32 mph between cushions. Vehicle flows have fallen by approximately 23% on Hillsborough Road.

**Comments:** Support for cushions has been received by the City Council from the emergency services and provisionally from bus operators. In some cases however the bus company is asking for the installation of more 7m long flat top humps. Problems have occurred in Leicester with the use of block paving for the construction of cushions, maintenance has been required at least one cushion group in Eyres Monsell.

**12. Wycombe Road, Leicester. Leicester City Council.**

**Location:** Wycombe is a 500m long straight residential street with a large collage fronting onto the road. The road is a secondary emergency access route and is used as a route by midi type buses.

**Layout:** Five three-abreast cushion groups were installed on Wycombe Road. Groups of 1600mm wide, 1950mm long and 75mm high cushions were installed within a 8.2m wide carriageway. Four 7.0m long flat top humps have also been installed along Wycombe Road. Spacings between measures range from 27 to 87m.

**Construction:** Block paving, kerbing.

**Results:** 85% speeds of 38 mph were reduced to 23 mph at and 25 mph between cushions.

**Comments:** The emergency services and bus operators are reported to be satisfied with the scheme.

**North Yorkshire**
**13. Eastfields Estate, Haxby and Wigginton.**

**Location:** The Eastfields Estate is a large residential area with two Primary schools. The scheme was designed to reduce car speeds to approximately 20 mph whilst allowing buses and emergency vehicles to pass with minimum discomfort. A total of 22 personal injury accidents occurred within the estate between January 1989 to May 1994. The scheme was installed in July 1994 along Oak Tree Lane, Eastfield Avenue and Westfield Lane.

**Layout:** A variety of measures have been used in the Eastfields traffic calming scheme. A total of 10 single cushions with buildouts, 31 cushion pairs, 1 three-abreast cushion group, 2 flat top road humps and three chicane type arrangement have been installed. The cushion dimensions installed were width 2000mm, length 3000mm and height 100mm. Single cushions (with buildout widths of 3000mm) and cushion pairs were installed on 7.0m wide carriageways. Spacings between measures varied from 28 to 88m.

**Construction:** Asphalt

**Results:** 85% speeds have been reduced within the scheme from 36 - 39 mph to 23 - 27 mph, an average reduction of approximately 13 mph. Vehicle flows have been reduced by an average of about 30% on roads where measures have been installed.

**Comments:** Support for the Haxby and Wigginton scheme was received from the emergency services and the local bus operator, the bus company requested 1650mm cushions to be used.

**14. Askham Lane, York. York City Council.**

**Location:** Askham Lane is a local distributer road, cushions were installed in May 1994 over a length of 1200m to enforce the 30 mph speed limit. The road is not heavily parked. The calming scheme was aimed at addressing the roads poor accident record of 36 injury accidents between 1988 to 1992.

**Layout:** Twelve single pair and two double pair cushion arrangements were installed along Askham Lane, two paired arrangements were staggered cushions associated with a pedestrian crossing islands. Pairs of 1700mm wide, 2000mm long and 75mm high cushions were installed within a 6.7m wide carriageway, spacings between cushion groups ranged from 44 to 88m. Pairs of cushions in the double pair arrangements are separated by 3.5m.

**Construction:** Asphalt, cost per cushion £448

**Results:** Before 85% speeds of 40.5 mph have been reduced to 23 mph at, and 26 mph between cushion pairs (distance between cushions 85m).

**Comments:** Emergency services consulted before the scheme generally accepted the proposals with the exception of the Police. The Police objected to the scheme on the grounds that vertical deflections were the wrong measures to employ when calming an important ‘secondary’ route. It has generally been conceded that the speed reductions achieved on Askham Lane have been greater than required. Following off-road trials, the cushions on Askham Lane were replaced with lower (65mm), narrower (1600mm) and longer cushions (3500mm).

**15. Chapelfields Area, York. York City Council.**

**Location:** Chapelfields is a residential area covered by an area wide 20 mph zone approximately 700 x 600 square metres, the scheme was installed in January 1994. There is some on street parking.

**Layout:** A total of 14 single cushion groups with buildouts were installed in the Chapelfields area. In addition to cushions, a total of 48 round top and 4 flat top humps were installed. The dimensions of cushions installed are, width 1750mm, length 2000mm and height 75mm, on and off ramp gradients were 1:6, greater than the recommended maximum 1:8 gradient. A typical single cushion group was installed on a 4.9m wide carriageway, total buildout distance being 1650mm (a 1300mm buildout with a 350mm kerb drainage gap). Spacings between measures ranged between 40 to 81m.

**Construction:** Asphalt, cost per cushion group £212.

**Results:** Mean speeds have been reduced from approximately 24 mph to 15 mph at, and 18 mph between cushions (distance between cushions 50m).

**Comments:** The emergency services and bus operator did not object to the installation of this scheme.

**16. Cornlands Road, York. York City Council.**

**Location:** Cornlands Road is a residential road linking Askham Lane and Gale Lane, two other cushion schemes installed by York City Council. The road is not heavily parked, some off street parking is available. Cushions were installed in May 1994 along the 800m length of Cornlands Road. The main entrance of a secondary school is located on Cornlands Road.

**Layout:** Eleven cushion pairs, 1 single cushion and 2 flat top humps were installed along Cornlands Road. Pairs of 1700mm wide, 2000mm long and 75mm high cushions were installed within a 6.7m wide carriageway. Spacings between groups ranged from 26 to 73m.

**Construction:** Asphalt, cost per cushion group £448.

**Results:** Before 85% speeds of 35 mph were reduced to 25 mph at, and 27 mph between cushions (distance between cushions 73m)

**Comments:** The emergency services and bus operator did not object to the installation of this scheme.

**17. Danebury Drive, York. York City Council.**

**Location:** Danebury Drive is a residential road and the main route through a residential area. The Cushions installed on Danebury Drive are part of an area wide 20 mph zone. Off street parking is available so little parking occurs on the road. Cushions were installed in March 1994 along the 1050m length of the road.

**Layout:** A total of 16 cushion groups were installed on Danebury Drive, 10 cushion pairs and 6 three-abreast cushion groups. The dimensions of cushions installed were, 1800mm width, 2000mm length, 75mm high. Cushion pairs were installed on carriageway widths of between 6.1 to 6.4m, with three-abreast cushion groups installed within a 9.25m carriageway. Spacings between cushions ranged between 56 to 88m.

**Construction:** Asphalt, cost per cushion £165

**Results:** Before 85% speeds on the widest section of road were reduced from 40 mph to 23.5 at, and 26.7 mph between the cushions (average distance between cushions 76m). Speeds over cushions were generally lower along the narrower section of Danebury Drive where before speeds were also lower and parking poses a greater problem, preventing vehicles straddling cushions.

**Comments:** The emergency services and bus operator did not object to the installation of this scheme.

**18. Gale Lane, York. York City Council.**

**Location:** Gale lane is a local distributer road lined with residential property. The road became a target for calming because of its poor accident record, 40 injury accidents 1986 to 1990. Cushions were used on the route because of objections to the use of standard road humps by local bus operators and the emergency services. The road has a 30 mph limit and covers a length of 1050m.

**Layout:** The scheme consists of 17 cushion pairs (3 of these associated with pedestrian islands) and 2 double pair arrangements. Pairs of 1700mm wide, 2000mm long and 75mm high cushions were installed within a 6.7m wide carriageway. The pairs of cushions comprising the double cushion pairs were separated by 3.5m. Where cushion pairs have been installed with pedestrian islands the carriageway is wider, typically 9.0m, with a 2000mm wide central island. Cushions were staggered either side of the crossing, positioned between oncoming traffic and the crossing. Spacings between the cushion groups range from 30 to 70m.

**Construction:** Asphalt, cost per cushion £120.

**Results:** Before 85% speeds of 37 mph have been reduced to 21 mph at, and 23 mph between cushions pairs (average spacing 63m), speeds were also reduced to 21 mph at the double pair arrangements.

**Comments:** The bus operators consulted indicated support for the installation of cushions in order that their effect on buses and bus passengers could be observed. The local bus operator has since considered removing minibus services from Gale Lane because of the severity of the measures. In general the severity and spacing of the measures installed in Gale lane has created greater speed reductions than necessary on this type of road, initiating complaints from bus operators and residents. Following off-road trials, the cushions on Gale Lane were replaced with lower (65mm), narrower (1600mm) and longer cushions (3500mm).

**19. Foxwood Lane, York. York City Council.**

**Location:** The Foxwood Lane cushion scheme was installed in two phases, the first phase being part of the initial on road trials of speed cushions in 1993. Phase two was installed in May 1994 to complete the calming scheme along the 1250m length of Foxwood lane. Foxwood Lane is a main route with speed limit 30 mph through a residential area, there is some on street parking. There is a parade of shops halfway along the road and a local school borders the road. The second phase of the Foxwood Lane scheme covers a less residential length of the road.

**Layout:** A total of 5 cushion pairs with buildouts, 12 three-abreast cushion groups, 1 round top and 1 flat top hump have been installed on Foxwood Lane. Groups of 1650mm wide, 2500mm long and 75mm high cushions were installed within a 7.3m wide carriageway. Cushion pairs were installed with 1800mm buildouts, providing sheltered parking. Spacings between cushion groups vary between 50 to 92m. Standard round top and flat top humps were positioned either side of the shopping area.

**Construction:** Asphalt, cost per cushion £448

**Results:** Mean speeds of 32 mph were reduced to approximately 19 mph at, and 22 mph between (average spacing 66m) the cushion groups installed in phase one of the Foxwood Lane scheme. In the second phase area of Foxwood Lane mean before speeds of 29.5 mph were reduced to 21 mph at, and 23 mph between the cushion groups (average spacing 73m). Vehicle flows were monitored in phase one of the scheme, these showed a 17% reduction in flows at one end of the scheme, with negligible changes at the other end.

**Comments:** Foxwood Lane is an important emergency access route, and a heavily used bus route. Before the installation of phase two on Foxwood Lane the emergency services and local bus operators were contacted for their opinions in the light of their experiences with phase one of the scheme, full support was given to the second phase by all the agencies contacted.

**20. Kingsway West Area, York. York City Council.**

**Location:** Kingsway West is a residential area which has been targeted for area wide traffic calming. The scheme includes both standard road humps and on three roads speed cushions. The three roads calmed with speed cushions are Kingsway West, Danesfort Avenue and Tudor Road. Kingsway West and Danesfort Avenue are residential streets with Tudor Road being a more important distributer road with higher traffic flows. The area wide scheme extends over 450 by 600m and was installed in April 1994.

**Layout:** Three different speed cushion designs were installed within the Kingsway west traffic calming area.

Seven single cushion groups with buildouts, and two round top humps were installed on Kingsway West. Single 1800mm wide, 2000mm long and 75mm high cushions were installed within the 4.95m wide carriageway. Single cushions were installed alongside 1750mm wide buildouts (1450 buildout with 300mm drainage gap).

Four paired cushion arrangements were installed on Danesfort Avenue. Pairs of 1750mm wide, 2000mm long and 75mm high cushions were installed within the 5.55m wide carriageway.

Six pairs of cushions were installed on Tudor Road. Pairs of 1700mm wide, 2000mm long and 75mm high cushions were installed within the 6.2m wide carriageway. Spacings between cushions in the Kingsway West Area vary between 38m to 94m.

**Construction: Asphalt, cost of cushion £152**

**Results:** No before data is available for this scheme, however after data was collected giving approximate speeds both at and between cushion groups. On Kingsway West (1800mm wide cushions) the mean speed recorded at and between cushions was 16 mph and 19 mph (spacing 64m) respectively. On Danesfort Avenue (1750mm wide cushions) mean speeds at and between cushions were 16.5 mph and 21.5 mph (spacing 86m) respectively. On Tudor Road (1700m wide cushions) the mean speed at and between cushions was 19 mph and 24 mph (spacing 94m) respectively.

**Comments:** There were no objections to the implementation of the scheme prior to installation from either the emergency services or the local bus operators.

**21. Mill Lane, York. York City Council.**

**Location:** Mill Lane is a residential street but also forms an important link in the 'secondary' road network. The road carries a relatively high volume of traffic and local residents are very concerned about vehicle speeds. Three injury accidents were recorded between 1988 to 1993. The scheme was installed over the 175m length of Mill Lane in March 1994. The total cost of the scheme was £2190.

**Layout:** Two cushion pairs and one flat top speed hump were installed in Mill Lane. Pairs of 1650mm wide, 2500mm long and 75mm high cushions were installed within the 6.1m wide carriageway.

**Construction:** Asphalt

**Results:** No before data is available for Mill Lane however mean speeds of approximately 16 mph and 20 mph were recorded at and between the cushions respectively.

**Comments:** Responses from the emergency services have generally been supportive. The Police indicated that they had no evidence to suggest that there was a particular speed or accident problem on Mill Lane, however as the road is not an important response route they have no objections to the scheme. The Ambulance Service were supportive of schemes which reduce road accidents but concerned that vertical deflection measures in the road may cause great discomfort to patients and increase response times.

**22. Muncaster Area, York. York City Council.**

**Location:** Three roads forming the main links through the Muncaster Area, a residential area with regular bus services, local shops and relatively light traffic flows, were calmed with speed cushions in 1993 as part of the on-road trials of these measures. The three roads vary slightly in character but are all residential. Elmfield Avenue, Monkton Road and Byland Avenue are long straight roads varying between 300 to 440m in length. In the 5 year period 1988 to 1992 there were 10 injury accidents in the Muncaster Area.

**Layout:** A different cushion design was installed on each of the three roads. In Elmfield Avenue 5 cushion pairs were installed, with an additional pair of cushions associated with a chicane. Paired arrangements of 1880mm wide, 1880mm long and 80mm high, cushions with on, off and side ramp gradients of less than 1:5 were installed within the 6.2m carriageway of Elmfield Avenue. Spacings between cushions varied between 52 to 65m.

Four cushion pairs, 1 double pair and 2 flat top humps were installed on Monkton Road. Pairs of 1900mm wide, 1950 long and 75mm high cushions were installed along the 6.2m carriageway width of Monkton Road. The gap between cushion pairs in the double pair arrangement was 4.0m. Spacings between measures varied between 23 to 75m.

Four cushion pairs and one double pair arrangement were installed on Byland Avenue. Pairs of 1700mm wide, 1700mm long and 60mm high cushions with on, off and side gradients on 1 in 3.5 were installed on the 6.2m carriageway width of Byland Avenue. Spacings between measures ranged from 45 to 65m.

**Construction:** Moulded rubber sections, cost £600 to £950 depending on type.

**Results:** Mean before speeds (for cars) of 28.6 mph on Elmfield Avenue were reduced to 13.3 mph at (not including chicane) and 18.2 mph between cushions. On Monkton Road mean before speeds (for cars) of 28.9 mph were reduced to 14.6 mph at and 20.8 mph between cushions. On Byland Avenue mean before speeds (for cars) of 25.9 mph were reduced to 13.5 mph at and 17.9 mph between cushions.

In all cases speeds at double cushion groups were between 0.5 and 1.0 mph slower than single cushion pairs. Double and single decker bus speeds were also recorded on each of the roads, it was generally found that bus speeds (4 to 5 mph slower than cars in the before period) were slowed to a much lesser extent than cars. Over the cushion groups installed bus speeds generally averaged higher than car speeds in the after period, particularly over the 1700mm cushions. Vehicle flows dropped considerably between the before and after periods.

**Comments:** The cushions installed in the Muncaster area were criticized by the Fire service and Bus operators for being too severe as compared to other schemes in York. Parking in the Muncaster area was also highlighted as a problem for buses attempting to straddle the cushions. Following off-road trials the cushions in the Muncaster area were replaced with lower (65mm), narrower (1600mm) and longer (3500mm) in July 1997.

**23. Skeldergate, York. York City Council**

**Location:** Skeldergate is an important link road in York City centre, there is a large sheltered housing scheme fronting onto the road. Skeldergate is used by many of the local Park and Ride buses. The road lacks a continuous footpath on one side forcing pedestrians to either walk along or across the road. The scheme was installed in April 1994 and covers a length of 490m.

**Layout:** Three sets of cushion pairs (one pair with pedestrian crossing island), 1 three-abreast cushion group and 2 flat top humps were installed in Skeldergate. The cushion groups consist of 1800mm wide, 2000mm long and 75mm high cushions. Cushion pairs were installed on a carriageway 6.0 to 6.25m wide. The cushion pair with 1800mm wide crossing island was located within a 8.2m section of carriageway. The Three-abreast cushion group was installed on a 8.0m wide section of carriageway. Measures were spaced between 50 to 100m apart.

**Construction:** Asphalt, cost per cushion £545

**Results:** Mean before speeds of 21 mph were reduced to approximately 15 mph at a cushion pair.

**Comments:** Support was given to the installation of this scheme by both the Ambulance service and the local bus company. Cushion sizes altered to the new City of York ‘standard’ cushion size of 1600mm wide, 65mm high and 3500mm long when the road was resurfaced in February 1997.

**24. Tang Hall Area, York. York City Council.**

**Location:** The Tang Hall Area is a residential area with shops and a Primary school. Phase one of a traffic calming scheme was installed in 1993 over a length of 640m of Fourth and Fifth Avenue. The installation of speed cushions in Tang Hall formed part of the initial on road trials of speed cushions. There were a total of 4 injury accidents with a total of 7 pedestrian or cyclist injuries between 1988 and 1992.

**Layout:** Seven cushion pairs, 1 three-abreast cushion group, 1 round top hump and 2 flat top humps were installed on Fourth and Fifth Avenue. Pairs of 1800mm wide, 2500mm long and 75mm high cushions were installed on the 6.1m carriageway width of Fourth Avenue. The three-abreast cushion group was installed on the 7.9m wide carriageway of Fifth Avenue, spacings between measures varied from 42 to 70m.

**Construction:** Block paving.

**Results:** Mean car speeds on Fourth Avenue fell from 29.9 mph before to 14.0 mph at and approximately 19.0 mph between cushions after installation. Traffic flows dropped after the introduction of traffic calming by between 20 to 35% on the calmed roads, some traffic flows have migrated increasing flows on nearby roads.

**Comments:** The bus operator and emergency services are reported to prefer narrower 1600-1650mm wide cushions to the 1800mm cushions installed. On going maintenance has been required for several of the block paved cushions installed. Eventual replacement was required and the cushions on Fourth and Fifth Avenue have been replaced with lower (65mm), narrower (1600mm) and longer cushions (3500mm).

**Northamptonshire**
**25. Billing Brook Road, Northampton.**

**Location:** Billing Brook Road is a local distributer route, the road runs past the Weston Favell shopping centre, health centre and two schools. The scheme was installed in July 1994 over a 650m length of Billing Brook Road. There were 19 injury accidents along this section of Billing Brook Road in the 3 year period before the installation of speed cushions, including 13 pedestrians.

**Layout:** Five cushion pairs and 3 double cushion pairs were initially installed along Billing Brook Road. Cushions of 1880mm width, 2380mm length and 80mm height, with on, off and side ramp gradients of approximately 1:5, were installed within the 7.3 to 8.6m wide carriageway. Central gaps of 1300 to 2740mm were initially left between cushion pairs. The large central gaps between cushions encouraged large numbers of drivers to bypass the measures by driving centrally between cushions. In order to reduce the central gap between cushions, cushions were removed and groups reorganised into 2 cushion pairs, 2 double pairs and 3 three-abreast cushion arrangements, with a maximum central gap of 1300mm.

**Construction:** Moulded rubber sections

**Results:** 85% speeds of approximately 38 mph near Weston Favell Police station have been reduced to approximately 27 mph.

**Comments:** Problems have occurred with cushions becoming detached from the road surface, ongoing maintenance has been required. The County Council has received support for the scheme from the local bus operator. The emergency services have supported the scheme as an experiment.

**Nottinghamshire**
**26. Bagnall Road, Nottingham.**

**Location:** Bagnall Road is largely within a residential area and suffers high volumes of traffic flow. Bagnall road is considered a primary emergency access route, it is also a relatively high priority public transport route. The Bagnall Road traffic calming scheme was installed in January 1994 over the 1100m length of the road.

**Layout:** Five cushion pairs, and six three-abreast cushion groups were installed on Bagnall Road, cushion dimensions being different for the paired and three-abreast groups. The dimensions of cushions installed as cushion pairs were, 1880mm width, 1880mm length and 80mm height with on, off and side gradients approximately 1:5. Three-abreast cushion groups were made up of cushions of 1600mm width, 1950mm length and 75mm height with 1:8 and 1:4 on, off and side gradients respectively. Bagnall Road has an approximate carriageway width of 8.2m, at cushion pairs the road is narrowed on one side by a 1400mm buildout.

**Construction:** Moulded rubber sections. Cost of 1880mm cushion £656, cost of 1600mm cushion £476.

**Results:** 85% speeds of 47 mph were reduced to 30 mph between both cushion pairs and three-abreast cushion groups, at spacings of 126m between cushion pairs, and 100m between three-abreast groups. A study of driver behaviour indicated between 50 to 65% of drivers straddled cushions, at three-abreast cushion groups however over 40% of drivers put one wheel up onto both the nearside and central cushion.

**Comments:** Partial lifting of the 1880mm wide moulded rubber cushions has resulted in their removal and replacement with concrete cushions (1900mm wide, 1900mm long, 70mm high with 600mm on/off and 300mm side ramps). Hatching was added to the 3 abreast cushion layouts.

**Shropshire**
**27. Brookside Avenue, Telford.**

**Location:** Brookside Avenue is an orbital route, 2600m in length, surrounding a large residential area. The road is a primary emergency access route and carries all types of public transport vehicle. There are many side road junctions with cul-de-sacs running inward. The road has a bad accident record with 37 personal injury accidents, with over 60 casualties in the 5 year period 1989 to 1993. The construction of the scheme was completed in April 1994. Brookside Avenue has a 30 mph speed limit.

**Layout:** A total of 15 cushion pairs and 12 flat toped humps were installed in Brookside Avenue. The dimensions of the cushions installed were: width 1600mm, length 4300mm, height 75mm and a shallow on/off ramp gradient of 1:12. Brookside Avenue has a carriageway width of 7.3m, cushion pairs were spaced with 1000mm cushion kerb gaps and 2100mm central gap between cushions. The central gap between cushions has created a problem with cars driving down the middle of the road to avoid cushions. Spacings between measures ranged from 40 to 105m.

**Construction:** Asphalt, cost per cushion £250

**Results:** 85% speeds of 38 to 43 mph have been reduced to 25 to 30 mph at the new 1900mm cushions, 29 to 33 mph at 1600mm cushions and 30 to 40 mph between cushion groups.

**Comments:** The gap running problem between cushions has been reduced by increasing the cushion width at affected cushion groups to 1900mm, thus reducing the central gap between cushions. Flat top humps are distributed relatively evenly along Brookside Avenue, however where several cushions exist in series without a flat top hump 85% speeds still exceed the speed limit. The Fire service are reported to have complained about the flat top humps installed, the use of which is resulting higher attendance times.

**South Yorkshire**
**28. Lindsay Avenue, Sheffield. Sheffield City Council.**

**Location:** Lindsay Avenue is a residential distributor road with local shops half way along its length. The road is a heavily used bus route for mainly single and double deck buses. Between 1988 and 1992 there were 6 injury accidents on Lindsay Avenue with 7 pedestrian or cyclist casualties. The road formed part of the initial on road trials of speed cushions in 1993. There is some but not heavy on street parking.

**Layout:** A total of 9 cushion groups were installed on Lindsay Avenue, 6 different types of trial layout were installed comprising of 1 to 5 cushions. There was one arrangement each of cushion groups with 1, 3, 4 and 5 cushions and two arrangements of cushion groups with 2 cushions (a cushion pair and two cushions arranged in series within a carriageway narrowing). Cushions were installed with widths of 1600mm and 1300mm, length 3250mm and height 75mm. Spacings between measures ranged from 88 to 130m.

**Construction:** Preformed concrete sections, cost per cushion £340 (plus £2750 for installation per pair)

**Results:** Before mean speeds of approximately 27.5 mph have been reduced to 19 mph and 17 mph at the 1600mm and 1300mm cushions respectively. The slower speeds at the 1300mm cushions may be explained by the use of these cushions at single file road narrowings. Traffic flows were observed to fall by approximately 13% after the construction of the scheme.

**Comments:** Comments received by Sheffield City Council from the emergency services and bus operator indicated that the cushion designs were satisfactory. The Fire service indicated a single cushion within a narrowing to be their preferred arrangement, with arrangements requiring weaving (such as arrangements of 3 and 5 cushions) to be less desirable. The bus operator indicated arrangements of cushions allowing two way flow were preferable to one way working at narrowings. A number of cushions at Lindsay Avenue have cracked and/or rocked, resulting in a difference in level between adjacent cushion halves and/or between the cushion and the adjacent carriageway. These failed cushions are to be replaced with stronger precast concrete units in due course.

**Tyne and Wear**
**29. Ocean Road, South Shields. South Tyneside Metropolitan Borough Council.**

**Location:** Ocean Road (A183) is an important and heavily trafficked route from the centre of South Shields to the coast. The road is primary emergency route and busy shopping street used by both midibuses and larger single and double deckers. Sheltered parking prevents any obstruction to cushions. The calmed section of the road is approximately 250m long with a 30 mph speed limit.

**Layout:** Two cushion pairs with central islands and one raised Zebra crossing have been installed. Pairs of 1750mm wide, 3700mm long and 80mm high cushions, with 1:10 on, off ramp gradients and 1:4 side ramp gradients were installed. Ocean Road has a carriageway width of 7.3m, the central island installed was 800mm wide. The separation between cushions is approximately 55m.

**Construction:** Red Asphalt.

**Results:** 85% speeds of approximately 28 mph were reduced to approximately 18.5 mph between measures.

**Comments:** No Comments have been reported from bus operators or the emergency services.

**Warwickshire**
**30. Camp Hill Area, Nuneaton.**

**Location:** The Camp Hill area is a residential area, it has one of the worst accident records in Warwickshire with 60 injury accidents in a 1km square area in the three year period 1990 to 1992. Cushions were installed in May 1994 as a form of traffic calming acceptable to both the emergency services and bus operators, with whom off road trials of cushions had been carried out. Part of the scheme was designated a 20 mph zone with other calmed routes remaining 30 mph.

**Layout:** Three types of cushion layout were installed with cushions of various dimensions, these being a cushion pair with central island, a road narrowing with central cushion and a chicane or offset road narrowing with a narrow central cushion. The cushions installed have been constructed with circular profiles, the dimensions being width 2100mm or 1000mm (narrow cushion installed at chicane), length 9500mm (at cushion pair) or 6000mm, and height 65mm with on and off ramp gradients of 1:10.

**Construction:** Asphalt, all layout types £1500.

**Results:** At the 1000mm wide cushion and chicane mean car speeds were reduced from 35 mph to approximately 29 mph at and 30 mph between the measures, at a spacing of 130m. At the 2100mm speed cushion and narrowing mean car speeds of 35 mph were reduced to approximately 24 mph at and 27 mph between the cushions at a spacing of 100m. Twenty four hour average vehicle flows along the calmed route have fallen by approximately 23%.

**Comments:** Both the emergency services and bus operators were consulted extensively prior to the implementation of this scheme cushions were found to be preferable to standard road humps. Since the installation of the scheme the narrow chicane cushion has been reduced to 55mm in height.

**West Midlands**
**31. Charles Road, Small Heath, Birmingham. Birmingham City Council.**

**Location:** Charles Road forms part of the Small Heath traffic calming scheme. The Small Heath area is a residential area of high density housing. The area covered by the Small Heath scheme had 115 injury accidents in the 5 year period 1987 to 1991, with 36 of these on Charles Road. Cushions were installed on Charles Road in 1992, over a length of 700m.

**Layout:** Two sets of double pair cushion arrangements with central pedestrian crossing islands were installed within slight narrowings. The dimensions of cushions installed were, width 1800mm, length 2500mm and height 80mm, with a central island of 1830mm. Charles Road is 9.25m wide, at the cushion groups the carriageway has been narrowed by 460mm wide buildouts on each side.

**Construction:** Block paving and Trief-kerbing at pedestrian refuge and narrowings.

**Results:** No before speeds are available for Charles Road, however the road is relatively wide with long sight lines which would have encouraged relatively high speeds before measures were introduced. The average speed over the cushion groups is approximately 16 mph, no between cushion speeds are available.

**Comments:** Both the emergency services and local bus operators were consulted about the Small Heath traffic calming project and support was given to the installation of cushions.

**West Yorkshire**
**32. Grosvenor Road, Manningham, Bradford. City of Bradford Metropolitan Council.**

**Location:** Grosvenor Road is a short link of approximately 190m long. The road contains both residential and commercial property as well as a playground. Grosvenor Road could be classed as a secondary route for the emergency services, the road is not a bus route. There were 12 injury accidents reported in the 5 year period prior to the installation of the scheme. Cushions were installed in March 1994.

**Layout:** Three cushion pairs with buildouts (providing sheltered parking) were installed in Grosvenor Road. Pairs of 1900mm wide, 1950 long and 75mm high cushions were installed on the 8.3m carriageway width of Grosvenor Road. Cushions were installed alongside 2100mm wide buildouts. The spacings between cushion groups are 55 and 58m.

**Construction:** Moulded rubber sections.

**Results:** 85% speeds have been reduced (at a point midway along the road) from 31 to 15.5 mph at and 21 mph between the cushions (spacing 58m). Vehicle flows have fallen on the road by approximately 25% with an even greater reduction in the flow of HGVs.

**Comments:** Tests carried out on the Grosvenor Road cushions by the Ambulance service indicated there to be no problems for ambulances crossing the cushions.

**33. Hollings Road, Bradford. City of Bradford Metropolitan Council.**

**Location:** Hollings road is a residential distributer road. The road is a secondary emergency access route, the road is not a bus route. In the 5 year period before the installation of the scheme there were 10 injury accidents on Hollings Road, involving 14 casualties. The scheme covers the 600m length of the road and was installed in May 1994.

**Layout:** Twelve three-abreast cushion groups were installed with spacings of 37 to 80m between groups. Cushions of 1880mm width, 1880mm length and 80mm height were installed on the 8.5m wide carriageway of Hollings Road.

**Construction:** Moulded rubber sections.

**Results:** 85% speeds of 40 mph mid way along Hollings Road were reduced to 19 mph at and 22 mph between cushions (spacing of 58m). Light vehicle flows mid way along Hollings Road fell by 26% with HGV flows falling nearly 38%.

**Comments:** No comments received.

**34. New Cross Street, Bradford. City of Bradford Metropolitan Council.**

**Location:** New Cross Street is a local distributer road with some residential frontage and a school located approximately half way along its length. The road is a primary emergency access route and route for double decker bus services. Cushions were installed in April 1994 along the 500m length of New Cross Street. In the 5 year period 2/1989 to 2/1994 a total of 20 injury accidents were recorded, involving 23 casualties.

**Layout:** Nine cushion pairs within narrowings were installed on New Cross Street. Pairs of 1880mm wide, 1880mm long and 80mm high were installed on the 8.5m wide carriageway of New Cross Street. Cushion pairs were installed within pinch points with 1250mm wide buildouts either side of the road. The carriageway width on New Cross Street is approximately 8.5m. The spacing between cushion groups ranges between 46 to 98m.

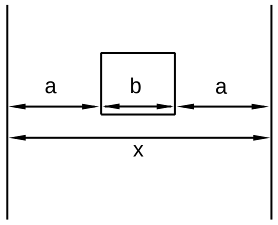
**Construction:** Moulded rubber sections.

**Results:** 85% speeds at approximately 175 to 225m from the eastern end of the scheme were reduced from 39 mph to 18 mph at and 23 mph between cushions (spacing of 98m). Light vehicle flows have been reduced by over 40% at the eastern end of the scheme, HGV flows have reduced by 20%.

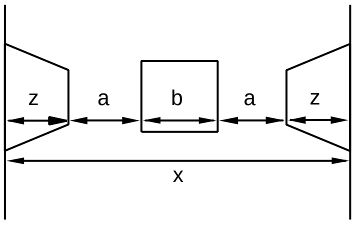
**Comments:** The New Cross Street traffic calming scheme has received wide support from both the emergency services and the local bus operator.

# Appendix B: Cushion layouts

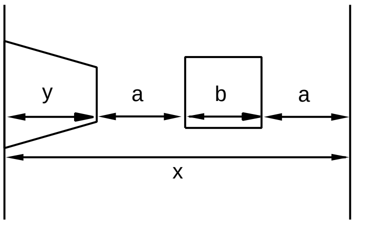
**Table B1 Dimensions of cushions, gaps and buildouts at single cushion layouts**




Type 1




Type 2

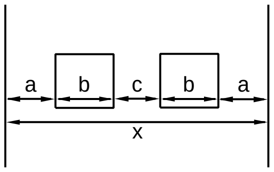



Type 3

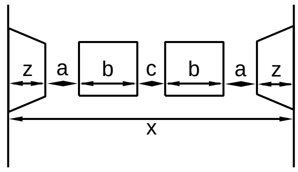
| | | Layout dimensions (mm) | | | | | Cushion dimensions (mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| *Site number* | *Name* | *Layout type* | *Road width 'x'* | *Cushion kerb gap 'a'* | *Buildout width 'z'* | *Buildout width 'y'* | *Width 'b'* | *Height* | *Length* |
| 30. | Camp Hill | 2 | 6400 | 350 | 1880 | - | 2100 | 65 | 6000 |
| 28. | Lindsay Av | 2 | 7700 | 950 | 2100 | - | 1600 | 75 | 3250 |
| 4. | Peterborough Rd | 2 | 8000 | 1230 | 1920 | - | 1700 | 75 | 3400 |
| 15. | Chapelfields | 3 | 4900 | 750 | - | 1650 | 1750 | 75 | 2000 |
| 20. | Kingsway West | 3 | 4950 | 700 | - | 1750 | 1800 | 75 | 2000 |
| 7. | Richmond Hill | 3 | 6300 | 1250 | - | 1800 | 2000 | 75 | 3700 |
| 13. | Eastfields Est | 3 | 7000 | 1000 | - | 3000 | 2000 | 100 | 3000 |

*No examples of Type 1 layout in the 34 schemes included in this study*

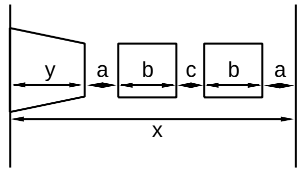
**Table B2 Dimensions of cushions, gaps, buildouts and islands at pair or double-pair cushion layouts**



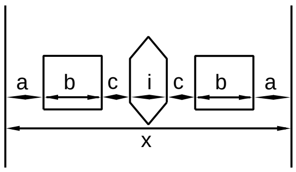

Type 1



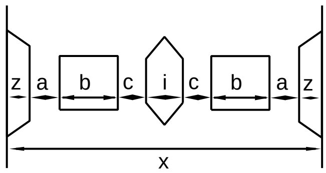

Type 2




Type 3




Type 4

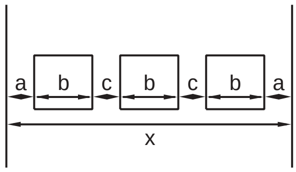



Type 5

| | | | *Layout dimensions (mm)* | | | | | | *Cushion dimensions (mm)* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Site number* | *Name* | *Layout type* | *Road width ‘x’* | *Cushion/ kerb gap ‘a’* | *Central gap ‘c’* | *Buildout width ‘z’* | *Buildout width ‘y’* | *Island width ‘i’* | *Width ‘b’* | *Height* | *Length* |
| 11. | Eyres Monsell | 1 | 5500 | 725 | 850 | - | - | - | 1600 | 75 | 2200 |
| 20. | Kingsway West | 1 | 5550 | 675 | 750 | - | - | - | 1750 | 75 | 2000 |
| 9. | Chadderton Pk Rd | 1 | 5600 | 800 | 1000 | - | - | - | 1500 | 75 | 1800 |
| 23. | Skeldergate | 1 | 6000 | 800 | 800 | - | - | - | 1800 | 75 | 2000 |
| 17. | Danebury Dv | 1 | 6100 | 800 | 900 | - | - | - | 1800 | 75 | 2000 |
| 21. | Mill Ln | 1 | 6100 | 1000 | 1000 | - | - | - | 1650 | 75 | 2500 |
| 24. | Tang Hall[1] | 1 | 6100 | 850 | 800 | - | - | - | 1800 | 75 | 2500 |
| 20. | Kingsway West | 1 | 6200 | 900 | 1000 | - | - | - | 1700 | 75 | 2000 |
| 22. | Muncaster | 1 | 6200 | 810 | 820 | - | - | - | 1880 | 80 | 1880 |
| 22. | Muncaster | 1 | 6200 | 800 | 800 | - | - | - | 1900 | 75 | 1950 |
| 22. | Muncaster | 1 | 6200 | 950 | 900 | - | - | - | 1700 | 60 | 1700 |
| 23. | Skeldergate | 1 | 6250 | 850 | 950 | - | - | - | 1800 | 75 | 2000 |
| 3. | Ivy Rd | 1 | 6600 | 1100 | 1000 | - | - | - | 1700 | 80 | 2320 |
| 14. | Askham Ln[1] | 1 | 6700 | 1100 | 1100 | - | - | - | 1700 | 75 | 2000 |
| 16. | Cornlands Rd | 1 | 6700 | 1100 | 1100 | - | - | - | 1700 | 75 | 2000 |
| 18. | Gale Ln[1] | 1 | 6700 | 1100 | 1100 | - | - | - | 1700 | 75 | 2000 |
| 10. | Ringmore Rd | 1 | 7000 | 1100 | 1000 | - | - | - | 1900 | 80 | 2280 |
| 13. | Eastfields Est | 1 | 7000 | 1000 | 1000 | - | - | - | 2000 | 100 | 3000 |
| 6. | Poplar Neigh’d | 1 | 6800 | 770 | 1000 | - | - | - | 2130 | 90-100 | 2750 |
| 25. | Billing Brook Rd | 1 | 7300 | 1120 | 1300 | - | - | - | 1880 | 80 | 1880 |
| 27. | Brookside Av | 1 | 7300 | 1000 | 2100 | - | - | - | 1600 | 75 | 4300 |
| 27. | Brookside Av | 1 | 7300 | 1000 | 1500 | - | - | - | 1900 | 75 | 4300 |
| 8. | Windmill Rd | 2 | 7500 | 700 | 700 | 1000 | - | - | 1700 | 70 | 2500 |
| 28. | Lindsay Av | 2 | 7700 | 1100 | 900 | 700 | - | - | 1600 | 75 | 3250 |
| 34. | New Cross St | 2 | 8500 | 750 | 750 | 1250 | - | - | 1880 | 80 | 1880 |
| 3. | Ivy Rd | 3 | 7300 | 800 | 800 | - | 1500 | - | 1700 | 80 | 2320 |
| 19. | Foxwood Ln | 3 | 7300 | 700 | 800 | - | 1800 | - | 1650 | 75 | 2500 |
| 5. | Blomfield Rd | 3 | 8000 | 700 | 1400 | - | 2000 | - | 1600 | 75 | 3400 |
| 26. | Bagnall Rd | 3 | 8200 | 1000 | 1000 | - | 1400 | - | 1880 | 80 | 1880 |
| 32. | Grosvenor Rd | 3 | 8300 | 800 | 800 | - | 2100 | - | 1900 | 75 | 1950 |
| 30. | Camp Hill | 4 | 6800 | 350 | 350 | - | - | 1200 | 2100 | 65 | 9500 |
| 29. | Ocean Rd | 4 | 7300 | 750 | 750 | - | - | 800 | 1750 | 80 | 3700 |
| 2. | Chairborough Rd | 4 | 7400 | 860 | 860 | - | - | 1200 | 1380 | 80 | 1380-1880 |
| 23. | Skeldergate | 4 | 8200 | 700 | 700 | - | - | 1800 | 1800 | 75 | 2000 |
| 18. | Gale Ln[1] | 4 | 9000 | 900 | 900 | - | - | 2000 | 1700 | 75 | 2000 |
| 31. | Charles Rd | 5 | 9250 | 725 | 725 | 460 | - | 1830 | 1800 | 80 | 2500 |

*[1]Cushions replaced with narrow (1600mm), low (65mm), long cushions (3500mm).*

**Table B3 Dimensions of cushions and gaps at three-abreast layouts**




Type 1

| | | | *Layout dimensions (mm)* | | | *Cushion dimensions (mm)* | | |
|---|---|---|---|---|---|---|---|---|
| *Site number* | *Name* | *Layout type* | *Road width 'x'* | *Cushion kerb gap 'a'* | *Cushion/ cushion gap 'c'* | *Width 'b'* | *Height* | *Length* |
| 6. | Poplar Neigh'd | 1 | 6750 | 200 | 1000 | 1000-2130[1] | 90-100 | 2750 |
| 1. | Coventry Rd | 1 | 7200 | 350 | 700 | 1600-1900[2] | 75 | 3725 |
| 11. | Eyres Monsell | 1 | 7300 | 600 | 650 | 1600 | 75 | 2200 |
| 19. | Foxwood Ln | 1 | 7300 | 650 | 525 | 1650 | 75 | 2500 |
| 24. | Tang Hall | 1 | 7900 | 650 | 600 | 1800 | 75 | 3500 |
| 25. | Billing Brook Rd | 1 | 7950 | 650 | 500 | 1880 | 80 | 1880 |
| 23. | Skeldergate | 1 | 8000 | 700 | 625 | 1800 | 75 | 2000 |
| 12. | Wycombe Rd | 1 | 8200 | 850 | 850 | 1600 | 75 | 1950 |
| 26. | Bagnall Rd | 1 | 8200 | 850 | 850 | 1600 | 75 | 1950 |
| 33. | Hollings Rd | 1 | 8500 | 720 | 720 | 1880 | 80 | 1880 |
| 25. | Billing Brook Rd | 1 | 8600 | 980 | 500 | 1880 | 80 | 1880 |
| 3. | Ivy Rd | 1 | 8700 | 900 | 900 | 1700 | 80 | 2320 |
| 13. | Eastfields Est | 1 | 9000 | 750 | 750 | 2000 | 100 | 3000 |
| 17. | Danebury Dv | 1 | 9250 | 900 | 1025 | 1800 | 75 | 2000 |
| 13. | Eastfields Est | 1 | 10000 | 1000 | 1000 | 2000 | 100 | 3000 |

[1]*Middle cushion 2130mm wide, outer cushions 1000mm wide*
[2]*Middle cushion 1900mm wide, outer cushions 1600mm wide*

## Abstract

The most effective forms of traffic calming measure usually involve some degree of vertical deflection. Road humps have proven to be highly effective at reducing vehicle speeds, but discomfort to drivers and passengers is increased, particularly in larger vehicles such as buses, lorries, fire engines and ambulances. Speed cushions are designed to limit the vertical deflection of large vehicles with wide track widths by allowing these vehicles to straddle the cushions. Vertical deflection for smaller vehicles, such as cars, with smaller track widths is maintained as these vehicles are forced to ride over the cushions with at least one set of wheels.

This report describes a study of 34 local authority speed cushion schemes. It assesses their effect on vehicle speeds, traffic flows, accidents, driver behaviour and passenger discomfort. It considers public reaction to the schemes and the likely impact of cushions on vehicle generated noise and vibration. The effects of differences in cushion dimensions and cushion spacing on vehicle speed are examined and relationships provided.

## Related publications

TRL311 *Traffic calming — Public attitude studies: a literature review* by D C Webster. 1998 (price code H, £30)

TRL313 *Traffic calming — an assessment of selected on-road chicane schemes* by I A Sayer, D I Parry and J K Barker. 1998 (price code E, £20)

TRL307 *Traffic calming and vehicle emissions: A literature review* by P G Boulter and E C Webster. 1997 (price code H, £30)

TRL235 *Traffic calming: vehicle generated ground-borne vibration alongside speed control cushions and road humps* by G R Watts, G J Harris and R E Layfield. 1997 (price code H, £30)

TRL215 *Review of traffic calming schemes in 20 mph zones* by D C Webster and A M Mackie. 1996 (price code H, £30)

TRL212 *Traffic calming on major roads: the A49 trunk road at Craven Armes, Shropshire* by A H Wheeler, P G Abbott, N S Godfrey, D J Lawrence and S M Phillips. 1996 (price code L, £40)

TRL186 *Traffic calming — road hump schemes using 75 mm high humps* by D C Webster and R E Layfield. 1996 (price code H, £30)

TRL180 *Traffic calming: vehicle noise emissions alongside speed control cushions and road humps* by P G Abbott, J Tyler and R E Layfield. 1995 (price code H, £30)

PR103 *Vehicle and traffic noise surveys alongside speed control cushions in York* by P G Abbott, S M Phillips and R E Layfield. 1995 (price code E, £20)

PR58 *Speed, speed limits and accidents* by D J Finch, P Kompfner, C R Lockwood and G Maycock. 1994 (price code E, £20)

PR32 *Speed control humps — a trial at TRL* by A R Hodge. 1993 (price code H, £30)

PR18 *Road humps for controlling vehicle speeds* by D C Webster. 1993 (price code J, £35)

CT1.2 *Traffic calming update (1994-1997)* (Current Topics in Transport: selection of abstracts added to TRL Library's database) (price £15)

Prices current at March 1998

For further details of these and all other TRL publications, telephone Publication Sales on 01344 770783 or 770784, or visit TRL on the Internet at http://www.trl.co.uk.