Appendix A

Road accident countermeasures

Anti-skid/high-friction surfacings

A.1

High-friction or ‘anti-skid’ surfacings are surfacings that make use of aggregates with better skid-resistance properties than normal, generally an artificial aggregate produced out of the “residue” from aluminium called calcined bauxite. In order for the aggregate to be retained on the surface with the high stresses expected, the binder needs to be stronger than can generally be achieved with conventional materials.

The use of epoxy-resin as the binder in surface treatment has increasingly been adopted across the United Kingdom on approaches to pedestrian crossings and roundabouts. With the introduction of a national Departmental Standard for skid resistance in 1988 on motorways and trunk roads and a similar policy being adopted by other highway authorities, the use of high-friction surface systems has grown substantially.

The systems currently available can be split into two categories:

- **Chemical cure systems:** These systems use multi-part binders that cure chemically when the parts are combined just before being applied to the road.
- **Thermoplastic systems:** The powdered materials are put into boilers and heated up before being hand-screed onto the road.

High-friction surfacings was the first product area to be covered by the *Highway Authorities Products Approvals Scheme* (HAPAS), operated by the British Board of Agrément (BBA, 1998) on behalf of the Highways Agency and other highway authorities throughout the United Kingdom. The first BBA-HAPAS certificates were issued in 1998 and the three types of certified systems (see Nicholls, 1997) are expected to have a service life of between five and ten years provided they are used on sites with traffic levels no higher than the following:

Site definition	Maximum traffic levels (commercial vehicles per lane per day)		
	Type 1	Type 2	Type 3
Approaches to and across major junctions (all limbs) Gradient 5% to 10%, longer than 50m Bend (not subject to 40mph or lower speed limit) radius 100m – 250m Roundabout	3,500	1,000	250
Gradient >10%, longer than 50m Bend (not subject to 40mph or lower speed limit) radius <100m	2,500	750	175
Approaches to roundabout, traffic signals, pedestrian crossing, railway crossing, etc	2,500	500	100

Some of the advantages and disadvantages of high-friction surfacings are:

- **Speed of application:** The chemical cure systems can be mechanically applied quickly over a site, but the binder needs to cure before the road can be re-opened to traffic and the time required can be considerable at low air temperatures. The thermoplastic systems are labour intensive to apply, but they can be trafficked as soon as they have cooled sufficiently, which is obviously advantageous for some roads.

- **Initial skid-resistance:** As all the faces of the aggregate particles in the thermoplastic systems start by being encapsulated by the binder, this resin film on the top surface needs to be worn off by traffic before giving the intended level of friction. The chemical cure system does not have this disadvantage but inadequately bonded particles on the surface may be dislodged during the early life of the surfacing.

- **Visual impact:** Unlike bitumen-based surfacings, resins tend to be colourless, and can thus be coloured much more easily to make a visual impact, generally for demarcation between different uses or zones (see Appendix A.7). If there is no requirement for high frictional properties at a location, aggregate with high skid-resistance need not be used, but if the material is not being used across the whole width of any lane, the aggregate should match that of the remainder of the surfacing.
- **Driver attitude:** High-friction surfacings are used extensively on the approaches to almost all the roundabouts (and/or pedestrian crossings) in some areas. It has been argued that this near-universal use could lead to some drivers approaching all roundabouts at such high speeds that they need the high-friction surfacing to be able to stop under normal, rather than emergency, conditions. If this is the case the lack of high-friction surfacing or worn surfacing may make such approaches particularly unsafe.
- **Stability of lorries:** On sites with extended approaches, again it has similarly been argued that the use of high-friction surfacing has led to commercial vehicles cornering at high speeds which could result in vehicles with high centres of gravity overturning in extreme cases.

The current MOLASSES accident database indicates that for applications of high-friction surfacings in urban locations an average saving of 32 per cent has been achieved.

Some examples of the use of high-friction surfacings are included in this appendix.

High-Friction Surfacings: Suburban

Rowton Heath Way and Shaw Road, Swindon

Location:	Shaw Road (above photographs) and Rowton Heath Way	
Site Description:	Bend with Cycle/pedestrian crossing	
Problems:	Poor definition of footpath/cycle track crossing	
Aims:	To reduce speed and raise awareness of crossing and the profile of cycling/walking	
Treatment:	Green anti-skid surfacing before crossing and warning signs	
Implemented:	August 1999	
Cost:	£3000 each scheme	
Comments:	Low cost scheme to assist cyclists	
Effectiveness:	Accidents (pia) Rowton Heath	Accidents (pia) Shaw Road
Before:	1 cycle accident in 3 years	2 cycle accidents in 3 years
After:	0 to date	0 to date

Authority: Swindon Borough Council

High-Friction Surfacings: urban

Hetton-le-Hole, Sunderland

Location:	Hetton-le-Hole, Sunderland
Site Description:	District shopping centre – A182 mixed use Primary Route 30 mph, lit urban. Pelican crossing.
Problems:	High degree of conflict between pedestrians and vehicles resulting in injury accidents. Injuries mainly involving pedestrians. Difficulty in providing any further separation between pedestrians and vehicles. Injury accidents occurred mainly in the dry.
Aims:	Help drivers stop more quickly in emergency.
Treatment:	Application of high friction surface dressing to each approach (50m) to the pelican.High friction surface dressing comprised a resin binder with calcined bauxite aggregate which has a PSV of 70+.
Implemented:	1991
Cost:	£3,500 (approx)
Comments:	This was an early treatment which involved the application of a thermoplastic material to bond the high friction aggregate to the road surface. The buff colour may have helped alert drivers to the need for caution.
Effectiveness:	Accidents (pia)
Before:	5 in 3 years
After:	0 in 3 years

Authority : Sunderland City Council

A.2 Bus stops and lanes

With greater traffic flows in towns and cities it is becoming increasingly necessary to provide buses with priority over other forms of traffic, ie. by giving buses exclusive or priority access to a section of road. This can be achieved by using some of the following features:

- Full or part-time, with-flow bus lane
- Bus-only roads
- Contra-flow bus lane
- Exemption from banned turn
- Bus gate
- Bus way

Full segregation should be considered where road space is available but this is not always possible. It is especially important that bus lanes are kept clear of obstruction. As a bus moves round the obstruction there is a danger that it will be in collision with other vehicles or have to brake heavily to avoid collision. If bus lanes are to work effectively, other vehicles must be prevented from driving or parking in them.

There are a number of solutions to the problem associated with keeping bus facilities clear of obstruction:

- *Colour differentiation of road surface.* Red or green surfacing is increasingly being adopted, which is intended to reduce unintentional encroachment by other vehicles. (Refer to following example site).
- *Full segregation.* Here the bus lane is separated from the remainder of the carriageway by a kerb. This solution is most commonly used for contra-flow bus lanes. This solution should only be considered if there is sufficient available road width, and separate provision has been made for cyclists.

- *Traffic Islands.* Islands make separation of the bus lane from the rest of the carriageway more obvious and may mean that a conscious driving decision is needed to enter the priority lane.

In general, it is recommended that the solution adopted is, as far as possible, self-enforcing.

Care should be taken in the design and location of ***bus stops***. At bus stops there is a danger of pedestrians stepping out from the kerb, especially at more informal bus stops. Ideally the location of the bus stop should have the following characteristics:

- The bus driver and the prospective passengers should be clearly visible to each other (refer to following site example).
- The footway width should be adequate to maintain a clear route for pedestrians around the back of the shelter or queue.
- It should be located away from sites likely to be obstructed by parked vehicles. If this is not possible then bus boarders should be considered (see following example), or making the road an urban clearway.
- It should be relatively close to pedestrian crossings, although at a position where vision is not obstructed by stationary buses, and should be clear of junctions, bends, traffic signs, traffic signals, and other traffic hazards.
- Stops should be located where possible “tail to tail” on opposite sides of the road allowing sufficient space between the rear-ends of the bus stop markings for other vehicles to pass.
- Located near pedestrian routes to principal focal points and sited to minimise walking distance between interchange stops and crossroads.
- Located clear of large objects such as hoardings or bushes which carry a personal security risk.
- Always well lit and possibly equipped with CCTV.
- It should be of a standard and consistent design.

Also at many bus stops there is a problem of illegal parking. This is inconvenient and can lead to the bus not being able to take up the correct position at the stop. This may result in part of the vehicle jutting out into the carriageway. Also if the kerb height is similar to the height of the floor of the bus, then illegal parking may result in a gap between the bus and the kerb that could lead to a passenger falling.

One solution that could be considered is the construction of a *Bus Boarder* (refer to following example). These pavement build-outs have several advantages:

- They allow the bus to pull up easily alongside the kerb.
- They discourage parking opposite the bus stop.
- They bring the bus to a stop in the main carriageway, which has a calming influence on other traffic.
- They ensure that passengers and pedestrians have a clearer view of their surroundings.

Where space permits in busy town areas where several bus services operate, the use of staggered or ‘saw tooth’ bus bays (such as those shown in the following example) is thought to be beneficial as it ensures a more precise stopping zone, a clear view between drivers and waiting passengers, and a more deliberate, slower (and hopefully more cautious) exit of buses from the stop.

Mixed Priority Route: use of bus boarders

Shirley Area, Southampton

Location:	Shirley Road/Shirley High Street, Southampton.		
Site Description:	Mixed Priority Route with through traffic and residential functions.		
Problem:	Large proportion of accidents involving vulnerable road users.		
Aims:	Reduce speeds and reduce the number of vulnerable road user accidents. Improve facilities for pedestrians.		
Treatment:	Footway extensions, pedestrian crossings, special bus stops, sheltered parking, central islands, visually narrowed appearance of the carriageway, pedestrian clearways.		
Implemented:	In phases between July 1995 and January 2001.		
Comments:	Use of many different measures in combination.		
Effectiveness: (Shirley Road only)	Accidents (pia)	Pedestrian accidents (pia)	Pedal Cycle accidents (pia)
Before:	70 in 3 years	20 in 3 years	18 in 3 years
After:	68 in 3 years	10 in 3 years	17 in 3 years

Authority: Southampton City Council

Bus Route: coloured bus lanes and staggered bus bays

Fleming Way

Location:	Fleming Way, Swindon.
Site Description:	Dual Carriageway with bus stops and bus lane.
Problems:	Conflict between vehicles and buses rejoining the main carriageway and inadequate passenger waiting facilities.
Aims:	To reduce conflict and to provide a bus passenger facility in keeping with the council's strategy for encouraging the use of public transport.
Treatment:	'Saw tooth' bus bays, bus only lane with coloured surface, quality shelters and pedestrian railings along centre of dual carriageway.
Implemented:	Late 1990s
Cost:	£50,000
Effectiveness:	Accidents (pia)
Before:	N/a
After:	N/a

Authority: Swindon Borough Council

Red light cameras

A.3

The objective of red light cameras at signal controlled junctions is to reduce the number of accidents caused by drivers' non-compliance with a red signal. Like speed cameras, the equipment automatically gathers photographic evidence of vehicles not complying with the red signal to which it is linked. The evidence needs to be studied by a police officer, and offenders are then issued with a conditional offer of fixed penalty.

The Road Traffic Act 1991 permitted evidence from type-approved automatic devices to be used as the sole evidence that an offence had been committed. Research in other European countries has indicated greater overall public acceptance of red light cameras to detect traffic light offences compared with speed cameras, probably because the offence is considered to be more likely to result in accidents (Muskaug,1993).

The red light camera detects red signal infringements normally by means of inductive loops spaced about 1 metre apart, with the first being a short distance beyond the approach arm stop line. This accurately detects the time (into the red phase) of an infringement and the vehicle speed as well as taking two photographs of the offending vehicle.

Like speed cameras, automatic enforcement systems require annual calibration and servicing in addition to the costs of changing and collecting a film, though some authorities are finding red light cameras somewhat less costly than speed cameras. However, it is expected that legislation will soon be enacted following the current trial of netting-off fine revenue in 8 areas in England, Scotland and Wales, whereby fixed penalty fines can be used directly to cover installation and running costs of red light and speed enforcement cameras.

Red Light Cameras: urban locations

Glasgow

Location:	Bridge Street, Garscube Road, Edinburgh Road, Ballater Street, Auldhouse Road, Aikenhead Road, Glasgow.
Site Description:	Six junctions within the City of Glasgow were used in the red light initiative, chosen on the basis of their accident histories. For the purposes of the evaluation a further six 'non camera' control sites were identified for inclusion in the surveys.
Problems:	An analysis of injury road accident data for Glasgow District in 1992 revealed that red-light running was the primary cause of 17% of accidents at signal controlled junctions and it was a possible contributory factor in a further 8% of accidents.
Aims:	The objective of Strathclyde's red light camera initiative (jointly funded by Strathclyde Police and Glasgow City Council) is to promote road safety and to reduce road accidents associated with non-compliance with traffic signals.

Treatment:	Six junctions had speed cameras fitted to one arm of the junction.		
Implemented:	Installed in Spring 1990, although not operational until late 1991.		
Cost:	£452,000 including operation (3 years & includes 2 more sites by 1996). NPV= £1million.		
Comments:	Successful in altering behaviour. Indications of reduced infringements also on approach arms without cameras and at junctions within signed area but without cameras. Publicity and signing an important component of the initiative.		
Effectiveness:	Injury accidents (red running primary cause)	Infringement rate*	Infringement time into red > 1sec**
Before:	71 in 3 years	6.1%	137 cases
After:	27 in 3 years (62%reduction)	2.7% (59% reduction in numbers)	57 cases (58% reduction)

* The infringement rate is the total number of infringements divided by the total number of opportunities to infringe, ie. it takes account of variable flow or congestion levels at the junctions.

** Number of infringements by more than 1 second into red phase over 19-hour survey. After survey = 3 years later.

Ref: The Scottish Office, (1995a).

Authority: Glasgow City Council

Speed cameras

A4

The objective of speed camera enforcement is to persuade drivers exceeding a specific speed limit to slow down. Lower speeds can be expected to result in fewer road traffic accidents and less severe casualties. However, camera detection of offences needs to work together with engineering and educational measures aimed at safe driver behaviour, not to replace them.

Commercially produced speed cameras linked to either inductive road loops or pneumatic tubes (and latterly to radar, piezo cables, video, or lasers) have been available for about thirty years and have been used in the UK since 1991. The Road Traffic Act 1991 permitted evidence from type-approved automatic devices to be used as the sole evidence that an offence had been committed. This was supported by the ability to forward conditional offers of a fixed penalty to offenders by post. This has led to a rapidly increasing number of cameras for the enforcement of speed limits (and also traffic signals).

Speed enforcement equipment can be used in the 'stand alone' mode (unattended), or the 'manned mode' (with police officers present). The stand-alone mode of operation at a fixed location is normally mounted in an enclosure on a pole (see following example). Mobile tripod mounted systems are used in the manned mode and can be deployed quickly at a site where enforcement is required. Secondary checks are employed to the system to confirm the accuracy of the speed measurement. For example, normal systems take two photographs of an offence, separated by 0.5 seconds. With road markings of a known fixed distance apart appearing in the photographs (see following example photograph), it is possible to calculate the speed of the offending vehicle by photogrammetry.

High-resolution film enables recording of an offence with sufficient contextual information, such as the location of the site and colour of the vehicle, to put the offence beyond dispute. Vehicle registration numbers can be read easily using a specialised viewer and since a flashgun operates each time a picture is taken, darkness presents no difficulties. Lower resolution video based systems require two pictures:

a close-up of the registration number for vehicle identification purposes and a wider-angle picture for the contextual information.

The disadvantage of film based systems is that they can only record a limited number of offences (up to 400 per roll) before the site has to be visited in order to change the film. Video based systems in principle allow instant data transmission via a telemetry link so that processing can be speeded up, although this is not generally used. A new digital system, SPECS, uses information collected at two points to calculate average speeds between those points. This new SPECS digital system can hold many thousands of offences that can be stored by the roadside, which results in considerable savings in running costs. (It is currently operating in Nottingham which forms part of the netting-off trial).

Enforcement systems require annual calibration and servicing in addition to the costs of changing and collecting films. The annual cost of running a fixed camera site may be as much as 50 per cent of the initial installation. The Vehicle (Crime) Act 2001 permits the Secretary of State to make payments to Local Authorities and the police to cover safety camera activity. However, results of the current trial of netting-off fine revenue in 8 areas of England, Scotland and Wales, whereby fixed penalty fines can be used directly to cover installation and running costs of enforcement cameras, will inform decisions about whether the arrangements will be extended nationally. Based on provisional results it is very likely that Ministers will agree to national roll out in Summer 2001.

General observations from speed camera sites are:

- The cameras are effective in deterring speeding drivers.
- The mean and 85th percentile speeds are reduced at the site itself, though often by small amounts (e.g. 3mile/h in mean and 4.5 mile/h in 85th percentile).
- The lengths of road over which the cameras are effective can be quite small (as little as a few hundred metres).
- Speeds may be reduced in both directions while enforcing in only one direction.
- Speeds are reduced at sites that are not actively enforcing (i.e. no camera present in housing).

- There are also indications of the signing of speed cameras (without even the housings installed) having a speed reducing effect for many drivers (Corbett & Simon, 1999).
- Under high flow conditions such as daytime motorway contra-flows, cameras can be very effective (up to 10mile/h reduction in mean speed).
- Accident reductions are achieved when sites are selected appropriately. The current average reduction in injury accidents has been found to be 28 per cent from an average 4.2mile/h reduction in mean speed. Accident reductions may also occur at junctions on the camera routes (see Hooke et al, 1996).
- Accident benefits in the ‘fatal’ and ‘serious’ category are greater than in the slight category.
- There appears to be little change in accidents or speeds on roads adjacent to the sites.

Individual cameras have been shown to have rather localised effects, and considerable numbers of camera installations may be required for effective speed control within an area.

Speed Cameras: various urban locations

East Dereham, Norfolk

Location:	Toftwood, East Dereham, A1075 Dereham-Thetford, Norfolk.	
Site Description:	Southern spur (A1075) linking Dereham to Thetford passes through the conurbation of Toftwood.	
Problems:	The speed limit on the A1075 is 30mph through Toftwood but due to the road being straight and wide, speeds are higher than this and considered to be a major contributor to casualties. There are numerous features that create conflicts along this road such as schools, social clubs, public houses and shops.	
Aims:	To reduce the speeds of the fastest drivers through Toftwood on the approach to a dangerous junction.	
Treatment:	Installations of automatic speed camera and two Police enforcement camera signs.	
Implemented:	1997	
Comments:	Signs shown separately to have a highly significant effect on vehicle speed reduction. Vehicle speeds are affected in both directions even though the speed camera was uni-directional in its operation. Accident benefits may be much greater than predicted from the accident model. Drivers acknowledged the safety benefits that were possible as a result of speed camera installation but did not understand the penalty system: increased publicity may improve deterrent effect.	
Effectiveness:	Accidents (pia)	Percent of vehs. exceeding 35mph
Before:	N/A	Site1:12% Site2: 42%
After:	N/A (22-34% predicted)	Site1: 4% Site2: 29%

Authority: Norfolk County Council

Speed Camera: suburban

Bicester, Oxfordshire

Location:	Launton Road, approximately 30m north east of Lamborne Crescent, Bicester.			
Site Description:	Urban single carriageway with a 30mph speed limit.			
Problem:	Accidents and conflicts involving excessive speed.			
Aims:	To reduce speed of at least eastbound vehicles.			
Treatment:	Provision of Gatso fixed site speed camera (for eastbound vehicles).			
Implemented:	March 1994.			
Cost :	£7,500.			
Comments:	Monitoring of speed camera sites shows wide variation in observed accident changes. In built-up areas, there has been an average 30% reduction in accidents (measured over 0.5km road length each side of camera housing). Accident benefits have been less in rural areas, though again there is a wide variation between sites).			
Effectiveness:	Accidents (pia in 5 years)	Casualties (5 years)	85th Percentile Speeds (mph)	Traffic Flow (AADT)
Before:	29	37	35	12161
After:	18	21	33	13182

Authority: Oxfordshire County Council

A.5 Chevron markings

Chevron markings are inverted 'V'-shaped markings, laid at intervals in the centre of traffic lanes. The markings are designed to improve safety by encouraging better driver following behaviour. Trials were carried out on the M1 in 1990 (Webster et al, 1992; Helliar-Symons and Butler, 1995; Helliar-Symons et al, 1995a).

At the two trial sites the markings were laid for 4-5km at 40m intervals in the nearside and centre lanes. Roadside signs advise drivers to 'Keep apart, 2 chevrons' (see example).

The following results were achieved:

- a 15% reduction in the percentage of drivers following with a gap of less than one second (two marked lanes).
- a 5% reduction in the percentage of drivers following with a gap of less than two seconds (two marked lanes).
- an improvement in close-following behaviour in the unmarked (outside) lane.
- little change in vehicle speeds.
- a statistically significant overall accident reduction of 56%.
- a beneficial safety effect persisting for 18km beyond the start of the Chevrons.
- a reduction of 40% in multi-vehicle accidents.
- an even greater reduction in single vehicle accidents.

The latter result may be due to the Chevrons acting as an alerting device to drivers travelling in a relatively stimulation-free environment.

Opinion surveys established that the vast majority of drivers:

- understood the purpose of the markings.
- felt they were helpful.
- tried to use the Chevrons and had done so without difficulty.

Application:

- Chevrons are intended for use in relatively low flow conditions; if flows are high it is unlikely that drivers will respond to them effectively.
- All drivers travelling in a lane marked with Chevrons should be able to see the signs explaining their use.
- Markings at intervals of 40m, if used correctly, will encourage drivers to adopt a two-second gap at a speed of 70 mile/h.

An example of a Chevron installation is included in this appendix.

Note that these markings require special authorisation. Future installations will be required to place the Chevrons in all three lanes. Guidance on the correct layout and criteria for their use will be published in the new edition of TSM Chapter 5 (expected 2001).

Chevrons: motorway

M1 – Northamptonshire

Location:	M1 southbound between junctions 17 and 16, Northamptonshire.
Site Description:	Relatively flat, 3-lane motorway.
Problems:	Large numbers of nose-to-tail multi-vehicle collisions owing to drivers following too closely to the vehicle ahead.
Aims:	To attempt improvement in drivers' following behaviour and reduce frequency of such collisions.
Treatment:	Chevrons (3m in length) marked on the road surface in lanes 1 and 2 every 40m for a length of approximately 4kms. Roadside signs to advise drivers of the marking (DETR Drawing WBM390 – "Keep apart , 2 chevrons") provided at 100m, 1km and 2 km from start of pattern.
Implemented:	Dec 1990.
Cost:	£20,000 (1993 prices).

Comments:	Large reduction in single vehicle accident unexpected. Positive effect on close following estimated to persist for 18kms. 98% of drivers interviewed noticed chevrons and signs and 89% thought helpful.			
	Note: that these markings require special authorisation. Future installations will be required to place the Chevrons in all three lanes. Guidance on the correct layout and criteria for their use will be published in the new edition of TSM Chapter 5 (expected 2001).			
Effectiveness:	Accidents (all pia)	Multi-vehicle (pia)	Percentage of drivers with gaps < 1sec	Flow
Before:	93 in 3 yrs	69 in 3 yrs	21.6% – on chevron site 22.6% – downstream	55,000
After:	24 in 2 yrs (42% reduction)	22 in 2 yrs (56% reduction)	14.1%- on chevrons 16.1% downstream	47,400

Authority: Highways Agency

A.6 Chicanes/ narrowings

Various types of *horizontal deflections* have been used in traffic calming schemes to reduce the speed of traffic. Chicanes are one type of horizontal deflection, formed by building out the kerbline to narrow the carriageway, usually on alternate sides of the road. Drivers reduce speed to negotiate the lateral displacement in the vehicle path.

There is generally less passenger discomfort, particularly for disabled people, associated with chicanes than with road humps, and it is possible to narrow the carriageway, while still allowing accessibility for large vehicles and emergency vehicles, by incorporating overrun areas into the chicane design.

Chicane designs vary considerably but two broad categories exist:

- single-lane working – consisting of staggered buildouts, narrowing the road so that traffic in one direction has to give way to opposing traffic;
- two-way working – using buildouts to provide deflection, but with lanes separated by road markings or a central island.

Chicane dimensions and spacing can be varied depending upon the road type and the 'target' speed required. Traffic Advisory leaflets 9/94 and 12/97 give advice on the acceptable levels of flow for single lane working chicanes, the principles governing chicane design, and summarise the results of test track trials and public road studies carried out by TRL (Sayer and Parry, 1994; Sayer et al, 1998).

Cyclists often express concern about being "squeezed" by motor vehicles when cycling through narrowings such as chicanes. Where possible, a cycle bypass around the chicane as described in TAL 1/97 should be considered (TAL 12/97).

Reductions in speeds, flows and injury accidents

The speed of vehicles through chicanes is influenced by the chicane width and the path angle (*the angle through which the traffic is displaced*). An increased path angle leads to a reduction in speed. In general path angles greater than 15° are likely to reduce mean speeds to less than 20 mph, while path angles of less than 10° are likely to give mean speeds of 25 mph or more (TAL 12/97).

Chicanes have tended to be installed on roads with higher *Before* speeds than road humps or speed cushions (Sayer et al, 1998). While average speed reductions of 12 mph have been achieved in chicane schemes, the *After* mean speeds at and between chicanes are higher than that for road humps or speed cushions.

At single-lane working chicanes (with generally greater path angles), the average mean speeds were 21 mph at the chicanes and 23 mph between chicanes. At two-way working chicanes (with generally smaller path angles), average mean speeds were 27 mph at the chicanes and 31 mph between the chicanes (Sayer et al, 1998).

Changes in flow at chicane schemes were highly variable (-55% to +12%). On average, flows were reduced by 15 per cent at single-lane working and 7 per cent at two-way working.

Limited accident data for chicane schemes indicate a reduction in injury accidents (54%) and accident severity (TAL 12/97). Current MOLASSES data show that injury accidents at chicanes or narrowings in urban areas have been reduced, on average, by 47%.

Although chicanes have shown an overall reduction in injury accidents, vehicles are known to have collided with the kerb buildouts at some chicanes resulting in damage only and injury accidents. TAL 12/97 gives guidance on the location and signing of chicanes and the need to check and maintain signs and illumination.

Public attitudes

It is important that the design and location of chicanes are carefully considered as operational problems and public disapproval can result in scheme removal (Sayer et al, 1998).

Attitudes towards traffic calming schemes which include chicanes are very variable (Webster, 1998). Schemes including horizontal deflections are typically less acceptable than road hump schemes, and chicane schemes are perceived to be less effective and are less popular than road humps.

Noise and vehicle emissions

Chicanes are likely to generate less vehicle body rattle noise than road humps. However, chicanes may encourage more stopping, starting, acceleration and braking noise, and at times these can create a nuisance (TAL12/97).

Boulter (2000) found a good deal of overlap between the effect of different types of traffic calming measure on vehicle exhaust emissions. The increases in emissions at a single-lane working chicane varied between pollutants. Vehicle emissions are likely to be higher at chicanes where the opposing flows result in substantial queues of vehicles occurring.

Chicanes: residential estate

Pinehurst, Swindon

Location:	Pinehurst Road C404, Swindon.
Site Description:	Straight sub-urban tree lined road residential frontages little parking, major bus route. Traffic calmed over approximately 1 mile.
Problems:	Child pedestrian accidents.
Aims:	Reduce accidents, reduce speed and discourage through traffic.
Treatment:	Four Chicanes, two pedestrian refuges and build outs at Pelican Crossing.
Implemented:	April 1994.
Cost:	£25,000.
Comments:	Drivers are dissatisfied by delays at chicanes. Reports of aggressive driving against priority flow. Problems with illumination of build outs due to trees. *Note: Worded legend on sign should be lower case.*
Effectiveness:	Accidents (pia)
Before:	24 in 4 years
After:	13 in 6 years

Authority: Swindon Borough Council

Chicanes: major road traffic calming

Huntington Road, York

<table>
<tr><td>Location:</td><td colspan="4">Huntington Road, York.</td></tr>
<tr><td>Site Description:</td><td colspan="4">Arterial route towards city centre.</td></tr>
<tr><td>Problem:</td><td colspan="4">Poor accident record. Relatively high speeds (85th percentile speed of 35mile/h, but maximum recorded =61mile/h).</td></tr>
<tr><td>Aims:</td><td colspan="4">To reduce speeds with cycle and bus- friendly measures. Emergency service vehicles should not be impeded.</td></tr>
<tr><td>Treatment:</td><td colspan="4">Road narrowings on main road – scheme also includes mini-roundabouts.</td></tr>
<tr><td>Implemented:</td><td colspan="4">March 1998.</td></tr>
<tr><td>Cost :</td><td colspan="4">£33,000.</td></tr>
<tr><td>Comments:</td><td colspan="4">Spacing of measures considered critical (approximately 55m). There was a need to consider carefully the location of bus stops.
Note: The chevron sign (diag. 515 of HMSO, 1986b) is normally intended for use on sharp bends.</td></tr>
<tr><td rowspan="2">Effectiveness:</td><td rowspan="2">Accidents (pia in 3 years)</td><td colspan="2">Speeds (mph)</td><td rowspan="2">Traffic Flow (daily)</td></tr>
<tr><td>Mean</td><td>85th per centile</td></tr>
<tr><td>Before:</td><td>6</td><td>32</td><td>35</td><td>8,000</td></tr>
<tr><td>After:</td><td>2</td><td>22</td><td>29</td><td>6,500</td></tr>
</table>

Authority: City of York

A.7 Coloured road surfacing

The availability of coloured road surfacing has increased dramatically over the last five years or so. Coloured road surfacing is now commonly used to:

- highlight traffic calming features and village gateways.
- visually segregate the road space, enhancing bus lanes, cycle lanes and central hatched islands without the need for physical engineering measures (see CSS, 2000).

Highway engineers have experimented freely with colours to try to enhance the impact of schemes in a cost-effective way. Consequently, across the network, different colours have been used for the same type of application and little robust monitoring has been carried out to assess the effectiveness of the use of colour.

Recently, the County Surveyors Society and the Highways Agency have drawn on shared experiences to provide some advice on good practice (CSS, 2000; DMRB TA 81/99). The advice addresses the issues relating to choice of colour and material, type of application, skid resistance, maintenance, colour fading and disintegration, possible confusion to road users, danger of over-use and environmental acceptability.

Some examples of coloured road surface installations are included in this appendix.

Coloured Road Surfacing: used outside a school

Vale of Glamorgan

Location:	Cadoxton School, Vale of Glamorgan.
Site Description:	School crossing patrol on brow of hill and slight bend outside entrance to junior school.
Problems:	Four reported accidents during times of school crossing patrol. Drivers approaching quickly and unsure where to stop, frequently coming too close and also not applying handbrake, intimidating the patrol and schoolchildren.
Aims:	To make crossing area more noticeable to approaching drivers.
Treatment:	Trial coloured red road surface for approximately 5m section in zone of school crossing patrol, and temporary narrowing of road width.
Implemented:	Aug 1999.
Cost:	£1800.
Comments:	There is no legal obligation for drivers to stop when the school crossing patrol is not present. Trial now extended to 18 other schools.
Effectiveness:	All drivers observed to be stopping well in advance of the coloured zone allowing a well defined clear area for the patrol to operate and children to cross.

Authority: Vale of Glamorgan Council

Coloured Road Surfacing: And Cycle Lanes

North Moor Road and Strensall Road, York

Location:	Huntington, York.			
Site Description:	Arterial route towards city centre.			
Problem:	Poor accident record with concerns expressed by many over safety of school children.			
Aims:	Improve safety for cyclists.			
Treatment:	Coloured road surfacing as part of traffic calming scheme – also includes cycle lanes.			
Implemented:	Phase I: April 1999 and Phase II: April 2000.			
Cost :	£15000 and £2000.			
Comments:	Part of rolling programme of measures. *Note: cycle lanes are less than 1m width in places.*			
Effectiveness:	Accidents (pia)	Speeds (mph) Mean	85th percentile	Traffic Flow (daily)
Before:	15 in 3 years	31	36	8,000
After:	5 to date	N/A	N/A	8,000

Authority: City of York

Cycling facilities

A.8

Research has shown that cyclists' greatest concern in the journeys they make is the danger from motor vehicles. This is a major deterrent to increasing the use of the bicycle as a means of transport (Davies et al, 1998; ETSC, 1999). Although it might be argued that 'more cycling means more accidents', cities like York (IHT, 1996a) have achieved substantial reductions in casualty numbers, including cyclists, whilst promoting cycling and maintaining high levels of use. From the MOLASSES database, cycling schemes have produced an overall reduction of 58 per cent in injury accidents.

To reduce the feeling of intimidation by motor vehicles, there is generally a need to redistribute road carriageway space using techniques such as cycle lanes, bus/cycle lanes, wider nearside lanes, and vehicle access restriction. Many of these also require complementary enforcement and education measures. The most common journeys by bicycle, like routes serving schools, railway stations, large employers and town centres should be given a high priority. However, those that serve both leisure and utility services, (eg. linking town centres and the countryside) should also be assigned additional priority.

Cycle contra flow systems have a good safety record and are well liked by cyclists, particularly if they provide a more direct route through a town. Even shared ***bus lanes*** are generally regarded as safer for cyclists than sharing the normal carriageway space, that is, where restricted width precludes the marking of a designated cycle lane.

Traffic calming should bring welcome benefits to cyclists but unfortunately not all highway authorities do consider cyclists, and sometimes new hazards are introduced, eg. where the carriageway is narrowed by central refuges, pinch points, chicanes etc. Ideally, either adequate width should be left available or cycle by-passes provided (see example in Appendix A6).

Advanced stop lines have been found to be a useful facility for cyclists at signalised junctions (Ryley, 1996). However, if straight or right-turning cyclist flow or left-turning motor flow is high it is preferable to install a central or offside approach cycle lane (see TA 5/96). Toucan crossings for pedestrians and cyclists (two can cross – see TA 4/98) have also proved successful, particularly when fitted with infra-red detection.

Most pedal cyclist accidents occur at or close to junctions and ***roundabouts*** tend to be particularly hazardous for cyclists: small island roundabouts having the highest cyclist accident rate (Kennedy et al, 1998) where the predominant accident type is an entering driver colliding with a circulating cyclist. It has been recommended that for total vehicle inflows of less than 2,500 per hour, tighter geometry similar to that common in continental Europe is safer for cyclists (Davies et al, 1997). Key features for this design of roundabout are:

- Radial arms (instead of tangential to the roundabout centre).
- Single lane entry and exits (with width 4-5m).
- Minimal flare in entry.
- An inner circle (centre island) of 15-25m diameter.
- An external circle (inscribed circle) of 25-35m diameter.
- A circulatory carriageway of 5-7m.

Cycle track at roundabout: use of coloured road surfacing

A4259 County Road/Station Road, Swindon

Location:	A4259 County Road/ Station Road, Swindon (Transfer Bridges South).
Site Description:	Large roundabout with high flow.
Problems:	Cyclists – accidents.
Aims:	To provide road space for cyclists and raise the profile of the cycletrack network.
Treatment:	Coloured road surfacing to provide channelisation.
Implemented:	November 1999.
Cost:	£10,000.
Comments:	Scheme linked to dual Toucan Crossing on B4289 Gt. Western Way. *Note: The hatched marking is normally bounded by dashed rather than solid lines.*
Effectiveness:	Accidents (pia)
Before:	6 (3 cycle) accidents in 3 years
After:	1 (1 cycle) accident in 1 year

Authority: Swindon Borough Council

Annular cycle track at multiple roundabout

'Magic Roundabout', Swindon

Location:	Magic Roundabout, Swindon.
Site Description:	Multiple mini-roundabouts.
Problems:	Cyclists accidents at busy complex junction.
Aims:	Provide alternative route for cyclists.
Treatment:	Introduction of short lengths of cycle tracks (arrowed on photograph above) and signal controlled crossings.
Implemented:	March 1995.
Cost:	£65,000.
Comments:	Encouraging accident results. *Note: Regulations do not allow use of concentric circles on mini-roundabouts.*
Effectiveness:	Accidents (pia)
Before:	27 accidents in 5 years
After:	19 accidents in 4 years

Authority: Swindon Borough Council

Gateways

A.9

Gateways are devices used to mark a threshold – to a village or special road environment requiring lower speeds and greater attentiveness than on the present road on which the driver is travelling. They are provided for in The Highways Regulations 1999: to be used "to indicate the presence on a length or lengths of highway of traffic calming works".

Gateways now exist in a very wide variety of forms but their common main feature is the conspicuous vertical element at the side of the road, normally constructed on the verge. The following elements have been widely incorporated:

- Enhanced signing, often with yellow backing boards.
- Coloured surfacing, often with a speed limit roundel.
- Narrowing, either by physical measures or by road marking.
- 'Dragon teeth' which create a visual impression of the traffic lane narrowing.

Paving, grass or other cover, walls, rails, fences or plants may also be included.

Countdown signs have been used on the approach to gateways.

The reductions in average vehicle speeds achieved by gateway treatments vary considerably (Wheeler et al, 1994; Wheeler and Taylor, 1999). Typically they are:

– 1-2 mile/h from simple signing/marking;

– 5-7 mile/h from more comprehensive signing/marking with high visual impact; and

– about 10 mile/h with physical measures.

Measures need to be continued beyond the gateway (through a village for example) if speed reductions are to be maintained there.

Generally speaking, the more measures used in combination and the greater their conspicuity, the better the effect. This does, however, present a conflict, particularly in rural situations between effectiveness and visual intrusion, which is not easily resolved.

Injury accident reductions are now known to have been achieved across villages in which a range of measures (mainly gateway, with or without additional measures in the village) have been installed. Wheeler and Taylor (2000) show a reduction in all injury accidents of up to a quarter and in fatal/serious injury accidents of up to a half.

Gateways need to be sited with a clear sight line, which is recommended to be at least the stopping distance for the 85th percentile approach speed (TAL 13/93). They should not be sited where they may cause a hazard, ideally avoiding encroachment of footway or cycle track, and should not interfere with access to frontage property. They should also be designed to be structurally ‘forgiving’ so as to minimise the likelihood of increasing injury in the event of a vehicle colliding with them.

Gateways: rural village

Sanquhar, Dumfries & Galloway

Location:	A76, Sanquhar.		
Site Description:	Large village on trunk road; straight northern approach.		
Problems:	Local concern about speeding to north of village centre in area of pedestrian activity connected with school.		
Aims:	To reduce accidents and excessive speeds in this part of the village.		
Treatment:	Gateway preceded by bar and school markings before start of 30mph limit and roundels on one approach.		
Implemented:	December 1992.		
Cost:	£20,000 (1999 prices).		
Comments:	Speed limit of 30mph through village. No measures in centre because carriageway narrowing by projecting building already constrained speeds. Larger reduction (6mph) in 85th percentile speeds inside gateway. *Note: The elongated road markings require special authorisation and should also be accompanied by prescribed upright signs (as the former can be very difficult to see on a wet road, especially at night).*		
Effectiveness:	Injury accidents*	Mean Speed after gateway	Flow
Before:	2.0 per year	36 mph	5000
After:	0.5 per year	34 mph	5000

* Before and After periods were approximately 6 years

Authority: Scottish Executive South West Scotland (Trunk Road) Unit (Originally: Dumfries and Galloway Council).

Gateways and other treatments: rural village

Craven Arms, Shropshire

Location:	A49, Craven Arms.			
Site Description:	Large village on trunk road with straight approaches.			
Problems:	Volume and speed of traffic, heavy goods vehicles, perceived danger to pedestrians and cyclists.			
Aims:	To reduce accidents and excessive speeds through the village.			
Treatment:	Gateways preceded by countdown signs and dragon's teeth markings, areas of red surface with 30 roundels, mini roundabouts, speed cushions, pedestrian refuges and centre hatching on a red background. Original 40 mph speed limit reduced to 30 mph.			
Implemented:	May 1995.			
Cost:	£88,000 (1999 prices).			
Comments:	The additional traffic calming measures were only implemented over a distance of 400m of the ~1.5km overall length of village. Before and after speeds in village centre 28mph and 18mph between speed cushions and mini roundabouts. *Note: Upright mini roundabout signs should be placed about 1.5m back from the Give Way line (TSM Ch. 5).*			
Effectiveness:	Injury accidents*	Mean Speed after gateway	Mean speed between cushions & roundabouts	Flow
Before:	5.0 per year	41 mph	28 mph	9000
After:	2.3 per year	33 mph	18 mph	10000

* Before period 8 years and after period 4 years.

Authority: Highways Agency Area 9 (Originally: Shropshire County Council)

Pedestrian crossings

A.10

Much of the safety engineering work to help pedestrians has been concentrated on the more major roads, and has consisted of the installation of pedestrian crossings where either a site-specific history of accidents has occurred, or simply to help appreciable numbers of pedestrians cross a busy road, or on a route to school. Different types of pedestrian crossing have been developed:

– Zebra;

– Pelican (traffic light controlled);

– ‘Puffin’ crossings which have infra-red detection of pedestrians;

– ‘Toucan’ crossings with cycle crossing facilities; and

– pedestrian phases at signalised junctions.

The Pelican crossing, using pedestrian-operated push button control, was designed for higher flows of pedestrians and/or vehicles travelling at relatively high speeds. There are signals for drivers and pedestrians, instructing each when to stop and go. Pedestrians at Pelican crossings only have priority to cross whilst their signal is on steady green but do have ‘right of precedence’ to complete their crossing during the flashing green (flashing amber to vehicles) stage.

The Puffin crossing (**P**edestrian **U**ser **F**riendly **In**telligent Crossing) is a development of the Pelican crossing and is planned to replace the Pelican type as the standard stand-alone pedestrian crossing. It has automatic detection of pedestrians to extend or reduce the all-red period as required to suit the crossing speed of the pedestrian. As well as on-crossing detectors, kerbside detectors can cancel a pedestrian demand if the pedestrian walks away from the crossing point, perhaps having crossed the road in a gap in traffic.

The Toucan (two can cross – see TA4/98) crossing is designed to be a shared crossing for pedestrians and cyclists, with the same form of pedestrian or cyclist on-crossing detector as the Puffin crossing. Kerbside detectors can also be employed but only when nearside signalling is used.

Signalled crossings (which are Puffin-type or Toucan) have been incorporated into the signalling arrangement at junctions, where the red phase for drivers includes a signal aspect for pedestrians crossing at the junction. Indeed, nearside type pedestrian/cyclist signalling is recommended for all such crossings.

Pedestrian crossings are generally placed on busy roads, their function being both to assist pedestrians to cross roads and to do so in greater safety. In making decisions about whether to install a pedestrian crossing, a recommended site assessment framework is described in LTN 1/95, with special provision for Northern Ireland contained in TA 68/96 (DMRB). These procedures include the collection of site information, photographs, maps, difficulties experienced by vulnerable road users etc. so that the road authority can make a balanced judgement on whether the decision can be justified.

Guidance on the installation of pedestrian crossings is given in LTN 2/95 and in DETR (1998d).

The MOLASSES database indicates that casualty savings at pedestrian crossings are between one third and one half of *Before* levels. However, it should be noted that these are average casualty savings and some crossings may actually increase the number of accidents.

Pedestrian crossings

Schemes in MOLASSES database – 64 sites

Raised zebra crossing.

Puffin crossing.

Location:	Various sites in UK.
Site Description:	Mainly urban major links.
Problems:	Pedestrian casualties from crossing the road.
Aims:	To improve safety and make easier the crossing of busy urban streets.
Treatment:	Zebra, pelican and puffin crossings.
Implemented:	1980 to 1998.
Cost:	Average costs: Zebra = £1,800 Pelican = £16,800 Puffin = £22,000
Comments:	In recent years Pelican crossings have generally been installed rather then zebras, without any particular research evidence in their favour. Zebras may be preferable in less busy locations.
Effectiveness:	Injury accidents
Before:	770
After:	449 (42 % Reduction)

Traffic Calming: raised zebras, humps, mini roundabouts

Kennington, Oxfordshire

Location:	Kennington Road and The Avenue between Upper Road and St Swithuns Road junction, Kennington, Oxfordshire.			
Site Description:	Main road through village.			
Problem:	High accident numbers with no dominant types.			
Aims:	To reduce speeds and improve crossing facilities for pedestrians.			
Treatment:	15 road humps (round top 85mm height), 3 mini-roundabouts on flat top humps and 3 raised flat-top pedestrian crossings.			
Implemented:	May 1991.			
Cost :	£65,000 (1991).			
Comments:	The scheme appears to have been very effective in reducing the number of injury accidents. However, concern was expressed by the emergency services and bus operators. In response to this feedback, in early 1999, the profile of humps was amended to present a less severe shape. Monitoring data currently available does not suggest that these modifications have impaired safety.			
Effectiveness:	Accidents (pia in 5 years)	Casualties (5 years)	85th Percentile Speeds (mph) Kennington Rd	Traffic Flow (AADT) Kennington Road
Before:	25	29	37	7125
After:	10	11	28	6332

Authority: Oxfordshire County Council

Refuges/traffic islands

A.11

Islands can be introduced in the highway for a variety of purposes such as: separating traffic moving in opposite directions, facilitating movement by pedestrians and controlling vehicle speeds. However care needs to be taken that islands which substantially narrow the carriageway are not encountered at high speeds, especially if they are combined with kerbside buildouts (TAL 7/95).

It is recommended that islands used for traffic calming purposes should be indicated by internally illuminated bollards incorporating keep left signs if appropriate (TAL 7/95).

In siting islands, consideration should be given to existing and likely pedestrian flows and movements, remembering that pedestrians will cross the road where it is most convenient for them to do so. Where an island is likely to be used as a pedestrian crossing facility, a pedestrian refuge may be more appropriate with dropped kerbs and tactile surfacing (TAL 7/95).

The proximity of motor vehicles is often threatening to cyclists when negotiating localised carriageway narrowings at islands if the width is not sufficient for the two to pass comfortably side by side (TAL 7/95).

Local Transport Note 2/95 recommends that where a pedestrian refuge island is introduced, a vehicle lane width of 4.5m is maintained. Whilst this allows motor vehicles to pass cyclists safely, it has little or no speed reducing effect and, if narrowing is being introduced for traffic calming purposes, a reduced width will normally be necessary.

A cycle bypass should be the first option where a narrowing is introduced on a road subject to a speed limit of 30 or more. If adequate width for a cycle bypass cannot be found, a cycle lane will be the next best solution. Where average speeds are below 20 mph, cyclists and motorists should be able to share space comfortably (TAL 1/97).

Islands do not have to be centrally positioned relative to the carriageway, an offset island may be used, for example, to provide protection for a cycle lane or introduce a cycle bypass, in addition to its speed control purpose (TAL 7/95).

Effect on speeds

Limited studies of specific sites (Cloke et al, 1999; Boulter, 2000) indicate that the speed reducing effect of carriageway narrowings achieved by a series of central islands is likely to be modest (about 4 to 5 mph).

Pedestrian refuge: principal radial route

Tettenhall Road A41, Wolverhampton

Location:	Tettenhall Road (A41), Wolverhampton.
Site Description:	Class 1 Road – Principal radial route serving Wolverhampton City Centre. Site located 600 metres north of Ring Road. Bus stop Clearway Order and Peak period restrictions in force. Adjacent bus stops within 40 metres N of location. Opposing hospital and hotel accesses located within 20 metres S.
Problems:	Pedestrians attracted to this location, (due to proximity of bus stops and the adjacent elderly and rehabilitation hospital) are having difficulty crossing busy road resulting in serious casualties. Traffic speed and volume, on-street multi-occupancy residential parking and location of bus stops considered to be contributing to the dangers. Low PV^2 and local traffic conditions impractical for a formal crossing installation.
Aims:	To provide improved safety at this location for elderly pedestrians and all road users, reduce traffic speed and address the accident rate.
Treatment:	Install 2.0m x 7.2m parabolic pedestrian refuge with tactile paving and flush kerbs on pedestrian desire line. Localised central hatching and access protection markings at hotel. Relocate existing bus stop (E) to left (S) side of hospital access, replacing on-street parking.
Implemented:	May 1999.
Cost:	£7000.

Comments:	Reduction in traffic speed and improved forward visibility. Visibility splays at hospital access also increased. Scheme funded from Minor Works budget (Minor Improvements Programme), usually reserved for small accident remedial schemes. Schemes appear on this programme through either AI identification or by public request.	
Effectiveness:	Accidents (pia – within 100m of refuge)	Traffic Flow
Before:	9 in 5 years (2 fatal, 1 serious, 6 slight)	15000 (12hrs)
After:	2 in 2 years (2 slight)	N/a

Authority: Wolverhampton City Council

Road humps and raised junctions

A.12

Background – Road hump legislation

The 1986 UK Road Hump Regulations allowed round-top humps of 75 mm and 100 mm in height, and 3.7 m in length to be installed on roads in England and Wales with a speed limit of 30 mph or less. The subsequent 1990 Hump Regulations (TAL 2/90) allowed flat-top humps and round-top humps of 50 mm to 100 mm in height, and 3.7 m in length (minimum length for flat-top). Other hump profiles were not permitted under the Hump Regulations (TAL 2/90) but it was possible for local authorities to apply to Department of Transport for special authorisation.

The current Highways (Road Hump) Regulations 1999, which are similar to the 1996 Regulations (TAL 7/96), do not specify an exact hump profile and allow local authorities to install humps (including speed cushions), on roads with a speed limit of 30 mph or less, without the need for special authorisation, providing the humps are between 25 and 100 mm in height, at least 900 mm long, and no vertical face is greater than 6 mm. It should be noted that markings for some types of road humps (e.g. speed cushions) are not yet included in the Traffic Signs Regulations and General Directions, and will require special authorisation. Humps where the height can be varied mechanically will also need special authorisation as their dimensions are unlikely to be included in the aforementioned Regulations.

Road hump installations

Since 1990, when lower height humps and flat-topped humps were allowed, traffic calming has become more widespread in England and Wales. Humps are an important safety/traffic management tool for Highway Authorities because they are effective at controlling speeds, they discourage through traffic and are generally applicable to most road layouts. Humps can be parked on and thus there is no loss of parking space for simple hump designs. Humps and raised junctions can enhance the appearance of a road if designed and built to a high standard but streets fitted with only standard humps may not be visually attractive.

The main objective of road humps is to slow traffic. Drivers experience little discomfort when passing over the humps at low speeds and greater discomfort as speed is increased. Buses, ambulances and commercial vehicles are generally driven over road humps at a slower speed than cars because of the greater levels of discomfort experienced in these vehicles.

Humps need marking, signing and lighting except in 20mph zones (TAL 7/96, TAL 9/99).

Reduction in speeds, flows and injury accidents

The degree of discomfort and subsequent speed reduction can be altered by using different hump profiles and hump dimensions such as height, length and ramp gradient. Humps 75 to 100mm in height reduce mean speeds (midway between humps) by about 10mph and traffic flows by an average of 25% (TAL 2/96; Webster, 1993b; Webster and Layfield, 1996). Injury accidents in hump schemes have been reported to be reduced by up to 70% (Webster, 1993b; Webster and Mackie, 1996), with current average savings on the MOLASSES database showing an even higher reduction of 88%.

TAL 2/96 gives recommended dimensions and spacings for 75mm high road humps. For sites with mean *before* speeds of about 30mph, 75mm high humps can reduce mean speeds midway between the humps to below 20 mph, providing the hump spacing is less than 80m. Spacing in excess of 100m may increase mean "between speeds" significantly (TAL 7/96).

50 mm high humps (Webster, 1994) and thermoplastic 'thumps' (TAL 7/94) have also been used but they have less effect than higher humps and are therefore best suited to 30 mph roads where moderate speed reductions are required.

Hump profiles

Round-top. Round-top (*circular profile*) humps 4ins (102mm) high and 12ft (3.66m) long were developed as a result of track trials at TRL in the 1970s (Watts, 1973). These showed that higher humps were too severe and low/short humps became less effective as speeds were increased. Round-top humps longer than 3.7m cause less discomfort and allow higher speeds. Track trials (Sayer et al, 1999) indicated that a 75mm high, 5m long round-top hump might be appropriate to limit speeds to 30 mph.

Sinusoidal. Humps with sinusoidal profile are similar to round-top humps but have a shallower initial rise. They were developed in the Netherlands and Denmark to provide a more comfortable ride for cyclists (TAL 9/98).

Track trials at TRL (TAL 9/98; Sayer et al, 1999) have shown that compared with a round-top hump, a sinusoidal hump would produce a small reduction in discomfort for cyclists (both humps 75mm high, 3.7m long). Cyclists taking part in the tests indicated that the benefit gained was small and that it was probably more important for local authorities to ensure that there was no large upstand at the leading edge of a hump where it meets the road surface.

Flat-top. Flat-top humps (speed tables) are a commonly used alternative to circular profile humps; they provide flat crossing places and can be used with zebra or signal controlled pedestrian crossings with tactile paving. However, they can cause more discomfort to cyclists, motor cyclists and motorists than similar height round-top humps (Sayer et al, 1999).

The gradient of the flat-top ramps (max 1:10) affects driver/passenger discomfort, with shallower gradients reducing discomfort and allowing higher speeds. The length of the plateau also affects discomfort but in a less systematic manner. Most bus companies prefer a plateau length of at least 6m and a gradient of 1:15 or shallower (Webster and Layfield, 1996).

Raised junctions. Raised junctions are a form of flat-top hump covering the whole junction. The extent to which a raised junction extends into the side road will depend on local factors at the site. An extension of at least 6m will allow cars to be level on the immediate approach to the junction and 'give way' markings placed in the conventional position (Webster, 1993b).

Raised table

Raised junctions may be constructed to 100mm high to bring them close to the level of the adjacent footways. When this height is used ramp gradients should be in the order of 1:15 to 1:20 (TAL 9/99).

Consideration needs to be given to the requirements of visually impaired people where raised junctions are provided.

'H' and 'S' humps. The 'H' hump, which was first developed in Denmark, is a combined car and bus hump (flat-top) with two longer shallower outer profiles to take the tyres of buses, and with shorter inner steeper profiles to take cars. The 'S' hump, developed on similar principles by Fife Council, has an alternative ramp design eliminating some of the problems encountered with the 'H' hump (TAL 9/98).

The 'S' hump, as with most traffic calming measures, does not offer a complete solution in terms of speed reduction. 'S' humps allow higher car speeds and are more 'bus friendly' for large buses than conventional humps but less 'bus friendly' than speed cushions. 'S' humps could be usefully installed within a speed cushion scheme, where raised junctions or pedestrian crossings are required. (TAL 9/98; Webster and Layfield, 1998).

Grounding

Grounding of vehicles can be a problem for some low ground clearance and/or long wheelbase vehicles when crossing 100mm high humps but generally there should not be a problem for 75mm high humps with ramp gradients 1:10 or shallower. Other considerations such as inclines may demand shallower gradients (TAL 7/96; Webster, 1993b; Webster and Layfield 1996).

Buses and emergency service vehicles

Concerns from the emergency services (TAL 3/94) and bus operators about levels of discomfort of 100mm high road humps have led to widespread use of lower height (75 mm) road humps with shallow gradients (TAL 2/96). Alternatively, speed cushions (TAL 1/98) are commonly used on bus routes or where the emergency services may be expected to pass on a regular basis.

Emergency services and bus companies are often concerned when areas start becoming blanketed with traffic calming measures as this may affect response times and operational viability. DETR has issued Traffic Advisory Leaflet 3/94 which gives guidance to Local Highway Authorities on consulting the emergency services about traffic calming schemes. Access can be helped by a well planned road hierarchy that takes account of emergency routes and bus routes.

Public attitudes to humps

Road humps can be unpopular with some residents, particularly disabled people, due to discomfort, fear of damage to vehicles, and a perception of increased noise and vibration. However surveys indicate that, in general, residents support road hump schemes with an average of 72 per cent expressing approval (Webster, 1998).

Studies comparing different traffic calming measures indicated that round-top humps were perceived to be the most effective measure followed by flat-top humps, speed cushions, chicanes and mini roundabouts in descending order (Webster, 1998).

It should be noted that non-residents are generally less in favour than residents. Public attitudes vary considerably at individual schemes and perceptions of changes in speeds, flow, and safety are relatively poor (Webster, 1998).

Effect of humps on noise

Results from track trials indicate that changes in noise levels are related to the proportion of large commercial vehicles in the flow and the type of road hump used (Abbott et al 1995).

Where traffic flow consists predominantly of light vehicles, the installation of road humps should reduce noise levels due to the reduced speeds. Noise levels may increase where there is a regular flow of commercial vehicles and this starts to become a noticeable component of the overall traffic flow. Flat-top humps were found to produce substantially higher noise levels with commercial vehicles than round-top or sinusoidal profiles (TAL 6/96, Abbott et al, 1995; Harris et al, 1999).

Where traffic calming has been installed, the perception of residents about changes in noise nuisance is not always in agreement with measured changes in noise levels. This discrepancy could be due to changes in noise characteristics, which can contribute to noise disturbance (Abbot et al, 1997).

Effect of humps on ground-borne vibration

Track trials at TRL assessed the ground-borne vibration levels generated by a wide range of vehicles crossing a selection of humps and cushions. As with noise levels, flat-top humps produced higher vibration levels than round-top or sinusoidal profiles (Watts et al, 1997; Harris et al, 1999).

It was concluded that ground-borne vibration from vehicles travelling over road humps was unlikely to cause any superficial damage to buildings. However, disturbance might be experienced by some residents from air borne vibration or from ground-borne vibration, which can be amplified in upper floors of buildings. Guidance as to the minimum distance that road humps could be placed to avoid vibration exposure is given in TAL 8/96.

Effect of humps on vehicle emissions and air quality

Studies of driving behaviour and vehicle exhaust emissions at schemes where traffic calming measures have been installed indicate that emissions per vehicle have increased (Cloke et al, 1999; Boulter, 1999; Boulter, 2000). The percentage change in emissions depends upon the type of engine and emission control, the nature of the pollutant being considered and the traffic calming measure used.

In a study by TRL of 9 different types of traffic calming measures (including road humps), the mean emission rates of CO, HC, NOx, CO_2 and particulates from petrol non-catalyst, petrol catalyst, and diesel cars increased by 1 to 60 percent. In general there was a good deal of overlap between the effects of the different types of traffic calming measure on emissions. However, those measures likely to produce the largest speed reduction and accident savings (e.g. road humps) had some of the largest increases in emissions (Boulter et al, 2001).

To minimise the increase in vehicle emissions, traffic calmed areas require a good design that encourages smooth driving behaviour and avoids harsh acceleration and deceleration (TAL 4/96).

Although emissions per vehicle increase after traffic calming, the impact on air quality is likely to be small. The low traffic flows and increasing performance of engine emission control make it unlikely that the pollutant concentrations would result in poor local air quality (Boulter et al, 2001). Also, as the installation of road humps usually leads to a reduction in traffic flow (typically 24%), although individual vehicle emissions may increase, the overall vehicle emissions may not.

Road Humps: residential road

Abingdon, Oxfordshire

Location:	Saxton Road, Abingdon, Oxfordshire.			
Site Description:	Residential road.			
Problem:	Child pedestrian accidents, possibly aggravated by parked vehicles and excessive speed.			
Aims:	To reduce speeds and discourage through flow.			
Treatment:	Flat-top humps, 70mm height.			
Implemented:	January 1993.			
Cost :	£10,000 (1993).			
Comments:	Good reduction in vehicle speeds but surprising increase in flows by 450 vehicles per day. It should be noted that although accident reductions were smaller than achieved at most other road hump schemes the severity of injuries was substantially reduced i.e. 40% serious injury in before period; all slight injury in after period.			
Effectiveness:	Accidents (pia in 5 years)	Casualties (5 years)	85th Percentile Speeds (mph)	Traffic Flow (AADT)
Before:	10	10	31	1280
After:	7	8	25	1734

Authority: Oxfordshire County Council

A.13 Road restraint systems

Where a vehicle leaves the carriageway, injury can be minimised in some situations by redirecting it from its errant path and containing it within its roadway area. If a vehicle leaves the carriageway it may well collide with an oncoming vehicle, roll over, or collide with a solid obstacle. Many types of road restraint have been devised to provide containment, including:

- Safety barriers.
- Vehicle parapets.
- Terminal and transitions.
- Crash cushions.
- Arrester beds.

Pedestrian restraint systems (and those for other users like equestrians, cyclists and cattle) are also classified as a road restraint system. These are generally to provide guidance along the edge of footways rather than to protect the more vulnerable road user from out-of-control vehicles. However, according to MOLASSES data, new pedestrian guard rail installations have reduced injury accidents by at least 40 per cent.

Since 1986, a programme to install vehicle restraints in the central reserves of all-purpose trunk roads has been underway. They are extremely effective in preventing cross over accidents. Although their primary role is to contain errant vehicles, they have a secondary function of redirecting vehicles such that they are not deflected back into the stream of traffic.

The range of possible vehicle impacts into an on-road restraint system is large in terms of speed, approach angle, vehicle type and road conditions. Nevertheless, standards are considered essential and are currently being harmonised across Europe. British Standards are under revision to reflect this (BSI, 1998, 2000; with parts 4 to 6 in draft form only).

Only safety barriers having type approval must be used on the UK network. These include:

• tensioned and untensioned corrugated beams.

• hollow section beams.

• open box beams.

• wire ropes.

• concrete barriers.

Most performance tests prescribe a vehicle of mass 1500Kg travelling at 113km/h at an angle of 20° to the barrier, though there are some variations in these values (see HMSO, 1998a).

There have been objections to many of the designs currently in use, principally from motorcyclist groups where the main complaint tends to be over the design of support posts (FEMA, 2000). If a motorcycle and rider is tilted over at an acute angle or is sliding towards and collides with a rail where posts are exposed beneath, these can easily cause snagging, which stops the vehicle/rider too abruptly. The sharp edges and corners of the posts exacerbate the potential for injury. It has been suggested that an extra rail covering the posts down to ground level (preferably of a more energy-absorbing material), would prevent this effect. Indeed, full concrete walls (whether flat-sided, stepped or New Jersey profile) are preferred, despite their lack of kinetic energy absorption properties.

Wire rope safety fences (TD 32/93) are normally a four rope system with two upper and two lower steel ropes intertwined around steel posts. The full height posts at the end of each anchorage must be firmly concreted into the ground. They should not be used on bends due to the posts being designed to sheer at their base. On straight sections they are much less expensive to install with maintenance costs found to be only ¼ of that of steel beam section barriers. However, motorcycle groups have also widely criticised wire rope safety fences chiefly because the posts are more exposed and it is believed that their tops will act as a saw tooth edge increasing the risk of lacerations.

Hollow box section and concrete barrier bridge parapet.

Concrete motorway divider.

Safety Barriers: rural dual carriageway

A27, West Sussex

Original A27.

After safety fencing installed.

Location:	A27 between Fontwell and Arundel, West Sussex.				
Site Description:	Unrestricted rural dual carriageway, originally with no central safety fencing (left-hand photograph).				
Problems:	Crossover accidents occurring and the possibility of vehicles losing control and striking trees in the central reserve.				
Aims:	To reduce the seriousness of accidents occurring on this high speed section of road.				
Treatment:	Provision of central safety fencing and study into strategy of closure of crossing points in central reserve.				
Implemented:	January 1999.				
Cost:	£45,000.				
Comments:	The safety barrier was designed to TD 19/85 and subsequent advice notes.				
Effectiveness:	Injury accidents	Speed (mph) – estimated		Traffic Flows (AADT)	
		Eastbound	Westbound	Eastbound	Westbound
Before:	3 in 10 years	60	70	12177	12278
After:	0 in 1.5 years	60	70	11871	12401

Authority: Highways Agency

Rising bollards

A.14

These are automatic, electrically-operated bollards that retract into the road surface when they have detected a valid electronic tag (usually mounted on selected vehicles), often during specific times of day. In installations where drivers do not have a clear view of the bollards, it is recommended that special small signal indicators are installed telling road users when the bollards are fully lowered. These require special authorisation. If traffic signals are required, only three aspect signals would be permitted.

Rising bollards are becoming more widely used in town locations to restrict use of the road to those drivers with authorised access, such as service vehicles and emergency vehicles. Their restrictive nature will, of course, reduce traffic using the network of roads contained within a system and this, in turn, may help to reduce road accidents on those roads.

The posts are usually mounted within a tube located beneath the road surface. Maintenance and operating costs may be expensive and any system, however well designed, will fail to operate on occasions and must fail to a safe state, ideally with bollards retracted.

A full risk assessment should be made when considering whether to install a system of rising bollards. Care should be taken in choosing equipment that cannot injure pedestrians or cyclists, and ensuring that the bollards have a fail safe system that prevents the bollard rising beneath a vehicle. They should also be of a design that is less likely to be a hazard for visually impaired people, i.e. 1m high with a clear colour contrast around the top. See TAL 4/97 for other issues.

Road closure using a rising bollard:

New George Street, Kingston-upon-Hull

Location:	New George Street, Kingston-upon-Hull.
Site Description:	Residential road subject to a 20mph speed limit.
Problem:	Road used as a cut through.
Aims:	To reduce the flow, slow vehicles and provide more parking.
Treatment:	Road closure with rising bollard used by emergency vehicles only. Ambulances have a transponder to automatically lower the bollard. Police and Fire services have a key.
Implemented:	October 2000.
Comments:	Scheme had full support of local residents through wide public consultation.
Effectiveness:	No data available

Authority: Kingston-upon-Hull City Council

Roundabouts and mini-roundabouts

A.15

Roundabouts have central islands with diameter greater than 4m and between 3 and 7 arms. They may be used in both rural and urban areas, on single and dual carriageways, and may be signalised. They are most common away from town centres because of the land take required. Traffic entering a roundabout must give way to that already on the roundabout or coming from the right (for drivers in the UK). Entry arms are often flared to increase capacity. A full account of design is given in Brown (1995). Chevron block paving on the central island of roundabouts is sometimes used to increase their conspicuity (Warwickshire County Council, 1997).

Mini-roundabouts are used on urban single-carriageway roads where the speed limit is 30 mph or less. They have central islands with a diameter up to 4m that are capable of being driven over. The islands are generally smooth and white and either flush or domed; they may also have a noticeably textured surface or edge and may be non-white. Mini-roundabouts are often used as part of traffic-calming schemes.

The standard, TD16/93 should be followed and the computer program ARCADY (Binning, 2000) can be used to aid the design of both roundabouts and mini-roundabouts for safety and capacity.

Both roundabouts and mini-roundabouts that have deflection to prevent vehicles taking too straight a path through the junction tend to have fewer accidents (see Maycock and Hall 1984; Kennedy et al, 1998). This is because deflection encourages slower approach speeds and may increase driver alertness, though too much deflection can lead to loss of control accidents on high speed approaches. Deflection can be achieved by providing angled deflection islands on the arms and a suitably sized central island. Opposite pairs of approach roads can be staggered to help increase deflection.

Pedal cyclists and motor cyclists tend to have increased risk at roundabouts, probably because entering traffic must give-way and car drivers sometimes fail to ‘see’ two wheelers (Morgan, 1997; Davies et al, 1997; Kennedy et al, 1998). In continental Europe, two main methods are used to improve pedal cyclist safety at roundabouts:

1. Combined pedestrian/pedal cyclist crossings on each roundabout arm.

2. Cycle lane round the perimeter of the circulatory carriageway.

Neither method has been much used in the UK. With method 1, use of flaring at UK roundabouts results in crossings being set well back from the entry so that pedal cyclists using them must take a longer route through the junction; cyclists must also give way on each arm crossed, increasing their delay. Thus the crossings are likely to be used only by nervous or novice cyclists. With a dedicated cycle lane (method 2), cyclists must pass directly in front of entering traffic, which may be intimidating. Also, as motorised vehicles do not enter the cycle lane, it is not swept by traffic action and the build up of debris may lead to the lane being unused.

Pedestrians tend to have relatively low accident risk at roundabouts and mini-roundabouts, probably because drivers are alert to the possible need to stop at the junction. Traffic islands on the arms allow pedestrians to cross the road in two stages. They are most at risk on wide arms. Pedestrian crossings may be signalised or not; they are best installed upstream of any flaring, to reduce the distance crossed.

Measures found to be useful in reducing accidents at roundabouts with poor safety records (DMRB TD 16/93) include:

- The re-positioning or re-enforcement of warning signs, the provision of map type advance direction signs, making the Give-Way line more conspicuous, and the relocation of Chevron signs (diagram 515, TSRGD) to ensure they are in the driver's direct line of sight.

- The provision of transverse yellow bar markings on fast dual-carriageway approaches. These have been shown to reduce accidents at appropriate locations, probably by increasing driver alertness (see Appendix A.26). However, they require authorisation and must meet certain criteria. The required criteria will be set out in the new TSM Chapter 5 (publication expected 2001).

- The provision of appropriate levels of skidding resistance on approaches and the circulating carriageway.

- The avoidance of abrupt and excessive superelevation in the entry region.

- The reduction of excessive entry width by hatching or physical means.

The MOLASSES database indicates that new roundabouts and mini-roundabouts in urban areas have reduced injury accidents, on average, by 40 per cent, and in rural areas by 76 per cent.

Mini roundabouts: residential

Didcot, Oxfordshire

Location:	Park Road between Portway and Colborne Road junctions, Didcot, Oxfordshire.			
Site Description:	Urban single carriageway, mainly residential.			
Problem:	Junctions accidents and pedestrian accidents, probably due to inappropriate speeds.			
Aims:	To reduce approach speeds and ease turning movements.			
Treatment:	Mini-roundabouts at Colborne, Park Close, Queensway, Edwin and Portway; and rumble strip on approach.			
Implemented:	March 1994.			
Cost :	£40,000 (1994).			
Comments:	The scheme was introduced in the context of local concern by the emergency services of road hump schemes. Only modest speed reduction measured compared with hump schemes, though some accident saving achieved. *Notes:* *1) Where signs are situated back off the carriageway or under trees then consideration could be given to using yellow backing boards.* *2) An upright Give Way sign would normally accompany Give Way road markings. (See TSM Chapter 5 Fig.5.16). Diagram 1003.3 (TSRGD) would normally accompany an upright mini-roundabout sign.*			
Effectiveness:	Accidents (pia in 5 years)	Casualties (5 years)	85th Percentile Speeds (mph) Park Road	Traffic Flow (AADT) Park Road
Before:	6	8	37	7161
After:	4	4	34	6260

Authority: Oxfordshire County Council

Mini roundabout: semi-rural

Bicester, Oxfordshire

Location:	Junction of A421/A4095, Bicester, Oxfordshire.	
Site Description:	Major road single carriageway T-junction at edge of town.	
Problem:	Accidents involving turning movements.	
Aims:	To reduce approach speeds and ease turning movements.	
Treatment:	Provision of mini-roundabout.	
Implemented:	October 1991.	
Cost :	£5,000 (1991).	
Comments:	This treatment appears to have worked extremely well despite its low budget. *Note: Generally, it has been found particularly important in the case of mini-roundabouts to follow the recommendations in TD16/93 (eg. with respect to deflection and approach lanes) to ensure maximum safety benefits.*	
Effectiveness:	Accidents (pia in 5 years)	Casualties (5 Years)
Before:	11	16
After:	5	5

Authority: Oxfordshire County Council

A.16 Roundel road markings

Roundels are elongated circles with the speed limit in their centre, laid in white thermoplastic on the road surface at one or more positions within an area restricted by a speed limit. They were first used in rural villages in 1992. They were designed to alert drivers to a change in speed limit and the presence of a residential environment (particularly when preceded by a long, fast section of road or poor forward visibility) and to encourage drivers to reduce their speed through rural villages.

In a trial of 30mph and 40mph Roundel markings carried out in eight villages in Great Britain (Barker and Helliar-Symons, 1996), small mean speed reductions of about 3mph were observed overall at the 40mph sites only. Since then, roundels have been used more successfully in combination with other measures, such as coloured road surfacing and gateway signing (Wheeler & Taylor, 1999 – see App A.9).

The use of Roundel markings at other urban sites is now fairly widespread but requires special authorisation. However, the new TSRGD (publication expected 2001) will permit the use of Roundels at speed limit boundaries (30mph, 40mph and 50mph), and the use of repeater Roundels as appropriate (40mph and 50mph only).

Rumble-devices

A.17

Rumble devices are small raised areas across the carriageway with a vibratory, audible and visual effect that are used, usually in rural areas, to alert drivers to take greater care in advance of a hazard such as a bend or junction. In combination with a gateway they can indicate the entry to a village or the start of a series of traffic calming measures (TAL 11/93).

Rumble devices come in a variety of different forms, which have been described as rumble strips, rib lines, jiggle bars and rumble areas. Rumble strips, rib lines and jiggle bars are similar in concept and comprise of narrow strips of material laid across the carriageway.

Dimensions and layout

The Regulations permit rumble devices up to 15mm in height, provided no vertical face exceeds 6mm in height, although special authorisation can be sought for devices that might exceed these dimensions. However, vertical faces greater than 6mm could create difficulties for cyclists (TAL 11/93). To allow for drainage and help cyclists avoid rumble devices it is advisable to provide a gap, preferably in the range 750mm to 1m, between the edge of the carriageway and the device.

Rumble *strips* can be laid out as a single group of strips or as a series of groups of strips. Decreasing spacing between the groups is generally the most effective. Rumble areas can be laid as a single area or series of areas in advance of a hazard. Single areas unless accompanied by other measures are likely to have a very limited effect, not only with regard to speed reduction but also as an alerting device (TAL 11/93).

Speed and accident reduction

Speed reductions are likely to be small and to be eroded over time. Reliance should not be placed on using rumble devices alone to reduce speed (TAL 11/93).

Average reductions in 85th percentile speeds of about 2 to 6mph have been found (Webster and Layfield, 1993; Barker, 1997). Injury accident reductions were reported but are not statistically significant.

Noise

Rumble devices can generate considerable noise over a large area depending upon the topography and ambient noise levels. To avoid complaints arising and the subsequent need to remove the device, the possible noise nuisance should be considered at the outset (TAL 11/93).

The noise generated will vary from location to location and will depend on the pattern and type of device used. Where a conflict arises between safety gains and increased noise levels, consideration could be given to using a lower height device, though this may be at the expense of overall effectiveness. In general, siting rumble strips close to residential properties should be avoided and therefore their use in urban areas will be limited (TAL 11/93).

Safe routes to school

A.18

Children (under 16 years old) comprised about 34 per cent of all pedestrians and cyclists killed or seriously injured on Britain's roads in 1999, and one of the most common types of journey for unaccompanied children is the journey to school.

The proportion of journeys to school by car has nearly doubled in the past ten years, such that a significant proportion of the morning peak hour traffic is comprised of vehicles involved in this journey. This is therefore contributing to the deterioration of local air quality and increasing journey times, and the hazards for those who do travel to school by foot or bicycle are probably increasing.

Local authorities have been asked to include an integrated area-wide strategy for reducing car use and improving children's safety on the journey to school in their local transport plans. In this they should indicate how they will work with individual schools to develop comprehensive ***school travel plans***, which may include:

- improved pavements or crossings.
- provision of cycle lanes.
- traffic calming.
- lower speed limits.
- pedestrian and cycle training.
- escort schemes such as the "walking bus".
- enhanced facilities within the school (eg. secure cycle parking).

Examples of some facilities provided within a 'safe routes to school' strategy are included in this appendix.

School Zone:

Estcourt Primary School, Kingston-upon-Hull

Location:	Estcourt Primary School, Kingston-upon-Hull.		
Site Description:	Primary school with 350 pupils on a 20 mph one way street with humps.		
Problem:	Pedestrians (including child pedestrians).		
Aims:	To reduce the flow, slow vehicles and improve safety of children.		
Treatment:	Staggered road narrowing, ‘Stop, Look and Listen’ logo, dinosaur feet from school to crossing place.		
Implemented:	1994.		
Cost:	£15,000.		
Comments:	Scheme had full support of local residents, parents and teachers through wide public consultation.		
Effectiveness:	Accidents (pia)	Speeds (mph)	Traffic Flow (Daily)
Before:	1 per year	Mean speed 30mph	1192
After:	0.33 per year	N/a	N/a

Authority: Kingston-upon-Hull City Council

Segregation

A.19

Three main functions of roads have been identified as:

- a flow function;
- a distribution function; and
- an access function.

Ideally a safe design would try to segregate these functions. This segregation has generally been achieved at the highest category of road (motorways and some trunk roads) as:

- there is no frontage access.
- intersections are designed as slip roads for fast moving traffic.
- some categories of road user are prohibited.
- overbridges or under-passes provide for traffic and pedestrians needing to cross the road.

Separate cycle tracks and separate footways have also been provided in some areas, both urban and rural. However, unless this is well designed and convenient it will not be popular, eg. over-bridges and subways for pedestrians and cyclists are often little used.

For many roads, segregation has not been a feasible option, and a compromise solution has been the use of *"separation"* and *"channelisation"* within the same road space.

Although in the past the throughput of motor vehicle traffic was seen as paramount, more recently it has been seen as important to try to manage speeds (beyond simply having a speed limit) by using either traffic calming measures or speed cameras. Where downgrading of function is planned, attempts should be made to balance the priority of each function. For example, the slow and fast moving traffic can be kept separate wherever possible by applying separate frontage access by means of a parallel service road, with a physical separation from the through traffic space. It should not be possible for vehicles to cross the verges between the through traffic space and the parallel service space, except at specific entry points. Where “through” and “access” traffic have to intersect, the driving speed should either be low or they should be separated in time (by signals).

Ideally, in general, there should be:

- only one lane in each direction for through traffic, separated by a central physical median or intermittent islands.
- access roads provided, parallel but separate from the through traffic lanes.
- separate defined space provided for cyclists, pedestrians and parking.
- control of through traffic speeds, probably by traffic calming.

Good accident reductions have been achieved by this type of treatment, although the purpose is not purely, or indeed firstly, safety, but rather to achieve a broader objective of creating a more acceptable urban street environment.

Segregation: urban town centre

Borehamwood, Hertfordshire.

Location:	Borehamwood, Hertfordshire.	
Site Description:	Main road through town high street.	
Problem:	Conflict between functions.	
Aims:	Provide for different functions and improve safety.	
Treatment:	Separation (with service roads, footways/cycleways), channelisation using centre median, and flat-topped humps to control speed.	
Implemented:	1995	
Cost:	£1.2M	
Comments:	Good example of public space design. *Note: The signing was given special authorisation.*	
Effectiveness:	Accidents (pia)	Mean Speed
Before:	15 in 3 years	26mph
After:	8 in 3 years (47% reduction}	20mph

Authority: Hertfordshire County Council

A.20 Signs and markings

The scope for signing and marking roads is too great for full coverage here. Options and good practice are well-documented and well-known to practitioners (see paragraphs 3.61 and Appendix C of this Guide; Traffic Signs Manual, TSM; DETR, 1994).

However, the less well-established applications of safety benefit relate to the use of white-lining for hazard marking and the use of channelisation marking. These should not be over-used to ensure that the current (very good) compliance with white-lining by drivers is maintained.

Continuous edgelining is recommended to provide a hardstrip on major roads where there is sufficient spare width (TSM Chapter 5). It prompts drivers to position their vehicle in the centre of the new traffic lane, thus reducing the opportunity to practice close, staggered following. The system also enables slower drivers to move to the left, crossing the edgeline if needed, to provide space for overtaking.

Channelisation (or hatching marking) in the carriageway centre is suitable for roads where there is sufficient width. It encourages drivers to position their vehicle towards the left of the carriageway and discourages overtaking. Double line and hatched channelisation is recommended in TSM Chapter 5 and in Highway Link Design (DMRB TD 9/93) for use on non-overtaking horizontal crests and curves, especially following overtaking sections and on severe bends. The area marked is narrower than ghost islands at junctions as it is not intended to protect turning vehicles and a lane width of 3.5m should remain. Hatched areas can be highlighted with coloured surface dressing for added impact.

Three lane roads with equal priority to drivers in each direction are not recommended. Instead a double white line system giving overtaking priority for each direction in turn should be considered. These can be particularly useful on hills to provide uphill crawler lanes for the slowest vehicles or downhill ‘escape’ lanes to assist vehicles who lose control to be able to stop.

Road marking: with other measures – on principal road

Cannock Road, Wolverhampton

Location:	Cannock Road (A460) Wolverhampton (Cross Street to Victoria Road).	
Site Description:	Class 1 road – Principal radial route of approx 1.5km length serving Wolverhampton City Centre and providing an important link to junction 1 of the M54. Frontage development is predominantly residential with amenities including shops, places of worship, a school, and light industrial development.	
Problem:	A high number of pedestrian accidents (23%) resulting from pedestrians having difficulty crossing the busy road. There are also a high number of wet road accidents (48%), as well as accidents at specific junctions along the route. Traffic volume and speed with some drivers making unsafe overtaking manoeuvres were also contributory factors to the hazards on this road.	
Aims:	Reduce vehicle speeds and address the current accident problem, notably in discouraging overtaking, and generally improve safety along the route.	
Treatment:	Provide central hatching (reducing running lane width), additional crossing points in the form of pedestrian refuges (1.8m x 7.6m), anti-skid surfacing, improved facilities at existing controlled crossings, junction treatments including a mini-roundabout and traffic signal junction, cycle facilities, sheltered parking and improved signing.	
Implemented:	Completed March 2000.	
Cost :	Total scheme cost £100,000.	
Comments:	Reduction in traffic speed and overtaking manoeuvres, improved pedestrian facilities, improved traffic flow in and out of specific junctions, improved surface skid resistance.	
Effectiveness:	Accidents (pia)	Traffic Flow (5 years)
Before:	106 in 5 years (12 serious, 94 slight)	17,000 (12hrs)
After:	9 in 1 year (all slight)	

Authority: Wolverhampton City Council

A.21 Speed cushions

Speed cushions are an alternative form of road hump that were developed in Germany to assist the emergency services and bus operators whilst still reducing the speed of cars. A speed cushion occupies part of the traffic lane in which it is installed and can be straddled by large vehicles with wide track widths such as buses and emergency service vehicles (TAL 4/94 & 1/98).

Speed cushions produce less discomfort than road humps to occupants of large buses and commercial vehicles and less delay to fire appliances. Discomfort is experienced by drivers and passengers in smaller vehicles such as cars, light commercial vehicles, minibuses and ambulances. The degree of discomfort is governed by vehicle type, vehicle track width, vehicle speed, cushion dimensions and vehicle path over the cushions (Layfield and Parry, 1998).

Recommended cushion dimensions are: side ramp gradients no steeper than 1:4; on/off ramp gradients no steeper than 1:8; maximum width of 2000 mm and a width of 1600-1700 mm for bus routes (TAL 1/98). Grounding of vehicles should not be a problem for cushions but a maximum height of 65 mm is advisable for short length cushions (2000 mm or less) as longer cars can straddle them lengthways.

Cushion layout and driver behaviour

Cushion layouts can be varied to suit road width. Cushions can be arranged as a series of single cushions between carriageway narrowings, groups of cushions in pairs or groups of cushions three abreast. Where pairs of cushions are used, some car drivers may drive in the centre of the road if the central gap between the cushions is too wide (greater than 1200mm). If the gap is too narrow, opposing vehicles may not be able to pass each other with both vehicles straddling the cushions (TAL 1/98).

Depending on the layout used, some car drivers may drive closer to the kerb or deviate towards the kerb to attempt to fully straddle the cushions. This may be intimidating for cyclists. A minimum gap width of 750mm between the cushions and the kerb is recommended (TAL 1/98).

Traffic islands can be used with cushion pairs but it is important that pedestrian crossing points are constructed near, but not at, the cushions so that pedestrians do not trip on the cushions (TAL 1/98). 'H' or 'S' humps are more bus friendly than conventional road humps and could usefully be installed within a speed cushion scheme, where raised junctions or pedestrian crossings are required (TAL 9/98).

Parked cars can prevent vehicles straddling the cushions between the nearside and offside wheels, and so increase driver/passenger discomfort. It is important that cushions are located so that vehicles, particularly buses, can straddle them. This may demand removal of parking in the immediate vicinity of the cushions so that large vehicles have a clear path over the cushions (TAL 1/98).

Speed cushions should not be placed where pedestrians normally cross the road as they can trip on them.

Reductions in speeds and flows and injury accidents

Speed cushions can reduce and control speeds but they do not match the speed reducing effect of 75mm high road humps and a closer spacing is required to achieve comparable speeds. With a cushion spacing of 60m a mean speed of about 20 mph between cushions might be expected (TAL 1/98).

The overall reduction in traffic flow at cushion schemes has been found to be about 24%, similar to the average reduction on roads with 75mm high humps (Layfield and Parry, 1998).

Average speed reductions of about 10 mph (between cushions) have been found (Layfield and Parry, 1998) and it is estimated that speed cushion schemes could produce injury accident savings of 60 per cent (TAL 1/98).

Speed over the cushions is mainly determined by cushion width. Narrower cushions (1600mm wide) can be used to reduce discomfort to passengers in mini-buses and ambulances but will allow higher car speeds (TAL 1/98).

Using narrow cushions (1500mm to 1700mm) in a 20 mph zone may not result in an average speed of 20 mph or less being achieved, particularly where before speeds are higher than 30 mph (TAL 1/98; TAL 9/99).

Speed cushions are not suitable for reducing the speeds of two-wheeled vehicles and large vehicles such as buses are likely to be slowed down to a lesser extent than cars (TAL 1/98).

Public attitudes

Responses as to the suitability of speed cushion schemes can vary considerably from place to place but bus companies and the emergency services have been found to be generally supportive of speed cushion schemes (TAL 1/98).

Speed cushion schemes are perceived by residents to be less effective than road humps (Webster, 1998). Some criticisms are that cushions are too uncomfortable, not wide enough to slow all vehicles, cause drivers to become impatient, damage cars and encourage people to drive on verges (Cloke et al, 1999). The need for drivers to adjust the vehicle path as well as speed, and the increased discomfort when it is not possible to straddle the cushions, may also contribute to their relative lack of popularity.

Noise, ground-borne vibration and vehicle emissions

Similar considerations to road humps will apply. Where the proportion of heavy commercial vehicles is high, narrower 1500mm wide cushions may have some advantage in limiting any adverse traffic noise and ground borne vibrations (TAL 6/96; TAL1/98).

Noise and vibration levels increase when heavy vehicles do not straddle cushions. Care should be taken in the placement of cushions so that they can be easily straddled by the axles of commercial vehicles (TAL 8/96; Layfield and Parry, 1998).

Speed cushions schemes are likely to produce smaller speed reductions and lower increases in exhaust emissions per vehicle than road humps (Boulter, 2000).

Cushions and Humps in 20mph Zone: residential estate

Byland Avenue Area, York

Location:	Muncaster Estate, York.		
Site Description:	Large residential area linking two radial roads – Malton Road and Huntingdon Road. Important bus and emergency vehicle link road.		
Problem:	Local concerns about excessive traffic speeds and amount of traffic taking shortcut through area.		
Aims:	To slow traffic, reduce speeds and amount of traffic using road as shortcut.		
Treatment:	17 speed cushion pairs including 2 sets of double pairs 13 standard road humps 1 chicane (experimental and withdrawn in 1994) 2 speed tables near shopping arcade (to assist pedestrians) 2 pavement buildouts to enforce junction priority		
Implemented:	March 1993.		
Cost:	£30,000.		
Comments:	Comprised part of DETR-sponsored trials of cushions (initially pre-formed rubber cushions were used – subsequently changed to red-coloured hot rolled asphalt in 1996).		
Effectiveness:	Accidents (pia)	85th percentile	Traffic Flow (daily)
Before:	3 (in 3 years)	32	2000
After:	3 (in 6 years)	18	1600

Authority: City of York

Speed Cushions: residential distributor road

Westlea Drive, Swindon

Location:	Westlea Drive, Swindon.	
Site Description:	30mph residential distributor with no direct frontage access. School Crossing Patrol site.	
Problem:	Child Pedestrian accident at School Crossing Patrol and traffic speed too high (85th percentile speed = 37 mph).	
Aims:	Reduce speed and discourage through traffic to Business Park.	
Treatment:	Speed cushions.	
Implemented:	February 1996.	
Cost:	£34,000.	
Comments:	No adverse reaction to scheme. Good results.	
Effectiveness:	Accidents (pia)	85th Percentile Speed (mph)
Before:	4 in 4 years	37 mph
After:	1 in 4 years	N/a

Authority: Swindon Borough Council

Speed Cushions: shopping street

South Shields

Location:	Ocean Road, South Shields.
Site Description:	30mph town shopping street.
Problem:	Pedestrian accidents.
Aims:	Change environment and reduce road width in order to reduce speeds.
Treatment:	Speed cushions.
Implemented:	April 1994.
Cost:	£88,000.
Comments:	No adverse reaction to scheme. Good results. *Note: the siting of the cushions in relation to the crossing, as they cannot be placed within the zig-zag markings. The layout, signs and markings for this site were given special authorisation.*
Effectiveness:	Accidents (pia)
Before:	16 (in 3 years)
After:	0 in 3 years

Authority: South Tyneside Metropolitan Borough Council

A.22 Speed limits

The DETR Guidance on Full Local Transport Plans states that "Research has shown that speed is a contributory factor in a third of road accidents and that higher speeds produce much higher risks" (DETR, 2000e). Taylor et al (2000) showed that each 1 mph reduction in mean speed can be expected to lead to a 5 per cent reduction in road accidents. (This percentage varies depending upon the initial speed).

The guidance on Local Transport Plans stresses the need for a Local Authority to put in place a speed management strategy. It is important that the strategy is developed in partnership with the police (possibly under the auspices of the Crime and Disorder Act, 1998). The police have the responsibility for enforcing speed limits and they will not support a strategy that stretches their resources unnecessarily. Once the strategy has been developed it should be applied consistently, as any inconsistencies are likely to be seized upon and used to undermine the whole strategy. The strategy needs to be backed up with Education, Training and Publicity. Speeding is still not considered sufficiently socially unacceptable to ensure as safe a road environment as possible, and this attitude needs to be changed.

The strategy should address the setting of speed limits. Local Authorities now have the power to impose 20mph speed limits and zones (see Appendix A.23) without having to obtain consent from the Secretary of State.

There should be a general strategy for enforcing realistic speed limits in order to reduce overall speeds. Reducing speed limits without self-enforcing measures will not necessarily lead to a reduction in overall speed. In fact, there have been some occasions where a reduced speed limit has led to an increase in overall speed.

It is important that when a speed limit is changed, it is appropriate, consistent and enforceable. It is generally accepted that for an imposed rule, such as a speed limit, to be acceptable it must be seen as reasonable and appropriate, and therefore tends to become, to a large extent, self-enforcing.

Guidance on setting local speed limits is currently given in Circular Roads 1/93 (DETR, 1993). The most important factor to consider is what the road looks like to the road user. The existing speed of traffic is a reliable indicator of how acceptable a new speed limit would be. A speed restriction is unlikely to be effective if the current 85th percentile speed is 7 mph or more (or 20 per cent or more) above the proposed limit. In these cases, it would be necessary to use continual enforcement before reducing the limit or to give the road a 'self explaining' character in terms of the appropriate speed that drivers should adopt.

This might be achieved by introducing 'mild' traffic calming techniques. For example, coloured road surfacing and central hatching can be used to give the impression that the road is narrower than is actually the case. Gateway treatments can be used to emphasise the change in character (Appendix A.9). Pinch-points can also be used to reduce the width of the road at strategic locations (A.6) and rumble strips could also be considered (A.17).

The analysis of accident data plays an important role in considering speed limit changes. A study of the types and causes of accidents may show that factors other than speed (eg. sight lines, perceptual traps) are involved and these should be addressed in other ways.

Speed Limit Change: rural village

Llechryd, Ceredigion

Location:	Llechryd village on the A484 between Cardigan and Newcastle Emlyn. Grid Ref: SN21-43.
Site Description:	Elongated village sited on rural Class 1 road with Primary School, small side road junctions, estate road junctions, garage and pub present. The village is situated 3 miles to the south-east of Cardigan, which is the largest town in a 25 mile radius and has many shops, services and a superstore. Thus Llechryd receives substantial through traffic.
Problems:	Relatively high speeds in central part of village – carriageway 'over-wide' for much of the village. Also the accident record, though not high (3 in three years prior to implementation) included 1 accident to a child pedestrian and 1 to a School Crossing Patrol officer in the vicinity of the Primary School. Previously there were no pedestrian crossing facilities present in the village.
Aims:	Reduce vehicle speeds; protect vulnerable road users via provision of crossing points; provide increased warning to motorists of the presence of the Primary School.
Treatment:	Speed Limit alterations: existing 40 mph limit changed to 30 mph, provision of new 30 mph zone, provision of 40 mph 'buffer zone'; carriageway narrowing; pedestrian refuges (3); school warning signs replaced with backgrounds and flashing amber lights in gateways; 30 mph terminal signs in gateway with village nameplates; jiggle bars (at speed limit terminal plates, repeater signs and countdown signs).
Implemented:	October 1997.
Cost:	£45,000.

Comments:	Although the accident record has increased slightly post-implementation over the length of highway in question (being 2.5 km), there have been no accidents involving pedestrians following implementation. The 4 personal-injury accidents to have occurred since October 1997, (3 slight injury, 1 serious injury), have all been directly attributed to driver error (2 were solitary vehicles leaving the carriageway, 2 were shunts of vehicles waiting to turn right off the carriageway). Therefore the intention of the scheme, as set out in 'aims' above, can be said to have been realised.
Effectiveness:	
Before:	3 (2 pedestrians) in 3 years.
After:	4 (0 pedestrians) in 3 years. (see under 'comments' above).

Authority: Ceredigion County Council

A.23 20mph zones

Following a change to legislation in June 1999, local authorities can either make 20mph speed limits employing only speed limit signs, or traffic calmed 20mph zones using prescribed 20mph zone signs. Central government advice is that, where traffic speeds are only a little over 20mph, the placing of speed limit signs might act as an additional warning signal to drivers, so that the required small reduction in speed is likely to be achieved. The key to a successful 20mph zone is to have in place, speed-reducing features of a significant number and appropriate design, to be able to reduce the speed of most traffic to 20mph or less, without the need for speed enforcement.

Scheme Design. 20 mph zones should have physical engineering measures. Measures to keep speeds low will generally be either adjustments to the:

Horizontal alignment	**Vertical alignment**
• narrowings	• round top humps
• chicanes	• flat top humps
• mini-roundabouts	• speed cushions (on bus routes)
• staggered parking arrangements	• speed tables or raised junctions

The vertical measures are generally more effective in reducing speeds, although a combination of the two can be satisfactory, and a mix of measures is likely to give a more aesthetic design. Measures need to be repeated frequently (within 100 metres) to maintain low speeds, and the maximum distance apart is specified as 100m in the TSRGD (HMSO,1994c).

Choice of areas. 20mph zones are most appropriate on residential and local distributor roads. They will usually be in residential areas but other locations such as shopping streets may be suitable. Ideally they should form part of an overall safety management strategy, rather than be created as isolated schemes, and should be used in the residential cells which are identified after a hierarchy of through routes and local distributor roads has been designated.

Each entrance to the zone should be indicated by signing and a 'gateway'. The signing of individual calming measures within a 20 mph zone is then not necessary, thus dispensing with the need for some of the signing which can be expensive and intrusive.

Accidents. Comparisons of *Before* and *After* accident data in 20mph zones, show that the average annual accident frequency fell by about 60 per cent, and child pedestrian and cyclist casualties decreased by about 70 per cent. Both reductions are statistically significant. (Webster and Mackie, 1996).

20mph Zones: residential estate

Worcester Park, Sutton

Location:	Worcester Park, Sutton.	
Site Description:	Network of residential roads.	
Problems:	Scattered accidents within the area, and use of streets as 'rat runs' for through traffic.	
Aims:	Reduce accidents and improve living environment by reducing through traffic. Manage speed.	
Treatment:	Traffic calming using road humps in a 20mph zone included: • round top humps • flat-top humps • cushions on bus route	
Implemented:	1990.	
Cost:	£200,000.	
Comments:	Good example of fairly large zone.	
Effectiveness:	Injury accidents	Mean Speed
Before:	10.5 per year	29.6
After:	2.4 per year (77% reduction)	17.1

Authority: London Borough of Sutton

Traffic signals

A.24

Traffic signals may be installed on any type of all-purpose road but are most common on 30 to 40 mph single carriageway roads, which may be either one or two-way. In town centres, where signal junctions are close together, the timings are often linked in a UTC system. Software programs such as TRANSYT (Binning and Crabtree, 1999) can be used to calculate coordinated timings, and SCOOT (Bretherton et al, 1998) is an automatic control system that adapts and responds to monitored traffic fluctuations. Research on safety showed no clear evidence of any change as a consequence of the installation of SCOOT (Hunt et al, 1990).

Where signal junctions occur in isolation, they may be vehicle-activated, and may be controlled by the MOVA system (Vincent, Peirce and Webb, 1991). Use of MOVA tends to reduce 'red-running' and improve safety (Webb and Harrison, 1992).

The computer program OSCADY (Binning, 1998) calculates capacity, queue lengths and delays for isolated signal junctions. It can also be used to predict accident frequency at urban signal junctions from traffic flow and site data. Accident problems and solutions include:

- *'Right angle'* accidents at crossroads, in which vehicles going ahead from adjacent arms collide, are not eliminated when the junction is signalised and these accidents are often serious. The situation tends to worsen with shorter cycle times but staggering one pair of arms slightly to produce a right/left stagger may help to reduce the risk of these accidents (TD50/99 gives guidance on this).

- *'Principal right turn'* accidents, in which a vehicle turning right collides with a vehicle going ahead from the opposite arm. Research has shown that at 4-arm signal junctions, completely separate stages for the right turners and the opposite ahead traffic, or the use of 'early cut-off' or 'late release' is associated with lower accident risk. Increasing intergreen times to deal with right turners needs to be exercised with caution, as doing so by more than 1 second may well increase accident risk. At 3-arm signal junctions, a separate stage again tends to reduce these accidents, but an 'early cut-off' design will only do so under certain circumstances (Taylor et al, 1996).

- Busy town centre junctions tend to have a high proportion of accidents involving a *pedestrian* and care needs to be taken in the design of signals at such junctions. An all-red phase during which all traffic stops and pedestrians can cross any arm of the junction (red/green man signals) may be appropriate when there are large numbers of pedestrians and the junction is not too congested. Alternatively, a pedestrian phase may be used on one or more arms whilst traffic continues to flow on some of the other arms. Although there is no evidence that the provision of guard-railing reduces pedestrian accidents at signal junctions (Hall, 1986; Taylor et al, 1996), this can help to guide pedestrians towards an appropriate crossing point and deter them from crossing elsewhere, though it does need to be used with sensitivity.

Other good design practice is detailed in DMRB TD 50/99 and includes: the use of guardrail that provides good inter-visibility between drivers and pedestrians; high friction surfacing on high speed approach roads; clear traffic signs and road markings on approaches; and the provision of backing boards to signal heads.

Advanced stop lines are designed to help cyclists move ahead of motor vehicles and clear the junction first (Wheeler, 1995). No modification to signal timings is required.

The use of speed cameras (Winnett, 1994) may reduce accidents at traffic signals, particularly those that are fatal or serious (see Appendix A.3).

According to the MOLASSES database new signal installations in urban areas have produced, on average, a 53 per cent reduction in injury accidents and modifications to existing signals have reduced them by 33 per cent. In rural areas the reductions have been even greater at 75 and 48 per cent respectively.

Traffic Signals: rural T-junction

Steventon Hill, Oxfordshire

Location:	A4130 / B4017, Steventon Hill, Oxfordshire.	
Site Description:	Rural T-junction on bend and gradient.	
Problem:	Accidents and conflict with turning movements, particularly right turn from minor road – having uphill gradient.	
Aims:	To reduce turning accidents and improve throughput.	
Treatment:	Provision of traffic signals.	
Implemented:	June 1996.	
Cost:	£60,000.	
Effectiveness:	Accidents (pia)	Casualties
Before:	9 (in 5 years)	18 (in 5 years)
After:	1 (in 4 years)	1 (in 4 years)

Authority: Oxfordshire County Council

A.25 Vehicle-activated warning signs

Vehicle-activated (or 'secret') signs are roadside signs which only target selected drivers. Sensors measure the speed of approaching vehicles and if this speed is in excess of a pre-set trigger speed the 'secret' sign lights up, displaying a message. Hence, only drivers travelling at a speed that is regarded as unsuitable for the conditions on that particular stretch of road activate the sign.

The main objective of vehicle-activated warning signs is to alert the targeted drivers to the hazard such that they reduce their speed. The signs have the advantage of being blank (i.e. black) when not activated, limiting their visual intrusion, which is particularly relevant in rural areas.

Research has shown that these signs are effective in reducing both speeds and accidents (Barker, 1997; Farmer et al, 1998; Webster, 1995; Winnett et al, 1999). Generally, mean speed reductions of about 3-6mph can be expected following the installation of a vehicle-activated sign on the approaches to bends, junctions or a speed limit change, depending on vehicle flows and *Before* speeds.

A variety of methods have been used to:

- Power the signs and detectors (eg mains supply, battery, solar panel, wind generator);
- Determine appropriate threshold speed (eg limit, 85th percentile speed, weather/road surface sensor);
- Display timing of message; and
- Determine distances between speed measurement position, sign and hazard location.

Signs using similar technology have also occasionally been used to warn tall vehicles that they are too high to pass under a bridge ahead and warn vehicles of a queue ahead.

Advice on the application of these signs is currently being developed.

Some examples of vehicle-activated warning sign installations are included in this appendix.

Vehicle-Activated Warning Sign: rural crossroads

Felthorpe, Norfolk

Location:	Felthorpe, Norfolk. National speed limit (60mph).		
Site Description:	De-restricted rural crossroads – junction of B1149 with a minor road east of Felthorpe with a speed limit of 60mph on the B road and 50mph on the minor road.		
Problems:	Collisions between turning vehicles and speeding vehicles on the major arm were the main accident problem. A previous local safety scheme, comprising visibility improvements to the north of the junction and improved static signing was completed in 1995. However, this had little effect on accidents and there were a further 7 accidents to November 1997. Vehicle-activated signs were installed in 1998 in an attempt to reduce the accidents.		
Aims:	To reduce the speeds of the fastest drivers on the approach to a dangerous junction.		
Treatment:	Vehicle-activated warning sign incorporating a red triangular warning sign with a standard crossroad symbol and 'SLOW DOWN' below the symbol. Blank when not operating.		
Implemented:	February 1998.		
Cost:	£14,000.		
Comments:	Vehicle-activated warning sign required special authorisation from DETR. The percentage of vehicles travelling over 50mph reduced on both approaches.		
Effectiveness:	Accidents (pia)	Speeds (mph)	Traffic Flow
Before:	31 in 10 years	51.4 southern major arm (s) 44.3 northern major arm (n)	15976 (mean) (s) 16579 (mean) (n)
After:	0 in 3 years	45.3 southern major arm (s) 41.4 northern major arm (n)	16461(mean) (s) 16599 (mean) (n)

Authority: Norfolk County Council

Vehicle-Activated Warning Sign: rural bend

Felbrigg, Norfolk

Location:	Felbrigg, Norfolk. National speed limit (60mph) *Before* scheme installation.		
Site Description:	De-restricted rural bend on the approach to the village of Felbrigg B3430.		
Problems:	Bend with a poor accident history. All accidents occurred in the wet and involved vehicles travelling south.		
Aims:	To reduce the speeds of the fastest drivers on the approach to a dangerous bend.		
Treatment:	Vehicle-activated warning sign incorporating a red triangular warning sign with a standard crossroad symbol and 'SLOW DOWN' below the symbol. Blank when not operating. The speed threshold of the sign is automatically determined by the prevailing weather conditions to take account of dry, wet or icy conditions. The speed limit was also reduced from 60mph to 30mph. Measurements below are all post speed limit change.		
Implemented:	September 1996.		
Cost:	£11,500 including special detector/data logging system.		
Comments:	Vehicle-activated warning sign required special authorisation from DETR.		
Effectiveness	Accidents (pia)	Speeds (mph) post speed limit change	Traffic Flow (daily)
Before:	11 in 3 years	40.7 at the trigger point (t) 33.9 at the bend apex (a)	776
After:	1 in 4 years	35.8 at the trigger point (t) 31.6 at the bend apex (a)	664

Authority: Norfolk County Council

Yellow bar markings A.26

In the 1970's, transverse bar markings with an irregular (approximately logarithmically decreasing) spacing pattern were suggested as a possible solution to the effect known as 'speed adaptation'. This is where a driver who has been driving at high speed for a considerable distance and then reduces speed (from 70mph to 30mph, for example) feels as if he or she is travelling much slower than is actually the case. The spacing pattern, therefore, was designed to manipulate a driver's visual field so that, as a driver travelled over the markings, perceived speed was greater than actual speed. The objective of the markings was to slow drivers on the approach to a hazard, such as a junction.

A trial of Yellow bar markings on the approaches to 42 at-grade roundabout junctions (Helliar-Symons, 1981) showed overall accident reductions of 57 per cent (with respect to Control accidents). A trial of similar markings on 44 motorway off-slip road, junction approaches gave a (non statistically significant) 15 per cent reduction in injury accidents (relative to Control sites) (Haynes et al, 1993). The pattern used was shorter than that used on dual-carriageways.

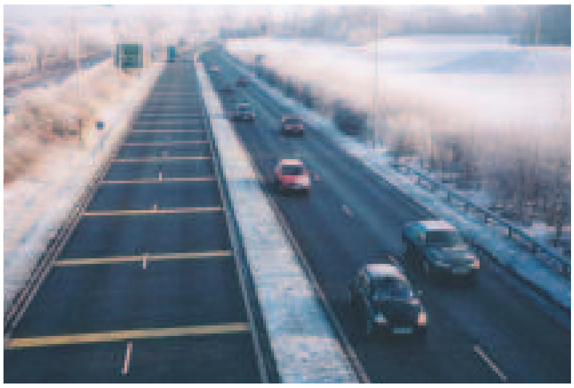
Design details will be provided in the new Traffic Signs Manual Chapter 5 (publication expected in 2001).

An example of yellow bar markings on a dual-carriageway approach to an at-grade roundabout is included in this appendix.

Note that these markings require special authorisation.

Yellow bar markings before roundabout: dual carriageway

Bracknell, Berkshire



Location:	A329, Berkshire Way roundabout, junction with Doncastle Road, Bracknell, Berkshire.
Site Description:	De-restricted dual carriageway approach to roundabout.
Problems:	The construction of a flyover over the existing A329/A329(M) Coppid Beech Roundabout as part of an A329(M) extension (where previously the A329(M) ended) created a potential road safety hazard at the next roundabout junction downstream, (i.e. above site). It was considered that potential traffic speeds would make this roundabout unsafe without any safety measures.
Aims:	To reduce speeds approaching this roundabout, or at least serve as alerting device for drivers.
Treatment:	Installation of Yellow Bar Markings on the Eastbound approach to this roundabout, according to DMRB TD 6/79 specification.
Implemented:	June 1987.
Comments:	These proposed road markings were installed as a reaction to a potential safety problem: ie prior to the opening of a flyover approximately 1 mile upstream.
Effectiveness:	Accidents (pia)
Before:	1.0 per year (eastbound approach)
After:	0.3 per year (eastbound approach)

Authority: Bracknell Forest Borough Council