First Edition

A Road Safety Good Practice Guide

THINK! Road Safety

A Road Safety Good Practice Guide for Highway Authorities

First Edition

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Contents

01 Introduction

Purpose

1.1 This is the second publication in the good practice advice series on local transport. This guide shares good practice, to help achieve the targets set out in DETR's road safety strategy *Tomorrow's roads – safer for everyone* (DETR, 2000b).

1.2 This guide has been developed primarily as a reference for local authority staff with an interest in road safety engineering and associated issues. However, we also hope that it will interest a wider audience, including the police, the Highways Agency, local health authorities, local communities, businesses, and transport interest groups.

1.3 It is hoped that the guide will particularly benefit those new to road safety engineering, whether they are just starting their careers or are transferring from a related discipline.

1.4 This guide is intended to be a living document, which will be updated over time as knowledge and experience develop. Consequently other existing and new examples of good practice will be sought and we particularly welcome feedback from practitioners (see chapter 8).

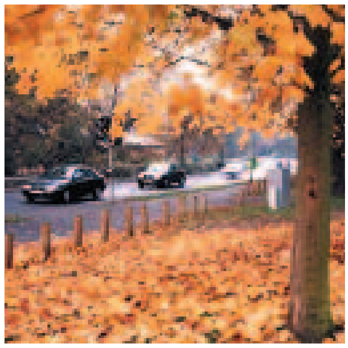
Scope

1.5 A number of documents that advise on various aspects of road safety[1] management, including the design of engineering measures and schemes, are already in the public domain. This document aims to draw together existing advice as far as possible into one document, and to update it, based on the most recent experience of local authorities and agencies (see examples, Appendix A), and on research results.

1.6 Consequently, the level of detail varies, and it follows that this guide is not intended to be a fully comprehensive document to be used in

[1] This guide is concerned with road safety only. It does not deal directly with the security of persons or property.

isolation. Where a subject is covered in depth in up-to-date publications elsewhere, the subject may be dealt with more briefly and reference will be made to the other sources of information in the text. Additional references that may be of use are given only in the bibliography. Where there is little current published information available, we deal with the topic more fully in this guide.



1.7 The good practice in this guide is not only based on the full Local Transport Plans (LTPs) submitted by local authorities, but also on other aspects that DETR considers good practice. Also included are innovative examples provided by local authorities, thought to be successful, but which are too recent to be proven so.

1.8 Strenuous efforts have been made to provide accurate, up-to-date and full coverage of the issues relating to road safety engineering and good practice, with the focus on engineering. However, it should be noted that much of the contents is taken on good faith and some subjective judgements have been relied upon in the choice of approach. Readers should also be aware that what constitutes good practice in one authority, or on a particular road, or under one set of specific conditions, may not be good practice if simply replicated elsewhere. This is due to the complexity of the many interacting factors affecting safety. Similarly, it should also be noted that there is not one definition of good practice, as no single definition could cover everything.

Structure

1.9 This guide has eight chapters:

- **Chapter 1** comprises the above purpose and scope of this guide and a background introduction to road accidents in Great Britain. It also describes how safety problems are currently being tackled;
- **Chapter 2** looks at the management of road safety on the network, including staffing, training, planning, liaison and consultation processes. This chapter also considers the roles of road safety officers, road safety engineers and safety qualifications;
- **Chapter 3** describes the general principles of road safety work. The role of Local Transport Plans (LTPs) is discussed. It provides methods of identifying and prioritising problems using accident and casualty analysis techniques (including the need to consider urban and rural problems separately and how to take exposure to risk into account – particularly for vulnerable road users). The chapter also deals with finding solutions to accident problems, prioritising schemes, and economic justification in terms of accident reductions.

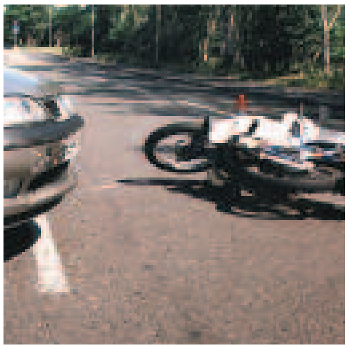
This chapter also raises issues relating to the funding, installation, safety audit, and monitoring of schemes;

- **Chapter 4** (in conjunction with Appendix A) comprises the main body of the guide. It describes specific national safety problems (including accident and casualty statistics not published elsewhere) and a selection of engineering measures offered as potential solutions, according to location and road type;
- **Chapter 5** describes many of the methods available to monitor and evaluate the success of schemes, including some which may be useful when accident numbers are small and the levels of exposure to risk are unknown;
- **Chapter 6** is the **bibliography**. It contains:
  - the contents list for the *Traffic Signs Manual* (TSM – chapters one to eight);
  - a list of Traffic Advisory Leaflets (TALs);
  - a list of Local Transport Notes (LTNs);
  - a list of the highway standards and advice notes found in the *Design Manual for Roads and Bridges* (DMRB); and
  - a large list of other publications relevant to road safety, including those referred to in this guide. The latter are listed alphabetically by author;
- **Chapter 7** lists **abbreviations** used in this guide;
- **Chapter 8** describes how readers can give feedback;
- **Appendix A** contains brief descriptions of individual engineering measures and key references on proven performance, where available. The appendix also gives one or more example schemes (generally) submitted by local authorities, with a brief description of their purpose and performance;
- **Appendix B** gives basic details on applying various statistical techniques, including some worked examples;
- **Appendix C** is the standard data input form for the safety scheme accident monitoring database, MOLASSES.

Background

1.10 Over the last 50 years, the number of motor vehicles in Great Britain has increased dramatically. Motor traffic levels are about ten times greater today. In 1950 there were about 550 people injured in road accidents every day, about 14 of who were fatally injured.

1.11 Both central and local government have made substantial efforts to reduce the road accident toll and, despite the large increase in traffic, accident rates (per vehicle-km travelled) have declined dramatically. In 1966, the number of fatalities peaked at 22 per day. Since then the number of fatalities has gradually fallen. In 1999, there were about nine and a half per day.



1.12 Many factors are involved. However, we can identify three major contributions to the drop in casualty numbers and their severity:

a) legislation requiring that seat belts be fitted (1967) and worn (1983 onwards);

b) drink-driving legislation (the current legal limit of 80mg of alcohol in 100ml of blood was introduced in 1967) and changes in the attitude of the public to drink-driving;

c) traffic calming schemes on local roads (1980s onwards).

1.13 In addition, in 1987 the government of the day focussed attention on road safety by setting a national target to reduce road accident casualties by one third by the year 2000 (compared with the 1981-85 average). A great deal of effort and initiatives followed and since that target was set, road injuries have fallen by only 0.5 per cent but road deaths have fallen by 39 per cent and serious injuries by 45 per cent. However, the volume of traffic has increased by 160 per cent over the same period, and those slightly injured may previously have been seriously injured or killed.

1.14 Compared with the rest of the world, and the rest of Europe in particular, we have one of the lowest levels of road deaths per head of population, and per licensed motor vehicle (DETR, 2000a). We also have one of the lowest car occupant deaths per car-km (Automobile Association – AA, 1999a).

1.15 However, 320,310 people were still injured in a single year in road accidents in Great Britain (1999 data) of these casualties 3,423 were fatally injured – nearly nine and a half a day (DETR, 2000a)[2]. Although in many respects our roads are safe compared with others in Europe, our child pedestrian fatality rate is one of the highest in Europe (DETR, 2000b).

1.16 While most road accident casualties in Great Britain are car occupants, this reflects the fact that the car is the main type of road transport.

[2]These include the figures for motorway and trunk road accidents, which comprise 12 per cent of all casualties and, because of relatively high severities on trunk roads, 18 per cent of all fatalities.

Other types of road users are subject to a higher risk of accidents, despite their relatively low exposure on the network (in terms of time spent or distance travelled). These are known as vulnerable road users and include pedestrians, pedal cyclists, motor cyclists and equestrians. Many of these road users are children who suffer serious injuries, as they are generally less well protected in accidents than people in cars. The safety needs of vulnerable road users are extremely important.

1.17 DETR published a national cycling strategy in 1996 (DETR, 1996). *Encouraging walking: advice to local authorities* was published in March 2000 (DETR, 2000c). It is a working guide for the people who turn policy into action. It is not an exhortation to the public to walk more, but aims to make it safer, easier and more convenient for them to choose to do so. It shows how improvements to the walking environment can be made at both the strategic and the tactical level.

1.18 Accidents place a large financial burden on the nation, not only in terms of the costs associated with personal injury but also in terms of damage to property. The current estimated annual savings from preventing all (including about £3,520,000 damage only) road accidents is £16,310,000 (DETR, 2000a).

1.19 These statistics reflect the need for a continued, concentrated and well-managed approach in order to reduce the number and severity of accidents.

1.20 DETR has published a road safety strategy *Tomorrow's roads – safer for everyone* (DETR, 2000b)[3]. The strategy sets casualty reduction targets for the year 2010 (with progress to be measured by comparison with 1994-98 averages)[4]. The 2010 road safety casualty reduction targets are:

- **a 40 per cent reduction in the number of people killed or seriously injured in road accidents[5];**
- **a 50 per cent reduction in the number of children (under 16 years of age) killed or seriously injured; and**

[3]The equivalent for motorway and trunk roads is the Highways Agency's *Safety Strategy*, safety being one of eight strands of an overall strategy. The strategy aims to spread good practice and help those without any safety training. The Highways Agency published it in March 2000 (Highways Agency, 2000a).

[4]These targets are also those adopted by the Scottish Executive and the National Assembly for Wales. Implementation of the strategy will be taken forward by the UK and devolved administrations in accordance with their respective roles and responsibilities. Northern Ireland will have its own road safety strategy.

[5]The target for the motorway and trunk road network is a reduction of 33 per cent (Highways Agency, 2000a).

- **a 10 per cent reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 million vehicle kilometres.**

1.21 The road safety strategy also outlines strategies to tackle problems associated with:

- children and the most vulnerable road users;
- driver training;
- drink, drugs and drowsiness;
- the road infrastructure;
- speeds;
- vehicle design and maintenance; and
- enforcement, education and information.

1.22 Alongside the safety strategy, DETR published *New Directions in Speed Management – A review of policy* (DETR, 2000d). This contains the latest information on the relationship between vehicle speed and accidents and other factors including air quality, noise, quality of life, and health.

1.23 Directly or indirectly, everyone can influence road safety. We are all responsible for controlling the risk we expose ourselves to and the risk we subject others to. No one is excluded from using the road network, so everyone must work towards the common goal of accident reduction. Stakeholders will include:

- individual road users using the network for work or leisure (motorists, pedestrians, motorcyclists, pedal cyclists and equestrians, including those with special needs, such as those with disabilities); and
- those in national and local government, Northern Ireland, the Scottish Executive, the National Assembly for Wales, government agencies, Transport for London, local authorities, the police, health, education, public transport, commercial companies, charities, research bodies and special interest groups.

1.24 There have been changes recently in the way local highway authorities (LHAs) bid for a share of DETR funding. The Department has replaced the old Transport Policies and Programme (TPP) system with Local Transport Plans (LTPs)[6]. The funding for safety under TPP was ring-fenced and distributed annually, based to some extent on the road

[6]Note that separate systems are in place in London, Wales and Scotland.

safety plans produced by local authorities. From 1999-00, authorities submit LTPs that cover all aspects of local transport management, including safety. Capital funding for road safety measures is now awarded as part of a wider block of local transport funding over which local authorities have discretion. From 2001-02, DETR has given an indication of local transport funding levels for five years.

1.25 Two recently published documents give guidance on developing full LTPs (DETR, 2000e) and examples of good practice in LTP development (DETR, 2000f).

1.26 The first of these documents states that LTPs should "describe the specific road safety policies in a local road safety strategy" and that "the strategy must contain local casualty reduction targets for 2005, broken down into annual milestone targets, so that local authorities can monitor progress. Authorities will want to establish targets to reflect the national targets".

1.27 The document goes on to outline the expected contents of a local safety strategy, including details of proposed and existing engineering schemes and non-engineering approaches. It emphasises the need for monitoring and the benefits of contributing to Great Britain's central database, known as MOLASSES (Monitoring Of Local Authority Safety SchemES – see Appendix C and paragraph 5.4 below). It requires the production of an annual progress report and tables of performance indicators for measuring progress. Guidance has been produced to assist authorities in monitoring and reporting on progress in implementing their Local Transport Plans, including progress towards all local objectives and targets (DETR2001).

1.28 If safety is to improve, local highway authorities must allocate resources for staff and materials within the overall programme. These resources should be sufficient to design for safety, and allow authorities to implement, monitor and assess good practice. In the long term, if a coherent approach is adopted, society ought to profit from such an approach in terms of accident savings and an improved quality of life.

Local arrangements, liaison and consultation

02

Management of safety

2.1 General principles of road safety management are dealt with in several documents. For examples, see LAA (1996), RoSPA (1995a), IHT (1990a, 1990b, 1999c).

2.2 The Road Traffic Act 1988 (Section 39), specified that local highway authorities must provide a road safety service. This service includes education, training and publicity (ETP) programmes and engineering schemes[7]. In other words, they must try to 'prevent' as well as to 'cure' road accidents. Local highway authorities vary greatly in how they provide this service.

2.3 The Highways Agency has 38 agents[8] to run, maintain and improve its trunk roads. These agents are generally not local authority employees. The boundary of each agent's area does not generally coincide with county boundaries, and each area usually includes parts of several counties.

2.4 Most commonly, road safety officers (RSOs) take responsibility for the ETP programmes and road safety engineers (RSEs) plan, design and install the safety engineering schemes. Often these roles are carried out by personnel who are exclusively concerned with safety. In others these roles are part-time, carried out by several personnel alongside their other duties.

2.5 The *LAA Road Safety Code of Good Practice* (LAA, 1996) recommends one full-time RSO per 50,000 population and one full-time RSE per 1,000 personal injury accidents.

[7]Safety on the motorway and trunk road network is the responsibility of the agents acting on behalf of the Highways Agency.

[8]Including 14 Design, Build, Finance and Operate (DBFO) groups.

2.6 Local highway authorities must assign responsibilities clearly. Contracts delegating responsibility for certain aspects of safety should be carefully drafted. It is equally important to monitor compliance.

Liaison and consultation

2.7 Paragraph 1.23 above lists many of those who have an impact on road safety. It is imperative that effective links are built and maintained between these players so that all of them remain informed about current strategies and have an opportunity to express opinions and work together to shape outcomes.

2.8 As a general rule, everyone likely to be affected by a planned course of action (eg the introduction of a new engineering scheme) should be consulted at appropriate points throughout the planning process.

2.9 Councillors (elected members), parish councils and local committees represent local communities who need to be kept informed of road safety issues and planning. Public consultation is invaluable and you can find practical advice in, for example, IHT (1996a) and IHT (1999b).

2.10 The structure and organisation of traffic policing varies from area to area. However, in general, traffic police will assist road users, enforce road traffic law and supervise any necessary temporary changes in traffic management. The police, ambulance and fire services may all be present at the scene of an accident. The police also play a significant role in encouraging, publicising and educating road users about traffic law. Sometimes the police will also be involved in safety audit and accident investigation.

2.11 The Crime and Disorder Act (1998) requires police and local authorities to carry out a three yearly audit of problems affecting their area and draw up a plan to deal with them (DETR, 2000b). This should include road safety.

2.12 Therefore, the police[9] need to be informed of any relevant changes to the network, such as scheme installation, special events and roadworks. The links between the police and local authorities are invaluable and, indeed, they often collaborate in strategies such as speed management and setting speed limits, the provision and operation of speed cameras, training programmes, driver rehabilitation projects. In addition, the decriminalisation of parking offences and the proposed decriminalisation of unauthorised use of bus lanes will raise road safety issues and opportunities. The police can also advise on road traffic patterns and driver behaviour because of their specialised knowledge of the network.

[9]Other emergency services will also need to be informed, when appropriate.

2.13 Perhaps most importantly, the police collect all the information on reported road traffic accidents. For each accident resulting in personal injury, the police record the circumstances surrounding the accident and details of the vehicles and casualties. They may also include contributory factors, participant and witness statements, photographs or sketch plans. The accident, vehicle and casualty information is included in the national STATS19 accident database and this helps to identify the problems that road safety strategies must tackle.

2.14 Consultation between LHAs and HA agents is also important, particularly on schemes where the trunk road network adjoins or crosses the local network and for joint publicity initiatives. In addition, the trunk road network has been divided into 'core' and 'non-core'[10] elements and in the near future local authorities will take over responsibility for the non-core elements (DETR, 1998a). It will take excellent liaison for the handover to go smoothly.

2.15 The various departments within a local authority should liaise to avoid conflicts of interest and to provide a cost-effective service. There is particular value in incorporating the efforts of RSOs and RSEs in the planning stages and especially when introducing innovative schemes. We generally recommend that communication with colleagues in:

- policy;
- planning and development;
- maintenance;
- highways (engineers responsible for new roads and major schemes);
- public transport;
- traffic management and control;
- access and mobility; and
- trading standards.

2.16 Consultation and co-operation between local authorities and outside bodies is also important. For example, develop links with:

- the general public;
- local residents and businesses;

[10]Approximately one third of all trunk roads.

- landowners and farmers;
- motoring organisations;
- driving instructors;
- cycle and motorcycle trainers;
- HGV driving instructors;
- freight transport groups;
- special interest road user groups;
- public transport companies;
- construction companies;
- charities;
- professional organisations (e.g. IHT, ICE, IRSO etc);
- environmental groups;
- private companies;
- teachers;
- local health authorities; and
- hospital trusts and other organisations (such as CAPT, RoSPA, CPRE etc).

2.17 There is often potential for joint projects – perhaps targeting a road safety problem from more than one direction – to make the most of financial and human resources. Some examples of this approach include:

- local highway engineers working with the local health authority on cycle scheme initiatives, to help meet both road safety and health of the nation targets;
- a local authority and a car manufacturer jointly funding training schemes for young drivers.

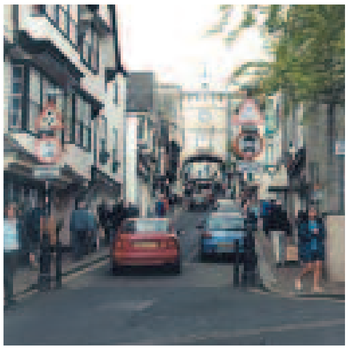
2.18 Local authorities can also benefit from co-working, sharing information and experience and acting consistently:

- locally, working with other authorities through, for example, the regional Government Offices and accident reduction working groups, Local Authority Road Safety Officers Association (LARSOA), Association of London Borough Road Safety Officers (ALBRSO), Transport for London and so on;

- at a national level through, for example, the DETR, Highways Agency, County Surveyors Society, Parliamentary Advisory Committee on Transport Safety (PACTS), Local Government Association etc.

2.19 Some guidance on forming partnerships is given for the purpose of developing LTPs (DETR, 2000e and 2000f).

2.20 Disseminating the results of local authority road safety work to a wide audience is essential. This can be done through formal or informal presentation and through publication, either individually or by gathering information from several sources together. DETR regularly gathers, analyses and interprets this sort of information to develop its advice – see also chapter 6.



2.21 It may be a good idea to set up a formal approach to consultation and liaison on a regular basis. The Gloucester Safer City project found this useful (DETR, 2001b). For example, meetings could be pre-arranged at regular intervals and an annual diary of events, campaigns and initiatives could be issued.

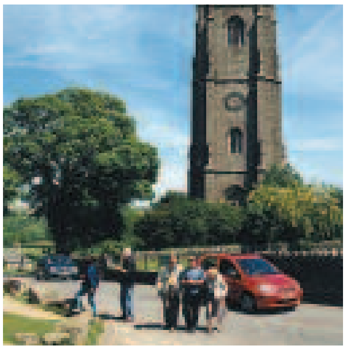
Role of road safety officers

2.22 In general terms, road safety officers are involved in education, training and publicity (ETP) and encouragement programmes. These approaches help to change road users' attitudes and behaviour. The full benefits of these approaches are often long term. They may never be measurable as it may not be possible to assess their specific effects.

2.23 Education programmes are largely school-based. The programmes usually involve informing and advising teachers. They may have specific objectives or be part of a long-term development of learning and ideas. Programmes aimed at children will match their physical and mental development. Often, road safety education can be planned to complement other topics in the National Curriculum. Some programmes and advice can be directed through parents.

2.24 Training programmes are mostly targeted at specific types of road user or age group. They are designed to develop practical road use skills; for example, cycling and walking.

2.25 Publicity campaigns generally use the media, leaflets and advertising.



These are often the only ways to reach a wide audience, and adults in particular. The campaigns may, for example, inform of new developments, changes to the network, traffic or the law. They provide advice on the latest best practice, or the most recent research. They often aim to change road user behaviour and attitudes to road safety. Many publicity campaigns are organised nationally by DETR, for example. They target national problems or reflect national policy. These campaigns often rely heavily on support from local health authorities and schools for maximum effectiveness.

2.26 ETP programmes often involve a combination of the above approaches and may involve RSOs working together with other outside bodies.

2.27 It is important that ETP work is monitored so that future programmes can be even more effective.

Role of road safety engineers

2.28 Road safety engineers are responsible for designing the road network to be as safe as possible, for all types of road user. They design road safety engineering schemes to reduce the number and severity of casualties and to prevent them in the first place.

2.29 Road safety engineering involves physical changes to the network. Nowadays this predominantly involves light, rather than heavy, engineering schemes (ie signing, marking, or making minor modifications to the existing road network), rather than constructing new roads.

2.30 An engineering scheme immediately affects all road users who travel through it and its effects are also measurable.

2.31 Chapter 3 outlines the general principles for road safety engineering work. Chapter 4 details a number of safety engineering accident-remedial treatment measures for use on a wide range of roads. Chapter 5 deals with the measurement and evaluation of the effects of safety engineering schemes. Appendix A contains examples of successful schemes installed by local authorities across Great Britain.

2.32 Road safety schemes must be maintained, just like the road network generally. Liaison with those responsible for maintenance (eg operating the UK Pavement Management System) is essential to ensure that new schemes are integrated within the maintenance programme. For optimal safety of the network, we generally recommend that you maintain the best value indicators specified as minimum levels for principal roads (BVPI96 – see DETR, 2000j) and for non-principal roads (BVPI97).

Role of Road Planning Officers

2.33 The Planning process should take account of road safety and planning offices must liaise closely with RSOs and RSEs.

Road safety qualifications

2.34 Few people currently working in road safety have had any formal or comprehensive training in safety. However, many may have been trained in associated disciplines, such as civil engineering, teaching or traffic management.

2.35 In general, safety personnel have gained their valuable knowledge through observation and 'on-the-job' experience. Some have also attended a few seminars or been on short training courses, for example in the use of specialised software. Currently[11] available safety qualifications include the National Vocational Qualifications (NVQs levels 3 and 4 – contact IHT for details: iht@iht.org).

2.36 Other safety training available includes:

- two week RoSPA road safety engineering course (contact RoSPA);
- one week course for Road Safety Officers (contact BITER);
- road safety courses for local authority staff (contact local police);
- miscellaneous road safety audit courses (generally advertised in magazines and journals – contact TMS Consultancy, for example);
- other miscellaneous road safety courses (contact PTRC, for example); and
- miscellaneous software training workshops such as for SafeNET, OSCADY, ARCADY, PICADY etc[12]. (contact TRL Limited).

This list is not comprehensive and several other courses are available within the UK.

[11] A few personnel have qualifications that are no longer offered: eg 'Road Safety Engineering' MSc (Middlesex University).

[12] SafeNET is used to estimate the frequency of accidents on an urban network (from traffic and pedestrian flow and geometric information provided). OSCADY, ARCADY and PICADY are used as aids to the design of signalised, roundabout and priority junctions, respectively.

03 General principles

3.1 This chapter outlines the general principles associated with road safety work, and engineering in particular. It begins by describing the role of road safety in Local Transport Plans (LTPs). It then goes on to describe accident and casualty analysis techniques to identify road safety problems. The next sections address how to find solutions to the problems and to prioritise work programmes and issues relating to the installation and safety audit of safety schemes. The final section stresses the importance of learning from the success or failure of a scheme.

Integration with Local Transport Plans

3.2 A Local Transport Plan is a statutory document produced by a local authority. It sets out a five-year integrated transport strategy devised in partnership with the community[13]. The Local Transport Plan covers every transport related activity carried out by the local authority. Two recently published documents give guidance on developing full LTPs (DETR, 2000e) and examples of good practice in LTP development (DETR, 2000f).

3.3 It is not a requirement for a Local Transport Plan to present detailed lists of the schemes that the local authority will implement. Rather, the plan is required to present a local vision of what the community wants to achieve. Local authorities should develop this vision, as well as all other aspects of the Local Transport Plan, through public consultation.

3.4 The Local Transport Plan needs to take account of the data required for monitoring the performance of local safety schemes, and to ensure that accurate data is collected on a regular basis. Background sources of data may include the *National Travel Survey, Transport Statistics Great Britain* (DETR, 2000h) and *Road Accidents Great Britain* (DETR, 2000a). Local authorities need to ensure that casualty statistics are accurate and effectively monitored. This will involve close co-operation with the police. Local authorities also need to develop a

[13]Note that separate systems are in place in London, Wales and Scotland.

comprehensive set of targets and performance indicators, which must include road safety Best Value Indicators (BVPI99 – see DETR 2000k, Best Value Performance Indicators 2001/02). These need to take account of national targets.

3.5 It is important to ensure that local safety schemes and other road safety activities are integrated with the aims and objectives of the Local Transport Plan. Local safety schemes and education, training and publicity initiatives should be designed in the context of an integrated approach to transport and careful consideration should be given to their effect on other activities.

3.6 The aims of the Local Transport Plan should be assessed in accordance with the Department's New Approach to Appraisal (NATA)[14]. NATA sets out the Government's five objectives for transport, which are:

- environment
- safety
- economy
- accessibility
- integration

Therefore when a new safety scheme is required, the impact against each of these objectives should be considered. To be consistent with NATA, the assessment should also examine the impact on local objectives, local problems and other issues including distribution and equity, practicality and public acceptability, and affordability and financial sustainability. However, as described below, the general principle is that the level of detailed appraisal should be that required to establish clearly whether the scheme represents value for money.

3.7 DETR (2000j) has said that building in accessibility for disabled people in all new investment is a condition of public money being spent. Clearly, not all of the above questions would be relevant for each new scheme. However, it is important to realise that a new scheme will influence other activities within the Local Transport Plan. Local authorities are encouraged to develop 'causal chains' in order to show this interaction. For example, a 'safer routes to school' scheme may provide safer pedestrian crossing points. This improves safety, leading to more cycling and walking, which in turn leads to health benefits.

[14]For more details on the New Approach to Appraisal (NATA) see DETR 2000e and paragraph 3.87.

3.8 Each Local Transport Plan requires the setting of targets for each activity and road safety is no exception. The performance of local safety schemes should be measured against a series of local targets and the national targets for casualty reduction. Chapter 1 summarises the national targets.

3.9 Local authorities are encouraged to set targets that are tougher than the national target. In addition, the Local Transport Plan is required to have a local casualty reduction target for the year 2005 supported by annual milestones.

3.10 To achieve the objectives of the Local Transport Plan, it may be useful to use more sophisticated criteria for the selection of local safety schemes. As well as the normal criteria of a certain number of accidents within a given location, other criteria such as the severity of injury, flow levels and proximity to schools could be considered. A well designed scheme implemented outside schools may reduce accidents and casualties, improve social inclusion and encourage walking. However, the need to reduce casualties must remain the first priority. It is important that the criteria reflect the priorities of the Local Transport Plan.

3.11 The integrated approach of Local Transport Plans opens up the possibility of designing schemes that can address a number of issues at the same time. A simple example would be where a road is due for renewal and, although this is normally a maintenance issue, there is no reason why a safety scheme could not be included in the works. This integrated approach extends to the relationship between local planning authorities and developers. It is a requirement that developers take account of road safety in the design and layout of their proposals.

3.12 It is important that authorities should monitor the progress they are making in implementing their Local Transport Plans. Authorities have been asked to prepare Annual Progress Reports which identify the progress being made in working towards the local objectives, targets and outputs contained in their Local Transport Plans, including all road safety targets. These reports will also help to indicate the link between local and national targets, and may help to identify any barriers to the achievement of local objectives or targets.

Accident and casualty analysis: identifying problems

3.13 Local authority engineers and others responsible for road safety need regularly to assess the problems on their network. This will involve studying accident patterns over a period of time according to location, circumstances and the vehicles and casualties involved. The relative size of the problems and the ability to tackle them must be assessed and suitable cost-effective solutions devised and planned.

3.14 Traditionally, this is known as an accident investigation and prevention (AIP) approach. Local authorities have reduced casualties by identifying the locations with the highest accident frequencies and giving them priority over others for remedial treatment as local safety schemes (LSS).

3.15 73 per cent of all accidents are concentrated on urban[15] roads. Consequently, traffic authorities have directed most of their casualty reduction efforts on these roads, tackling locations where accidents are tightly clustered (often at junctions).

3.16 This has proved successful and road safety engineering budgets have been spent accordingly. Of course, other factors such as the vehicle capacity of the road, land development, policy issues and environmental matters often affect budgeting decisions as well.

3.17 Many local authorities now programme their work to take other factors into account (as part of a speed management plan, for example) and adopt any of four strategic approaches:

- **single site action** – addressing a specific site with a much higher than average concentration of accidents of a particular type;
- **mass action** – addressing all locations having a similar accident problem over the whole area under consideration using proven remedial measures – eg at all T-junctions;
- **area action** – addressing a number of problems over a network of roads in one part of the total area under consideration; and
- **route treatment** – addressing a number of problems on one or more routes – ie adjoining road sections with broadly similar characteristics and traffic.

3.18 Methods for such approaches have been well-documented elsewhere, for example by the IHT (1990b) and RoSPA (1995b).

3.19 However, with the Government's integrated transport policy, there are now good reasons to broaden the approach to include analysis of:

- urban and rural[16] accidents separately (see paragraphs 3.36 to 3.40 below)
- accident numbers <u>and</u> accident rates for all classes of road user, including vulnerable road users (see paragraphs 3.41 to 3.51 below)
- each class of road separately (see paragraphs 3.52 to 3.53 below).

[15] Urban (or 'built-up') roads are defined as those with speed limits of 40 mph or less.

[16] Rural (or 'non-built-up') roads are defined as those with speed limits of 50 mph or more. Roads through villages with speed limits of 20, 30 or 40 mph are not included. A rural road may or may not have buildings alongside it.

3.20 The separate analyses suggested above should be carried out with a view to allocating resources to both urban and rural areas, and to each class of road, and to different classes of road user.

Identifying and prioritising problems

3.21 Accident and casualty analysis is a complex procedure because the factors affecting accident occurrence are numerous and not independent. Ideally, the direction that a comprehensive accident analysis takes will be led by accident data. Experienced road safety engineers will carry out the analysis. They will understand the importance of different types of result and be able to identify and balance conflicting levels of accident risk[17].

3.22 In practice, it may be useful to follow a guide (such as that in paragraph 3.23 below), which ensures that the key areas and types of accident are addressed. Further analyses should be carried out whenever budgets and the relevant expertise are available, and particularly if it is clear that special problems exist.

3.23 The basic approach for separate urban and rural accident analyses can both be summarised in the following steps.

- Look at injury accident data for the relevant area for a period of three to five years[18]. Plot the location of accidents on maps. This can be done with a GIS system or an accident analysis package, initially distinguishing killed and seriously injured (KSI), child accidents and/or other vulnerable groups separately.
- Examine accident patterns in terms of type, contributory factors[19] and location[20], considering accident numbers and rates for each class of road[21].
- Identify any significant changes in accident trends and factors over time.

[17] Accident risk is a general term for the likelihood of an accident occurring, given a certain level of exposure.

[18] If accident numbers are high (hundreds or thousands) then one year's data may be sufficient. However, if numbers are small and the data are broken down further into small groups by type of accident, for example, then the data will vary too much between years or sites for meaningful comparisons to be made and may be misleading. Much more than three to five years data will lead to a tendency for changes in flow and significant changes in the network to affect the accident picture.

[19] The analysis of the types of accident and the causal factors contributing to the accident is a vital step to reach an understanding of why accidents occur and how to treat the problem. Some of the most important aspects to be studied include casualty severity, weather and road surface condition, road layout and junction type, vehicle manoeuvres, vehicle types, vehicle speeds, driver compliance with the Highway Code, driver age, pedestrian involvement etc.

[20] This should include an analysis of types relevant to local and national targets and performance indicators in LTPs – ie will include accidents involving child casualties, vulnerable road user casualties and analyses by severity.

[21] See also DETR (2001a) and Barker et al (2001) for detailed methods.

• For each road in the area, tabulate the results as you go.

• Prioritise roads for further investigation and treatment (see paragraphs 3.30 to 3.34 below).

3.24 It is important to consider not only the local picture, but the wider picture too. For example, over the same period:

a) have accident frequencies changed nationally (or over another large area, such as the neighbouring county)?

b) have traffic levels changed?

c) has the composition of traffic changed?

d) what other local or national events may have affected accident frequencies?

3.25 To explore a) above, some useful publications are:

• *Road Accidents Great Britain – The casualty report*. This is published every year, the most recent being DETR (2000a). DETR also produce quarterly summary information.

• Some authorities publish road safety plans or accident reports in addition to their Local Transport Plans. The latter must be made publicly available and include their local road safety strategies.

• Transport for London, London Accident Analysis Unit (LAAU) publishes regular reports on the accident and casualty data for all the London authorities (see London Research Centre, 1999a, 1999b, 1999c for examples);

• Publications by interest groups, such as the Child Accident Prevention Trust (CAPT, 2000a).

3.26 To explore b) and c) in paragraph 3.24 above, the possible safety effects of encouraging more cycling and walking (DETR, 1996; DETR, 2000c) and the possible effects of the Road Traffic Reduction Act (1997 and 1998) should be considered. Some useful publications are:

• *Transport Statistics Great Britain*. This is an annual publication (DETR, 2000h). DETR also produce quarterly summary information;

• *National Travel Survey*; and

• *National Household Census*.

3.27 Factors affecting d) in paragraph 3.24 above may include almost anything from the installation of a scheme (within the last three to five years), to temporary road closures, to a large sporting event, to a petrol shortage, to a new law or publicity campaign.

3.28 Any changes to the local network in terms of the road length under study should also be taken into account. For example, the introduction of lower speed limits in villages and the new responsibilities for non-core trunk roads may both affect the proportion of rural and urban roads (and so casualties) in the network year by year.

3.29 It may be helpful to tabulate the results of the analysis, to assess the relative seriousness of problems to help prioritise them. This will be particularly useful in identifying any overall problems, such as speeding, skidding, or bend accidents. It may provide justification for a mass action treatment (see paragraph 3.17 above).

3.30 The information used on accident rates during the prioritisation process will vary, depending on the situation and the quantity and reliability of exposure data. The use of more than one type of accident analysis approach will often be appropriate.

3.31 When ranking problems a balanced assessment of all the data has to be achieved, based on:

- accident rate (see paragraphs 3.41 to 3.44 below);
- number of accidents; and
- severity of injuries sustained in accidents.

3.32 An intervention level is a numerical value of a measure of an accident problem (such as accidents/year, accidents/vehicle-km). If the values for a particular road exceed the relevant intervention levels, then select that road for more detailed analysis and subsequent treatment.

3.33 Over time, most of the worst accident problem sites have been ‘cured’. Accidents now tend to be spread more evenly across whole areas. For this reason, ‘mass action’, ‘route action’ or ‘area action’ remedial treatments may be preferable to treatments at a few specific sites (see paragraph 3.17 above). The treatments selected may be chosen to tackle one or more particular types of accident, rather than all accidents.

3.34 Low-cost measures may make these other approaches just as cost-effective as the traditional site-specific approach. In addition, some accident problems may be tackled more effectively through enforcement, training and publicity than by engineering alone.

Data issues

3.35 The nationally collected accident database using material from the STATS19 form, described in paragraph 2.13 above contains objective information about accidents. A sample form can be found in the back of RAGB (DETR, 2000a). STATS20 (DETR, 2000g) accompanies the STATS19 form. It advises on the meaning of certain aspects of the form. The following points may also help in accident analysis:

- Many villages have 30 or 40 mph speed limits[22]. They are therefore classified as urban, even if the surrounding roads are rural and the land is predominantly not built on. It is not easy to identify such sites from accident data, except with the use of maps.
- The 'road type' (was 'carriageway type') variable in STATS19 does not include the categories 'roundabout' and 'one way street' as either single or dual carriageways. The two together account for approximately 10 per cent of all accidents so take care to account for them in analyses that consider single and dual carriageways separately.[23]
- There is no specific definition of a bend or the severity of a bend. This is because in terms of safety many factors are important, including the type of approach, camber, superelevation, radius, transition, road surface, aspect, verge width, gradient etc. It is up to the reporting officer to decide how to classify the accident. In addition, a bend feature is only specified as a category in the 'vehicle manoeuvre' variable. This means that the reporting officer may record the vehicles in an accident that happens at a junction on a bend as either a junction or a bend-related manoeuvre.
- Horses are now included as a vehicle type on the STATS19 form[24].

[22]Government policy is now that speed limits in all villages should be 30 mph.

[23]The convention adopted in the casualty analyses in this guide is to combine these data with dual-carriageway data for motorway and A-road accidents and to combine them with single-carriageway data for accidents on lower class roads.

[24]In 1999, 181 horse rider casualties were reported, two of whom were fatally injured. 40 per cent of casualties occurred on urban roads and 60 per cent on rural roads (DETR, 2000a). It is not known how many horses were injured or involved in road accidents where the rider was uninjured.

- Police authorities should record all injury accidents. Of course, not all accidents are reported to the police. Research using hospital and insurance records has shown that recording levels for accidents involving vulnerable road users and for those involving only a single vehicle are particularly low (eg Mills, 1989; James, 1991).

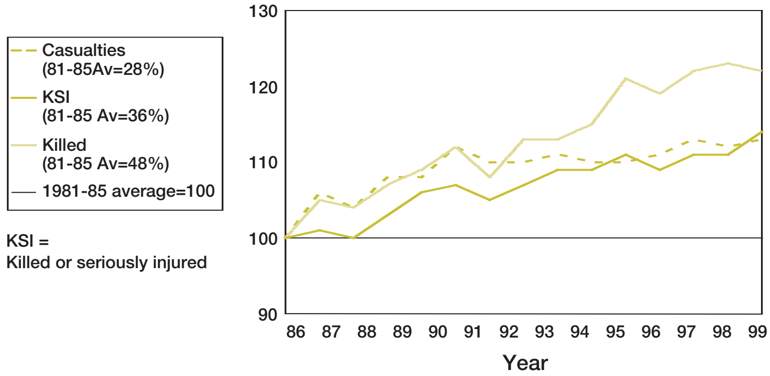
- There is some evidence that the precise location given for an accident is often inaccurate. It may be hard to ascertain precisely where the accident occurred, with respect to where the vehicles came to a halt, particularly in the case of a high speed accident. Also, the police will not always attend the accident scene immediately after the accident.

Importance of rural accident remedial work

3.36 Although rural accidents account for only 31 per cent of all casualties, these accidents contribute 44 per cent of the total cost of injury accidents in Great Britain because they result in more serious injuries than on urban roads. What is more, a study of the past decade shows that the proportion of total accidents and casualties in rural areas is increasing, particularly of the most severe accidents. In fact, currently 59 per cent of all deaths occur on rural roads.

3.37 Fig. 3.1 shows the trend in the proportion of casualties on rural roads compared with the 1981-85 averages, by severity.

Fig 3.1: Indices of the proportion of all casualties that were on rural roads (including motorways), by injury severity (1986-99)



3.38 Rural roads (excluding those through villages) are less likely than urban ones to be treated with safety engineering schemes. The main reasons for this are that:

- local authorities tend to identify sites for treatment on the grounds of injury accident numbers; and

- accidents in rural areas are even more likely than those in urban areas to be widely scattered.

3.39 Intervention levels (see paragraph 3.32) suitable for urban (but not rural) roads will be well known to local authority RSEs from their knowledge of their local network. Intervention levels suitable for use in rural accident analysis[25] (including some relating to vulnerable road users) have been developed recently, based on national data (Barker et al, 1999). A methodology for rural accident analysis using these intervention levels is given in DETR (2001a) and Barker et al (2001).

3.40 There is also another good practical and financial reason for considering the separate analysis of urban and rural roads. The *Highway Maintenance Code of Good Practice* (LAA, 1989) recommends creating a highway maintenance management strategy and a maintenance road hierarchy of urban and rural roads separately. It recommends that it should be further broken down by traffic flow and composition. Efficiencies will result if maintenance and safety scheme programmes can work together as suggested in paragraph 3.74 below.

Importance of exposure

3.41 It is well known that accidents are highly correlated with traffic flows and road length (for example, see Walmsley and Summersgill, 1998). In other words, you would generally expect to find more accidents on a long road with high flows than on a short road with low flows. It is important, therefore, to take account of 'exposure' (or the opportunity for accidents to occur) when ranking accident problems.

3.42 Although it is also important to tackle the largest number of accidents and casualties possible with the budgets available, it is important to note that this does not necessarily mean treating the sites with most accidents. This is because sites with a high accident risk (ie the sites that do not have the largest number of accidents, but do show a greater propensity for accidents than one would expect for a given level of exposure to risk) are the sites that are most likely to be amenable to treatment.

3.43 Although the most important exposure variables are likely to be road length and vehicle flow, others will often be important too, especially when considering certain types of accidents. Examples include pedestrian flow, pedal cycle flow, junction and bend density (the number of junctions or bends per km of road).

[25]Intervention levels (see paragraph 3.32) suitable for motorway and trunk road accident analysis are provided annually to route managers under the Highways Agency Safety Strategy.

3.44 In the case of vulnerable road users this approach is especially important as, although accident and casualty numbers may be low, their accident casualty risk is very high.

Proxies for exposure variables

3.45 Often there will be no suitable exposure data available, especially for vulnerable road users. In this case suitable proxies need to be found.

3.46 Sometimes, accident risk can be calculated in terms of ‘per head of population’ or ‘population density’, or ‘per trip’ or ‘per licensed vehicle’ etc, instead of per km travelled.

3.47 Another option not often considered is to use comparisons with another (control) area[26] where exposure levels such as the amount of cycling, for example, are considered similar to those in the area under study. These comparisons remove the need to collect exposure data explicitly.

3.48 This method of comparing accident types between areas identifies accident types that feature disproportionately more often than their expected frequencies[27] would suggest.

3.49 To illustrate, if only 5 per cent of all accidents in the study area involve pedal cycles then, in terms of accident numbers, it is not immediately apparent that this is a high priority accident problem. Now, suppose we find that only 1 per cent of all accidents in a similar control area involve pedal cycles. Assuming that the level of cycling is similar in the two areas, it is evident that cycle accidents in the study area deserve further investigation. It is possible that such an accident type (because of its abnormally high level of risk) will be more amenable to preventative engineering treatments than another accident type with a higher observed and expected frequency of accidents.

3.50 Statistical tests may be used to evaluate whether the difference between the proportions of each accident type are unlikely to be due to chance (ie the difference between 5 per cent and 1 per cent in the example above). The statistical test used will depend on whether the control area is mutually exclusive of the study area – see Appendix B5 for details.

3.51 The use of the control does not, of course, prove that a problem exists. No control is perfect and the results may reflect different levels of exposure between the study and control areas. The control data

[26] Very often national data are suitable and readily available in RAGB (DETR, 2000a). Other suitable Control areas might include the rest of the county, a group of neighbouring counties etc.

[27] See DETR (2001a) and Barker (2001) for detailed method.

could equally well camouflage a particular problem. Nevertheless, the use of a control is a valuable way of identifying accident characteristics for further investigation.

Importance of traffic flows and road class

3.52 The relationship between accidents and vehicle flows is not a linear one (see Walmsley and Summersgill 1998). For this reason, it is recommended that roads with very different flow levels are not studied together. As detailed flow data are rarely available, grouping roads for analysis according to road class is one good alternative. Typically, accident and flow data are readily available by class of road.

3.53 There is a need to consider each class of road separately as far as intervention levels are concerned, because of the generally different levels of vehicle flow found on each class of road. For example, while motorways have higher accident numbers per kilometre than B/C/unclassified roads, they have much lower accident rates (per vehicle-km – see Figs 3.2 and 3.3).

Fig 3.2: Accidents per km by road class, GB 1999

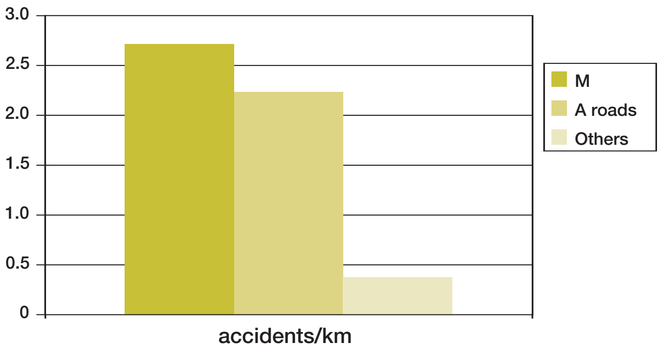
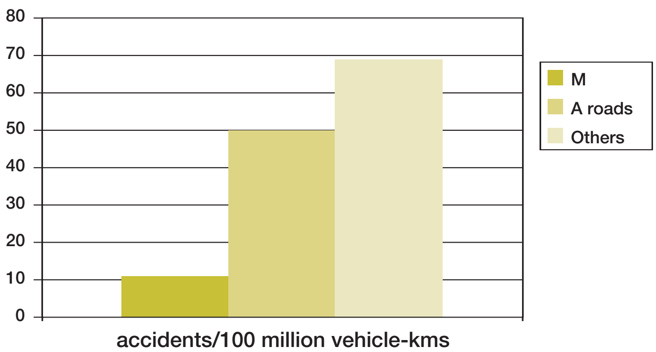


Fig 3.3: Accidents rates (per 108 vehicle-kms) by road class, GB 1999



[28]Hereon, the term ‘site’ may refer to short or long sections of road, or to a network of roads.

Finding solutions

Detailed investigation

3.54 The next step in tackling the road safety problem is to investigate further the sites[28] identified as having problems. Once this has been done, and solutions identified a cost-benefit analysis (see 3.77 below, for example) will provide the final information required to prioritise remedial treatments.

3.55 It is important to consider road hierarchies. The actual use of different parts of the network should be assessed as it may not be in keeping with the design function of the road. If changes need to be made to address accident problems, then the method and overall potential effect of such changes will need to be addressed.

3.56 A more detailed accident and casualty analysis of the possible remedial sites will normally include plotting accidents on a larger scale map and considering the commonality of accident types and the movements of vehicles and pedestrians.

3.57 Stick diagrams[29] can be useful to identify predominant accident types, but become unmanageable if the number of accidents is greater than 20 or so.

Site visits

3.58 Site visits are an essential part of the detailed investigation process. Ideally, they should involve more than one person visiting a site on more than one occasion, in different weather, lighting and traffic conditions.

3.59 On-site observations of layout, signing, markings and traffic movements can often reveal possible explanations as to why accidents are happening that are not apparent from studying maps and accident reports alone.

3.60 The main reference sources for road layout, signing and marking are in paragraph 3.68 to 3.71 below and are listed in full in the first part of Chapter 6, the bibliography.

3.61 Typically, a site inspection should involve a road safety engineer addressing the following types of questions.

[29] A stick diagram is a table with one column for each accident. Each row of the table represents an accident, vehicle or casualty category (eg junction type, number of vehicles, type of vehicle, casualty severity etc). Pictograms showing vehicle movements or other categories are often used to facilitate quick analysis. The columns in stick diagrams are sorted by one or more row categories, repeatedly, so that predominant category types become apparent.

- Is there a consistency and clarity of approach in the quantity, quality, type and standard of maintenance of layout, signs and markings along the road?
- Is correct warning of a hazard given on the approach by use of the proper road markings – hazard centre line, SLOW marking and so on – as set out in the *Traffic Signs Manual* (TSM), Chapter 5 – (see bibliography)?
- Are the markings and road studs properly maintained, so that they are clearly visible by day and by night and give the necessary minimum preview time (two seconds)?
- Are the prescribed warning signs provided (see TSM Chapter 4 for guidance)?
- Are the signs the correct distance from the hazard?
- Are the signs the correct size for the prevailing traffic speeds?
- Are the signs properly maintained and in good condition? (Worn or dirty signs cannot deliver the intended level of service.)
- Can the signs be clearly seen over the full recommended visibility distance – or are they obscured by foliage, other signs, parked vehicles etc?
- Are the signs sited under trees or otherwise in deep shadow for much of the day? If so they may be prone to algae growth which obscures them and seriously degrades retroreflective performance. Fluorescent backing boards will greatly enhance conspicuity in daytime, when ultraviolet radiation is present.
- Are signs difficult to see because they are viewed against a complex background? (If so a yellow backing board might greatly improve conspicuity).
- Are signs difficult to pick out at night because they compete for attention with brightly-lit advertisements, shop fronts etc? (If so, retroreflective yellow backing board might improve conspicuity).
- Have the needs of <u>all</u> road users and vehicle types been taken into account, as far as is practically possible?

Vulnerable road users

3.62 It is important to promote cycling and walking (DETR 1996 and 2000c) and it is known that pedestrians and cyclists and other vulnerable road users (such as equestrians and two-wheeled motor vehicle riders) have especially high levels of accident risk. Therefore, it is important to consider their needs and make provision for them.

3.63 For example, is there a need and would it be possible to provide:

- footways, cycle lanes, cycle tracks, bridleways?
- controlled or uncontrolled crossing facilities?
- grade separated crossings?
- crossing points for slip roads on major roads?
- facilities for cyclists where vehicles merge at high speed?
- roundabout designs to benefit cyclists and pedestrians (eg incorporating signals; or 'continental' design with tighter entries to slow vehicles entering the circulating traffic flow – Davies et al, 1997; TAL 09/97)?
- segregation?

Detailed design

3.64 It is important that the objectives of introducing a scheme (such as speed reduction, improving pedestrian safety and so forth) are clearly thought out before beginning the detailed design process.

3.65 An *outline* scheme design should be drawn up which may include several different approaches and engineering measures for achieving the objectives of the scheme. The next stage is to identify the individual elements of a scheme and to put them together to form a cohesive, detailed design.

3.66 Engineers should consider all aspects of safety throughout the design process, as specified in the Contract (Design and Management) Regulations 1994 (HMSO, 1994a).

3.67 Engineers should consider the needs of all road users, including the disabled, pedestrians and motorists. They should also consider social inclusion[30] and accessibility.

3.68 *The Traffic Signs, Regulations and General Directions* (TSRGD – HMSO, 1994c) provides drawings of all prescribed Traffic Signs together with relevant Regulations and Directions that apply to them. Detailed information and advice concerning design and application of signs, markings and other engineering measures are given in:

- *Traffic Signs Manual* – Chapters one to eight (DETR, various dates). The Chapter titles are given in the front of the bibliography and are referred to in the text as 'TSM Chapter No.'

[30]Including issues that may affect road users travel patterns such as personal safety at night, the ability to combine parenthood and work etc.

- Traffic Advisory Leaflets (DETR, various dates). These are listed here in the front of the bibliography (Chapter 8) and are referred to in the text as 'TAL No./yr'.
- Local Transport Notes (DETR, various dates). Relevant ones are listed in the bibliography (after the Traffic Advisory Leaflets). They are referred to in the text as 'LTN No./yr'.
- *Design Bulletin 32* (DETR, 1992) and its companion guide (DETR, 1998c) cover the design of residential road and footway layouts.
- *Transport in the Urban Environment* (IHT, 1997) promotes the design and management of urban transport infrastructure and systems. Part III includes safety related issues.

3.69 The principal documentation for trunk roads is:

- the set of Design Standards and advice notes brought together in *Design Manual for Roads and Bridges* (DMRB – DETR, various dates). The constituent parts of this document are given here in the bibliography (after the TALs and LTNs, Chapter 8) and referred to in the text as 'DMRB, XX No./yr.'. Some of DMRB may be appropriate when considering non-trunk roads but the possible effect of differences in traffic flows and traffic mix should be reviewed.

3.70 If non-prescribed signs or markings are to be used then non-prescribed sign authorisation must be sought from DETR.

3.71 The current advice on speed limits can be found in *Circular Roads 1/93* (DETR, 1993) and TAL 1/95. Since changes in legislation in 1999 (DETR, 1999c; Scottish Office, 1999; Welsh Office 1999), local authorities are free to introduce self-enforcing 20 mph zones and 20 mph speed limits, where appropriate.

3.72 The design process will include draughting clear, well-annotated, vertical and horizontal drawings for the engineers. Outline plans should be on a scale of 1:5000 for a route. Otherwise they should be 1:2500 or 1:1250. Full detailed plans should be on a scale of at least 1:500, or 1:200 for a more complex scheme.

3.73 Consultation will largely take place after an outline scheme design has been proposed and before the full detailed design is finalised. Consultation can take up a significant amount of time and budget during the design process. Those to be consulted will vary from scheme to scheme, but will usually include internal consultees, local residents, emergency services and other representatives or road user groups likely to be affected by the scheme (see Chapter 2).

3.74 Ideally, consultations will include establishing that no other works are planned in the near future for the road that is to be treated, preferably for at least a three year period. This will ensure that:

- the scheme has a reasonable future lifespan;
- scheme monitoring will not be compromised; and
- different work schedules may be combined (such as maintenance and scheme installation) so that some necessary costs will be incurred only once.

3.75 It is important that sufficient money is set aside for monitoring a scheme. In the long term, monitoring will justify future similar schemes and make their design and installation more cost-effective.

3.76 The various stages of scheme design, consultation etc should all be well documented to reduce the amount of work necessary should a similar scheme be installed in future.

Economic justification

3.77 The economic justification for installing a safety scheme is usually based on its economic return. This is generally calculated as an estimated 'First year rate of return' (FYRR) which is an estimate of the monetary benefits to be gained in accident savings in the first year set against the cost of the scheme[31]. While many schemes will only save a small number of accidents a year, this can still produce a good rate of return.

3.78 Sometimes, particularly for the large schemes, the lifetime of the scheme may be taken into account with a 'net present value' being calculated (calculated in a similar way to compound interest – Highways Agency, 1996).

3.79 The estimated average accident prevention savings for accidents and casualties for 1999 (DETR, 2000a) are:

Severity	**£ per accident saved**				**£ per casualty saved**
	All	Urban	Rural	Motorways	All
Fatal	1,262,090	1,182,910	1,316,780	1,361,690	1,089,130
Serious	146,890	138,490	162,180	166,720	122,380
Slight	14,540	13,690	16,570	19,550	9,440
Average (all severities)	49,920	38,620	83,350	62,280	34,540
Damage only	1,300	1,220	1,800	1,730	–

[31]The simplest FYRR will be estimated as 100*(number of accidents in 12 months before installation – predicted number of accidents in 12 months after installation)*(average cost of an accident)/total scheme costs. Note that there will be a considerable degree of uncertainty associated with the estimation of any such economic indicators.

3.80 Predicting the percentage of accidents and casualties that are expected to be saved by a scheme is a difficult task. Consideration needs to be given to the recent accident history, the type of accident the scheme is designed to minimise, and the effect of the scheme on other (and potentially new) types of accident. The accidents to be saved should relate directly to the type and objectives of the scheme.

3.81 In some instances, robust information on the performance of particular measures may be available as a result of previous monitoring. For example, try the MOLASSES database, the SafeNET software (TAL 08/99; TRL Limited, 1999), *Traffic calming in practice* (CSS et al, 1994a) and as detailed in Appendix A of this guide.

3.82 Take care to assess how the scheme will affect existing and surrounding roads and traffic to ensure that one problem is not solved by creating another (use SafeNET, for example).

3.83 When potential schemes are identified on the basis of high accident rates, the numbers of accidents to be targeted may be smaller than at low risk sites, but more likely to be treatable. Take this into account when estimating FYRRs. In other words, the potential proportion of all accidents saved may be greater at sites selected on the basis of having high accident <u>rates</u>, than purely on the basis of high <u>numbers</u> of accidents.

3.84 The IHT (1990b) recommends appropriate levels of FYRR to aim for when considering the implementation of single site, mass action, route action and area action schemes.

3.85 Some authorities weight their estimated FYRRs according to the severity of road accidents. Depending upon individual circumstances, it is possible that this can lead to greater attention being given towards treating roads with vulnerable road user casualties.

3.86 When calculating scheme costs, in addition to those for construction time and materials, take into account the contributions due to:

- design;
- consultation;
- traffic management;
- relocating statutory undertakers' apparatus;
- providing power supplies;
- maintenance;
- monitoring;

- supervision of works; and
- safety audit.

New Approach to Appraisal

3.87 As well as the use of economic indicators (such as FYRRs) the assessment of local safety schemes should examine wider impacts in accordance with the New Approach to Appraisal (NATA) as set out in DETR (2000) Guidance on Full Local Transport Plans. This assessment involves the consideration of the Government's five objectives for transport:

- **environment** – to protect the built and natural environment
- **safety** – to improve safety
- **economy** – to support sustainable economic activity and get good value for money
- **accessibility** – to improve access to facilities for those without a car and to reduce severance
- **integration** – to ensure that all decisions are taken in the context of the Government's integrated transport policy

Using this approach the impact against each of these objectives should be recorded in an Appraisal Summary Table. This table presents an unbiased summary of the impacts against the Government's objectives. To be consistent with NATA the summary should be supported by an assessment of how the measure meets local local objectives and the extent to which problems are addressed. NATA also includes analyses of the impacts on distribution and equity, practicality and public acceptability, and affordability and financial sustainability.

The required level of detail will be proportionate to the size of the scheme. The general principle is that the appraisal should be conducted at a level of detail sufficient for the value for money of the proposal to be demonstrated clearly. A working note *Appraisal of LTP: advice on simplified procedure* provides guidance on the level of detail that may be appropriate for different policy instruments. For the majority of smaller safety schemes the key requirement is to ascertain that accident savings are likely and that together with any other associated benefits they exceed total costs imposed.

Options for funding schemes

3.88 Central government funds the majority of local authority safety schemes. The government allocates funds largely based on LTPs (and the HA bidding process for trunk road schemes).

3.89 Other funding may come from:

- local highway authorities own capital and revenue budgets;
- local government (other departments, such as health and education);
- parish councils;
- local businesses (including money from developers);
- local organisations (such as the police);
- residents' groups;
- research and development funding (governmental or private);
- special interest groups;
- charities;
- netting-off of fixed penalty fine revenue to fund speed limit and traffic signal enforcement cameras; and
- parking permits, meters and fines, road tolling (all subject to legislation).

Installation issues

3.90 For urban roads, *Transport in the Urban Environment* (IHT,1997) deals with many relevant issues. The main documentation for scheme installation on trunk roads is the *Manual of Contract Documents for Highway Works* (DETR, 1998b). However, much of this is relevant for works on local (particularly major) roads and local authorities often use it.

3.91 Qualified personnel who understand safe working procedures must supervise the installation of engineering schemes. There are legal issues to be considered.

3.92 Full and dated records should be kept detailing each phase of installation. This 'site diary' information is often lacking, particularly when the client hands over aspects of the design and installation to one or more outside bodies. However, it is crucial for the monitoring process to provide valid results.

3.93 There is a need to consider any safety issues that may arise specifically during the installation period. This is particularly relevant when installation is spread over several days, or even months, and if the site is to be left unattended.

Safety Audit

3.94 Safety Audit is a procedure introduced to prevent accidents. It is not an accident reduction procedure. In Safety Audit, safety (or accident potential) is formally, and objectively, considered at each stage of the design of a scheme.

3.95 A full Safety Audit will have four stages (IHT, 1996b):

- stage 1 – feasibility/initial design;
- stage 2 – preliminary design/draft plans;
- stage 3 – detailed design; and
- stage 4 – pre-opening (as soon as practical after completion).

3.96 A team of safety auditors carries out Safety Audits. They should be personnel with safety expertise and who are independent of the design team. The Safety Audit team will comprise more than one person and will include road safety engineers. It might also include police officers, road safety officers and other specialists, such as structural engineers. The size, breadth of expertise and number of members of the team will depend on the size and character of the scheme.

3.97 A prime objective of a Safety Audit is to consider the safety of all types of road users under all types of conditions, such as weather and time of day. The Safety Audit will not only consider the scheme itself, but its potential impact on the surrounding network. A necessary part of all Safety Audits will be to balance the needs of different road users (including those using all motorised transport, vulnerable road users and the disabled) under different conditions by assessing levels of accident risk. Naturally, the audit will also have to consider financial and design constraints.

3.98 Considering safety throughout the design process minimises the likelihood of unforeseen factors affecting the final costs. A final audit before opening the scheme is essential. This is because some aspects may be difficult to consider from two-dimensional plans and because installations may not match plans precisely.

3.99 In the longer term, Safety Audits encourage good design. They give safety a higher profile in the design process and act as a conduit for informing engineers of current safety understanding. The recommendations of safety auditors are not based on checking individual design elements against standards, but on considering how the scheme as a whole may affect overall safety, or deciding what to do when standards conflict.

3.100 It is recommended that a policy is adopted for Safety Audits to be carried out for all new road schemes and all modifications to the existing network, including re-design and maintenance.

3.101 Nationally, Safety Audits are only mandatory for trunk road schemes. The level of local authority safety auditing varies widely. Some authorities audit all schemes fully. Others reduce or eliminate the number of Safety Audit stages, depending on the scheme size, type or cost. The amount of documentation and the procedures for arbitration in the case of safety/design conflicts of interest also differ greatly between authorities. It is important that each authority has a clearly defined strategy and procedure for Safety Audit. The IHT (1996b) suggest that "Safety Audit is a part of a broader road safety strategy: priorities for audit need to be set within the total programme of highway schemes".

3.102 There is considerable guidance on the legal consequences of Safety Audit (eg Stewart, 1995; Heath, 1995). Note that legal actions might result following accidents at a scheme, particularly if the adopted procedures have not been followed and are not well-documented.

3.103 When highway works are commissioned to outside bodies the need for Safety Audits should be identified and documented when the contract is let. The various stages should be monitored and well documented throughout the scheme planning, design and implementation. The processes and responsibilities for departures from procedures and recommendations should be clearly specified.

3.104 There is now a wealth of information, advice and experience on Safety Audit. Several sources are listed in the bibliography, but useful examples include:

- *Guidelines for Safety Audit of Highways* (IHT, 1996b)
- *Standards for Road Safety Audits* (DMRB, HD 19/94) and Advice Note for Road Safety Audits (DMRB, HA 42/94)
- *What goes wrong in highway design* (AA, 1999b).

3.105 In addition, some authorities and other practitioners have set up forums and support groups where safety auditors can discuss common problems and solutions.

3.106 Some authorities advocate Safety Audits of existing roads. These may be useful to give a consistent approach or message to road users. This is particularly the case across networks where individual elements have been designed separately over time. However, many issues may be identified during the detailed design stages of accident analysis and reduction programmes.

Learning from success and failure

3.107 The importance of having good quality evidence about the performance of a safety scheme cannot be stressed enough; that is why monitoring is so important. The Guidance on LTP Annual Progress Reports emphasises the importance of ensuring that statistical information that is gathered about local targets including road safety targets is collected in a logical and well organised manner, using realistic sample sizes, and in accordance with existing statistical methodologies. Chapter 5 gives advice about the arrangements for monitoring the effects of individual safety schemes, but the following are some general points.

3.108 Do not repeat good schemes if better ones are available and appropriate.

3.109 Some schemes work well in some situations but will be inappropriate in others.

3.110 Some measures may work better alone or may only be effective when used in combination with other measures.

3.111 Sometimes an unsuccessful scheme need not be rejected outright. Investigations may prove that it only needs minor modifications to turn into a success.

3.112 Sometimes measures designed to reduce speeds may not do so, but may still reduce accidents by increasing driver awareness.

3.113 Sometimes it is hard to accept failure for financial or political reasons. However, it is important to be courageous and acknowledge that things did not go to plan. Consider challenging established policy and procedures if the evidence from monitoring warrants it.

3.114 Sometimes the effects of one scheme are hard to assess, perhaps because accident numbers are low or other factors influence the results. These problems can often be minimised or eliminated by considering data for a large number of similar schemes together. For example, pooling data related to changes at each site to reach an overall average figure. Such research can provide robust evidence about a scheme design in a way that is not feasible at a local level.

3.115 The MOLASSES database contains basic information about schemes installed on local authority roads and on trunk roads. The database is populated and managed at TRL (see web site at www.trl.co.uk/molasses). Contributors can interrogate the database for the latest evidence on the overall effectiveness of a type of measure in terms of accident reduction. It is planned that regular reports will also be produced. See Appendix C for an example data entry form.

3.116 Over the years, DETR and HA have funded a wealth of research into the safety effects of engineering measures and safety schemes. Some have been studied only in the test and development stages using off-road trials and simulator studies. The most promising ideas have gone on to be installed at sites across Great Britain and further monitoring undertaken to establish the effects of these on-road trials. The results of these research projects are usually published or provoke further research. They are used in the development of the engineering design Standards and Advice notes, Traffic Advisory Leaflets, software – such as SafeNET (TAL 08/99; TRL, 1999), and to shape road safety policy.

3.117 The TRL library has a vast amount of published research and maintains a database of international road research publications. A charge is made to provide some of this information.

3.118 Many of the more relevant publications are given in the bibliography, even if they have not been referred to directly in the text.

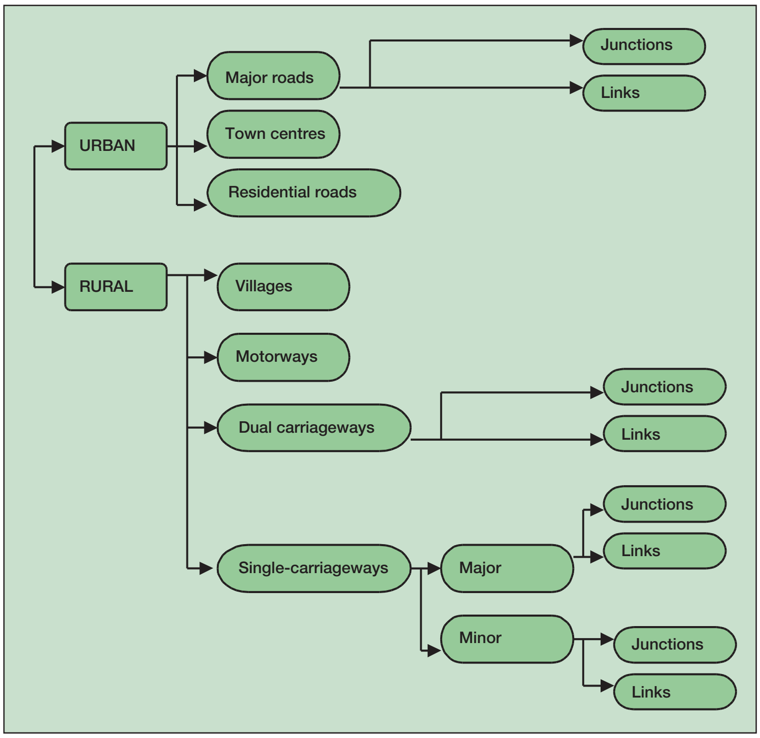
3.119 Chapter 4 describes accident problems at a national level and discusses potential engineering solutions (text in shaded boxes), by road type. It also includes a short section on non-engineering measures.

04 Treatment selection

Engineering measures

4.1 The nature of road safety problems commonly varies according to type of location. Due to the differing land use and traffic mix on the UK's roads, appropriate solutions will also vary. In the following sections, we look at common problems and safety engineering treatments for improvement under a simple location classification of URBAN[32] and RURAL[33], and the road types within these, as shown in the tree chart below.

Figure 4.1



[32]Urban (or 'built-up') roads are defined as those with speed limits of 40mph or less.

[33]Rural (or 'non-built-up') roads are defined as those with speed limits of 50mph or more. Roads through villages with speed limits of 20, 30 or 40mph are not included. A rural road may or may not have buildings alongside it.

Fig 4.2a: All Casualties GB 1999 (Total = 313,013)

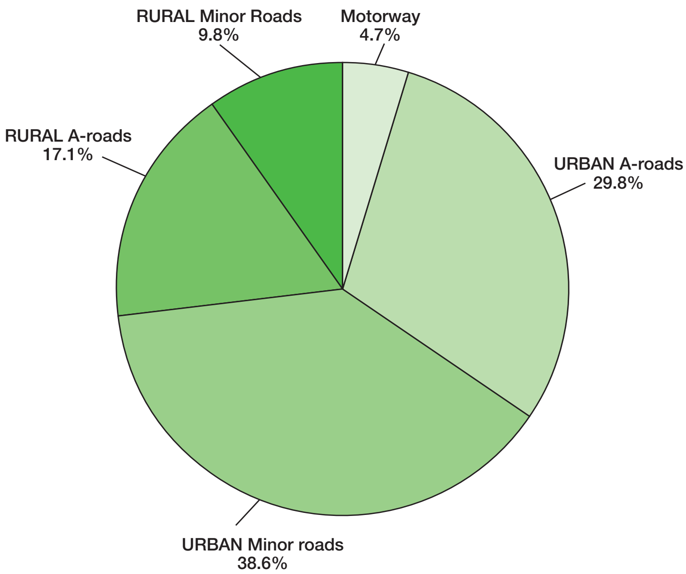
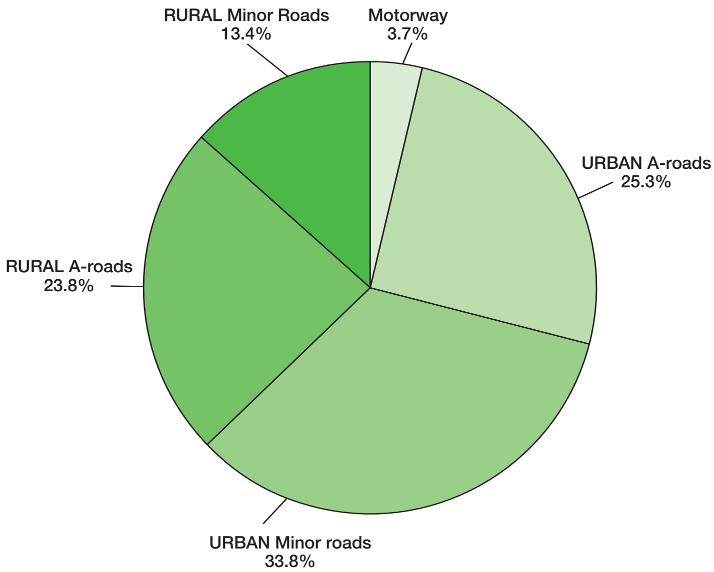


Fig 4.2b: Killed & Seriously Injured GB 1999 (Total = 42,545)



4.2 Fig 4.2a above for reported road accidents in 1999 from STATS19 data clearly shows that the majority of casualties (over 68 per cent) occur on urban roads. Fig 4.2b shows the predominance of urban roads is slightly less marked when killed and seriously injured (KSI) casualties only are considered, with 59.1 per cent on urban roads. This reflects the generally higher severity of accidents on rural roads. However, achieving the Government's casualty reduction targets still means that all road authorities need to investigate safety problems and come up with solutions.

4.3 As discussed in Chapter 2 and in paragraph 3.8 above, the national casualty reduction targets need to be disaggregated to annual figures for the individual authority's road network. The authority will need to decide which combination of strategies of single site, mass action, area action or route treatment is likely to best achieve these targets. The remainder of this chapter discusses, in general terms, the main safety problems found at different types of road location in Great Britain. It also suggests common solutions.

More details on each type of treatment together with real examples are in Appendix A.

URBAN roads

Fig 4.3a: ALL Casualties on Urban Roads 1999

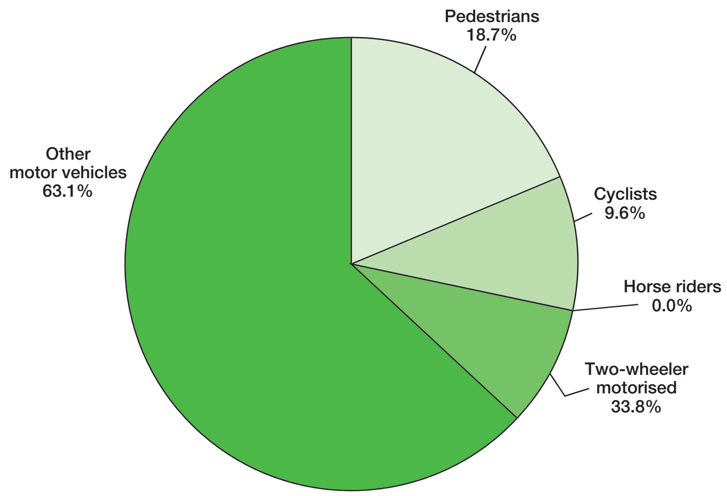
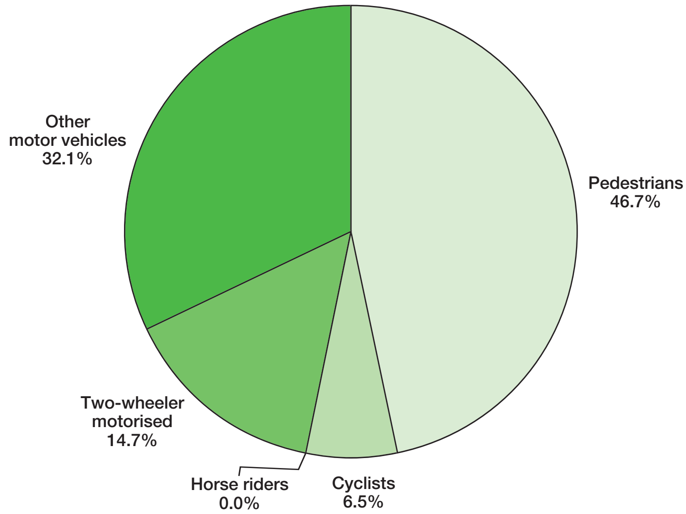


Fig 4.3b: ALL Fatalities on Urban Roads 1999



4.4 Urban areas are more complex than rural ones and are where the majority of casualties occur (ie 'built-up roads' in DETR, 2000a). These figures mask large differences between the figures for different road users.

4.5 Fig 4.3a shows the breakdown of casualties on urban roads by casualty type. About 19 per cent are pedestrians, 10 per cent are cyclists, 9 are two-wheeled motor vehicle users and the remainder (63 per cent) are users of other motorised vehicles. When fatalities alone are considered (Fig 4.3b) the figures are 47 per cent (pedestrians), 7 per cent (cyclists), 15 per cent (two-wheeled motor vehicle users) and 32 per cent (other motorised vehicle users).

4.6 The types of road user involved also differ substantially from one location to another. In town centres, casualties are often concentrated at specific locations. Outside these areas, they are more diffuse and include a markedly higher proportion of pedestrians and cyclists, particularly children (IHT, 1997).

4.7 The principle technique for tackling urban accidents is ‘blackspot’ treatment. Low cost solutions are applied to clusters of accidents with a factor in common. This approach has met with considerable success, but is becoming less beneficial as more and more sites are treated.

4.8 Urban Safety Management (USM) principles (TAL 3/90; IHT, 1990) were developed to address the urban accident problem more strategically, tackling both clustered and more thinly spread accidents. The approach was first demonstrated in five towns in the Urban Safety Project (Mackie et al, 1990). By managing traffic onto the right roads, the project achieved casualty reductions of 15 per cent.

4.9 The key elements of USM are:

- defining an appropriate road hierarchy;
- ensuring that traffic moves on the right roads;
- managing traffic speeds; and
- co-ordinating the activities which affect road safety (4.10).

4.10 USM deals with road safety problems as part of urban management. The process is flexible and involves a wide range of disciplines:

- traffic management;
- enforcement;
- education;
- training and publicity;
- health and education;
- public transport; and
- town planning.

4.11 A more comprehensive demonstration project has been undertaken in Gloucester (DETR, Safer City Initiative, Gloucester Safer City, 2001b) to raise awareness of the principles and potential benefits.

4.12 Reducing inappropriate speeds is likely to be the single most important factor in improving urban safety. Lower speeds will benefit all urban road users, but particularly the large number of pedestrians and cyclists. Currently more than two-thirds of car drivers exceed 30 mph on roads with this limit (DETR, 2000d). The disbenefit of increasing journey times of illegal, speeding drivers by reducing their speed should not be taken into account.

4.13 Taylor et al (2000) have shown that accident reductions typically of 5 per cent per mile per hour in average speed are achievable. The greatest benefits occur on congested roads in town centres and on residential roads. Reducing the speeds of the fastest drivers is the key objective. Drivers who habitually travel faster than average are involved in more accidents in a year's driving than those who travel at average speeds (Taylor et al, 2000).

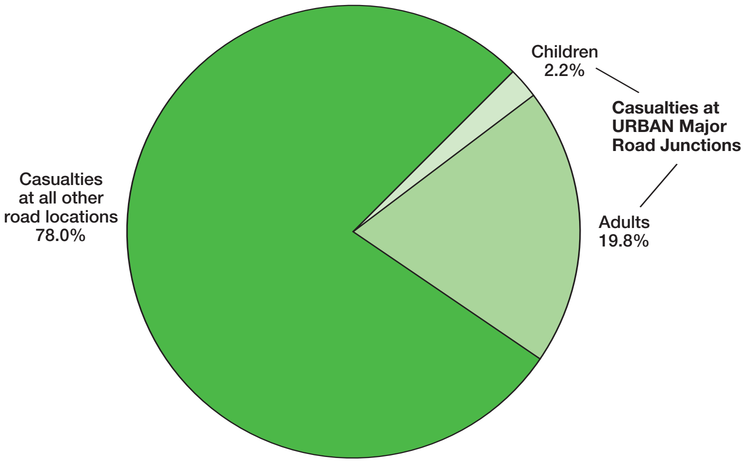
4.14 Your speed management policies must aim to achieve a 'safe' distribution of speeds according to the function of the road. This means an average speed appropriate to the prevailing conditions, and all vehicles moving at speeds as close to this average as possible (Taylor et al, to be published 2001).

4.15 Techniques that are cost effective need to be applied which convey to drivers the risks involved on different types of road.

4.16 In the following sections, pie charts have been used, where possible, to illustrate the size of the casualty problem on each type of road classification. Adult and child casualties are shown separately as a percentage of all casualties on the network. For consistency, we have included all severities of casualty, but differing proportions are likely to apply if, for example, only fatal/serious casualties are considered (for example, see Figs 4.3a and 4.3b).

URBAN major road junctions

Fig 4.4: All Casualties GB 1999

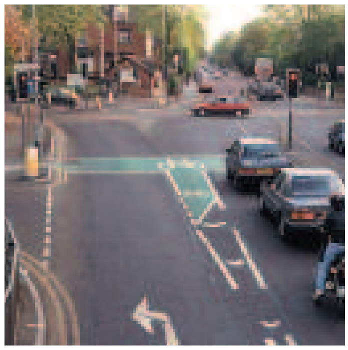


4.17 The number of casualties in accidents at junctions on major roads in the urban areas of Great Britain is currently 68,876 (1999 data). This represents 22 per cent of the total casualties on the network. The large volume of road users passing through them on conflicting paths often worsens the serious safety problems at these junctions. For the same level of turning traffic flows, an uncontrolled priority junction with a minor road will usually have more accidents per year than other junction types.

4.18 The speed of vehicles approaching a junction and the possibility of overtaking manoeuvres on the major road will also directly affect the number and severity of collisions. At traffic signals the risk of serious right angle collisions is increased if drivers infringe the red light, and the incidence of these infringements normally increases when drivers are approaching at high speeds – despite the use of sophisticated speed discrimination or assessment systems (Baguley and Ray, 1989). These systems help those drivers who, by virtue of their position, may be genuinely caught in a dilemma if a green signal were to change, by extending the green phase. However, the systems only work up until the time at which the pre-set maximum green time is reached.

4.19 Important considerations are thus to incorporate, either in the design of junctions or as remedial action, features that will help to ensure slower speeds through the junction and increased awareness of drivers, for example:

- effective signing (DETR, 1994);
- central refuges (Appendix A11);
- vehicle-activated signs (Appendix A25);
- other visual cues;
- speed cameras (Appendix A4);
- red-light cameras (Appendix A3); and
- MOVA signal system (TAL 03/97).



4.20 Problems can arise at uncontrolled junctions if there is any obstruction to drivers visibility. For example, this could be due to the building line, vegetation, parked vehicles or overtaking vehicles being masked by the vehicles being overtaken (despite the Highway Code stating that drivers should not be overtaking in these circumstances).

4.21 It is important that all road users have adequate visibility in each direction at a junction. This allows them to judge approaching traffic and to complete their manoeuvre with sufficient margins of safety. The visibility of vulnerable road users like pedestrians and cyclists is particularly important in this respect (see Chapters 4,5,7; DMRB, TD 50/99; DMRB, TD 42/95).

4.22 For junctions that have been specifically designed to provide maximum capacity and yet are experiencing safety problems, it may be advisable to consider a different form of control. In some situations a roundabout may be the best option. In others, the best solution may be a signalised junction (LTN 1/98; TAL 3/97; TAL 07/99; DMRB, TD 50/99) or a signalised roundabout (Appendix A15). The safest form of control will depend on the size of the junction, the overall level and pattern of traffic flow, and the presence of non-motorised road users (IHT, 1997). The use of the computer programs ARCADY, OSCADY, PICADY (Binning, 1998, 2000a, 2000b) is recommended to help design roundabouts, signals and major/minor priority junctions respectively. These programmes assess likely accident levels.

4.23 Evasive action to avoid a collision near a junction can often mean severe braking, but this relies on the friction between tyre and road surface being sufficiently high. Many highway authorities have found that one of the single most effective accident countermeasures (in the absence of speed reducing measures) has been the installation of anti-skid surfacing (Appendix A.1; DMRB, HD 28/94).

4.24 The presence of pedestrians and cyclists near the junction is another factor that can generate accidents and special consideration needs to be given to catering for these road users.

4.25 Design and modification to junction layouts must recognise that cyclists and pedestrians need to travel through junctions on their journeys (LTN 1/86). Where practical, the siting of separate routes for pedestrians and cyclists are generally recommended to be away from the junction where vehicle movements are more predictable. Ideally, they should cross where the road width can be minimised.

4.26 The installation of refuges where pedestrians normally choose to cross has been found to provide good safety benefits. The basic principles of a refuge are to:

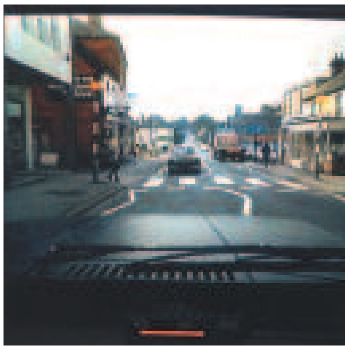
- reduce the number of streams of traffic in which pedestrians need to decide when it is safe to cross;
- minimise the distance over which they are exposed to traffic; and
- provide a relatively safe central area (see Appendix A.11).

4.27 The journey to school by children on foot or bicycle is often hazardous and many local authorities have adopted a ‘safe routes to school’ approach (paragraph 4.176 below and Appendix A18).

4.28 At signalised junctions, pedestrians and cyclists sometimes need exclusive signal stages. However, for adequate clearance and crossing times, the extended cycle time may lead to pedestrians seeking earlier opportunities to cross (ie against the red signal). Take great care in the system design (IHT, 1997; LTN 1/86).

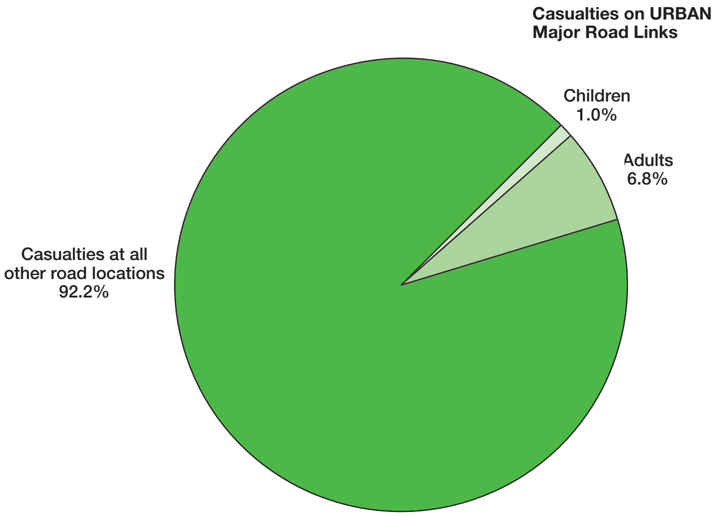
4.29 Roundabouts have the advantage of slowing vehicle approach speeds on all arms of the junction, but are generally less safe for two-wheelers. All roundabout design and modifications should now cater for increased safety of cyclists and motorised two-wheelers. ‘Continental’ design, with tighter entries, can help these road users (TAL 9/97; Davies et al, 1997).

4.30 For roads with heavy traffic flows the only solution may be to physically separate pedestrians by means of footbridges or subways. There is, however, a need to take account of pedestrians' general reluctance or inability to take longer routes or apparently unnecessary steps or slopes, and concern about their own security (eg fear of underground passages and crime). Successful grade separation keeps the pedestrians on the level following their desired path, whilst vehicles undergo the change in level. Important issues such as siting, sight line, lighting, dimensions etc need careful consideration (IHT, 1997; DETR, 1998c and HA, 1996 for Trunk Roads contains useful design guidance).



URBAN major road links

Fig 4.5: All Casualties GB 1999



4.31 On major road links in towns and cities in Great Britain, 24,428 people were injured in road accidents in 1999. This is about 8 per cent of all reported casualties.

4.32 Pedestrians tend to minimise their walking journey and will cross major roads where it is convenient to do so and not always where it is safest. The safest policy is normally to minimise conflict points between vehicles and pedestrians so that driver attention can be focussed at designated controlled crossing places.

4.33 Cyclists comprise 7 per cent of all casualties and motorised two-wheeler riders 8 per cent. In these accidents it is often the case that larger vehicle drivers fail to notice two-wheelers, probably due to their smaller physical size. Indeed, motorcycle and pedestrian accidents can be a particular problem in congested areas. Although studies of bicycle accidents have shown that most collisions with cyclists involve turning manoeuvres at junctions, more than a third are non-junction accidents, with cyclists often being hit from the rear. Accidents involving both motorcyclists and pedestrians are also a problem, particularly in congested conditions and at traffic signals.

4.34 On high flow major urban roads, where physical speed control devices are inappropriate to help reduce accidents, methods of automatic speed enforcement or speeding notification are in use to deliver accident reduction. These include speed cameras (Appendix A4)[34] and vehicle-activated speed signs (Appendix A25).

4.35 Adequate crossing facilities for pedestrians, with provision for disabled pedestrians, need to be provided along links. These include:

- refuges (Appendix A11);
- zebra crossings (LTN 1/95, 2/95; DETR, 1998d);
- school crossing patrol (RoSPA, 1990; Appendix A7);
- signal controlled crossings (pelican crossings; puffin crossings which incorporate pedestrian detection; toucan crossings which incorporate a cycle crossing facility (TAL 10/93; LTN 1/95; LTN 2/95); pegasus crossings which cater for equestrians, cyclists and pedestrians); and
- grade separated crossings (ie subways or footbridges – IHT, 1997).

4.36 Guard rail or fencing to channel pedestrians to the designated crossing may be deemed necessary on busy roads. However, their use should only be considered where the risks of walking onto the carriageway are very high, as they have a number of disadvantages. They are visually intrusive, reduce footway width, can obscure children, and can cause access difficulties to commercial premises (see IHT, 1997).

4.37 The fact that a relatively high proportion of bicycle accidents occur on links strengthens the case for properly planned and designed facilities for cyclists, particularly in urban areas. While there is no single solution to providing a suitable infrastructure for cycling, the hierarchy of measures set out in *Cycle-friendly Infrastructure* (IHT et al, 1996a) should be carefully considered before choosing the design solution. This includes:

[34] The police operate speed cameras. Local authorities must liaise with the police where the use of cameras is proposed.

- traffic reduction;
- traffic calming;
- junction treatment and traffic management;
- redistribution of the carriageway; and
- cycle lanes and tracks.

If road links remain with heavier vehicles or with a high speed differential between cyclists and other road users, then the case for segregation on-carriageway or off-carriageway is strengthened (see Appendix A8).

4.38 For school children the 'safe routes to school' approach is proving to be very successful (Paragraph 4.176 below and Appendix A18).

URBAN town centres

4.39 In many British towns, the main traffic routes often also have a commercial, shopping or residential function. These routes are commonly referred to as "Mixed Priority Routes" on account of this mix of functions with no clear priority. From a safety point of view, the variety of activities created by functions such as through traffic, local distribution traffic, residential, leisure, shopping frontages, pedestrians and cyclists is not ideal and gives rise to conflicts and accidents.

4.40 These roads have proved difficult to treat, partly due to the complexity and potential conflict of the activities and partly due to the perceived need to maintain high capacity for traffic flow, and to maintain relatively high levels of speed. In other words, the traffic function has been given priority over other activities.

4.41 Mixed Priority Routes are generally A or B class urban roads, and frequently radial roads which may pass through town centres. The speed limit is usually 30 mph, occasionally 40 mph. They are typically the main roads into and out of towns, and it is rarely feasible to provide alternatives to them.

4.42 Owing to the lack of specific definition in STATS19 accident data, it is difficult to determine a national figure for the number of accidents on Mixed Priority Routes, but 30 per cent of all casualties occur on urban 'A' roads. Vulnerable road user groups of pedestrians and two-wheeled vehicle riders, prevalent in town centres, have casualty rates many times higher than those of car occupants (see IHT, 1997).

4.43 The benefits from reducing speeds on this type of road are particularly high – offering up to a 7 per cent reduction in accidents per mph reduction in average speed (Taylor et al, 2000).

4.44 The most successful approaches to treating Mixed Priority Routes have involved instigating a change in road environment using a combination of measures to manage speed to appropriate levels, and to allocate different parts of the road space for the different functions. In particular the needs of the vulnerable road user have been a high priority. The through traffic function is still catered for but in a way that is compatible with the other users.

4.45 Consider the following measures when treating a Mixed Priority Route:

- separating the through-flow, distribution and access functions (Where there is insufficient width for separating functions, the through-flow function must be downgraded in priority);
- raising the priority given to pedestrians and cyclists, and giving them specific space such as cycle lanes and wider footways (LTN 2/86; LTN 1/89);
- using gateways to emphasise the transition from one type of road to another;
- reducing the difficulties of certain manoeuvres and preventing unsafe manoeuvres; and
- using narrow lanes and channelisation. (Care should be taken to ensure that provision for cyclists is still a consideration).

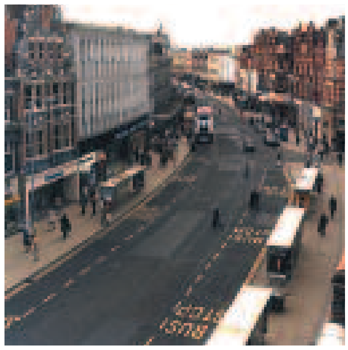
4.46 Depending upon the available road and pavement width, there are three broad types of treatment that can be applied to Mixed Priority Routes:

- full separation of functions;
- partial separation of functions; and
- one way solution – for narrow roads, though appropriate traffic calming measures may also be essential to prevent an increase in speeds.

(See Appendix A2, A8, A10, A19 for examples).

4.47 Town centre roads also often include bus facilities. As with all other traffic management measures, features designed to ensure bus priority have to be considered in the context of safe design and operation. Clearly safety risks are minimised if full physical separation from other traffic can be achieved. However, lack of available road space often precludes this option.

4.48 The main problems of 'with-flow' bus lanes (the most common form of bus priority) are maintaining segregation and ensuring that the lane is kept clear of obstruction[35]. It is also important to acknowledge that vehicles in the bus lane can move at a different speed from vehicles on the main carriageway. This can be a particular problem for pedestrians crossing the road. The road space taken up by the bus lane can result in less room for other road users such as cyclists.



4.49 Bus stops also have safety issues. There is always the danger of pedestrians stepping out from the kerb, especially at more informal bus stops. Many bus stops also suffer from illegal parking, which can impair safety.

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

- colour differentiation of road surface;
- textural differences;
- partial segregation;
- full segregation;
- traffic islands; and
- roadside or bus mounted enforcement cameras.

Refer to Appendices A2, A7, A11, A17 and A19, TAL 07/95 and LTN 1/97 for more details.

4.51 In general the best solution is probably the self-enforcing one of full segregation, though this may rarely be feasible.

4.52 The problems associated with pedestrians stepping out from bus stops onto the main carriageway can be limited by the use of pedestrian guard-rails at strategic locations. Pedestrian refuges to the rear of the stopped bus deter vehicles from overtaking and offer additional protection to the alighted passengers. (As a general rule, if passengers need to cross the road then they should be encouraged to cross behind the stationary vehicle see LTN 1/97).

[35] Over recent years, some authorities in London have introduced roadside or bus-mounted cameras to identify offenders.

4.53 Consideration needs to be given to possible conflicts between pedestrians and two-wheelers, particularly as some cities are trialling opening up bus lanes to motorcycle use. The problem of illegal parking at bus stops can be reduced by the use of bus boarders. These pavement build-outs (see example in Appendix A2) discourage parking opposite the bus stop. They have the advantage of bringing the bus to a stop in the main carriageway, helping to calm the traffic. They also ensure that passengers and pedestrians have a clearer view of their surroundings and are able to get on and off the bus more easily. (See LTN 1/97).

4.54 The design of traffic calming schemes on bus routes should take account of the following points:

- Road humps (Appendix A12) can adversely affect bus scheduling and can make passenger movement within the bus more difficult.
- Speed cushions (Appendix A21) have a minimal effect on buses and are a favoured solution on bus routes.
- Bus drivers must be able to negotiate chicanes and throttles used to create horizontal deflection (see Appendix A6) as a speed control measure.
- The location of bus stops should be agreed between the operators, highway authority, and the police. Consult nearby property owners/occupiers and bus user groups when appropriate. Refer to Appendix A2 for more details.

URBAN Residential roads

4.55 Residential roads in urban areas[36] make up the largest category of accidents, accounting for 38.6 per cent of all casualties and 33.8 per cent of fatal and serious casualties. Children make up a higher proportion of the casualties than they do on other roads. Accidents involving children are therefore an important category in any treatment programme.

[36]In STATS19 data these have been assumed to be non A class single-carriageway roads in built-up areas with speed limits of 40 mph or less.

Fig 4.6a: All Casualties GB 1999

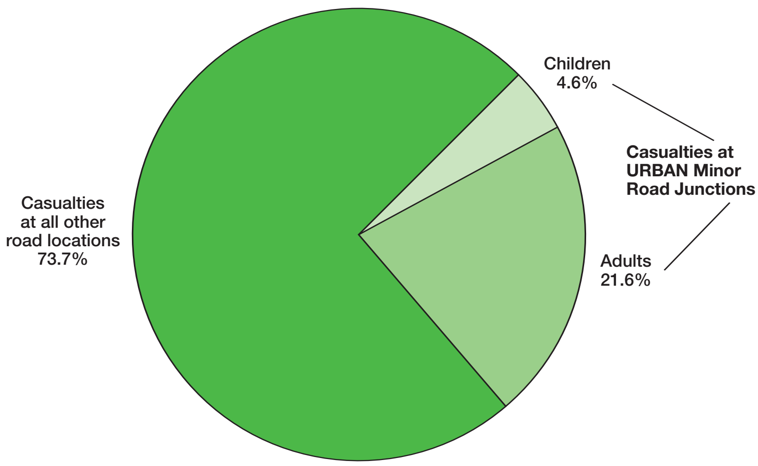
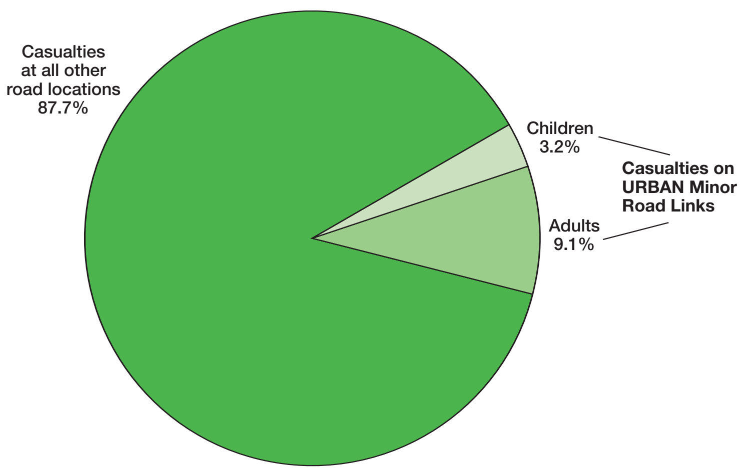


Fig 4.6b: All Casualties GB 1999



4.56 26.2 per cent of all casualties occur at minor urban road junctions, which are likely to be largely on residential roads. The problems are the complexity and uncertainty of vehicle movements, especially turning traffic, too high a speed of the straight ahead traffic, masking of vehicles, and the interaction of pedestrians and two wheelers. Overall numbers of vehicles and pedestrians are generally low and their presence by an individual road user often unexpected. Accident numbers at any one junction are usually low, and so consider the cost effectiveness of options carefully.

4.57 12.3 per cent of all casualties occur on urban minor (residential) road links. As at residential road junctions, the proportion of children involved is higher than on major roads. The problem is usually one of inappropriate speed, and the presence of more vulnerable and inexperienced road users – child pedestrians and child cyclists.

4.58 In recent years it has been recommended that efforts are made to eliminate through-traffic on residential roads using Urban Safety Management techniques, as described in 4.8. Speeds of the remaining traffic are then commonly reduced through the introduction of traffic calming measures, either as free standing schemes or as 20 mph zones (TAL 9/99; Appendix A23).

4.59 In 20 mph zones, appropriate speeds can be achieved through a combination of:

- road humps (Appendix A12);
- speed tables (Appendix A12); and
- horizontal deflections (such as chicanes, throttles or narrowings – Appendix A6).

4.60 Traffic calming on links also reduces speeds on the approach to junctions. Extension of the footway across the mouth of a side road by using a flat-topped hump (sometimes referred to as a footway crossover), can help to slow turning traffic at a junction and deter through traffic (IHT, 1997; County Surveyors Society et al, 1994a).

4.61 To further break up the speed of traffic, mini-roundabouts may be used at busier junctions (Appendix A15).

4.62 The use of speed cushions (Appendix A21) is appropriate where speeds are not required to be so low as in 20 mph zones, and/or on bus routes or through routes for emergency vehicles.

4.63 The speed achieved by traffic calming measures is closely related to the spacing of the measures.

4.64 Chicanes have been used less extensively than vertical measures and there is more variability in their level of acceptance by the public (Webster, 1998).

4.65 20 mph speed limits without self-enforcing measures have only a minimal effect on vehicle speeds (see Appendix A23; DETR, 1999c).

4.66 Physical traffic calming has achieved good reductions in casualties – 60 per cent reduction for all casualties but 70 per cent reduction for children (Webster and Mackie, 1996), though a little of this effect results from some re-distribution of traffic.

4.67 On residential access roads drivers need to be given visual cues that indicate strongly that this road space is part of the environment where people live, walk, talk and play.

4.68 A way to treat such roads may be to create Home Zones (first installed successfully in Holland as *Woonerfs*). In these zones, the full road space is very much shared between motorised and non-motorised users. A pilot programme of nine schemes of different types is currently taking place in England and Wales (Layfield, 2000).

4.69 The speed of traffic is kept very low by the intricate nature of the street layout, the placement of street furniture and features, and by generating 'local ownership' of schemes. However, these schemes are generally very costly.

RURAL roads

Fig 4.7a: ALL Casualties on Rural Roads 1999

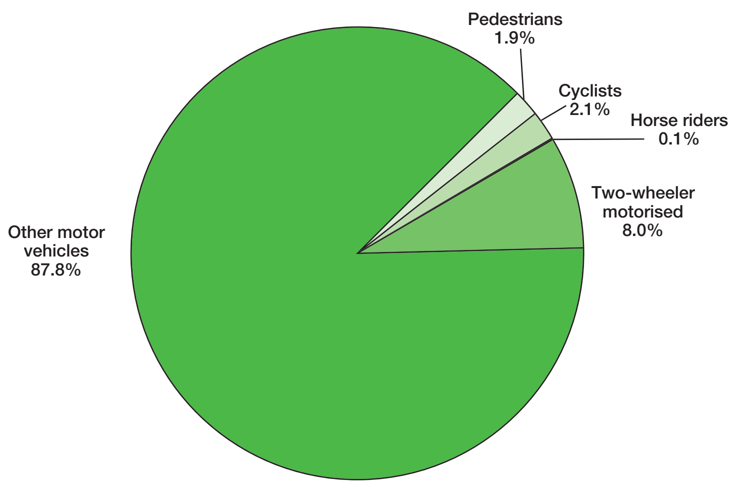
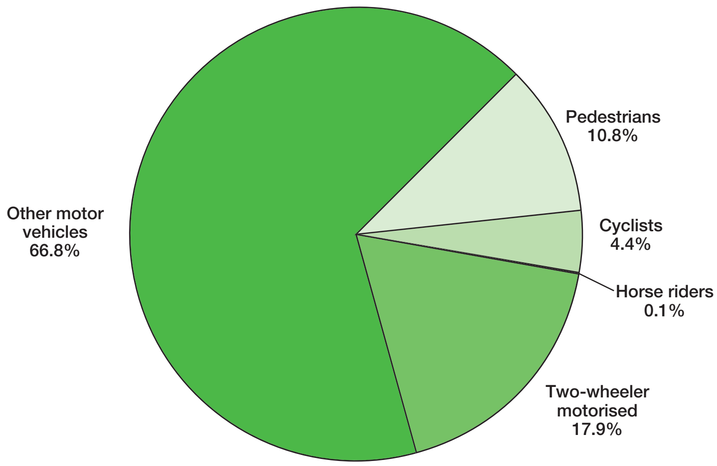


Fig 4.7b: ALL Fatalities on Rural Roads 1999



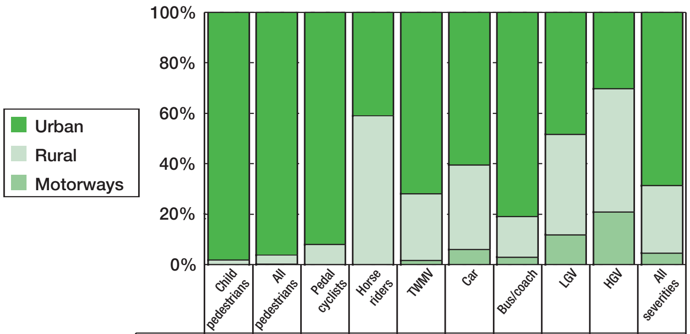
4.70 From Figs 4.7a and 4.7b it can be seen that the vulnerable road user groups on rural roads are again prevalent. As you might expect, they comprise higher proportions of the fatal than all-casualty category totals (though the proportions of pedestrian and pedal cycle casualties are lower than their urban equivalent, probably reflecting lower levels of walking and cycling).

4.71 A number of recent publications address rural accident problems and solutions separately from urban ones. For example, DETR (2000a); IHT, 1999c; Barker (1997); Barker et al (1998); Barker et al (1999); Gardner and Gray (1998); Hughes and Amis (1996); Hughes et al (1997); Pickering et al (1986); and for villages, reports relating to the VISP study such as CSS and DOT (1994b); Wheeler and Taylor (1995); Wheeler and Taylor (1999); Taylor and Wheeler (2000). In addition, note that many of the Design Standards etc in the bibliography relating to trunk roads, may be useful in the design of local roads, particularly major rural roads.

4.72 More than half of all fatalities and a third of all seriously injured casualties occur on rural roads (speed limit 50 mph and above) – see paragraphs 3.36 -3.40 above. Accident severity is higher on rural roads than in built-up areas (speed limit 40 mph and below), and vulnerable road users (pedestrians and cyclists) are particularly at risk. These results are, in part, likely to be due to generally higher vehicle speeds on rural than on urban roads. But of crucial importance is the fact that rural accidents are generally more thinly spread over a wider area than accidents in towns. Cost-effective treatment to prevent accidents is therefore more difficult to apply and the best locations for treatment harder to identify.

4.73 Figures 4.8a and 4.8b break down all casualties and all fatalities on rural and urban roads by casualty type. Figure 4.8b shows that almost a quarter of all pedestrian fatalities and almost a half of all pedal cyclist fatalities occurred on rural roads. These figures are worrying given that walking and cycling are mainly associated with urban travel.

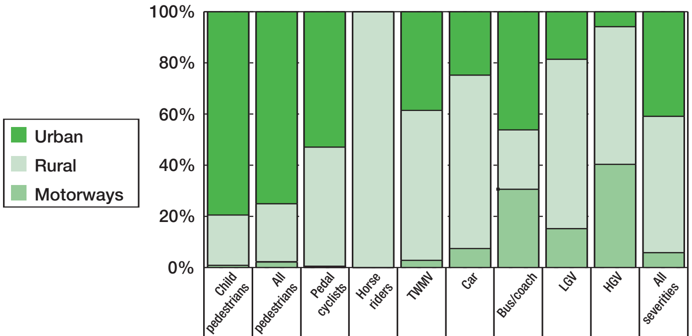
Fig. 4.8a: Proportion of all casualties on rural and urban roads, by road user type, 1999



	Child pedestrians	All pedestrians	Pedal cyclists	Horse riders	TWMV	Car	Bus/coach	LGV	HGV	All severities
Urban	16,553	41,204	20,990	74	18,830	123,599	9,578	3,448	1,057	219,759
Rural	318	1,602	1,836	107	6,904	68,232	1,890	2,841	1,698	85,687
Motorways	5	82	14	0	458	12,331	357	835	729	14,864

TWMV = Two-wheeled motor vehicles

Fig. 4.8b: Proportion of fatal casualties on rural and urban roads, by road user type, 1999



	Child pedestrians	All pedestrians	Pedal cyclists	Horse riders	TWMV	Car	Bus/coach	LGV	HGV	All severities
Urban	85	653	91	0	215	413	12	12	3	1,398
Rural	21	197	80	2	326	1,134	6	43	28	1,823
Motorways	1	20	1	0	16	125	8	10	21	202

TWMV = Two-wheeled motor vehicles

4.74 Two-thirds of accidents on rural roads occur on single carriageway roads. The accident rate (per vehicle-km) is higher on single carriageway roads than on dual carriageways and motorways.

4.75 TRL Report 304 (Barker et al, 1998) describes an analysis of the characteristics of injury accidents that occurred on all rural single carriageway roads in Great Britain in 1994-95, based on the national STATS19 data-base.

4.76 Rural safety management should involve:

- identifying a functional hierarchy of roads and encouraging traffic onto roads with an appropriate function; and
- managing vehicle speeds at the right level for the conditions on each type of road in the hierarchy.

4.77 Re-distributing traffic onto appropriate roads. Where alternative routes exist which enable heavy, through traffic to avoid villages, for example, or where rat-running is a problem, measures should aim to slow the traffic and thereby discourage the use of inappropriate roads. Other modifications may be necessary on alternative routes to cater for the additional traffic.

4.78 Managing vehicle speeds. On rural roads, speeds that are too high for the conditions are likely to be more of a problem than speeds in excess of the speed limit. High accident severity rates will be improved by reducing speeds. Vulnerable road users will particularly benefit.

4.79 Managing vehicle speeds will involve setting appropriate speed limits and the use of engineering and enforcement measures. Appropriate speed limits will be determined by many factors, including:

- traffic flows and speeds;
- pedestrian and vehicle traffic crossing the road;
- visibility splays;
- bends; and
- hills and other natural features.

(TAL 1/95; DETR, 1999c).

4.80 A major contribution to reducing rural accidents and achieving national casualty reduction targets will be made by addressing accidents at bends and junctions. Reducing speeds that are inappropriately high for the conditions will help to tackle accidents involving ‘loss of control’, and lack of awareness of these hazards.

4.81 Given that rural accidents are usually widely and thinly spread, a widespread, low-cost treatment approach to specific accident problems will generally be more cost-effective than treating a small number of individual sites. Sometimes more expensive treatment will be justified at certain locations (junction re-building for example) but this will often be to alleviate capacity problems.

4.82 The low-cost requirement means that the emphasis for reducing speeds will be on signing and/or marking treatments, which should be applied consistently. For example, if bends are to be treated to try to reduce approach speeds, the same kind of treatment should be used at each location where it is intended to convey the same message. Drivers then know what to expect and are less likely to be surprised or confused by different information.

4.83 Three types of strategy should be considered:

- mass action;
- area action; and
- route treatment (see paragraph 3.17 above).

A combination of these approaches might be adopted. The choice will be determined largely by the existing accident patterns and the availability of cost-effective treatments for tackling the prevailing accidents.

4.84 These principles should be complemented appropriately by other techniques: for example, publicity campaigns or training programmes may be more suitable to address accidents involving young drivers, while temporary increased enforcement may be applicable for drink-driving problems.

RURAL Villages

4.85 Local councils and residents have voiced concern over many years about traffic nuisance and perceived safety problems in villages. This is normally expressed in terms of too much traffic travelling too fast through the village.

4.86 The scale of the national problem is not easy to define since it is difficult to extract the relevant accident data from the national STATS19 database for all accidents in villages throughout the UK. Many villages have more of a perceived problem than a real one, as the numbers of injury accidents are often small. Nevertheless, there is often a case for the implementation of traffic calming type measures, as reductions in traffic speed can generally be expected to lead to reductions in accidents and casualties cost-effectively (Taylor et al, 2000; TAL 11/00).

4.87 Where traffic calming measures have been introduced in villages, they have reduced mean speeds by up to about 10 mph. Accidents (particularly the most severe accidents) have substantially reduced overall (Wheeler and Taylor, 2000; Taylor and Wheeler, 2000).

4.88 The differential between the speed limits inside and outside a village can be large. If drivers have been travelling along rural roads subject to the national speed limit for an appreciable distance, they may not recognise the need for greater care and lower speeds. They may be unaware of a lower speed limit or of their own speed and may respond late to the lower limit. In particular they may be unaware of the increased risk of an accident, especially with a vulnerable road user. Speeds observed through villages are often high compared to what is appropriate for the conditions.

4.89 The increased number of pedestrian movements and the greater concentration of cyclist and equestrian journeys within the environs of a village warrants special attention, particularly if accidents are taking place during the hours of darkness.

4.90 The principal aim is to alert drivers to the change in road environment. Although village name signs together with speed limit signs have been conventionally used to mark the entry to a village, a ‘gateway’ can make this change more prominent (see Appendix A9). Ideally the gateway and a speed limit change should coincide with the boundary of the village, to provide all the visual cues together.

4.91 Gateways are generally not enough to produce speed reductions that are sustained throughout the village. Other features within the village are required and these may include:

- narrowings (eg pinch-points, build-outs – see Appendix A6);
- traffic islands and pedestrian refuges (see Appendix A11; TAL 07/95);
- coloured surfaces and markings (see Appendix A7 and A20; TSM Chapter 5, CSS, 2000; DMRB, TA 81/99);
- over-run areas at junctions (see TAL 12/93);
- mini-roundabouts (see Appendix A15);
- signs (see Appendix A20; TSM Chapters 3, 4, 5; and 7);
- speed cameras, if cost-effective – (see Appendix A4).

4.92 Consider the need to light potential hazardous features where village lighting is poor or non-existent.

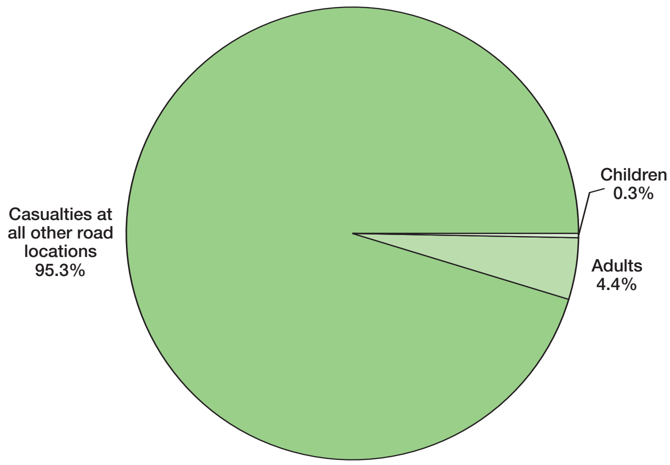
4.93 Features need to be designed sensitively to minimise impact on the rural character of villages and be located to minimise problems for local residents.

4.94 20 mph zones are only appropriate if supported by physical features that will ensure reduced speeds are achieved and are therefore unlikely to be used on major through routes.

4.95 A history of pedestrian injuries will need close examination to establish common factors. If pedestrians have been struck while walking along the road, check whether footways and perhaps lighting are adequate. If they have been hit while crossing the road, then it is likely that special provision is needed in the form of refuges and/or a zebra/pelican/puffin/toucan/pegasus crossing (see Appendix A10; LTN 1/95; LTN 2/95). Where such measures involve a reduction in carriageway width, cyclist and equestrian needs should be considered and special provision made where feasible (see Appendix A8).

Motorways

Fig 4.9: All Casualties GB 1999



4.96 The Highways Agency is responsible for motorways[37], so for completeness they are included here. Many of the problems and solutions are applicable on other major roads, especially dual-carriageways. In addition, some local authority schemes may include motorway/non-motorway intersections or roads/footways that cross, but do not intersect, motorways.

4.97 Almost 5 per cent of all casualties occur on motorways. Of these, about 6 per cent are children under 16 years of age.

[37]Some local authorities are responsible for motorway standard roads and some are Highways Agency Agents.

4.98 Motorway junctions are relatively widely spaced and consequently only 17 per cent of motorway casualties are injured in accidents at junctions. Motorways carry more traffic than other types of road but have the lowest accident rates and casualty severity indices[38] of all roads (11 accidents per 100 million vehicle-kms and 11 per cent casualty KSI index, compared with 50 per 100 million vehicle-kms and 13 per cent casualty KSI index for all roads, respectively – DETR, 2000a). These statistics reflect the high quality (dual-carriageway) design and build of motorway roads, the use of hard shoulders, the low junction densities, one-way traffic flow and the low opportunities for pedestrian and pedal cycle conflicts.

4.99 However, when motorway accidents do occur, they frequently involve more than two vehicles and result in a number of injuries. This may be a consequence of high quantities of traffic, high speeds and vehicles driving too close together. On average, there are 2.27 vehicles and 1.63 casualties per motorway accident, compared with averages of 1.83 and 1.36, respectively, for all accidents. It is partly for this reason, and partly because of the distances involved for recovery and emergency vehicles, that motorway accidents are the most costly.

4.100 Accidents on motorways are also more likely to involve only one vehicle (22 per cent compared with an average of 14 per cent on all roads), perhaps as long periods of driving without a break and a lack of visual stimulation can result in driver fatigue or distraction.

4.101 Motorways do not permit pedestrian or small two-wheeler vehicle traffic and so the largest differentials between the speed and mass of individual vehicles will usually be between cars/TWMVs and goods vehicles (HGV/LGVs)[39]. Most often it is the drivers and passengers in the cars/TWMVs that are injured, however, when HGV/LGV occupants are injured, they tend to be severely injured (perhaps if they are unrestrained by seat belts or are trapped in wreckage). About 38 per cent of all motorway casualties are injured as the result of an accident involving at least one HGV or LGV, and these casualties account for around half of all killed or seriously injured motorway casualties.

4.102 Although the vast majority of motorway casualties are car occupants (about 85 per cent), motorcyclists have accident rates about 10 times higher than the average for all road users (per vehicle-km travelled).

4.103 Almost all children injured in motorway accidents (94 per cent) are car occupants. Of these, 78 per cent were rear seat passengers.

[38]Casualty severity index (Casualty KSI index) = 100*Number of killed and seriously injured casualties/All casualties.

[39]TWMV = Two-wheeled motor vehicle; HGV = Heavy Goods vehicle; LGV = Light Goods Vehicle.

Information regarding rear seat-belt wearing compliance by these children is not known.

4.104 The numbers of pedestrians injured in motorway accidents is small but still of concern, as exposure is so low. Pedestrians are at particular risk on hard shoulders, at roadworks and at motorway junctions.

4.105 Accident rates in the vicinity of roadworks are higher than on similar road sections without works. 50 mph speed limits for these sections are now common practice and are often enforced with speed cameras. The majority of accidents involve shunts. Drivers often drive too fast for the conditions, too close, too aggressively or without due care and attention. For advice see Health and Safety Executive, 2000.

4.106 Close-following behaviour can be addressed through the use of appropriately worded variable message signs which require special authorisation. Most of the motorway network is monitored by cameras and once an incident, or congestion, is spotted the effects can be minimised by informing drivers of the problem ahead and advising/encouraging/enforcing action or diversions[40]. Such signs can comprise dot matrix symbols or include a worded message.

4.107 When a problem persists at a particular location, the provision of static signs (TSM Chapter 4) should be considered and, if the traffic flow levels are suitably light, the use of chevron spacer road markings might be considered. (Appendix A5).

4.108 The safety problems relating to fatigue and distraction and those regarding pedestrians and motorcycles may best be addressed through non-engineering techniques but should still be borne in mind whenever engineering work is carried out.

4.109 Roadwork sections need to be carefully designed – see TSM Chapter 8. Attention needs to be given to the use, the extent, and the enforcement of a lower speed limit.

RURAL Dual-carriageways

4.110 Many dual-carriageways, particularly the most recently built, are built to a high standard and designed to service the traffic they carry. Consequently, the accident problems on many dual-carriageway roads are similar to those observed on motorways (Walmsley and Summersgill, 1998). However, those built to older, lower standards may have more potential for improvement.

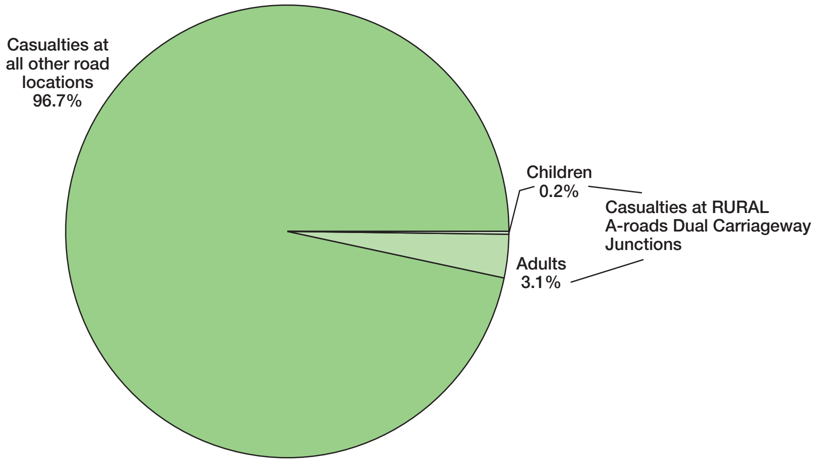
[40]On the M25, an interactive system of variable speed limits has been introduced. Speed limits change according to the prevalent traffic conditions ahead.

4.111 Although only about 4 per cent of all accidents occur on rural dual-carriageway A-roads, these accidents account for about 6 per cent of all casualties. The reasons for this are likely to be similar to those suggested for motorways in paragraph 4.99 above.

4.112 About half of casualties are injured in accidents on links and about half at junctions. The proportion at junctions is quite high when compared with that for all rural roads (38 per cent). The severities of rural dual-carriageway accidents are slightly higher than those on motorways with 20 per cent of accidents resulting in fatal or serious injury (Barker et al, 1999).

RURAL Dual carriageway junctions

Fig 4.10: All Casualties GB 1999



4.113 Of the accidents at junctions, about 54 per cent are at roundabouts. Many of the problems at other junctions are a consequence of drivers' difficulty in judging the speed and distance of other traffic, particularly at priority junctions.

4.114 The approaches to junctions should be adequately and clearly signed (see TSM Chapters 4 and 7 and TSRGD). This is of particular benefit to drivers on this type of road as safe opportunities to stop and consult a map or turn around may be few and far between. The provision of anti-skid surfacing on the approach to the junction may also be worthwhile (see Appendix A1; DMRB, HD 28/94).

4.115 Junctions (and traffic at or on the approaches) should be conspicuous and drivers should have adequate warning to slow down and be aware of the path they should take through the junction. Priorities should be clear. The provision of lighting may be appropriate, if a suitable power supply is nearby. Grade separation of the junction may be appropriate for the most major junctions.

4.116 The provision of yellow bar markings on the approaches to at-grade roundabouts is one option for giving drivers advance warning of the junction ahead (only if the approach is high speed) and may be particularly suitable on approaches with little visual stimuli. See Appendix A26.

4.117 On large roundabouts lane markings may help guide drivers and riders through the junction (TSM Chapter 5). Two-wheeled vehicles often experience problems at roundabouts and their needs should always be considered (Appendix A8 and A15).

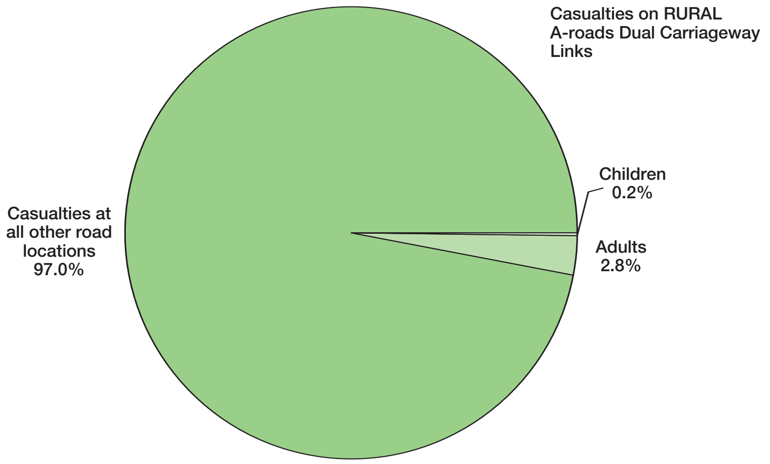
4.118 It is necessary to ensure that all accesses and not just those with other main roads are safe and of a suitable standard to accommodate the traffic using it. For example, laybys, private drives and businesses, farm accesses, bus stops etc should be designed so that traffic can join and leave the main road safely.

4.119 The safety of vulnerable road users crossing junctions should always be considered as junction widths can be very wide and traffic flow fast and heavy. The provision of signals with pedestrian phases can provide opportunities for pedestrians and cyclists to cross one arm of a junction in several stages (LTN 1/98; DMRB, TD 50/99). The provision of grade separated pedestrian, cycle and equestrian crossings may also be appropriate if flows are high enough (see paragraph 4.127).

4.120 If junctions are uncontrolled and traffic needs to cross the two carriageways in two stages, care should be taken that the central reservation holding area is sufficiently wide and that traffic on the main road is clearly visible to drivers using the gap.

RURAL Dual carriageway links

Fig 4.11: All Casualties GB 1999



4.121 Where accident problems on links closely resemble those on motorways they should be treated accordingly.

4.122 A consistent approach along a route (for example, to indicate the relative severity of bends) is important (TSM Chapter 4; TSM Chapter 5; IHT, 1999).

4.123 In addition, care should be taken to ensure that hazards are adequately signed or marked in advance so that drivers can adjust their speed or position accordingly.

4.124 In general, as many visual cues as possible of the changing alignment of the carriageway should be provided at bends. These may include chevron boards, reflectorised posts, white lining etc (see TSM Chapter 4 and TSM Chapter 5). On major routes that are predominantly straight, even moderate bends may need to be well signed (see TSM Chapter 4 and TSM Chapter 5).

4.125 The use of safety fences on the central reservation will substantially eliminate the opportunity for head-on collisions. Safety fences at the roadside can be used to protect vehicles leaving the road on the nearside from hitting objects such as trees and lampposts and from going over embankments into gullies by guiding them back onto the carriageway. Gaps in the central reservation should be kept to a minimum and restricted to locations where they can be safely used. (See Appendix A13; DMRB, TD 19/85; DMRB, TD 32/93.)

4.126 On routes with high volumes of HGV traffic the provision of climbing lanes uphill for overtaking traffic and escape lanes downhill may be considered appropriate.

4.127 The provision of crossing facilities for non-motorised road users should be given consideration (LTN 1/95; LTN 2/95). Although on busy roads the provision of subways or bridges may be justified for non-motorised users, these must be carefully designed and positioned to encourage people to use them, given past experience of their unpopularity. In some recent cases, road levels have been altered to allow footways and cycle tracks to remain at ground level.

4.128 Depending on demand, consider the need to provide facilities for cyclists along rural dual carriageway links. If there is a demand from pedestrians, then under the Highways Act, the highway authority has to make provision for pedestrians. In certain circumstances it may be appropriate to provide a shared use cycle track and footway segregated from the main carriageway. The principles set out in *LTN 2/86 Shared Use by Cyclists and Pedestrians*, will guide the designer to the most appropriate solution.

RURAL Major single-carriageways

4.129 11 per cent of casualties occur on single-carriageway A-roads, 42 per cent of who are injured at junctions.

4.130 About 28 per cent of accidents result in fatal or serious injury.

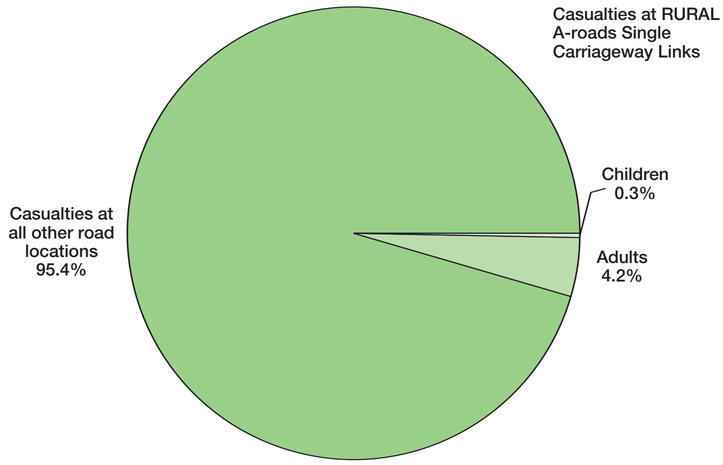
4.131 3 per cent of accidents involve at least one pedestrian, 2 per cent of vehicles in accidents are pedal cycles, 5 per cent are TWMVs and 12 per cent are LGVs or PSVs[41] or HGVs.

4.132 Overall, these roads carry a similar amount of traffic per year as motorways do – i.e. about 30 per cent of all rural traffic (Barker et al, 1999). However, at seven times the kilometre length of motorways, the potential for major redesign is low on grounds of cost. Therefore, more cost-effective solutions have to be adopted.

[41]PSV = Public Service Vehicle

RURAL Major single-carriageway junctions

Fig 4.12: All Casualties GB 1999



4.133 Older drivers are more likely to be involved in accidents at junctions than younger drivers.

4.134 The number of potential conflict points should be minimised; T-junctions have lower accident rates than crossroads and multi-arm junctions should be avoided (IHT, 1999). The use of traffic signals should also be avoided where possible. As speeds and flows increase, advance warning becomes essential.

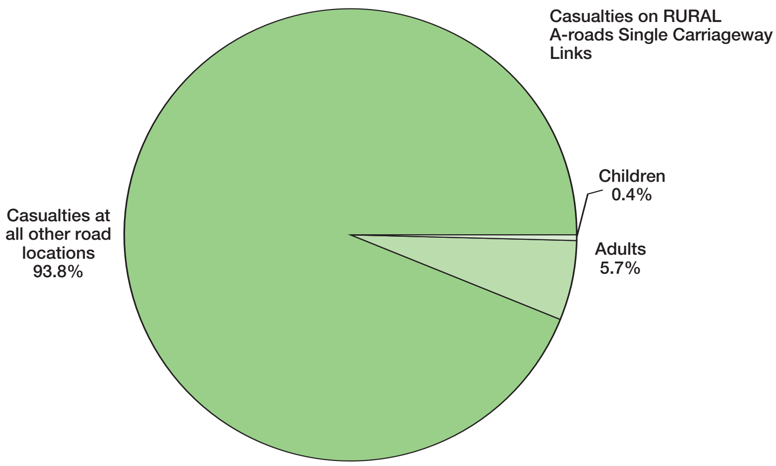
4.135 Anti-skid surfacing on high speed approaches can be effective (see Appendix A1 examples; DMRB, HD 28/94).

4.136 The presence of junctions must be made clear to drivers and riders with clear and consistent advance warning signs and carriageway markings (TSM Chapters 4 and 5) and by the presence of reflectorised posts, traffic islands and bollards. Through drivers must be alerted to the potential hazard of emerging traffic and encouraged to slow down; this is especially true where traffic turning off the major road impedes through traffic.

4.137 The design of turning facilities for major road traffic at T-junctions and crossroads is important. Vehicles, particularly cyclists, are vulnerable when positioned between fast traffic in both directions. Protected lanes for turning vehicles can reduce accidents, and conspicuous and consistent road markings are essential – see TSM Chapter 5.

RURAL Major single-carriageway links

Fig 4.13: All Casualties GB 1999



4.138 57 per cent of rural major single-carriageway casualties are injured on links.

4.139 Accidents on links are more likely than those at junctions to involve a single vehicle, young drivers, a pedestrian, bad weather, and (probably because vehicle impact speeds are, on average, higher on links) to result in more severe injuries.

4.140 Following distances are particularly important where forward visibility is restricted by, for example, hills and bends. The problem can be exacerbated by a wide carriageway which can encourage staggered following behaviour with shorter following distances (IHT, 1999c).

4.141 The use of white lining about 1m or more from the edge of the road (to provide a hardstrip) or continuous centre hatching to reduce the effective carriageway width to, say, 7m is likely to reduce accidents (TSM Chapter 5; IHT, 1999c).

4.142 Double white lines are used to indicate stretches of road with limited forward visibility (at hills or bends) where it is unsafe to overtake. TSM Chapter 5 gives advice on usage.

4.143 Speed cameras are an increasingly realistic option to enforce speed limits when there is a speed related accident problem (IHT, 1999c). However, enforcement in remote areas is a problem where the availability of power to such sites is a factor (See Appendix A4).

4.144 Speed differentials of mixed traffic should be reduced as far as possible. Careful consideration should be given to providing for the needs of pedestrians and cyclists and the principles set out in the hierarchy of measures in *Cycle-friendly Infrastructure* (IHT et al, 1996a) will assist the designer to adopt the most appropriate solution. Where space permits, segregation of these vulnerable road users from motorised vehicles may be appropriate. In certain circumstances it may be appropriate to provide a shared use cycle track and footway and the principles set out in LTN 2/86 should be followed. If the road is frequently used by equestrians, the provision of bridleways, which can also be used by pedestrians and cyclists, may be considered. Provision of climbing lanes up, and escape lanes with arrester beds down, steep hills may be relevant where the traffic has a high HGV content and the required road width is available.

4.145 Icy conditions and wet roads can be the catalyst for accidents involving skidding. Drainage and skid resistance should be checked and, if conditions merit, remedial action and signing should be implemented quickly when dangerous conditions arise.

4.146 For roads with steep drops close to the carriageway safety fences should be considered (DMRB, TD 19/85; DMRB, TD 32/93). Where there is livestock adjacent to the road, roadside fencing must be well-maintained and secure to prevent animals from straying into the paths of vehicles.

RURAL Minor single-carriageways[42]

4.147 Although only about 10 per cent of all casualties in GB occurred on minor rural single-carriageway roads in 1999, these accounted for 15 per cent of all fatalities.

4.148 The numbers of accidents per vehicle-km are also very high on these types of road. (45 accidents per 100 million vehicle-kms, compared with 26 for all rural roads – Barker et al, 1999).

4.149 This is to some extent likely to be due to inappropriately high speeds on such roads, especially on links, leaving drivers little time to react and recover when emergency situations arise, frequently resulting in very serious injuries.

4.150 In addition, today, these roads are often carrying large volumes of traffic, far in excess of the levels for which they were designed. They

[42]These have been defined as all non-motorway or A-roads with speed limits of 50mph or more.

are often built to older and lower design standards, and may not be subject to the same level of maintenance programming as those of more major roads and motorways.

4.151 The increased traffic has created rural roads that are unsafe for cycling, walking or horse riding. Efforts need to be made to reverse this perception especially on these minor roads if the aforementioned more healthy, often leisure pursuits are to be encouraged in favour of dependence on the motor car (IHT, 1999c).

4.152 Higher proportions of accidents than expected occur at night-time taking into account the relative traffic levels during the hours of darkness compared with daylight (IHT, 1999c).

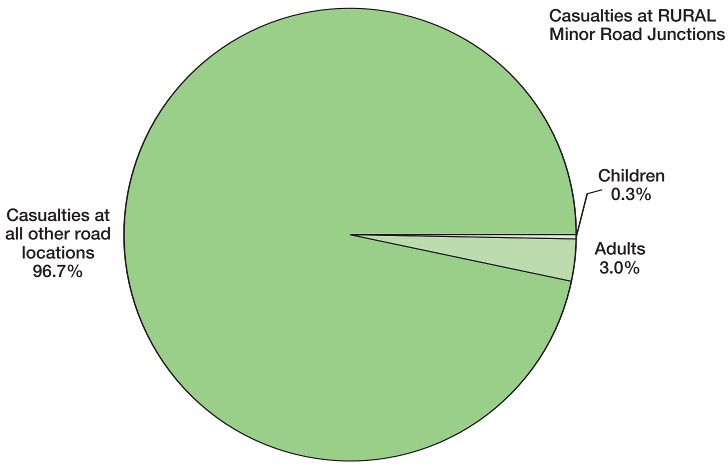
4.153 Rural locations are perhaps more likely to suffer from lower levels of regular maintenance than more major roads. Road surfaces therefore may become more slippery in general and this can produce problems for (especially two-wheeled) vehicle drivers and horse riders.

4.154 These roads are estimated to account for about 82 per cent of the total rural road length in Great Britain (Barker et al, 1999). Therefore, it is especially vital to adopt low-cost accident remedial measures, such as signing and marking in accordance with TSM Chapters 4 and 5.

4.155 In general, speed reducing measures and measures that act as 'alerting' devices for hazards (eg supplementary plates on signs or rumble areas (TSM Chapter 7; Appendix A17)), which may be obscured or difficult to judge or detect, are recommended and many of these are discussed below.

RURAL Minor single-carriageways junctions

Fig 4.14: All Casualties GB 1999



4.156 The situation with respect to numbers of casualties at junctions and on links tends to be reversed on minor roads in the rural environment in that fewer numbers occur at junctions, ie a third at junctions compared with two thirds on links. This may be largely due to the lower numbers of junctions and turning vehicles than in urban areas. Nevertheless over 100 people were killed in 1999 at rural minor road junctions.

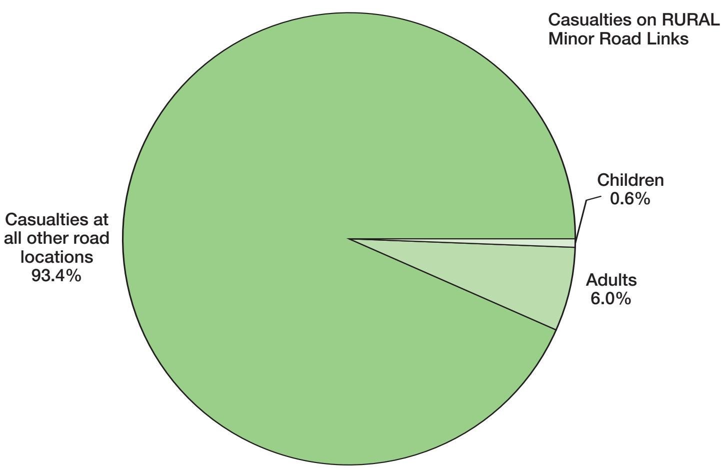
4.157 There can be a particular problem at crossroads where the road ahead, but not the junction, is clearly visible to those approaching drivers who need to give way or stop at the junction.

4.158 Junctions where minor road vehicles must give way to major road traffic need to be visible. Where skidding is evident or there are large numbers of recorded rear-end collisions, then there may be a case for special anti-skid surfacing to be laid in the approach to a rural junction (Appendix A1; DMRB, HD 28/94).

4.159 Vehicle-activated signs which warn drivers who are approaching too fast, of the junction ahead may be applicable at junctions with crossover accidents and high vehicle speeds on the approaches, if existing signing is of a high standard and if a power source is available (Appendix A25).

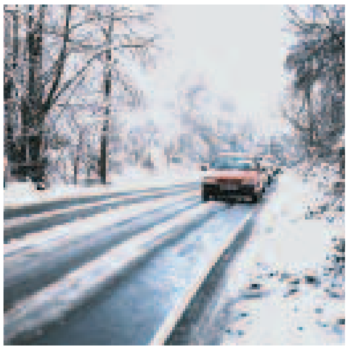
RURAL Minor single-carriageways links

Fig 4.15: All Casualties GB 1999



4.160 Although only about 7 per cent of all casualties injured on roads in GB in 1999 were injured on minor rural single-carriageway roads, these accounted for about 12 per cent of all fatalities. This gives some indication that the severity of accidents on rural minor roads tends to be generally higher than on other roads, which may be largely attributable to vehicle speeds often being generally too high on such roads.

4.161 Many accidents on rural minor roads tend to be associated with vehicles leaving the carriageway following a loss of control on bends.



4.162 Physical features (vertical/horizontal deflections such as road humps/narrowings) will be largely inappropriate on, even minor, rural roads that carry high speed traffic. One aim of signing/marking is to convey the *impression* of a hazardous situation – for example, markings can be used to give the impression of the road narrowing – such as channelisation or edgelining in accordance with TSM Chapter 5. These are **'perceptual' techniques.**

4.163 On minor unlit rural single-carriageway links without kerbs, TSM Chapter 5 recommends whitelining systems. Such systems will include edge-lining and centre-lining using solid, dashed, or double lines as appropriate and as specified in TSM Chapter 5 – see Appendix A20.

4.164 On wide roads, measures that appear to reduce the road width (eg centre channelisation) may be suitable to discourage overtaking and encourage lower speeds. The introduction of cycle tracks could also be considered to provide some degree of segregation between cycles and other traffic.

4.165 Options for making provision for equestrians, include bridleways, all purpose highways without motor vehicles[43], or a margin at the side of the highway[44]. These may also help pedestrians and cyclists.

4.166 As mentioned above, a predominant type of accident site is bends. Therefore, it is recommended that measures suitable for use at or on the approach to bends should be considered, perhaps as a mass action approach if the problem is widespread and existing signing and markings comply with advice in TSM Chapters 4 and 5.

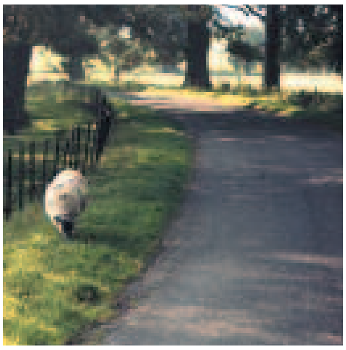
4.167 Vehicle-activated warning signs may be appropriate on the approaches to particularly hazardous bends. They alert drivers and slow and smooth vehicle speed profiles through a bend. If a power source is not easily available, the cost may be prohibitive (Appendix A25).

Non-engineering measures

4.168 Although this guide is primarily concerned with engineering good practice, modifying the road environment should not be done in isolation and the approach to improving road safety must be an integrated one. There are other very important areas where road safety activity should be carried out in an organised and efficient manner, often co-ordinated by road safety officers.

[43]Introduced by means of a traffic regulation order.

[44]Under powers available under Section 71 of the Highways Act 1980.



Role of road safety officers

4.169 In general terms, the role of an RSO is in education, training and publicity (ETP) and encouragement programmes. These approaches shape and change the behaviour and attitudes of individual road users. The full benefits of these approaches are often long term ones, which may never be measurable as their specific effects may not be able to be assessed in isolation.

4.170 Education programmes are largely school-based. The programmes usually involve informing and advising teachers, and they may have specific objectives or be part of a long-term development of learning and ideas. Those targeting children in particular will be shaped to match the physical and mental development of a child. Often, road safety education can be planned to complement other topics within the context of the National Curriculum. Some programmes and advice can be directed via parents.

4.171 Training programmes are mostly targeted at specific types of road user or age group and are designed to develop the practical skills required to use the road network safely.

4.172 Publicity campaigns generally use the media, leaflets and advertising to inform and advise road users. These are often the only ways to reach a wide audience and adults, in particular. The campaigns may, for example, inform of new developments, changes to the network, traffic or the law, advise of the latest best practice, advise of the most recent research. They will often aim to change road user behaviour and attitudes to road safety problems and issues. Many publicity campaigns are organised at a national level (by DETR, for example) to target national problems or to reflect national policy. These campaigns often rely heavily on support at a local level to ensure maximum effectiveness (e.g. health authorities and schools).

4.173 ETP programmes often involve a combination of the above approaches and may involve RSOs working together with other outside bodies.

4.174 It is important that any ETP work is monitored in some way in order that the effectiveness of future programmes can be optimised.

4.175 Some of the more recent strategies that are relevant to the latest national casualty reduction targets are discussed below.

Safe routes to school

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

4.177 About a fifth of cars on the road in urban areas during the morning peak are taking children to school (DETR, 1999a, DETR, 2001c). Several major changes in traffic have occurred in just the last ten years and these include the fact that:

- the proportion of journeys to school by car has nearly doubled, from 16 per cent to 30 per cent.
- the average length of the journey to school for secondary pupils has gone up by well over a third.

4.178 The problem directly affects more than nine million young people in education in the UK and their families. Indirectly it touches everyone through its effects on health, education, local air quality and congestion. The causes are complex and inter-related, but include:

- rising car ownership;
- a wider choice of schools other than neighbourhood schools;
- local changes in where people live and pupil numbers;
- inadequate bus services and high fares in some areas;
- increased traffic and fears about road safety;
- increased fears about personal safety, including bullying and abduction;
- children carrying more equipment and books to school; and
- parents under increasing pressure of time.

4.179 As a result, traffic and congestion is increased and, in many areas, fears about safety in traffic lead to less walking and cycling and more driving which in turn increases traffic. Local air quality and journey times deteriorate and the hazards for those who do travel to school in this way probably do increase.

4.180 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, pedestrian and cycle training, escort schemes such as the 'walking bus' and enhanced facilities within the school (see DETR, 1999a).

What is a school travel plan?

4.181 A high quality school travel plan puts forward a package of measures to improve safety and reduce car use. It is backed by a partnership to benefit children involving the school, education and transport officers from the local authority, the police and the health authority. It is based on consultation with teachers, parents, pupils and governors and other local people. The concept is intended to have more impact than initiatives which focus on a single issue or mode of travel as it uses measures which reinforce each other. It improves safety leading to reduced car use and still better safety.

4.182 A school travel plan works by looking in detail at children's needs on the school journey and can be geared to the needs of a primary or a secondary school. Ideas often include a rota for parents to accompany younger children on a 'walking bus', cycle stands at the school, cycle training, and low fare deals for children using public transport. A school 'safety zone' can transform children's journeys with crossing points, traffic calming and lower speed limits on nearby roads.

The walking bus

4.183 Many councils have to arrange education transport below the statutory or authority qualifying distances even when good, lit walking routes to school exist. Often the only reason a route might be deemed as being unsafe is if it passes through isolated areas. As a result the issues associated with personal security of children walking or cycling to school are so contentious that councils provide free transport for short distances even if there are no obvious hazards for a child to walk while accompanied by a responsible adult.

4.184 West Lothian and Hertfordshire County Councils were two of the first authorities to introduce the concept of a 'Walking Bus,' around 1997. It is perhaps best described as a mobile patrol. The patrol walks along a designated part of the route, with the objective being to provide an adult presence, not to escort children but to keep a watchful eye on them as they walk to school. It aims simply to:

- encourage less use of the car for short trips;
- enable children to get more exercise and learn pedestrian skills; and
- promote friendship and conversation between children.

4.185 The school plots pupils' homes on a map, as well as carrying out a survey to find out how many potential 'passengers' would be willing to participate. Safe 'Bus Stop' gathering areas can be selected, which should be as near to large areas of children's homes as possible. The routes should, of course, keep the need to cross roads to a minimum, and use safe crossing places wherever possible.

4.186 Schemes are commonly administered by the School Crossing Patrol Unit, which trains and recruits applicants on similar lines to that of their existing staff. Detailed guidance on operating a walking bus scheme is in DETR (1999a).

4.187 A typical cost has been found to be about £4,000 per year for each Walking Bus. However, the scheme can be extremely cost effective when compared with the cost of providing a real bus which can easily be more than £15,000 a year.

Pre-school – Children's Traffic Club

4.188 The concept of a Traffic Club for pre-school children originated in Scandinavia and has been operating in the UK since about 1990. The aim of the clubs is to involve parents or carers in teaching road safety to their children using both indoor and outdoor exercises set out in a series of books.

4.189 An evaluation of the pilot scheme Children's Traffic Club in the Eastern Region County Councils revealed various successes, including a contribution to a 12 per cent reduction in all casualties and a 4 per cent reduction in pedestrian casualties between four-year 'before' and 'after' periods. However, the most significant change was a 20 per cent reduction in casualties involving children emerging from behind a vehicle (Bryan-Brown, 1995).

Primary school training

4.190 Material for various child road safety education programmes has been produced over many years. Some is aimed at the five and six year age range (Reception, Year 1 and possibly Year 2) (DETR, 1998f and 1998g), but these can go up to age 12 by incorporating the subject within other main subjects like Mathematics, English, Science, Geography etc. (Thomson et al, 1996; Clayton et al, 1998).

4.191 This type of education is generally accepted to be effective, although it is very difficult, if not impossible, to demonstrate rigorously that the training has reduced casualties. In Sunderland for example, comparisons of periods before and after introduction of pilot schemes seemed to indicate that the pedestrian training is associated with a drop in casualty numbers of 36 per cent. However, this was not statistically significant as there was a general downward trend in casualties for the same period. However, observations by the road safety officers did show that the proportions of children performing safely at four crossings improved markedly and this was sustained one year after receiving training.

4.192 The schemes normally need to enlist volunteer trainers (like school staff, governors, parents, grand parents, and voluntary organisations – see Kerbcraft (DETR, 1998g)). However, by law, everyone working with children under the age of eight years must comply with the Children's Act 1989. This means that all volunteers and staff must complete a Police Criminal Records Office form. This must be submitted through the Education Department as the training scheme is non-registered and their agreement must be obtained. These checks can take time to process. The forms need to be submitted in good time so that the scheme can begin on schedule.

4.193 It is, if course, important to ensure good liaison and approval from all interested parties involved, like the head teachers, parents, road safety officer team and the police.

Cycle training

4.194 Road sense training for child cyclists has been provided for many years, normally out of school hours, and is regarded as a valuable exercise.

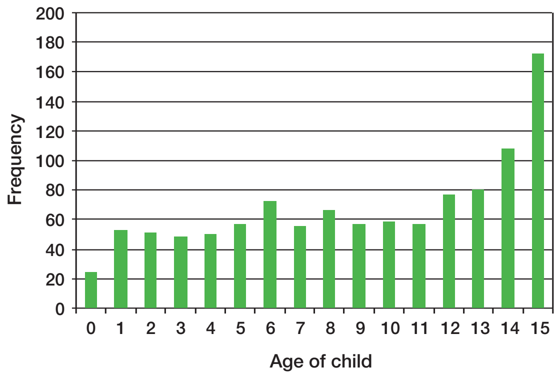
4.195 Savill and Bryan-Brown (1996) evaluated eight schemes around the UK. Groups of 13-year old children who had received training at age 11 were given a cycle riding and knowledge test by the local road safety officers. The study concluded that these children did indeed possess significantly safer riding skills and knowledge than those who had not taken part in the cycle courses.

4.196 A relatively new extension to cycle training carried out by some authorities (such as Surrey County Council) is safe cycling classes held for both parents and children. This also provides adults with useful points to be wary of when cycling with young children.

Pre-driver training

4.197 There is recent concern for the mid-teenager group. For example, the number of casualties killed or injured in cars appears to begin to rise sharply from the age of 14, with more than twice the numbers of casualties recorded for 15-year olds than any other single year child age-group under 14. Also, the 12 to 15 year age band is the only one where girls are proportionately more involved than boys.

Fig. 4.16: Killed & Seriously Injured in cars, 1999



4.198 Young drivers in the 17 and over age groups, continue to be a major problem, with casualty numbers of 18-year olds being about eight times higher than most of the single year child age-groups.

4.199 There appears to be a need to focus on both trying to instil responsible attitudes to driving while still in school. It is also advisable to get new immediate messages across to girls. For example, they should be told that they need to be aware when travelling with their young friends when these drivers are taking unacceptable risks, and ways in which they can try to modify such behaviour.

Adult road user training

4.200 Road safety officers should not ignore adult education and many carry out adult road user education programmes. For example, they train older road users how to use new crossings like pelicans and toucans, or advise regular drivers how to deal with a particular problem. This can be done by either roadside training or targeted publicity campaigns.

4.201 An example of this was Surrey County Council who successfully tackled a localised nose-to-tail collision problem by targeting residents with direct, narrow frontal access to their driveways off a busy main road. The council distributed leaflets advising resident drivers of the safety problem and to signal and slow down gradually, well in advance of their manoeuvre.

Publicity

4.202 Publicity campaigns are expensive but can be extremely effective, even though they may take many years to bring about a lasting change in attitude (such as the well-known change in public attitude towards drinking and driving). A study of evaluated campaigns has concluded that a well-designed publicity campaign can typically produce a 30 per cent reduction in casualties in the target group (Delhomme et al, 1999).

4.203 Recent areas where it has been identified that there is a need for publicity campaigns to be focussed (DETR, 2000b) are:

- improving child road safety;
- preventing speeding;
- drink and drugs driving;
- drowsiness;
- motorcycles;
- use of cycle helmets;
- mobile phones; and
- company car drivers (for both employers as well as employee drivers).

Measuring effectiveness

05

Monitoring matters

5.1 Through the LTP Annual Progress Reports authorities will monitor the progress that they are making in working towards the achievement of their local road safety targets contained in their Local Transport Plans (see Chapter 3). In addition, authorities are expected to monitor the effects of individual safety schemes. The following Chapter sets out advice on measuring the effects of such schemes.

5.2 What is required is some knowledge of how driver behaviour changes following the introduction of a scheme and, ultimately what are the effects of behavioural changes on accident frequencies and casualties.

5.3 Monitoring these changes is the only valid and objective way to be able to demonstrate the relative (cost-) benefits, and success in saving casualties, between more than one safety scheme. The results of monitoring feed into future work, rejecting less successful types of schemes in favour of more successful ones, or helping to make decisions about a number of small schemes over a single costly one. Ultimately, this should produce greater accident reductions and fewer casualties.

5.4 The County Surveyors' Society and Highways Agency's MOLASSES database stores information on safety schemes installed on local and trunk roads across Great Britain. The database can be interrogated to obtain information regarding the accident reductions achieved across all sites of a certain type eg roundabouts, road humps etc. See the web site at **www.trl.co.uk/molasses** and Appendix C for an example data entry form. However, note that TRL Limited, who manage the database, will accept data in almost any format.

When to monitor

5.5 The monitoring studies for measuring the effect of a safety scheme are usually by 'before' and 'after' analysis of factors that are likely to have a bearing on the safety of road users at the particular treated site(s). Although not an exhaustive list these may include:

- spot speed;

- speed variance;
- traffic conflict studies;
- traffic volumes;
- journey time/delay;
- compliance with traffic control devices;
- skid resistance;
- sight line/passing sight distance/superelevation;
- pedestrian safety gaps/kerb delay/crossing times;
- road accidents; and
- weather/season.

5.6 *Before* measurements should be made as close as possible to the time when the scheme is implemented. Ideally, this would be during the month before (except for accident monitoring – see paragraph 5.33). However, in some cases it may be sensible to make observations only after the changes, for example, with attitude surveys.

5.7 It would, of course, be impractical to carry out detailed behavioural studies for all minor alterations, but studies may be particularly important for expensive schemes like area-wide or mass action treatments. It must be noted, however, that the behavioural or geometric variables listed above have the disadvantage that they do not give a direct measure of the magnitude of safety improvement since the precise relation to accidents is uncertain. However, despite this drawback objective measurements are often considered very worthwhile, since they can give a good indication of a change in safety.

5.8 Measurements should not be taken during the installation period. Additionally, after installation, a week or more should be allowed as an adjustment period for road users to become familiar with the new scheme.

5.9 *After* measurements should commence within one month of site work being completed. It is often desirable to take several sets of *after* measurements, at various time intervals after the scheme is introduced, to investigate the extent to which any initial effect is sustained and to allow for seasonal variations.

5.10 Where possible, monitoring should take place under normal traffic conditions and not coincide with, for example, school and bank holidays, market days, early-closing days, poor weather or roadworks.

5.11 When comparing data between sites, it is useful if all monitoring can be carried out at the same time, or if careful cyclic monitoring techniques are planned in the design of trials. If several schemes with different installation periods are involved then consideration could be given to planning equivalent monitoring periods with respect to installation dates.

5.12 It should be remembered that *before* monitoring can never be repeated! It is important, therefore, to check *before* data before a scheme is installed.

5.13 It would be disappointing, to say the least, if there was not an immediate and noticeable improvement in driving behaviour at a scheme (eg particularly a reduction in speed in, say, a traffic calming scheme). What is more important, however, is that a worthwhile underlying improvement (that results in casualty savings) remains after any initial novelty effect has worn off. It is this underlying improvement which is the most important to measure. Experience from earlier research suggests that changes in behaviour should have stabilised by 12 months after installation and this is, therefore, recommended as a suitable period to judge the value of the scheme in behavioural terms.

5.14 The ultimate measurement to consider is the effect of the scheme on accidents and casualties. The main (but probably not the only) justification for introducing a scheme will probably be to improve safety. Many schemes are designed to achieve reductions in vehicle speed and, given the now well-proven correlation between speed and accident reductions (Taylor et al, 2000), one might reasonably expect accidents to be reduced also. However, when monitoring only one scheme or a small number of schemes over a short time, accident monitoring alone will only be a weak indicator, as it is most unlikely that small numbers of accidents and short time-scale of the monitoring will allow any changes to be statistically significant.

5.15 The extent of *before* and *after* measurements required is considered separately for each of the monitoring options discussed below.

Control sites

5.16 In a perfect monitoring trial, there would be an equivalent site to the treated site (the Test site) at which no changes were made throughout the monitoring period. Data from this perfect Control site would be entirely representative of what might have happened at the Test site had the scheme not been introduced. It would allow a more accurate comparison between *before* and *after* data, taking account of any general changes in driving behaviour, travel patterns, weather, economic activity, etc.

5.17 Unfortunately, it is rare indeed to find an individual site that matches the Test site in all respects, but Control sites should generally have similar features, traffic levels and traffic mix to Test sites. Generally, attempts by researchers (eg Hauer, 1992) to find suitable Control data for trial sites has led to difficulties in the interpretation of unstable data. In addition, collection of detailed Control data may add significantly to the cost of monitoring. If the Test site is a route or area, then similar route/s or area/s may be suitable as Controls. If the Test site is small, then using a large Control may be worthwhile because, by combining data from many sites, any fluctuations at individual sites will tend to cancel each other out giving a more accurate overall picture. This may include using data for a whole town, county, or even readily available national data covering the same period; eg if a junction is improved, then the control group may be all (similar type) junctions within the county.

5.18 In some cases, it may not be necessary to collect Control data, but to make the assumption that conditions at the Test site would have changed little, if at all, during the period of the trial. Thus the 'Control' would be no change, and the *after* data directly compared with the *before* data.

5.19 It is most desirable to have a Control in situations where outside influences are thought to have affected the Test site, for example, when a major external change occurs at the same time as the implementation of the scheme, or during the monitoring period. An example of such a change might be the opening of a parallel route that diverts traffic from the route through the scheme. If the scheme is installed, then an appropriate Control must be found, or direct *before-after* comparisons will be misleading.

5.20 In some instances, if a newly installed measure targets traffic in only one direction, traffic travelling in the other direction may provide suitable Control data. However, it should be noted that drivers might drive through the site in both directions and be familiar with the measure, which may affect their behaviour.

5.21 Alternatively, in some instances, it may be suitable to use data from vehicles upstream of a measure as control data. However, again, drivers may be familiar with the measure if they have travelled through the site on a previous occasion, and this may affect their behaviour.

Overall assessment of monitoring

5.22 The quality of the overall assessment will greatly depend on the number of monitoring options employed for each scheme and the amount of data collected for each. Obviously, the cost of monitoring is inextricably linked to the amount of data to be collected, analysed and reported on. It must be decided for each scheme, which of the engineering measures in the scheme will be monitored separately, in addition to the assessment of the effectiveness of the whole scheme.

Data quality

5.23 The conclusions of any monitoring programme are only as good as the reliability of the data on which they are based. Experience has shown considerable variation in the quality of data collection even when collected against a prior written specification. As a consequence, for data where an element of choice or selection exists on the part of the data-collector, a site visit by the agent responsible for commissioning the monitoring is always recommended to be able to brief the data-collector carefully on his or her duties.

5.24 Examples where data quality can be impaired through inadequate briefing include:

- collection in inappropriate weather conditions;
- collection at inappropriate locations;
- measuring both directions of travel (without identifying each measurement), when only one is required or both required separately; and
- not collecting sufficient, or even any, *before* data.

5.25 Where relevant, the same equipment and, preferably, personnel should be used for *before* and *after* monitoring to ensure the consistency of results.

5.26 Experience also suggests that automatic equipment should be checked more than once a week to ensure it is continuing to operate correctly and has not been vandalised.

5.27 In the case of attitude surveys, it is desirable that the commissioning agent attends the interviewer briefing meeting to maintain consistency of approach and hence quality of the data collected.

5.28 Data that can be collected automatically must still be analysed consistently. Careful specification, briefing and supervision of the analysis will be essential to obtain reliable results.

5.29 Back-up plans should be in place in case things do go wrong. It is recommended that a contingency element be included in the monitoring budget in case of such problems (eg vandalism, theft, bad weather).

Police involvement and publicity

5.30 It is usual to consult in detail with local police about proposed schemes and it would be particularly important to emphasise to them that any change in the level or type of policing at the site could upset the validity of the measurements being made. A specific request should therefore be made to the local police not to 'assist' the scheme in any way, most particularly with respect to enforcement.

5.31 During the *after* monitoring period (typically one year, and three years for accidents), a similar police presence to the *before* period is desirable. However, through co-ordination with the police, radar 'traps' or any other direct enforcement of speed limits should be avoided near the times that any speed measurements in connection with the trial are being made (unless, of course, enforcement is part of the scheme).

5.32 Early results are often very encouraging, but most innovative measures suffer from a novelty effect, which reduces with time. It is therefore important not to rush to the residents, press, councillors or pressure groups with these early results, as they are unlikely to be sustained. Ideally, wait for the 12 months *after* measurements to be analysed before announcing results.

Accident monitoring

5.33 For every safety scheme installed, the change in injury accident rates between the *before* and *after* periods will be a major consideration. Normally, all injury accidents which occurred in a period of three years before and three years after the introduction of the measures would be considered, but a preliminary look at the data one year after would be valuable.

5.34 Accident data should always be collected and examined for changes in the accident categories that a scheme is addressing. However, it is highly unlikely that a statistically significant result would be produced at a single site. This is much more likely to be achieved if the data from several schemes are combined and there are large changes.

5.35 The monitoring database MOLASSES addresses this problem by gathering together accident and design information from all local authorities and Highways Agency agents. By pooling all the information available for a particular type of scheme, a more robust picture of effectiveness can be achieved (see paragraph 5.4 above and Appendix C).

5.36 Many of the monitoring options discussed below are proxies for accident monitoring.

5.37 Monitoring accidents is important to ensure that the scheme has not introduced a new problem. It is also important as a reference tool to allow more accurate assessments of future benefits, when similar measures are used at other locations.

5.38 Statistical tests for analysing accident data are outlined from paragraph 5.113 onwards.

Monitoring vehicle speeds

5.39 The most important traffic parameter to be investigated for most schemes will usually be the measurement of vehicle speeds. Changes in speeds are a measure of a change in behaviour, indicating that drivers have reacted directly to the measures in a quantifiable way. A measure of the effect of the scheme on speeds could be obtained in one of three ways:

- an examination of the way in which individual components of the scheme work using automatic equipment, probably operating continuously for a seven day period, but giving breakdowns by time of day. Automatic equipment can either measure speeds of (most usefully) all individual vehicles[45] or (more commonly) 'bin'[46] data from all vehicles passing within a certain time period (eg 30 minutes). The data will include all detected vehicles including congestion;
- an examination of the way in which individual components of the scheme work – by measuring the speeds of free-flowing[47] vehicles with radar guns; and
- the overall 'journey' effect, taking the scheme as a whole – from journey time measurements.

5.40 The first two options involve spot measurements of speeds. These can give valuable information about changes in behaviour at one point, or about elements of the scheme, but not of the scheme as a whole. The third option, average speeds calculated from journey time measurements (over a measured distance – commonly referred to as journey speeds), is an excellent method of assessing the effect of the scheme as a whole, particularly for a large scheme, a village scheme, or a route scheme.

[45] Commonly referred to as 'PVRs' – per vehicle records.

[46] When data are 'binned', only the average values of speed for the vehicles passing within each time period are stored.

[47] Free-flowing vehicles are those where the driver has a clear choice of speed and is not influenced by a vehicle ahead.

5.41 If the speeds of cars and heavy vehicles are to be measured separately, then radar or laser measurements may be the most appropriate method as automatic equipment generally only gives a crude breakdown of the mix of traffic in the overall sample. A combination of all three forms of measurement would provide the most complete picture but is unlikely to be financially viable.

5.42 Monitoring equipment should be made safe and secure. This will often involve chaining data loggers and cameras to lampposts or installing unobtrusive lockable cabinets at the roadside.

5.43 As mentioned in paragraph 5.13 above, with any new road engineering measure, an *initial* effect on speeds is to be expected. Frequently, the initial effect is greater than the longer-term (underlying) effect, observed once drivers have become used to the new measures. One would therefore expect a gradual return towards the *before* level of behaviour, after the introduction of any novel scheme. It is important to be sure that the underlying effect of the measures is a lasting improvement and speed data should ideally be collected at intervals over a period of twelve months to assess any relaxation towards *before* levels.

5.44 The most commonly studied characteristics of speed used to identify changes are mean speeds and 85th percentile speeds[48]. Research (Taylor et al, 2000) has shown that the most important determinants of accidents are:

- the mean speed;
- the variability of speed; and
- the percentage of vehicles exceeding the speed limit, and the margin by which they do so.

Accident predictive relationships are available which use either the first two or the second two of these measures. Equipment that records individual vehicle speeds best allows these speed distribution parameters to be determined accurately.

Automatic speed monitoring

5.45 Automatic spot speed measurements (for weekly periods, say) will generate considerable amounts of data, which may be suitable for detailed analysis, but will generally only give information at specific points about traffic behaviour as a whole (as determined by the lead vehicles of platoons)[49]. They are, however, likely to provide the only

[48] The speed at or below which 85 per cent of the vehicles in a speed measurement sample set were travelling.

[49] Automatic individual vehicle speed logging equipment will provide data that (with extra technical effort) could be disaggregated according to headway information to isolate data from free-flowing vehicles.

data relating to weekend and night-time speeds. As the equipment would be expected to provide seven days of data, *at least* one set of *before* and two sets of *after* measurements (one month *after* and 12 months *after*) would be recommended.

5.46 Automatic vehicle speed detectors use either loops or tubes (or similar devices) as sensors. Loop installation is expensive, but the cost should only be incurred once. Tubes must be installed each time data are collected (probably three times) and can break after short periods of operation. It is these installation and retrieval costs which largely determine the cost of the measurements, not the length of time for which the equipment remains on site. An advantage of automatic (over radar/laser) speed measurements is that flows, and sometimes vehicle headways, are also measured as a consequence.

Radar or laser speed monitoring

5.47 A more flexible tool in the investigation of speeds is the radar gun, or the more recent laser gun. These instruments enable the measurement of changes in drivers' choice of speed. They also allow separate measurements of cars and heavy vehicles and, being highly portable, allow measurements to be made at several points in the scheme on one day (dependent on flow). Another advantage of speed measurement by radar or laser guns is that they do not require the installation of tubes or loops, as does automatic equipment.

5.48 With radar guns, data are collected only over relatively short periods of time, so they are more liable to inconsistencies from the inherent variability of speed data. For this reason, *before* data should be collected on at least two separate occasions (with at least 200 measurements per occasion at each monitoring point) giving at least 400 measurements for each monitoring point.

5.49 Care should be taken to ensure that the radar or laser guns are used as unobtrusively as possible to avoid influencing driving behaviour.

5.50 To ensure accuracy of readings care should also be taken to point the meter as straight as possible along the road in line with the vehicle movement (an error of 10° either way will cause the meter to under-read by 1½ per cent). Particular care needs to be exercised with radar guns in avoiding secondary reflections from other moving vehicles, which can cause spurious readings; for example, they are usually impractical for use on busy dual carriageways.

5.51 The *before* and *after* speed surveys should ideally be made at the same time of day and day of week, at each measuring position. The number of occasions on which data should be collected in the *after* period will depend on the depth of the investigation.

5.52 In order to examine any changes in speeds as drivers become used to the scheme over time, measurements should be made on at least four occasions (eg 1 month, 3 months, 6 months and 12 months) after the scheme is introduced.

5.53 The variation in mean speed between samples (taken on consecutive days, for example) can be of the same order as the variation in speeds before and after schemes are installed if sample sizes are not large enough (see paragraph 5.106 – statistical test for difference in means). Therefore, it is recommended that on each *after* occasion, at least 200 measurements should be made at each measuring point. If *after* measurements were made only twice (one month and one year) it would only be possible to indicate that there had been a change over the year, but not how quickly it had occurred.

Table 5.1 Summary of benefits and disbenefits of automatic versus radar/laser vehicle speed measurement

	Automatic traffic counters	Radar or laser guns
Benefits	Record all time periods (i.e. possible to isolate results for particular times or days of week)	Immediate (no installation of equipment required)
	Large amounts of data	Easy to isolate readings for individual vehicles, exclude certain vehicles etc
	Traffic flows also collected	Good to get indicative rather than comprehensive result
	Repeat monitoring periods easy if loop/tube equipment remains on site	
Disbenefits	May be difficult to install tubes/loops (unsuitable position, difficulty in fixing to road, may require traffic management)	Often hard to use discretely which might affect vehicle speeds
	May not be able to isolate individual vehicle speeds (depending on logger type)	On low flow roads, hard to get sufficient sample size without intensive use of staff resources
	May require cabinet installation	

Where to monitor vehicle speeds

5.54 The positions within each scheme at which speeds should be measured can only be determined for a particular scheme and the set of measures envisaged. However, ideally, measurements would be made in both directions at:

- each entry to a scheme;
- at any spots where accidents tended to occur; and
- at, or on the approach to, and after each individual measure or element of the scheme.

5.55 The spots at which speed measurements are made must be chosen carefully to avoid unwanted variability; eg on the approach to a measure but not in close proximity to other speed influencing features, such as pelican crossings or junctions.

5.56 It is imperative that locations are reproducible between periods and well documented (eg at third lamppost north of junction, 52 m west of garage exit).

5.57 The measurement and analysis of speed data is likely to be the largest cost in the assessment of any scheme. The number of measurement points is directly linked to the overall cost, both in terms of data collection and analysis.

5.58 For larger schemes it may be appropriate to monitor speeds with automatic and radar equipment and to monitor journey times.

5.59 When results from more than one scheme are to be combined, some effort should be made to make monitoring points comparable between schemes – ie at similar features – to allow cross-comparisons to be made.

Journey time monitoring

5.60 One method of considering the overall effect of a scheme would be through the measurement of changes in journey times through it, particularly if the scheme covers a whole route. If measures are designed to reduce speeds, then journey time measurements will not only provide an estimate of any extra time added to the journey by the measures, but also by how much the average speed through the whole scheme has changed.

5.61 Journey time measurements, by sampling vehicles travelling through a scheme over several hours, are likely to be more robust than small sample radar spot speed measurements (ie less between-sample variability). One *before* and two *after* (one month *after* and 12 months *after*) measurements should be sufficient to give an indication of any overall relaxation to *before* levels.

5.62 Journey time measurements have traditionally been labour-intensive. They involve recording the registration number and time as a vehicle passes into and out of the scheme (which may involve monitoring at more than two locations) and subsequently matching the registration numbers. Video image processing equipment is now available to identify registration numbers from video records, providing the raw data for computer matching programmes.

5.63 Peak and off-peak journey times may need to be explored separately.

5.64 Observers in instrumented cars can also measure journey times, just as they are used to investigate urban networks. However, this method is open to experimenter bias because they would often have the freedom to choose their own speed or the particular vehicle to follow through a scheme. It may also take considerably longer than the fixed observer/video method to collect enough data.

Flow monitoring

5.65 If there is an alternative parallel route to which drivers could divert in order to avoid a scheme, or part of it, then flow is an important parameter to measure accurately. It is unlikely that drivers would change their basic route for just one small scheme, but they might divert to parallel side roads if they saw an advantage in this (eg to avoid driving over a series of humps). It is recommended that flows should then be recorded and classified on both the original and alternative routes.

5.66 Background information on traffic flow data is likely to be available already for some roads, particularly major ones. If this is not fully classified (ie detailing volumes of heavy vehicles, two-wheeled motor vehicles and pedal cyclists separately), or up-to-date, then a classified flow count would be required as part of the monitoring programme. However, flow data is often easy to collect as a by-product of, or in conjunction with, other measurements (eg automatic speed monitors record flows as well as speeds).

5.67 As an alternative to automatic flow counts, observers at the roadside or on junction arms can carry out manual classified counts (particularly for junction turning counts). The count period should not normally be less than one hour but will depend upon flow levels and hourly, daily and seasonal variability of traffic. A 12-hour period is often used. Scaling factors based on national averages may be used to scale one hour flows (Highways Agency, 1996).

Monitoring pedestrian movements

5.68 Measures of exposure to risk for pedestrians are not well known because there is little data available for pedestrian movements. However, a project commissioned by DETR has attempted to establish the requirements for long term monitoring of pedestrian activity (see Ross Silcock, 1998).

5.69 Any objective measurements of pedestrian behaviour and how it changes as a result of a scheme is often best investigated by the analysis of video recordings. The main parameter to be measured is usually where pedestrians choose to cross and whether their waiting time has changed or safety gaps improved as a result of the scheme. Such issues can also be investigated using on-site observers or, less comprehensively, but at lower cost, with attitude surveys.

Monitoring pedal cycle and two-wheeled motor vehicle movements

5.70 Two-wheeler flows tend to be extremely low, compared with those of other motor vehicles, and therefore assessing, subjectively or objectively, the effect of the scheme on cyclists or motorcyclists is very difficult.

5.71 Automatic vehicle speed logging equipment does not consistently identify two-wheeled traffic. Analysis of video recordings is likely to be expensive but may yield some information. The best option may be to ask the police to stop two-wheelers in surveys with other road users and canvass their opinions – or where schemes relate specifically to cyclists, for interviewers to stop them.

Monitoring vehicle (time or distance) headways[50] or inter-vehicle gaps

5.72 Monitoring headways is likely to be most useful in a context where increasing the gaps between vehicles would be expected to improve safety (motorway chevron installations, for example). This needs automatic vehicle logging using loop detectors.

[50] A distance headway is the gap between the front of one vehicle and the front of the next vehicle at a moment in time. A time headway is the gap in time between the front of one vehicle passing a point and the arrival of the front of the next vehicle at that point.

5.73 The extent to which changes in inter-vehicle gaps makes it easier for pedestrians to cross the road is not easy to assess directly. It is easier to examine this matter through pedestrian studies or attitude surveys.

Monitoring traffic conflicts

5.74 The traffic conflict technique is simply a formalised method of observing and recording 'near-miss' situations at a specific location (Transport and Road Research Laboratory, 1987). Conflicts have been demonstrated to be related to actual collisions (see Asmussen, 1984); however, the relationships are somewhat complex and vary with the types of manoeuvres, road geometry and road users involved.

5.75 The collection of conflict data for a traffic stream is usually carried out by a trained observer, located in an unobtrusive position, where he or she can watch vehicles along a section of road (eg 100m), normally from the rear as they approach a junction. This needs to be sustained for relatively long periods (one to five hours) during which they record the details of near-miss incidents, normally recognised by brakelights (or swerving). The observer assigns a defined severity grade to each conflict incident (see Transport and Road Research Laboratory, 1987 for details).

5.76 The process is relatively labour intensive, requiring teams of trained observers, and may only be practical at junction-type locations owing to the limited distance over which observers can be expected to monitor. However, at certain locations they can be a valuable diagnostic tool in helping to highlight the circumstances and frequency in which road users are experiencing safety problems.

5.77 Conflict studies can also provide a means of evaluating a location before and after introduction of a safety scheme. The data is usually expressed in the form of daily rates of particular types of conflict. The rates are normally simply compared to answer the questions:

i) Has the remedial measure(s) successfully alleviated the problem(s) identified in the *before* study?

ii) Has the remedial measure introduced any undesirable secondary effects that may cause other safety problems?

5.78 If a full statistically valid result is required then, as we are dealing here with separate behavioural events (though remember that there is always a degree of subjectivity in how they are recorded), the frequency of conflicts can be analysed using the same methods as for accidents, as described below from paragraph 5.110 onwards.

Attitude surveys

5.79 The views of drivers, other road users, residents and traders about schemes are important. Ideally, some form of survey should be undertaken, preferably during the month after the installation of the scheme, to provide general feedback. However, the objectives, size and type of the proposed survey need to be carefully balanced against the costs of carrying it out.

5.80 Separate questionnaires for each of the target groups may be desirable.

5.81 The design of the questionnaire is very important. Questions must be clear and concise with open or specified-choice answers required. They should address all the key points pertaining to the particular scheme under evaluation. The questionnaire should be tested and designed for average completion in a maximum of, say, five minutes for a street interview, and 20 minutes for a home interview or postal questionnaire. Consideration may also need to be given to providing incentives for respondents to maximise response rates and accuracy.

5.82 Such surveys may require prior approval (from elected members, for example). Sufficient lead-time must be allowed for their consultation.

5.83 In most situations, only *after* attitude surveys will be needed in a monitoring programme, because it is difficult to ask about a scheme which does not yet exist, except in general terms about existing conditions. It is also likely that there might be a questionnaire survey to canvass local views as part of the consultation process about the scheme itself. It would not be desirable to conflict with any consultation process.

5.84 For most schemes it will also be appropriate to canvass the views of the emergency services, bus operators and others after scheme installation (as well as at the planning stage as part of the consultation process).

5.85 Remember that those who feel strongly are the most likely to respond to a postal survey, consultation etc., and their views may not be representative of the majority.

Road user surveys

5.86 The most efficient way to survey road user opinions is usually to stop them as they pass through the scheme and ask them to complete a questionnaire.

5.87 It is unlikely that enough motor vehicle drivers will park in or near the scheme and be available for interview. Only police officers can ask drivers to stop. Therefore a police presence and a suitable lay-by, or sufficient road width for other vehicles to overtake, would be required.

5.88 Useful information about the relative effectiveness of the various measures could be investigated through a questionnaire. It would also be possible to seek road users' views about the aesthetics of the scheme, or ways in which the measures might be improved.

5.89 The views of residents and non-residents may differ considerably. It might be useful to investigate them separately.

5.90 It may also be useful to collect some personal details about interviewees, such as their gender, age and whether they walk, cycle, drive or motorcycle through the scheme at other times.

5.91 A sample size of 200 interviewees or more is the minimum recommended, depending on the need to allow for stratified sampling and more detailed examination of data through cross-tabulation.

Environmental monitoring

5.92 If it is expected that the measures proposed might have an effect on noise generated (when introducing certain speed-reducing or alerting devices, for example), then some noise measurements would be desirable. However, these are expensive and could only be justified with larger schemes. Overall noise levels generally decrease with lower speeds, but the character of the noise may be affected by vehicles crossing a measure (eg a road hump) and by greater acceleration or deceleration. Whether the noise is a nuisance may also need to be assessed through a survey and complaints monitoring.

5.93 Both general background traffic noise and individual vehicle noise should be measured, both before and after introducing the scheme. One set of measurements in each period should be sufficient to provide a reasonable assessment of the change in noise.

5.94 Schemes that encourage a change in driving style may cause an increase in vehicle emissions. However, if the scheme also encourages a decrease in traffic flow, this can counteract these increases. The evidence so far suggests that the effect on air quality is likely to be small.

5.95 Quantifying the effect of a scheme on air quality is problematic because of the variability of measured concentrations. There is an underlying downward trend in traffic emissions as new vehicles, which comply with stricter emission limits, enter the fleet. Weather can also affect air quality, both seasonally and year to year.

5.96 It is therefore important that surveys are designed carefully. *Before* and *after* surveys should be carried out for at least three months and at the same time of year. Monitoring sites should be chosen to include those roads on which the main measures will be installed and the roads that you might expect traffic to use in order to avoid them. The sites should be located close to the emission source (ie close to the kerb) so as to be able to detect, with some confidence, the changes in air quality resulting from changes in emissions as a result of changes in driving pattern or traffic flow. A control site, outside the scheme and preferably away from main roads, should be included within the surveys in order to distinguish between the changes in air quality brought about by the measures and those resulting from 'cleaner' traffic and differences in weather conditions occurring between sampling periods.

5.97 Local authorities have a duty under Part IV of the Environment Act 1995 to review and assess air quality in their areas. The *UK Air Quality Strategy* identifies eight pollutants that should be included in local air quality management. Of these, nitrogen dioxide (NO_2) and particles (PM_{10}) are probably of most interest, as in some areas concentrations of these pollutants regularly exceed the current air quality standards. Road traffic makes a large contribution to emissions of these pollutants, and so their inclusion in routine surveys should be considered. Benzene and Carbon Monoxide should also be considered because of their importance in terms of local air quality and also because they are largely derived from vehicle exhausts. There are several methods of determining concentrations of these pollutants (for example, diffusion tubes, automatic and battery operated samplers).

5.98 If pollution levels exceed set levels then an Air Quality Management Area has to be declared. In these cases, local authorities are required to develop and implement air quality action plans, and it will be all the more important to evaluate the air quality and other environmental effects of any new road safety measures to minimise any conflict between them. It is necessary to adopt a balanced approach so that as far as possible, measures which reduce accidents do not seriously prejudice air quality.

5.99 If a scheme causes a change in the number of parking spaces available, then it might be desirable to survey parking habits on the main and surrounding roads. *Before* and *after* data, would be required

and, therefore, an assessment of the likely effect of the scheme on parking would have to be made at the planning stage. Two monitoring options might be to examine the number and the percentage of spaces in use over the period. Less objective information could also be made available from a resident or road user survey, in particular by canvassing any effect on traders.

5.100 Schemes planned for major roads designed to accommodate high flows may change the level of severance between the land use on both sides of the road. Severance will be a function of the demand to cross the road and the opportunities for being able to do so. This can be investigated through video analysis of pedestrian behaviour and crossing patterns, but this approach is expensive to analyse and changes in behaviour are likely to be small and difficult to identify, or prove. Severance is usually, therefore, most appropriately investigated subjectively through the attitude survey of road users, residents and traders.

5.101 The aesthetics of a scheme are extremely subjective. Also a particular measure in one location may be generally welcomed, whereas the same measure might cause disquiet in a more environmentally-sensitive area. It is important to consider aesthetics as part of the planning process and in public consultations. There may be a conflict of interest, as drivers need clear, bold measures, which catch their attention, while most residents are likely to prefer features that blend harmoniously with the local environment. The easiest way to monitor perceived effects is through opinion surveys.

5.102 It is often extremely valuable to have drivers' eye-view video and still photographic records of a scheme both before and after the safety engineering measures are introduced. They are useful in resolving subsequent queries about the changes and provide a ready means for interested parties to experience the scheme without the need to visit it. They are also useful to provide illustrations for reports and presentations, particularly of unusual or novel elements of a scheme.

Evaluation

5.103 Having devoted considerable effort and expenditure to improving hazardous sites, there is a need to evaluate these improvements.

5.104 This section briefly outlines the evaluation of schemes based on some of the types of monitoring already described. It mentions the simple statistical tests needed to interpret the results. Appendix B gives further detail.

5.105 To obtain statistically reliable results for accident changes, it is normally necessary to wait several years after introducing the countermeasure or package of measures has been introduced. It is, however, assumed that the user of this Guide will need to interpret accident and other data practically without necessarily having a full understanding of the underlying statistical theory, which can be quite complex. It is, however, important that the user is sufficiently confident with his or her analysis. If in doubt, it is strongly advised that help is sought from a professional statistician.

Evaluation of traffic speed data

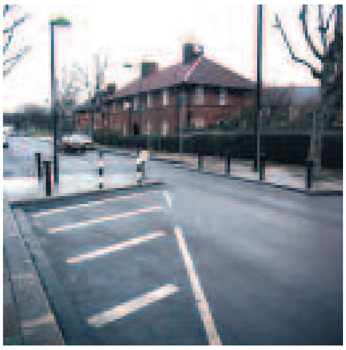
5.106 The t-distribution can be used to compare whether any changes in the measured mean speeds in two periods of measurement are statistically significant (see Appendix B.1). It can also test whether there is a significant difference between the speeds of groups of different vehicle types. The same tests can be used for similar types of measurements of traffic like travel times, vehicle headways, and pedestrian safety gaps.

5.107 If a particular scheme was actually intended to significantly change the speed distribution (eg to affect changes to the highest speed drivers only – to produce a markedly skewed distribution), then a Kolmogorov-Smirnov test would be appropriate (Appendix B.2). This is a powerful non-parametric test applicable for analysis on distributions that are not Normally distributed.

Evaluation of public perception

5.108 Often one of the main reasons why an area-wide scheme has been implemented is that residents have campaigned strongly for something to be done. Thus, it could be argued that one important factor to evaluate is how the residents and other road users feel about the safety elements of the scheme.

5.109 Results of opinion surveys tend to be reported in many different ways and the importance of designing questionnaires carefully and properly has already been stressed. Evaluation of public opinion by authorities tends to be a relatively straightforward matter of recording the level of public acceptance of the scheme, and the extent to which the public believe the scheme as a whole or perhaps certain aspects of the scheme have been a success (or otherwise).



Evaluation of accident changes

5.110 In evaluating a treatment or scheme the answers to the following questions will usually be required:

- has the scheme been effective?
- if so, how effective has it been?

5.111 The rare and random nature of road accidents can lead to quite large fluctuations in frequencies at a site from year to year, even though there has been no change in the underlying accident rate. This extra variability makes the effect of the treatment more difficult to detect, but a test of statistical significance can be used to determine whether the observed change in accident frequency is likely to have occurred by chance or not.

5.112 The use of control sites has already been discussed. It should be noted, however, that even when sites have been selected that represent good control groups which take account of the environmental influences, there are other confounding factors that need to be considered. These are discussed in later sections below.

Standard tests of accident changes

5.113 The following tests are those recommended and described in RoSPA, (1995b) which also contains simple worked numerical examples. For practical purposes it is sufficient to assume that the *'before'* and *'after'* accidents are drawn from a Normal distribution (see Graphpad Software Inc, 1999).

5.114 This means that we can use the chi-squared test to answer the first question as to whether the remedial action has been effective, ie whether the accident changes at the site were statistically significant. The common way of applying this is described in Section 5.116. However, the size of that change may first be investigated by using the Tanner k test.

The Tanner k test (magnitude of the change)

5.115 It is possible that although accident levels reduced at a treated site in an *'After'* period, the general level of accidents is also reducing; the 'real' reduction at the site due to the treatment being *less* than the actual numbers observed (ie overestimating effectiveness). Conversely, if the general level of accidents is increasing, an underestimate of the treatment would be obtained. The Tanner k test can be used to show how the accident numbers at a site change relative to control data (see Appendix B.3).

The Chi-Squared test (significance of the change)

5.116 The chi-squared test is traditionally used to determine whether a change in accidents is statistically significant or whether it could have happened by chance. The test makes certain distributional assumptions that may not strictly be appropriate when sites with high accident numbers have been treated (see discussion of the regression-to-mean effect in Section 5.119). Nevertheless it is easy to apply and is a good measure of whether the scheme was effective.

5.117 The test involves comparing data from the treated site with the untreated control sites by calculating the value of the statistic, chi-square, and looking this up in a table with the appropriate degrees of freedom to determine whether it has exceeded the appropriate table value (see Appendix B.4).

Test for statistical significance between two proportions

5.118 This test tells us whether the difference in the distributions of accident types in the study and control samples are significantly different from each other or if the difference is likely to have occurred by chance (see Appendix B.5). For example, it could be used to determine whether the proportion of accidents in the study area that involve cyclists is greater than expected (ie disproportionately large compared with the proportion of accidents in the control area that involve cyclists).

Other factors to consider:

Regression to the mean

5.119 This effect, sometimes called 'bias by selection', complicates evaluations at sites with high accident numbers ('blackspot' sites) in that these sites have often been chosen following a year with particularly high numbers occurring. In practice their accidents will tend to reduce in the next year even if no treatment is applied. Even if three-year accident totals are considered at the worst accident sites in an area, it is likely that the accident frequencies were at the high end of the naturally occurring random fluctuations, and in subsequent years these sites will experience lower numbers. This is known as regression-to-the-mean.

5.120 In practice it is believed that the regression-to-the-mean effect can over-state the effect of a treatment by 5 to 30 per cent, chiefly dependent on the length of accident period chosen. Possibly the most straightforward way of allowing for both the regression-to-mean effect and changes in the environment would be to use control sites chosen in exactly the same way as the treated sites, and identified as having similar problems, but left untreated. In practice, as stated earlier, it is both difficult to find matched control sites and, if investigated, to justify not treating them.

5.121 There has been much debate among statisticians over many years on this subject and the best way to deal with it (see: Wright and Boyle, 1987; Hauer et al, 1983; Abbess et al, 1981; Maher and Mountain, 1988; Kulmala, 1994).

5.122 The effect does, however, tend to be diminished if longer periods of time are selected. For example, in a study in two counties, Abbess et al (1981), calculated that regression-to-mean had the following effects at high accident sites (ie more than eight injury accidents per year), on average, on their accident rate:

Table 5.2 Empirical regression-to-mean effects on accident rate

Regression-to-mean change in annual accident rate	Period of accident data Considered
15 to 26 per cent	one year
7 to 15 per cent	two years
5 to 11 per cent	three years

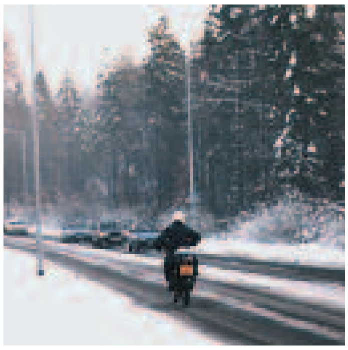
5.123 It is suggested, therefore, that where the highest accident sites are chosen for treatment, then the above levels of allowance should be made when quoting the actual reduction in accidents that the schemes have produced. The way in which a more accurate estimation can be obtained is rather complex requiring use of data from similar sites to the treated sites but a method described by Abbess et al (1981) is outlined in Appendix B.6.

Accident migration

5.124 The existence of accident migration is a fairly controversial issue but has been reported to be a real effect (Mountain et al, 1992; Boyle et al, 1984; Persaud, 1987). It is simply that an increase in accidents tends to be observed at sites adjoining a successfully treated site, giving an apparent transfer or 'migration' of accidents. It is unclear precisely why this effect occurs but is hypothesised that drivers are 'compensating' for the improved safety at treated sites by being less cautious elsewhere.

5.125 Obviously to detect such an occurrence, you need to compare the accident frequencies before and after implementation of a scheme and those for the surrounding area with a suitable control group.

5.126 However, research and practical evidence (eg Brindle, 1986; Webster and Mackie, 1996) have demonstrated that local area traffic restraint schemes do not create a significant increase in accidents on surrounding roads. Mountain (1998) has more recently concluded that a more likely explanation for any observed increase is a reverse regression-to-mean effect arising due to bias in the selection of the neighbouring sites.



Behaviour adaptation

5.127 The effect of road users tending to alter their behaviour following introduction of a new safety improvement, is now generally more accepted than the original, more controversial, philosophy of 'risk compensation' or 'risk homeostasis theory'. The latter suggested that road users maintain a fixed level of accepted risk, and so will take more risks when given greater accident protection, for example, by seat belts or anti-lock brakes.

5.128 However, Trimpop and Wilde (1994) concluded that accidents are not necessarily the result of risk-taking desire, but more of an inappropriate action based on faulty risk assessment. The challenge for the road engineer is to introduce schemes that minimise the chances of road users making faulty assessments; for example, in ensuring consistency in road users' expectations for the level of road surface friction, superelevation on bends, design of junctions and so forth.

5.129 Grayson (1996) concluded that evidence that adaptive or compensating processes are seriously reducing the effectiveness of safety measures is slender and poses little threat to current road safety practice.

Economic evaluation

5.130 For every scheme, the evaluation should include an indication of the benefits actually achieved in relation to cost. Even if the scheme has been designed to tackle a very specific target group of accidents, it is normal practice to include all accidents at the site in a full evaluation, in case the measure has had the unforeseen effect of increasing other accident types.

5.131 The previous sections have already outlined how the best estimate of the size of the effect of a scheme (or group of schemes) on accidents can be determined. If the site was one of the worst blackspots in the area, then make some allowance for the regression-to-mean effect.

First Year Rate of Return (FYRR)

5.132 If the evaluation period (for both *before* and *after* periods) was, say, three years then the saving in accident frequency (per year) should first be calculated. The monetary value of these accidents is then calculated using the current figures (see 3.79 above or DETR, 2000a). Highway authorities normally then calculate and quote the First Year Rate of Return to give a rough guide to the value of a scheme, ie

$$FYRR = \frac{\text{Value of annual accident savings}}{\text{Cost of scheme*}} \times 100$$

* A more accurate figure would be obtained by including only maintenance costs in this year and also increased journey time costs if this is applicable.

Net Present Value (NPV)

5.133 In some cases it may be advisable to carry out an evaluation which expresses the difference between costs and benefits that may accrue over several years, eg particularly if the installation covers more than one year or there are known to be inevitable new maintenance costs in future years. This accrual needs to be against a common year price base.

5.134 In the Net Present Value approach there is a need to take account of money having a changing value over time because of the opportunity to earn interest or the cost of paying interest on borrowed capital.

5.135 The major factors affecting present value are the timing of the expenditure and the discount (interest) rate. The higher the discount rate, the lower the present value of an expenditure at a specified time in the future. If the discount rate for highways is 6 per cent, then £1 of value this year, if it accrues next year would be valued at 6 per cent less (i.e. 94p, and the following year 88p etc).

5.136 The overall economic effectiveness of a scheme is indicated by the Net Present Value (NPV), which is obtained by subtracting the Present Value of Costs (PVC, which must also be discounted if spread over more than one year) from the Present Value of Benefits (PVB). This technique is described in more detail with examples in COBA (DMRB vol. 13); RoSPA (1995b).

Bibliography

06

The Traffic Signs Regulations and General Directions (1994)
Statutory Instrument 1994 No. 1519 Road Traffic London: HMSO

The Traffic Signs Manual (various dates; DFT, London: TSO)

Chapter 1. Introduction

Chapter 2. Directional Informatory Signs on Motorways and All-Purpose Roads*

Chapter 3. Regulatory Signs (1986)

Chapter 4. Warning Signs (1986)

Chapter 5. Road Markings (1985)

Chapter 6. Illumination of Signs*

Chapter 7. The Design of Traffic Signs (1997)

Chapter 8. Traffic Safety Measures and Signs for Road Works and Temporary Situations (1991)

* To be published

[Note: Current advice relating to speed limit signs is given in TAL 1/95]

Traffic Advisory Leaflets

TAL 10/00: Road humps: discomfort, noise, and ground-borne vibration

TAL 11/00: Village Traffic Calming – reducing accidents

TAL 12/00: Urban Street Activity in 20mph Zones – Ayres Road Area, Old Trafford

TAL 06/00: Monitoring Walking

TAL 05/00: Traffic Calming Bibliography

TAL 04/00: Cycling Bibliography

TAL 03/00: Walking Bibliography

TAL 02/00: Framework for a Local Walking Strategy

TAL 01/00: Traffic Calming on Major Roads

TAL 17/99: Code of Practice for Traffic Control and Information Systems

TAL 16/99: The Use of Above Ground Vehicle Detectors

TAL 15/99: Cyclists at Road Works

TAL 14/99: Traffic Calming on Major Roads: A traffic calming scheme at Costessey, Norfolk

TAL 13/99: Historic Core Zone: Bury St Edmunds

TAL 12/99: Cycling for Better Health

TAL 11/99: Improved Cycle Parking at South West Trains' Stations in Hampshire

TAL 10/99: Cycling Initiatives Register

TAL 09/99: 20 mph Speed Limits and Zones

TAL 08/99: Urban Safety Management: Using SafeNET

TAL 07/99: The 'SCOOT' Urban Traffic Control System

TAL 06/99: Bikerail – Combined Journeys by Cycle and Rail

TAL 04/99: Traffic Calming Bibliography

TAL 03/99: Cycling Bibliography

TAL 02/99: Leigh Park Area Safety Scheme, Havant, Hampshire

TAL 01/99: Monitoring Local Cycle Use

TAL 09/98: Sinusoidal, 'H' and 'S' Road Humps

TAL 08/98: The High Street Route, Shrewsbury

TAL 04/98:	Toucan Crossing Development
TAL 03/98:	Traffic Calming Bibliography
TAL 02/98:	Lincoln Historic Core Zone – Newport Arch
TAL 01/98:	Speed Cushion Schemes
TAL 12/97:	Chicane Schemes
TAL 11/97:	Cycling to Work
TAL 10/97:	Halifax Historic Core Zone
TAL 09/97:	Cyclists at Roundabouts: Continental Design Geometry
TAL 08/97:	Cycling Bibliography
TAL 07/97:	Supply and Demand for Cycle Parking
TAL 05/97:	Cycles and Lorries
TAL 04/97:	Rising Bollards
TAL 03/97:	The MOVA Signal Control System
TAL 02/97:	Traffic Calming on Major Roads – A49, Craven Arms, Shropshire
TAL 01/97:	Cyclists at Road Narrowings
TAL 10/96:	Traffic Calming Bibliography
TAL 08/96:	Road Humps and Ground-Borne Vibrations
TAL 07/96:	Highways (Road Humps) Regulations 1996
TAL 06/96:	Traffic Calming – Traffic and Vehicle Noise
TAL 05/96:	Further Development of Advanced Stop Lines
TAL 04/96:	Traffic Management and Emissions
TAL 03/96:	Bike and Ride
TAL 02/96:	75mm High Road Humps
TAL 01/96:	Traffic Management in Historic Areas
TAL 08/95:	Traffic Models for Cycling
TAL 07/95:	Traffic Islands for Speed Control
TAL 06/95:	Pedestrian Crossing – Assessment and Design
TAL 05/95:	Parking for Disabled People
TAL 04/95:	The ‘SCOOT’ Urban Traffic Control System
TAL 03/95:	Cycle Routes

TAL 02/95: Raised Rib Markings

TAL 01/95: Speed Limit Signs

TAL 11/94: Traffic Calming Regulations (Scotland)

TAL 09/94: Horizontal Deflections

TAL 07/94: ‘Thumps’ Thermoplastic Road Humps

TAL 04/94: Speed Cushions

TAL 03/94: Fire and Ambulance Services Traffic Calming: A Code of Practice

TAL 02/94: Entry Treatments

TAL 01/94: VISP – A Summary

TAL 13/93: Gateways

TAL 12/93: Overrun Areas

TAL 11/93: Rumble Devices

TAL 10/93: ‘Toucan’ – An Unsegregated Crossing for Pedestrians and Cyclists

TAL 09/93: Cycling in Pedestrian Areas

TAL 08/93: Advanced Stop Lines for Cyclists

TAL 07/93: Traffic Calming Regulations

TAL 04/93: Pavement Parking

TAL 03/93: Traffic Calming Special Authorisations

TAL 07/91: 20mph Speed Limit Zones

TAL 05/91: Audible and Tactile Signals at Pelican Crossings

TAL 04/91: Audible and Tactile Signals at Signal Controlled Crossings

TAL 03/91: Speed Control Humps Scotland, England and Wales

TAL 03/90: Urban Safety Management Guidelines from IHT

TAL 02/90: Speed Control Humps (superseded by TAL 07/96).

TAL 09/89: The South-East Cambridge Cycle Route

TAL 08/89: Innovatory Cycle Scheme Manchester – Mancunian Way Signalled Cycle Crossing

Local Transport Notes

LTN 1/98	The installation of traffic signals and associated equipment
LTN 1/97	Keeping buses moving: A guide to traffic management to assist buses in urban areas
LTN 2/95	The design of pedestrian crossings
LTN 1/95	The assessment of pedestrian crossings
LTN 1/94	The design and use of directional informatory signs
LTN 1/89	Making way for cyclists: Planning, design and legal aspects of providing for cyclists
LTN 2/87	Signs for cycle facilities
LTN 1/87	Getting the right balance: Guidance on vehicle restriction in pedestrian zones
LTN 2/86	Shared use by cyclists and pedestrians
LTN 1/86	Cyclists at road crossings and junctions
LTN 1/83	Signs for cycle facilities
LTN 1/79	Ways of helping cyclists in built up areas

Departmental Standards and Advice Notes in the Design Manual for Roads and Bridges

Note that these apply to trunk roads but some of the advice may be appropriate for non-trunk roads. (In particular, consideration should be given to traffic level and mix of road user type.)

Departmental Advice Notes

HA 12/81 Management of Contractual Claim (not applicable to Northern Ireland)

HA 13/81 The Planting of Trees and Shrubs (not applicable for use in Scotland, Northern Ireland; Addendum applicable for use in Northern Ireland)

HA 19/82 Engineer/Contractor Relationship on Trunk Road Contracts (not applicable to Northern Ireland)

HA 37/97 Hydraulic Design of Road Edge Surface Water Channels

HA 39/98 Edge of Pavement Details

HA 40/89 Determination of Pipe and Bedding Combinations for Drainage Works

HA 41/90 A Perimeter for Road Drainage Layers

HA 42/94 Road Safety Audits HA 43/91 Geotechnical Considerations and Techniques for Widening Highway Earthworks

HA 43/91 Geotechnical Considerations and Techniques for Widening Highway Earthworks

HA 44/91 Earthworks: Design and Preparation of Contract Documents (paragraph 3-5 is superseded by paragraph 2.22 of SA 3/93 (MCHW 0.3.3)) [Incorporating Amendment No. 1 dated April 1995] Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland

HA 46/92 Quality Assurance for Highway Design

HA 48/93 Maintenance of Highway Earthworks and Drainage

HA 55/92 Landform and Alignment

HA 56/92 Planting, Vegetation and Soils

HA 57/92 Integration with Rural Landscapes

HA 58/92 The Road Corridor [Amendment No. 1 Retaining Walls (Chapter 3) February 1997]

HA 59/92 Nature Conservation [Amendment No.1 Badgers (Chapter 5.3) February 1997]

HA 60/92	Heritage
HA 61/92	Contract and Maintenance Implementation
HA 62/92	Widening Options and Techniques
HA 63/92	Improvement Techniques
HA 65/94	Design Guide for Environmental Barriers
HA 66/95	Environmental Barriers – Technical Requirements
HA 67/93	The Wildflower Handbook
HA 68/94	Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques
HA 70/94	Construction of Highway Earthworks
HA 71/95	The Effects of Highway Construction on Flood Plains [Incorporating Amendment No. 1 (August 1998)]
HA 72/94	Use and Limitations of Ground Penetrating Radar for Pavement Assessment
HA 73/95	Site Investigation for Highway Works on Contaminated Land
HA 74/95	Design and Construction of Lime Stabilised Capping
HA 75/95	Trunk Roads and Archaeological Mitigation
HA 78/96	Design of Outfalls for Surface Water Channels
HA 79/97	Edge of Pavement Details for Porous Asphalt Surface Courses
HA 80/99	Nature Conservation Management in Relation to Bats
HA 81/99	Nature Conservation in Relation to Otters
TA 8/80	Carriageway Markings. Markings for Right Turning Movements at Cross Road Junctions Northern Ireland Addendum applicable for use in Northern Ireland
TA 11/81	Traffic Surveys by Roadside Interview (Clauses 6.1, 6.2, 6.5 and Figures 1 to 5 are superseded by Ch. 8 of TSM) Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TA 12/81	Traffic Signals on High Speed Roads Northern Ireland Addendum applicable for use in Northern Ireland

TA 19/81	Reflectorisation of Traffic Signs (Clauses 7.6 and 7.7 are superseded by Ch.8 of TSM) Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TA 22/81	Vehicle Speed Measurement on All Purpose Roads
TA 23/81	Junctions and Accesses: Determination of Size of Roundabouts and Major/Minor Junctions Scottish Addendum applicable for use in Scotland
TA 30/82	Choice between Options for Trunk Road Schemes Scottish Addendum applicable for use in Scotland
TA 44/92	Capacities, Queues, Delays and Accidents at Road Junctions – Computer Programs ARCADY/3 and PICADY/3 (TRRL)
TA 45/85	Treatment of Gaps in Central Reserve Safety Fences
TA 46/97	Traffic Flow Ranges for Use in the Assessment of New Rural Road Standards
TA 48/92	Layout of Grade Separated Junctions
TA 49/86	Appraisal of New and Replacement Lighting on Trunk Roads and Trunk Road Motorways [and Amendment No 3 dated July 1990] Scottish Addendum applicable for use in Scotland
TA 56/87	Hazardous Cattle Crossings: Use of Flashing Amber Lamps Northern Ireland Addendum applicable for use in Northern Ireland
TA 57/87	Roadside Features [Chapter 2 is superseded by TA 69/96] Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TA 58/92	Traffic Signs and Road Markings for Lane Gains and Lane Drops on All Purpose Dual Carriageway and Motorway Trunk Roads
TA 60/90	The Use of Variable Message Signs on All Purpose and Motorway Trunk Roads Northern Ireland Addendum applicable for use in Northern Ireland
TA 61/94	Currency of the Traffic Signs Manual
TA 63/97	Convoy Working
TA 64/94	Narrow Lane and Tidal Flow Operations at Road Works on Motorways and Dual Carriage Trunk Roads with Full Width hard Shoulders
TA 66/95	Police Observation Platforms on Motorways
TA 67/95	Providing for Cyclists

TA 68/96	The Assessment and Design of Pedestrian Crossings
TA 69/96	The Location and Layout of Lay-bys
* TA 70/97	Motorway. Introduction
* TA 71/97	Motorways. Overview
* TA 72/97	National Motorway Communication Systems (NMCS)
* TA 73/97	Motorway Emergency Telephones
* TA 74/97	Motorway Signalling
* TA 75/97	Motorway Transmission Design
* TA 76/97	Motorway Control Offices
* TA 77/97	Motorways
TA 78/97	Design of Road Markings at Roundabouts
TA 79/99	Traffic Capacity of Urban Roads [Amendment No. 1 (May 1999)]
TA 80/99	Surface Drainage of Wide Carriageways
TA 81/99	Coloured Surfacing on Urban Roads
TA 82/99	The Installation of Traffic Signals and Associated Equipment
* TA 70/97 to TA 77/97	now include Annex A which is specific to England and Annex C, which is specific to Wales.

Departmental Standards

HD 19/94	Road Safety Audits
HD 20/92	Loop Detectors for Motorways
HD 22/92	Ground Investigation and Earthworks – Procedure for Geotechnical Certification [Incorporating Amendment No. 1 dated June 1993 and Amendment No. 2 April 1994]
HD 23/99	General Information
HD 24/96	Traffic Assessment
HD 25/94	Foundations
HD 26/94	Pavement Design [Amendment No. 1 (March 1995, Amendment No. 2 (February 1996) and Amendment No. 3 (February 1998)]
HD 27/94	Pavement Construction Methods [Amendment No. 1 (March 1995) and Amendment No.2 (February 1999)]
HD 28/94	Skidding Resistance [Amendment No. 1 (February 1999)]
HD 29/94	Structural Assessment Methods [Amendment No. 1 (November 1996) and Amendment No.2 (May 1999)]
HD 30/99	Structural Assessment of Road Pavements
HD 31/94	Maintenance of Bituminous Roads [Amendment No. 1 (March 1995) and Amendment No. 2 (February 1998)]
HD 32/94	Maintenance of Concrete Roads
HD 33/96	Surface and Sub-surface Drainage System for Highways
HD 34/93	Implementation and Use of the Quality Control Reporting System
HD 35/95	Technical Information
HD 36/99	Surfacing Material for New and Maintenance Construction
HD 37/99	Bituminous Surfacing Materials and Techniques [Amendment No.1 (May 1999)]
HD 38/97	Concrete Surfacing and Materials [Amendment No.1 (May 1999)]
TD 6/79	Transverse yellow bar markings at roundabouts
TD 7/80	Type Approval of Traffic Control Equipment (not applicable to Northern Ireland)
TD 9/93	Highway Link Design

TD 11/82	Use of Certain Departmental Standards in the Design and Assessment of Trunk Road Schemes Scottish Addendum applicable for use in Scotland
TD 16/93	Geometric Design of Roundabouts
TD 17/85	Criteria for the Provision of Closed Circuit Television on Motorways Northern Ireland Addendum applicable for use in Northern Ireland
TD 18/85	Criteria for the Use of Gantries for Traffic Signs and Matrix Traffic Signals on Trunk Roads and Trunk Road Motorways. Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TD 19/85	Safety Fences and Barriers [Amendment No. 1 dated 11/86] Scottish Addendum applicable for use in Scotland
TD 22/92	Layout of Grade Separated Junctions
TD 23/86	Trunk Roads and Trunk Road Motorways: Inspection and Maintenance of Road Lighting Scottish Addendum applicable for use in Scotland
TD 24/97	All Purpose Trunk Roads: Maintenance of Traffic Signals
TD 25/86	Trunk Roads and Trunk Road Motorways: Maintenance of Traffic Signs Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TD 26/86	Trunk Roads and Trunk Road Motorways: Maintenance of Road Markings Northern Ireland Addendum applicable for use in Northern Ireland
TD 27/96	Cross Sections and Headrooms [This document supersedes TD 27/86 and SH 2/92]
TD 30/87	Design of Road Lighting for All Purpose Trunk Roads Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TD 32/93	Wire Rope Safety Fence
TD 33/90	The Use of Variable Message Signs on All Purpose and Motorway Trunk Roads Northern Ireland Addendum applicable for use in Northern Ireland
TD 34/91	Design of Road Lighting for Motorway Trunk Roads Scottish Addendum applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland
TD 35/91	All Purpose Trunk Roads – MOVA System of Traffic Control at Signals

TD 36/93	Subways for Pedestrians and Pedal Cyclists. Layout and Dimensions
TD 37/93	Scheme Assessment Reporting
TD 39/94	The Design of Major Interchanges
TD 40/94	Layout of Compact Grade Separated Junctions
TD 41/95	Vehicular Access to All Purpose Trunk Roads
TD 42/95	Geometric Design of Major/Minor Priority Junctions
TD 45/94	Motorway Incident Detection and Automatic Signalling (MIDAS)
TD 46/94	Motorway Signalling
TD 49/97	Mobile Lane Closures Supersedes those of Chapter 8, Topic 6 that deal with Mobile Lane Closures
TD 50/99	The Geometric Design of Signal Controlled Junctions

Departmental SH Standards – for use in Scotland only

SH 6/73	Criteria for Traffic Light Signals at Junctions
SH 5/77	Implementation of Bus Priorities
SH 7/83	Specification for Road and Bridge Works: Soil Suitability for Earthworking – Use of the Moisture Condition Apparatus [and Amendment No 1 dated February 1989]
SH 3/84	Model Contract Document for Topographical Surveys
SH 4/86	Scottish Routine Maintenance Management System
SH 5/88	Damage to Bridges by Road Vehicles – Traffic Signs at Bridges
SH 4/89	Geotechnical Certification Procedures: Trunk Road Ground Conditions [and Amendment No 1 dated March 1990]
SH 5/89	Topographical Surveys: Certification Procedures [and Amendment No 1 dated November 1989]
SH 1/97	The Traffic and Economic Assessment of Road Schemes in Scotland

Other references and publications (in alphabetical order)

ABBESS C, D JARRETT, and C C WRIGHT (1981). Accidents at blackspots: estimating the effectiveness of remedial treatment, with special reference to the `regression-to-mean' effect. *Traffic Engineering and Control*, 22 10.

ABBOTT P G, J W TYLER and R E LAYFIELD (1995). Traffic calming vehicle noise emissions alongside speed control cushions and road humps. TRL Report 180. TRL Limited, Crowthorne.

ABBOTT P G, M TAYLOR and R LAYFIELD (1997). The effects of traffic calming on vehicle and traffic noise. *Traffic Engineering and Control*, 38 9.

ADAMS J (1985). Risk and freedom: the record of road safety regulation. Transport Publishing Projects. Cardiff.

ADAMS J (1995). Risk. UCL Press, London.

ALLSOP R E (1996). How road infrastructure can help people to use the roads more safely. In: How safe? Foundations for the Future. AA Foundation for Road Safety Research 10th Anniversary Conference, Birmingham, September 1996, 55-63.

ASMUSSEN E (1983). International Calibration Study of traffic conflict techniques. NATO ASI Series F, Vol 5, ISBN 3-540-12716X, Springer-Verlag. Berlin, Heidelberg .

ASMUSSEN (1984). International Calibration Study of traffic conflict techniques. NATO ASI Series F: Computer and System Sciences. Springer-Verlag. Berlin, Heidelberg, New York, Tokyo.

AUSTROADS (2000). Bicycles – Guide to traffic engineering practice. Standards Australia, Part 14. Austroads, Sydney, Australia.

AUTOMOBILE ASSOCIATION (1996). Britain's roads- a national asset? AA Public Affairs, Basingstoke.

AUTOMOBILE ASSOCIATION (1999a). The Great British Motorist 2000. AA, Basingstoke.

AUTOMOBILE ASSOCIATION (1999b). What goes wrong in Highway Design- and how to put it right. AA Policy, TMS Consultancy. AA, Basingstoke.

BAGULEY C J and S D RAY (1989). Behavioural assessment of speed discrimination at traffic signals. TRL Report RR 177. TRL Limited, Crowthorne.

BARKER J (1997). Trials of Rural Safety Measures. TRL Report 202. TRL Limited, Crowthorne.

BARKER J and R D HELLIAR-SYMONS (1996). Count-down signs and Roundel markings trials. TRL Report TRL201. TRL Limited, Crowthorne.

BARKER J, S FARMER and D NICHOLLS (1998). Injury accidents on rural single-carriageway roads, 1994-95: An analysis of STATS19 data. TRL Report TRL304. TRL Limited, Crowthorne.

BARKER J, S FARMER and M TAYLOR (1999). The development of accident-remedial intervention levels for rural roads. TRL Report TRL425. TRL Limited, Crowthorne.

BARKER J, S FARMER and M TAYLOR (to be published 2001). Accident analysis methods for rural roads – a technical manual. TRL Report. TRL Limited, Crowthorne.

BARUYA A (1998). Master: Speed –accident relationships on different kinds of European roads. Master deliverable D7, EU Commission, Brussels.

BINNING J C (1998). Visual OSCADY/4 user guide. TRL Application Guide AG25. TRL Limited, Crowthorne.

BINNING J C (2000a). ARCADY 5 (UK) user guide. TRL Application Guide AG36. TRL Limited, Crowthorne.

BINNING J C (2000b). Visual PICADY 4 (International) User Guide. TRL Application Guide AG 30. TRL Limited, Crowthorne.

BINNING J C and M R CRABTREE (1999). TRANSYT 11 user guide. TRL Application Guide AG35. TRL Limited, Crowthorne.

BOULTER P (1999). Remote sensing of vehicle emissions near two traffic calming measures in Gloucester. TRL Report 423. TRL Limited, Crowthorne.

BOULTER P (2000). The impacts of the Safer City Project on road traffic emissions in Gloucester: 1996-1998. TRL Report 444. TRL Limited, Crowthorne.

BOULTER P G, A J HICKMAN , S LATHAM and R LAYFIELD (TRL Limited), P DAVISON and P WHITEMAN (AEA Technology) (to be published 2001). The impact of traffic calming measures on vehicle exhaust emissions. TRL Report 482. TRL Limited, Crowthorne.

BOYLE A J and C C WRIGHT (1984). Accident migration after remedial treatment at accident blackspots. *Traffic Engineering and Control*, 25 5.

BRETHERTON R D, K WOOD and G T BOWEN (1998). SCOOT Version 4. In: Proceedings of 9th International Conference on Road Transport Information and Control. Institution of Electrical Engineers, London.

BRINDLE R E (1986). The relationship between traffic management, speed and safety in neighbourhoods. In: Proceedings of 13th ARRB Conference 13(a), pp90-102. Australian Research Board, Vermont South.

BRITISH BOARD OF AGRÉMENT (1998). Guidelines document for the assessment and certification of high-friction surfaces for highways. Final draft, SG1/98/075, 21 September 1998. British Board of Agrément, Watford.

BRITISH MOTORCYCLISTS FEDERATION (1997). Powered two-wheeler use into the twenty first century. British Motorcyclists Federation.

BROWN M (1995). The design of roundabouts. TRL State-of-the-Art Review. The Stationery Office, London.

BROWN N C (1996). A Guide to the design and provision of secure parking for motorcycles. MAG, Kings Norton, Birmingham.

BRYAN-BROWN K (1995). The Effects of a Children's Traffic Club. In: Road Accidents Great Britain: 1994: The Casualty Report. Department of the Environment, Transport and the Regions. The Stationery Office, London.

BRYAN-BROWN K and G HARLAND (1999). The Children's Traffic Club in Scotland. Scottish Executive Research Unit Report. The Stationery Office, London.

BSI (1998). BS EN 1317-1, Road Restraint Systems-Part 1: Terminology and general criteria for test methods. The British Standards Institution, London.

BSI (1998). BS EN 1317-2, Road Restraint Systems-Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers. British Standards Institution, London.

BSI (1999). PrEN 1317-4: 17-18 June 1999 Not published – at committee stage. Road Restraint Systems – Part 4: Barrier systems: Terminals and Transitions – Performance classes, impact test acceptance criteria and test methods. Not published – at committee stage. British Standards Institution, London.

BSI (2000). BS EN 1317-3. Road Restraint Systems-Part 3: Crash Cushions – Performance classes, impact test acceptance criteria and test methods. British Standards Institution, London.

BSI (2000). PrEN 1317-6: September 2000. Part 6: Road restraint systems Pedestrian restraint systems – Part 6: Pedestrian Parapet. Not published – at committee stage. British Standards Institution, London.

BSI (2000). PrEN 1317-5: June 2000 Not published – at committee stage. Part5: Road Restraint Systems-Product Requirements, Durability and evaluation of conformity. Not published – at committee stage. British Standards Institution, London.

BSI (2000). BS EN 12767. Passive safety of support structures for road equipment – Performance requirements and test methods. British Standards Institution, London.

BSI (1998). BS6579: *(Parts 1 to 8)*. Safety fences and barriers for highways. British Standards Institution, London.

BSI (1999). BS6779: *(Parts 1 to 4)*. Highway parapets for bridges and other structures. British Standards Institution, London.

BURROW I J (1987). OSCADY: A computer program to model capacities, queues and delays at isolated traffic signals. TRRL Report RR105. TRL Limited, Crowthorne.

CHILD ACCIDENT PREVENTION TRUST (2000a). Accidents and child development. Child Accident Prevention Trust.

CHILD ACCIDENT PREVENTION TRUST (2000b). Checking child car seats. Child Accident Prevention Trust.

CLAYTON A, G DAVIES, G HARLAND and V PLATT (1998). Road safety education in schools. In: Proceedings of the road safety education conference, York. The Stationery Office, London.

CLOKE J, D WEBSTER, P BOULTER, G HARRIS, R STAIT, P ABBOTT and L CHINN (1999). Traffic calming: Environmental assessment of the Leigh Park Area Safety Scheme. TRL Report 397. TRL Limited, Crowthorne.

COOLICAN H (1994). Research Methods in Psychology. Holder and Stoughton, London.

CORBETT C and D SIMON (1999). The effect of speed cameras: how drivers respond. Centre for Criminal Justice Research. Brunel University.

COUNTY SURVEYORS' SOCIETY (2000). The Use of Coloured Road Surfaces. CSS (email: CSS@derbyshire.gov.uk).

COUNTY SURVEYORS' SOCIETY and DEPARTMENT OF TRANSPORT (1994a). Traffic calming in practice. Landor publishing Ltd, London.

COUNTY SURVEYORS' SOCIETY and DEPARTMENT OF TRANSPORT (1994b). Village speed control (VISP) Working Group – final report. DETR, London.

CTC WORKING FOR CYCLING (2000a). Delivering Safer roads- Managing the interaction of cycles and lorries. CTC.

CTC WORKING FOR CYCLING (2000b). The Cycle Safe Framework- A handbook for delivering cycling safely. CTC.

DANISH ROADS DIRECTORATE (1999). Speed management in urban areas. Report number 168. DUMAS.

DAVIES D G, M C TAYLOR, M C RYLEY and M E HALLIDAY (1997). Cyclists at roundabouts – the effects of 'Continental' design on predicted safety and capacity. TRL Report TRL285. TRL Limited, Crowthorne.

DAVIES D G, P EMMERSON and G GARDNER (1998). Achieving the aims of the National Cycling Strategy: Summary of TRL research. TRL Report TRL365. TRL Limited, Crowthorne.

DELHOMME P, V TRULS ET AL. (1999). Evaluation of road safety media campaigns: an overview of 264 evaluated campaigns and some meta-analysis on accidents. Arceuil, INRETS, Paris.

DENNING J H (1978). Epoxy-resin / calcined bauxite surface dressing on A1, Sandy, Bedfordshire: skid-resistance measurements 1968 to 1977. Department of the Environment, Department of Transport TRRL Report LR 867. TRL Limited, Crowthorne.

DENNING J H, and J CARSWELL (1983). High-performance surface dressing: 3. Properties of thermosetting binders related to road performance. Department of the Environment, Department of Transport TRRL Supplementary Report 798. TRL Limited, Crowthorne.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1992). Residential roads and footpaths. Layout Considerations, Second Edition. Design Bulletin 32. HMSO, LONDON.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1993). Road Traffic Regulation Act 1984: sections 81-85 Local speed limits: Circular Roads 1/93. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1994). Traffic Signs Regulations and General Directions. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1996). The National Cycling Strategy. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998a). Trunk roads review: detrunking of non-core routes, DETR Roads Policy Division, Zone 3/01, Great Minster House, 76 Marsham Street, London SW1P 4DR.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998b). Manual of Contract Documents for Highway Works, Volume 1 Specification for Highway Works, Series 1200 Traffic Signs. Highways Agency, Scottish Office Development Department, Welsh Office, Department for the Environment for Northern Ireland. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998c). Places, streets and movement. A companion guide to Design Bulletin 32. Residential roads and footpaths. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998d). A new deal for trunk roads in England. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998e). A new deal for trunk roads in England: Guidance on the new approach to appraisal. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998f). Let's Decide – Walk Wise. DETR, **http:/www.roads.detr.gov.uk/roadsafety/walk/**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1998g). Kerbcraft – smart strategies for pedestrian safety. DETR, **http:/www.roads.detr.gov.uk/roadsafety/rs2/**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1999a). School Travel Strategies and Plans: A Best Practice Guide for Local Authorities. Department of the Environment, Transport and the Regions, **http://www.local-transport.detr.gov.uk**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1999b). The Highway Code. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1999c). 20 mph speed limits. Circular 05/99. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1999d). Guidance on the Use of Tactile Paving Surfaces. DETR free literature.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (1999e). Speed camera funding – eight pilot schemes announced. Press Notice 1226. **http:///www.press.detr.gov.uk/9912/1226.htm**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000a). Road accidents Great Britain: 1999 – the casualty report. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000b). Tomorrow's Roads Safer for Everyone. DETR Free Literature.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000c). Encouraging walking: advice to local authorities. Available from DETR, Charging and Local Transport Division, Zone 3/25 Great Minster House, 76 Marsham Street, London SW1P 4DR Tel: 020 7944 2945, fax: 020 7944 2211, email **cycle_walk@detr.gov.uk.**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000d). New Directions in Speed Management – A Review of Policy. DETR Free Literature.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000e). Guidance on full Local Transport Plans. DETR Free Literature.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000f). A good practice guide for the development of Local Transport Plans. DETR Free Literature.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000g). STATS20 – Instructions for the completion of road accident reports. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000h). Transport statistics Great Britain 2000 edition. The Stationery Office, London.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000i). Transport 2010: The Ten Year Plan. **Http:///www.press.detr.gov.uk/trans2010/index.htm**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000j). Best value road condition surveys for local highway authorities. **http:///www.detr.gov.uk/roads/roadcond/**

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2000k) Best value Performance Indicators 2001/02

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (to be published 2001a). Accidents on rural roads. Traffic Advisory Leaflet.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (to be published 2001b). Gloucester Safer City Report.

DEPARTMENT of the ENVIRONMENT, TRANSPORT and the REGIONS (2001c). School travel. **http:///www.local-transport.detr.gov.uk/schooltravel/**

DEVON COUNTY COUNCIL (2000). Speed Management Strategy. Road Safety Group, Devon County Council.

DOWNING C S (1985). Pedal cycling accidents in Great Britain. In: Proceedings of Ways to Safer Cycling at Institution of Civil Engineers. Department of Transport. London.

ETSC: EUROPEAN TRANSPORT SAFETY COUNCIL (1999). Safety of pedestrians and cyclists in urban areas. ETSC, Brussels.

FARMER S, J BARKER and N MAYHEW (1998). A trial in Norfolk of interactive speed limit signs. *Traffic Engineering and Control* 39 5.

FEMA (2000). Final Report of the Motorcyclists and Crash Barriers Project. FEMA-Federation of Motorcyclists Associations.

FINCH D J, P KOMPFNER, C R LOCKWOOD and G MAYCOCK (1994). Speed, speed limits and accidents. TRL Report 58. TRL Limited, Crowthorne.

FORRESTER A and G HARLAND (2000). The effects of training children in Sunderland to be safer pedestrians. To be published by TRL Limited.

GARDNER G and S M GRAY (1998). A preliminary review of rural cycling. TRL Report 310. TRL Limited, Crowthorne.

GLOUCESTER CITY COUNCIL and GLOUCESTERSHIRE COUNTY COUNCIL (1997). Gloucester Safer City – road safety strategy. Gloucester Safer City.

GOVERNMENT OF IRELAND (1996). A guide to road safety engineering in Ireland. The Stationery Office, Dublin.

GRAYSON G B (1996). Behaviour adaptation : a review of the literature. TRL Report 254. TRL Limited, Crowthorne.

GRAPHPAD SOFTWARE INC. (1999). The Gaussian distribution.
http://www.Graphpad.com/articles

GREATER MANCHESTER PASSENGER TRANSPORT EXECUTIVE (1999). Quality Bus Routes consultation brochure, Manchester.

HALL R D (1986). Accidents at four-arm single carriageway urban traffic signals. Southampton University. TRRL Contractor Report CR65. TRL Limited, Crowthorne.

HARRIS G J, R E STAIT, P G ABBOTT and G R WATTS (1999). Traffic calming: vehicle generated noise and ground-borne vibration alongside sinusoidal round-top and flat-top road humps. TRL Report 416. TRL Limited, Crowthorne.

HAUER E (1992). How to do a before-and-after study: estimating the effect of highway and traffic engineering measures on road safety. Lecture notes: Transport Canada Workshop, Ottawa, Canada, 1992.

HAUER E, and P BYER (1983). Bias-by-selection: the accuracy of an unbiased estimator. *Accident Analysis and Prevention* 15 5.

HAYNES J P, G COPLEY, S FARMER and R D HELLIAR-SYMONS (1993). Yellow bar markings on motorway slip roads. TRL Report PR49. TRL Limited, Crowthorne.

HEALTH AND SAFETY EXECUTIVE (2000). Crossing high-speed roads on foot during temporary traffic management works. Construction Information Sheet No. 53. HSE Books, HSE, London.

HEATH M (1995). Legal aspects of safety audit. Road safety auditors forum, Mott McDonald. 1995.

HELLIAR-SYMONS R D (1981). Yellow bar experimental carriageway markings –accident study. TRL Report LR 1010. TRL Limited, Crowthorne.

HELLIAR-SYMONS R D and N BUTLER (1995). M1 Chevron Trial – accident study TRL Report PR118. TRL Limited, Crowthorne.

HELLIAR-SYMONS R D, P WEBSTER and A SKINNER (1995a). The M1 Chevron Trial. *Traffic Engineering and Control*, 36 10.

HELLIAR-SYMONS R D, N BUTLER and P CRITCHELL (1995b). Riblines in Hampshire. *Traffic Engineering and Control* 36 7/8.

HIGGINSON M (1999). Network Management Notes: Bus Priority. Oscar Faber.

HIGHWAYS AGENCY (1996). The COBA Manual. Design Manual for Roads and Bridges. Volume 13, Section 1, Part2, September 1996. The Stationery Office, London.

HIGHWAYS AGENCY (1998). Towards a balanced transport system: The Highways Agency's Toolkit. **http://www.Highways.gov.uk/info/toolkit/**

HIGHWAYS AGENCY (2000a). Making the network safer – Highways Agency strategic plan for safety. Highways Agency.

HIGHWAYS AGENCY (2000b). Encouraging Sustainable Travel. Highways Agency.

HIGHWAYS AGENCY (2000c). Making Maintenance the Priority. Highways Agency.

HIGHWAYS AGENCY (2000d). Trunk road traffic calming. Interim Advice Note 28/00. Highways Agency.

HMSO (1985). Traffic Signs Manual Chapter 5: Road Markings. The Stationery Office, London.

HMSO (1986a). Traffic Signs Manual Chapter 3: Regulatory Signs. The Stationery Office, London.

HMSO (1986b). Traffic Signs Manual Chapter 4: Warning Signs. The Stationery Office, London.

HMSO (1986c). Shared Use by Cyclists and Pedestrians. Local Transport Note 2/86. The Stationery Office, London.

HMSO (1991). New Roads and Street Works Act. Section 26 – Code of Good Practice, safety at street works and road works. The Stationery Office, London. (2nd edition due 2001).

HMSO (1994a). Contract (Design and Management) Regulations 1994. The Stationery Office, London.

HMSO (1994b). The design and use of directional informatory signs. Local Transport Note 1/94. The Stationery Office, London.

HMSO (1994c). The Traffic Signs Directions and General Directions. The Stationery Office, London.

HMSO (1995). The assessment and design of pedestrian crossings. Local Transport Notes 1/95 and 2/95. The Stationery Office, London.

HMSO (1997). Traffic Signs Manual Chapter 7: The design of traffic signs. The Stationery Office, London.

HMSO (1998a). Manual of contract documents for Highway Works. Volume 1 – Specification for Highway Works. The Stationery Office, London.

HMSO (1998b). Manual of contract documents for Highway Works. Volume 3 – Highway Construction Details. The Stationery Office, London.

HMSO (1998c). Traffic Signs Manual Chapter 8: Traffic safety measures and signs for road works and temporary situations. Consolidated issue. The Stationery Office, London.

HMSO (1998d). The Installation of Traffic Signals and Associated Equipment. Local Transport Note 1/98. The Stationery Office, London.

HOINVILLE J, R JOWELL and ASSOCIATES (1978). Survey Research Practice. Heinemann Educational Books. London.

HOOKE A, J KNOX and D PORTAS (1996). Cost benefit analysis of traffic light and speed cameras. Police Research Series Paper 20. Home Office: Police Research Group.

HUGHES W and G AMIS (1996). Accidents on rural single-carriageway ‘A’ class roads. Cambridgeshire CC and AA Foundation for Road Safety Research.

HUGHES W, G AMIS and A WALFORD (1997). Accidents on rural roads: dual-carriageway ‘A’ class roads. Cambridgeshire County Council and AA Foundation for Road Safety Research.

HUNT J G, J D GRIFFITHS and T S MOSES (1990). An evaluation of the effect of SCOOT on road safety. TRL Contractor Report CR 236. TRL Limited, Crowthorne.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1990a). Guidelines for Urban Safety Management. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1990b). Accident Reduction and Prevention. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1996a), DEPARTMENT OF TRANSPORT, BICYCLE ASSOCIATION, and CYCLISTS TOURING CLUB. Cycle-Friendly Infrastructure. Guidelines for Planning and Design. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1996b). Guidelines for Safety Audit of Highways. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1997). Transport in the Urban Environment. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1998). Cycle Audit and Cycle Review. IHT Guidelines. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1999a). Guidelines for providing for journeys on foot. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1999b). Planning for public transport in developments. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1999c). Guidelines for Rural Safety Management. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (1999d). Reducing Mobility Handicaps: towards a Barrier-Free Environment. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (2000). Parking problems hospitals face. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (2000). Providing for journeys on foot. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (to be published 2001). Environmental management of highways – guidelines on good practice. IHT, London.

INSTITUTION OF HIGHWAYS and TRANSPORTATION (to be published 2001). Pedestrianised High Streets – planning, design and management. IHT, London.

JAMES H (1991). Under-reporting of road traffic accidents. *Traffic Engineering and Control*. 32 12.

KALLBERG V-P, R E ALLSOP, H WARD, R VAN DER HORST and A VARHELYI (1998). Recommendations for speed management strategies and policies. Deliverable D12 of the MASTER (Managing Speeds of Traffic on European Roads) Project. VTT Communities and infrastructure, Finland. **http://www.vtt.fi/yki/yki6/master/master.htm**

KENNEDY J V, R D HALL and S R BARNARD (1998). Accidents at urban mini-roundabouts. TRL Report TRL 281 TRL Limited, Crowthorne.

KULMALA R (1994). Measuring the safety effect of road measures at junctions. *Accident Analysis and Prevention*. 26 6.

LAWSON S (1991). Red light running: accidents and surveillance cameras. AA Foundation for Road Safety Research and Birmingham City Council.

LAYFIELD R (2000). Home zones: monitoring the DETR pilot programme. Proceedings of Conference on Reducing Traffic Impacts on Local Communities. Aston University. PA2626-00. TRL Limited, Crowthorne.

LAYFIELD R E and D I PARRY (1998). Traffic calming – Speed cushion schemes. TRL Report 312. TRL Limited, Crowthorne.

LAYFIELD R E and G MAYCOCK (1986). Pedal cyclists at roundabouts. *Traffic Engineering and Control*, 1986.

LOCAL AUTHORITIES ASSOCIATION (1989). Highway Maintenance – Code of Good Practice.

LOCAL AUTHORITIES ASSOCIATION (1996). Road Safety – Code of Good Practice.

LONDON RESEARCH CENTRE (1999a). Levels of accident risk in Greater London. London Research Centre.

LONDON RESEARCH CENTRE (1999b). London Accident Analysis Unit Annual Report 1998. London Research Centre.

LONDON RESEARCH CENTRE (1999c). Towards the Year 2000: monitoring casualties in Greater London. London Research Centre.

MACKIE A M, H A WARD and R T WALKER (1990). Urban safety project 3: Overall evaluation of area-wide schemes. TRL Report RR263. TRL Limited, Crowthorne.

MACKIE A (1998). Urban speed management methods. TRL Report TRL 363. TRL Limited, Crowthorne.

MAHER M J and L J MOUNTAIN (1988). The identification of accident blackspots: a comparison of current methods. *Accident Analysis and Prevention*. 20 2.

MARTENS M and N KAPTEIN (1988). Speed behaviour before and after road design modifications – a meta review. Deliverable 2 of the MASTER (Managing Speeds of Traffic on European Roads) Project. VTT Communities and infrastructure, Finland. **http://www.vtt.fi/yki/yki6/master/master.html**

MAYCOCK G and R D HALL (1984). Accidents at 4-arm roundabouts. TRL Report LR1102. TRL Limited, Crowthorne.

MAYCOCK G, P J BROCKLEBANK and R D HALL (1998). Road layout design standards and driver behaviour. TRL Report TRL332. TRL Limited, Crowthorne.

MCCOLL E and R THOMAS (2000). Design and administration of postal self-completion surveys. National Centre for Social Research. Economic and Social Research Council (ESRC).

MEDD I (2000). The use of coloured road surfaces – CSS Accident Reduction Working Group Guidelines. Proceedings of CSS Conference ‘Safety through engineering’, CSS, October 2000, Leamington Spa.

MILLS PAULA J (1989). Pedal cycle accidents – a hospital based study. TRL Research Report RR220. TRL Limited, Crowthorne.

MORGAN J (1997). Roundabouts in Continental Europe designed with cycle facilities of ‘cycle-thinking’. TRL Report 302. TRL Limited, Crowthorne.

MOUNTAIN L and B FAWAZ (1992). The effects of engineering measures on safety at adjacent sites. *Traffic Engineering and Control*, 33, 1.

MOUNTAIN L, B FAWAZ and L SINENG (1992). The assessment of changes in accident frequencies on link segments: a comparison of four methods. *Traffic Engineering and Control*, 33, 7.

MOUNTAIN L (1998). Regression, migration and trend: road accident reductions aren’t always what they seem. **http://www.safety98.org/html/papers7/d-4.htm**

MUSKAUG R (1993). Drivers’ acceptance of automatic traffic surveillance. *Traffic Engineering and Control*, 34 4.

NATIONAL ASSEMBLY FOR WALES (2000). Traffic calming trials: a review of traffic calming schemes on the trunk and principal road network in Wales. Highways Directorate, Colwyn Bay.

NICHOLLS J C (1997). Laboratory Tests on High-Friction Surfaces for Highways. TRL Report 176. TRL Limited, Crowthorne.

NICHOLLS J C (1998). Trials of High-Friction Surfaces for Highways. TRL Report 125. TRL Limited, Crowthorne.

PACTS-PARLIAMENTARY ADVISORY COUNCIL FOR TRANSPORT SAFETY (1996). Taking action on SPEEDING. PACTS.

PACTS-PARLIAMENTARY ADVISORY COUNCIL FOR TRANSPORT SAFETY (1999). Road traffic law and enforcement: a driving force for casualty reduction. PACTS.

PERSAUD B (1987). Migration of accident risk after remedial treatment at accident blackspots. *Traffic Engineering and Control*, 28 1.

PICKERING D, R D HALL and M GRIMMER (1986). Accidents at rural T-junctions. TRL Report RR65. TRL Limited, Crowthorne.

ROSS SILCOCK (1998). Pedestrian behaviour and exposure to risk – final report and appendices. ISBN 0-9533722-2-7. Babtie Ross Silcock. Newcastle-upon-Tyne.

ROYAL SOCIETY for the PREVENTION OF ACCIDENTS (1990). Handbook for road safety officers. RoSPA, Birmingham.

ROYAL SOCIETY for the PREVENTION OF ACCIDENTS (1995a). Road Safety: A Manager’s Guide. RoSPA, Birmingham.

ROYAL SOCIETY for the PREVENTION OF ACCIDENTS (1995b). Road Safety Engineering Manual. RoSPA, Birmingham.

ROYAL SOCIETY for the PREVENTION OF ACCIDENTS (2000). Guidelines for the management and operation of practical cyclist training schemes. RoSPA, Birmingham.

RYLEY T J (1996). Advanced stop lines for cyclists: the role of central cycle lane approaches and signal timings. TRL Report 181. TRL Limited, Crowthorne.

SAVILL T and K BRYAN-BROWN (1996). The effectiveness of cycle training schemes. TRL Report 214. TRL Limited, Crowthorne.

Sayer I A and D I Parry (1994). UK Speed control using chicanes – a trial at TRL. TRL Project Report 102. TRL Limited, Crowthorne.

SAYER I A, D I PARRY and J K BARKER (1998). Traffic calming – An assessment of selected on-road chicane schemes. TRL Report 313. TRL Limited, Crowthorne.

SAYER I A, D A NICHOLLS and R E LAYFIELD (1999). Traffic calming: Passenger and rider discomfort at sinusoidal, round-top and flat-top humps – a track trial at TRL. TRL Report 417. TRL Limited, Crowthorne.

SCOTTISH EXECUTIVE (1999). Cycling by design.
http://www.scotland.gov/library2/cbd/

SCOTTISH OFFICE (1995a). Running the red – an evaluation of Strathclyde police's red light camera initiative. Research Findings No 7. The Scottish Office Central Research Unit. Edinburgh.

SCOTTISH OFFICE (1995b). THE SCOTTISH OFFICE ROAD SAFETY PLAN. HMSO Scotland.

SCOTTISH OFFICE (1999). 20 mph speed limits. SODD Circular No 13/99. Scottish Office.

SCOTTISH OFFICE INDUSTRY DEPARTMENT ROADS DIRECTORATE (1994). Hazard warning signs and markings on bends on trunk roads. Roads Directorate of the Scottish Office.

SILCOCK D, K SMITH, D KNOX and K BEURET (1999). What limits speed? Factors that affect how fast we drive. AA Foundation of Road Safety Research, Basingstoke.

STATSOFT INC. (1995). Experimental Design (Industrial DOE).
http://www.statsoftinc.com/textbook/stexdes.html

STEWART D (1995). Legal aspects of safety audit. Road safety auditors forum, Mott McDonald, 1995.

SUFFOLK COUNTY COUNCIL (1997). 30mph speed limit initiative: speed monitoring. Report 960297/R01.0. Suffolk County Council, Suffolk.

SUSTRANS and OVE ARUP (1997). The national cycle network – guidelines and practical details. Sustrans Limited.

TAS PARTNERSHIP (2000). Quality Bus Infrastructure: A Manual and Guide. The Tas Partnership Limited.

TAYLOR D and M TIGHT (1996). Feet First: Public Attitudes and consultation in traffic calming schemes. A report for Transport 2000.

TAYLOR M C and J K BARKER (1992). Injury accidents on rural single-carriageway roads – an analysis of STATS 19 data. TRL Report RR365. TRL Limited, Crowthorne.

TAYLOR M C and A H WHEELER (2000). Accident reduction resulting from village traffic calming. European Transport Conference, Cambridge. Proc. Seminar J. Assoc. for European Transport.

TAYLOR M C, R D HALL and K CHATTERJEE (1996). Accidents at 3-arm traffic signals on urban single-carriageway roads. TRL Report 135. TRL Limited, Crowthorne.

TAYLOR M C, LYNAM D A and BARUYA A (2000). The effects of drivers speed on the frequency of road accidents. TRL Report 421. TRL Limited, Crowthorne.

TAYLOR M C, A MACKIE and A BARUYA (to be published 2001). Vehicle speed distributions and safety on urban roads. TRL Report. TRL Limited, Crowthorne.

THAMES VALLEY POLICE (1999). Speed limits: The facts. Thames Valley Police.

THE MOTORCYCLE INDUSTRY ASSOCIATION (1999). Powered Two Wheelers – The SMART Choice in Local Transport Plans. Motor Cycle Industry Association Ltd.

THOMSON J A, A K TOLMIE, H C FOOT and B MCLAREN (1996). Child development and the aims of road safety education: a review and analysis. The Stationery Office, London.

TRANSPORT and ROAD RESEARCH LABORATORY (Now TRL Limited) (1987). The Traffic Conflict Technique Guidelines. IHT, London.

TRANSPORT FOR LONDON STREET MANAGEMENT (2000). Accidents and casualties on London's roads 1999. Transport for London Street Management.

TRIMPOP R M, and G J S WILDE (1994). Challenges to accident prevention: the issue of risk compensation behaviour. STYX Publications, Postbus 2659, 9704 CR Groningen, The Netherlands.

TRL Limited (1999). SafeNET User Guide v1. TRL Application Guide AG34. TRL Limited, Crowthorne.

URBAN DESIGN ALLIANCE (2000). Returning roads to residents. ICE, London.

VINCENT R A and J R PEIRCE (1988). MOVA: traffic responsive, self-optimising signal control for isolated intersections. TRRL Research Report RR 170. TRL Limited, Crowthorne.

VINCENT R A, J R PEIRCE and P J WEBB (1991). MOVA traffic control manual. TRL Application Guide AG10. TRL Limited, Crowthorne.

WALMSLEY D A and I SUMMERSGILL (1998). The relationship between road layout and accidents on modern rural trunk roads. TRL Report TRL334. TRL Limited, Crowthorne.

WARWICKSHIRE COUNTY COUNCIL (1997). A safety auditor's view of roundabout design. West Midlands Region Road Safety Audit Forum – An Update. Warwick.

WATTS G R (1973). Road humps for the control of vehicle speeds. TRRL Laboratory Report LR597. TRL Limited, Crowthorne.

WATTS G R, and G J HARRIS (1996). Traffic calming: Vehicle Generated Ground-borne Vibration alongside Speed Control Cushions and Road Humps. TRL Report 235. TRL Limited, Crowthorne.

WATTS G R, G J HARRIS and R E LAYFIELD (1997). Traffic calming: vehicle generated ground-borne vibration alongside speed control cushions and road humps. TRL Report 235. TRL Limited, Crowthorne.

WEBB P J and S HARRISON (1992). The safety record of MOVA signal controlled junctions. TRL Unpublished Working Paper WP/TO/102. TRL Limited, Crowthorne.

WEBSTER D C (1993a). Grounding of vehicles on road humps. *Traffic Engineering and Control* 34 07/08.

WEBSTER D C (1993b). Road humps for controlling vehicle speeds. TRL Project Report PR 18. TRL Limited, Crowthorne.

WEBSTER D C (1994). Speeds at thumps and low height road humps. TRL Project Report PR 101. TRL Limited, Crowthorne.

WEBSTER D C (1995). Traffic calming – vehicle-activated speed limit reminder signs. TRL Report 177. TRL Limited, Crowthorne.

WEBSTER D C (1998). Traffic calming – Public attitude studies: a literature review. TRL Report 311. TRL Limited, Crowthorne.

WEBSTER D C (2000). Traffic calming – a literature search on the design and performance of traffic calming measures. TRL Report TRL439. TRL Limited, Crowthorne.

WEBSTER D C and R E LAYFIELD (1993). An assessment of rumble strips and rumble areas. TRL Report PR33. TRL Limited, Crowthorne.

WEBSTER D C and R E LAYFIELD (1996). Traffic calming – Road hump schemes using 75 mm high humps. TRL Report 186. TRL Limited, Crowthorne.

WEBSTER D C and R E LAYFIELD (1998). Traffic calming – Sinusoidal, ‘H’ and ‘S’ humps. TRL Report 377. TRL Limited, Crowthorne.

WEBSTER D C and A M MACKIE (1996). Review of traffic calming schemes in 20 mph zones. TRL Report 215. TRL Limited, Crowthorne.

WEBSTER D C and P A WELLS (2000). The characteristics of speeders. TRL Report TRL 440. TRL Limited, Crowthorne.

WEBSTER P B, A J SKINNER and R HELLIAR-SYMONS (1992). Installation and evaluation of chevron markings on motorways. TRL Report CR304. TRL Limited, Crowthorne.

WELSH OFFICE (1999). 20 mph speed limits. Circular 28/99. Welsh Office.

WHEELER A (1995). Advanced stop-lines for cyclists – a simplified layout. *Traffic Engineering and Control* 36 5.

WHEELER A and M TAYLOR (1995). Reducing speeds in villages: the VISP study. *Traffic Engineering and Control*, 36 4.

WHEELER A and M C TAYLOR (1999). Traffic Calming on Major Roads: Final Report. TRL Report 385. TRL Limited, Crowthorne.

WHEELER A H and M C TAYLOR (2000). Changes in accident frequency following the introduction of traffic calming in villages. TRL Report TRL452. TRL Limited, Crowthorne.

WHEELER A, G HARRIS, L CHINN, M TAYLOR and P G ABBOTT (1997). A traffic calming scheme at Costessey, Norfolk. TRL Report 364. TRL Limited, Crowthorne.

WHEELER A, P G ABBOTT, D J LAWRENCE and S M PHILLIPS (1996). Traffic calming on major roads: the A49 trunk road at Craven Arms, Shropshire. TRL Report 212. TRL Limited, Crowthorne.

WHEELER A, P G ABBOTT, N S GODFREY, S M PHILLIPS and R STAIT (1997). Traffic calming on major roads: the A47 trunk road at Thorney, Cambridgeshire. TRL Report 238. TRL Limited, Crowthorne.

WHEELER A, M C TAYLOR and J BARKER (1994). Speed Reductions in 24 villages: details from the VISP study. Project Report PR85. TRL Limited, Crowthorne.

WILDE G J S (1994). Target risk. PDE Publications. Toronto.

WINN R. (1995). Running the red: an evaluation of Strathclyde Police's red light camera initiative. The Scottish Office Central Research Unit. HMSO, Edinburgh.

WINNETT M (1994). A review of speed camera operations in the UK. Traffic management and road safety. Proceedings of 22nd PTRC European Transport Forum, Seminar J.

WINNETT M (TRL), E WOODGATE (TRL) and N MAYHEW (NORFOLK COUNTY COUNCIL) (1999). Interactive Fibre Optic Signing at a Rural Crossroad. TRL Report TRL 401. TRL Limited, Crowthorne.

WINNETT M A, E WOODGATE and A MACKIE (1997). Rural Safety Measures – Vehicle Activated Bend Sign. TRL Project Report PR/TT/037/97. (Unpublished Report). TRL Limited, Crowthorne.

WRIGHT C C and A J BOYLE (1987). Road accident causation and engineering treatment: a review of current issues. *Traffic Engineering and Control*, 28 9.

WRIGHT C C, C R ABBESS and D F JARRETT (1986). Estimating the regression-to-mean effect associated with road accident blackspot treatment: towards a more realistic approach. *Accident Analysis and Prevention*. 20 3.

Abbreviations

07

AA	Automobile Association
AIP	Accident investigation and prevention
ARCADY	TRL software aid to design roundabout junctions
BITER	British Institute of Traffic Education and Research
CAPT	Child Accident Prevention Trust
CCTV	Closed circuit television
CPRE	Council for the Protection of Rural England
CSS	County Surveyors' Society
DFT	Department for Transport
DoE NI	Department of the Environment for Northern Ireland
DMRB	Design Manual for Roads and Bridges
85th percentile speed	The speed at or below which 85 per cent of the vehicles in a speed measurement sample set were travelling
ETP	Education, training and publicity
FYRR	First Year Rate of Return
GB	Great Britain
GIS	Geographical information system
HA	Highways Agency
HGV	Heavy goods vehicle
HMSO	Her Majesty's Stationery Office (now TSO)
HSE	Health and Safety Executive
ICE	Institution of Civil Engineers
IHT	Institution of Highways and Transportation

IRSO	Institute of Road Safety Officers
KSI (casualty)	Killed and seriously injured casualties in road accidents
KSI (accident)	Accidents in which at least one casualty was killed or seriously injured
LAA	Local Authority Association
LGV	Light goods vehicle
LHA	Local highway authority
LTN	Local Transport Note
LTP	Local Transport Plans
MCAP	Medical Commission for Accident Prevention
MOLASSES	Monitoring Local Authority Safety Schemes – A database managed by TRL Limited storing information about local and trunk road safety schemes which can be interrogated to ascertain the overall effectiveness of specific engineering measures. (See also the web site www. trl. co. uk/molasses)
MOVA	Microprocessor optimised vehicle actuation
NATA	New Approach To Appraisal
NPV	Net Present Value
NVQ	National Vocational Qualification
OSCADY	TRL software aid for designing signalised junctions
PIA	Personal injury accident
PICADY	TRL software aid for designing priority junctions
PSV	Public service vehicle
PTRC	Planning, transportation, research and computation
PVR	Per vehicle record – used to describe the type of automatic equipment that can measure speeds of all individual vehicles.
RAGB	Road Accidents in Great Britain
RoSPA	Royal Society for the Prevention of Accidents
RSE	Road safety engineer
RSO	Road safety officer
RSR	Road safety research

RTRA	Road Traffic Reduction Act
SafeNET	TRL software used to estimate the frequency of accidents on a network (when traffic and pedestrian flow and geometric information are provided).
SCOOT	Split cycle offset optimisation technique
SO	Scottish Office
STATS19	Database of standardised accident reports (using the STATS19 report form) sent to the Department of the Environment, Transport and the Regions by all police forces in Great Britain.
STATS20	Document with instructions for the completion of STATS19 road accident reports.
TAL	Traffic Advisory Leaflet
TPP	Transport Policies and Programme
TRANSYT	Traffic Network Study Tool
TRL	Transport Research Laboratory (now TRL Limited)
TSM	Traffic Signs Manual (Chapters 1-8)
TSO	The Stationery Office
TSRGD	Traffic Signs Regulations and General Directions (see Bibliography HMSO,1994c)
TWMV	Two-wheeler motorised vehicles
UK	United Kingdom
USM	Urban Safety Management
UTC	Urban traffic control system
VISP	Village speed control project (see references)
WO	Welsh Office

08 Feedback

We expect to review and update this guide. If you would like to make any suggestions or can offer any further site examples, please e-mail Miss C Britt: **Caroline_Britt@detr.gsi.gov.uk**, in the first instance, by 31 December 2001. We will consider all feedback in preparing the next update.

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

Location:	Huntington Road, York.			
Site Description:	Arterial route towards city centre.			
Problem:	Poor accident record. Relatively high speeds (85th percentile speed of 35mile/h, but maximum recorded =61mile/h).			
Aims:	To reduce speeds with cycle and bus- friendly measures. Emergency service vehicles should not be impeded.			
Treatment:	Road narrowings on main road – scheme also includes mini-roundabouts.			
Implemented:	March 1998.			
Cost :	£33,000.			
Comments:	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.*			
Effectiveness:	Accidents (pia in 3 years)	Speeds (mph) Mean	85th per centile	Traffic Flow (daily)
Before:	6	32	35	8,000
After:	2	22	29	6,500

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 Eastbound	Westbound	Traffic Flows (AADT) 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

- narrowings
- chicanes
- mini-roundabouts
- staggered parking arrangements

Vertical alignment

- round top humps
- flat top humps
- speed cushions (on bus routes)
- 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.

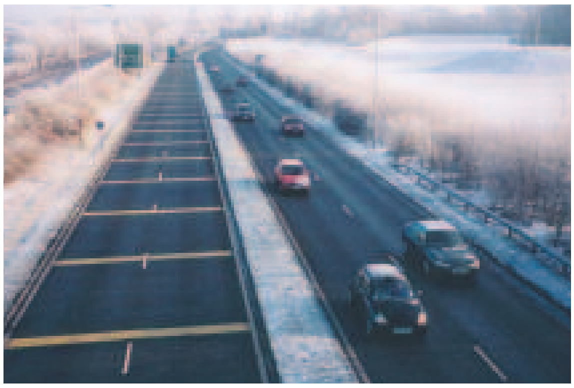
Design details will be provided in the new Traffic Signs Manual Chapter 5 (publication expected in 2001).

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

Appendix B

Statistical Tests

Student's t-test for comparison of samples

B.1

Student's t-test for comparison of samples (eg. sets of mean speed measurements)

To determine whether the mean speed of one set of speed measurements is significantly different from another (ie. between a "before" and "after" study), it is appropriate to use Student's two-tailed t-test, making the reasonable assumption that the variances of the two sets of measurements are drawn from the same population. The null hypothesis is thus that there is no difference in the means (ie. that drivers' speed has not been affected by the scheme). It is first necessary to determine the standard deviation of the difference in means.

Let $b_1, b_2, ...b_{nb}$ be the *Before* speed readings
and $a_1, a_2, ...a_{na}$ be the *After* speed readings

We then calculate the equations below:

$$\text{Means:} \quad \bar{b} = \frac{\Sigma(b_i)}{n_b}, \quad \bar{a} = \frac{\Sigma(a_i)}{n_a}$$

$$\text{Standard deviation: } \overset{2}{\sigma} = \sqrt{\frac{\Sigma(a_i^2) - \frac{(\Sigma(a_i))^2}{n_a} + \Sigma(b_i^2) - \frac{(\Sigma(b_i))^2}{n_b}}{(n_a + n_b - 2)}}$$

$$t = \frac{\bar{a} - \bar{b}}{\sigma} \sqrt{\frac{n_a \times n_b}{n_a + n_b}}$$

Having found the value of ***t*** we need to look at a table of Student's t values (see page B-4), with (n_a+n_b – 2) degrees of freedom. If the value of ***t*** exceeds that for the 5% level (the ***t*** = 0.05 column) we can be 95% confident that the true mean speed has changed.

Example

Assume that number of speed readings

before a scheme, $n_b = 210$

and the mean, $\bar{b} = 37 \text{ mile/h}$

sum of readings $\sum b_i = 7770$

sum of squares $\sum (b_i)^2 = 291{,}142$

Similarly, after a scheme,

$$n_a = 220$$

$$\bar{a} = 33 \; mile/h$$

$$\sum a_i = 7260$$

$$\sum (a_i)^2 = 243{,}760$$

From the above equations

$$\text{standard deviation, } \sigma = \sqrt{\frac{243760 - (7260)^2/220 + 291142 - (7770)^2/210}{220 + 210 - 2}}$$

$$= 18.299$$

$$t = \frac{33 - 37}{18.299} \cdot \sqrt{\frac{220 \times 210}{220 + 210}}$$

$$= 2.265$$

$$\text{for degrees of freedom, } \upsilon = 220 + 210 - 2$$

$$= 428$$

As the ***t*** value is greater than 1.96 (for the large number of degrees of freedom), then we can say that the mean difference in mean speeds (a 4 mile/h reduction) is significant at the 5% level.

Table of *t*-distribution

Degrees of Freedom, υ	*t*				
	0.10	0.05	0.02	0.01	0.001
1	6.314	12.706	31.821	63.657	636.619
2	2.920	4.303	6.965	9.925	31.598
3	2.353	3.182	4.541	5.841	12.941
4	2.132	2.776	3.747	4.604	8.610
5	2.015	2.571	3.365	4.032	6.859
6	1.943	2.447	3.143	3.707	5.959
7	1.895	2.365	2.998	3.499	5.405
8	1.860	2.306	2.896	3.355	5.041
9	1.833	2.262	2.821	3.250	4.781
10	1.812	2.228	2.764	3.169	4.587
11	1.796	2.201	2.718	3.106	4.437
12	1.782	2.179	2.681	3.055	4.318
13	1.771	2.160	2.650	3.012	4.221
14	1.761	2.145	2.624	2.977	4.140
15	1.753	2.131	2.602	2.947	4.073
16	1.746	2.120	2.583	2.921	4.015
17	1.740	2.110	2.567	2.898	3.965
18	1.734	2.101	2.552	2.878	3.922
19	1.729	2.093	2.539	2.861	3.883
20	1.725	2.086	2.528	2.845	3.850
21	1.721	2.080	2.518	2.831	3.819
22	1.717	2.074	2.508	2.819	3.792
23	1.714	2.069	2.500	2.807	3.767
24	1.711	2.064	2.492	2.797	3.745
25	1.708	2.060	2.485	2.787	3.725
26	1.706	2.056	2.479	2.779	3.707
27	1.703	2.053	2.473	2.771	3.690
28	1.701	2.048	2.467	2.763	3.674
29	1.699	2.045	2.462	2.756	3.659
30	1.310	2.042	2.457	2.750	3.646
40	1.684	2.021	2.423	2.704	3.551
60	1.671	2.000	2.390	2.660	3.460
120	1.658	1.980	2.358	2.617	3.373
∞	1.645	1.960	2.326	2.576	3.291

Kolmogorov-Smirnov test

B.2

The 'two-tailed' Kolmogorov-Smirnov test determines whether two independent samples have been drawn from the same population (or from populations with the same distribution). If the two samples have in fact been drawn from the same population (the null hypothesis), then the cumulative distributions of both samples may be expected to be fairly close to each other, ie. they should show only random deviation from the population distributions. If the two sample cumulative distributions are too far apart at any point this suggests that they come from different populations. Thus a large enough deviation between the two sample cumulative distributions is evidence for rejecting the null hypothesis.

Let $S_{Na}(x)$ be the observed cumulative step function of the first speed sample

ie. $S_{Na}(x) = K/N_a$ where K is the number of vehicles equal to or less than x km/h and N_a is the total number of the sample. Let $S_{Nb}(x)$ be the cumulative step function of the second sample. Now the Kolmogorov-Smirnov two-tail test focuses on the maximum deviation, D.

$$D = \text{maximum}\ |\ S_{Na}(x) - S_{Nb}(x)\ | \quad \text{.........................(1)}$$

For large samples (N>40) Kolmogorov-Smirnov tables show that the value of D must equal or exceed the value of:

$$1.36.\sqrt{\frac{N_a + N_b}{N_a N_b}}$$

to reject the null hypothesis at the 5 per cent level, that is, that they are not from the same population.

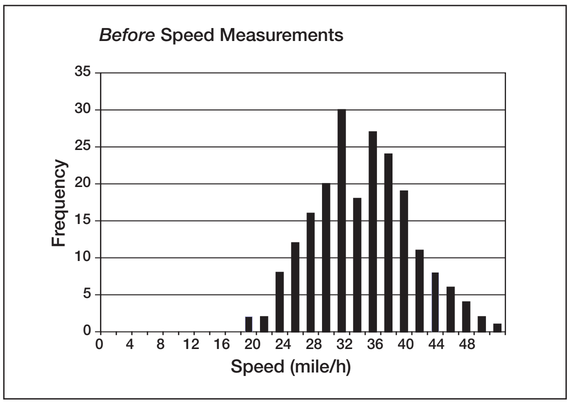
The 'one-tailed' Kolmogorov-Smirnov test determines whether the two samples have been drawn from the same population or whether the values of one sample are stochastically larger than the values of the population from which the other sample was drawn. The maximum deviation is again calculated using equation (1) and the significance of the observed value of D can be computed by reference to the chi-squared distribution. It has been shown that for large samples:

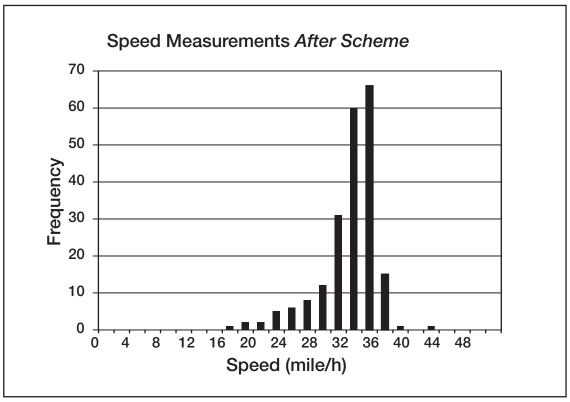
$$\chi^2 = 4D^2 \ \frac{N_a N_b}{N_a + N_b}$$

has a sampling distribution which is approximated to the chi-square distribution with two degrees of freedom. A chi-squared table for reference is given on page B-7.

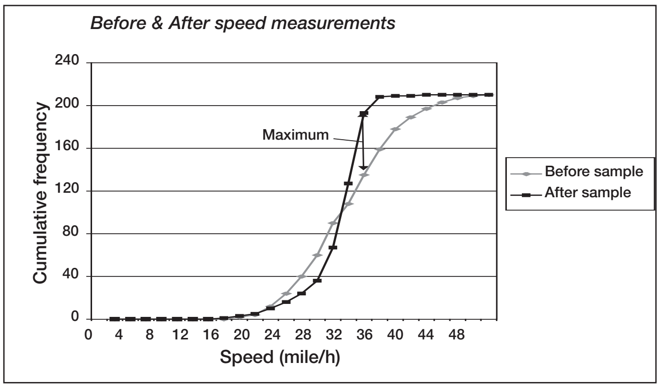
Example

Let us assume that *Before* and *After* speed measurements have given the following two distributions:–





If we plot these as cumulative speed distributions:



The observed cumulative step function of the *After* speed sample,

$$S_{Na}(x) = K/N_a = 193/210$$
$$= 0.919$$

For the *Before* sample,

$$S_{Nb}(x) = K/N_b = 135/210$$
$$= 0.643$$

The maximum deviation, $D = 0.919 - 0.643$
$$= 0.276$$

The Kolmogorov-Smirnov value at the 5% level
$$= 1.36\ (210+210/(210 \times 210))\text{-}$$
$$= 0.133$$

which is less than the maximum deviation, and thus we can reject the null hypothesis at the 5% level. That is, in this case there is a significant difference between the two speed samples.

Table of χ^2

Degrees of Freedom, υ	0.99	0.98	0.95	0.90	0.50	0.10	0.05	0.02	0.01	0.001
1	0.000	0.001	0.004	0.015	0.455	2.710	3.840	5.410	6.640	10.830
2	0.020	0.040	0.103	0.211	1.386	4.610	5.990	7.820	9.210	13.820
3	0.115	0.185	0.352	0.584	2.366	6.250	7.820	9.840	11.340	16.270
4	0.297	0.429	0.711	1.064	3.357	7.780	9.490	11.670	13.280	18.470
5	0.554	0.752	1.145	1.610	4.351	9.240	11.070	13.390	15.090	20.520
6	0.872	1.134	1.635	2.204	5.350	10.650	12.590	15.030	16.810	22.460
7	1.239	1.564	2.167	2.833	6.350	12.020	14.070	16.620	18.480	24.320
8	1.646	2.032	2.733	3.490	7.340	13.360	15.510	18.170	20.090	26.130
9	2.088	2.532	3.325	4.168	8.340	14.680	16.920	19.680	21.670	27.880
10	2.558	3.059	3.940	4.865	9.340	15.990	18.310	21.160	23.210	29.590
11	3.050	3.610	4.570	5.580	10.340	17.280	19.680	22.620	24.730	31.260
12	3.570	4.180	5.230	6.300	11.340	18.550	21.030	24.050	26.220	32.910
13	4.110	4.760	5.890	7.040	12.340	19.810	22.360	25.470	27.690	34.120
14	4.660	5.370	6.570	7.790	13.340	21.060	23.690	26.870	29.140	36.120
15	5.230	5.990	7.260	8.550	14.340	22.310	25.000	28.260	30.580	37.700
16	5.810	6.610	7.960	9.310	15.340	23.540	26.300	39.360	32.000	39.250
17	6.410	7.260	8.670	10.090	16.340	24.770	27.590	31.000	33.410	40.790
18	7.020	7.910	9.390	10.870	17.340	25.990	28.870	32.350	34.810	42.310
19	7.630	8.570	10.120	11.650	18.340	27.200	30.140	33.690	36.190	43.820
20	8.260	9.240	10.850	12.440	19.340	28.410	31.410	35.020	37.570	45.320
21	8.900	9.910	11.590	13.340	20.340	29.610	32.670	36.340	38.930	46.800
22	9.540	10.600	12.340	14.040	21.340	30.810	33.920	37.660	40.290	48.270
23	10.200	11.290	13.090	14.850	22.340	32.010	35.170	38.970	41.640	49.730
24	10.860	11.990	13.850	15.660	23.340	33.200	36.420	40.270	42.980	51.180
25	11.520	12.700	14.610	16.470	24.340	34.380	37.650	41.570	44.310	52.620
26	12.200	13.410	15.380	17.290	25.340	35.560	38.890	42.860	45.640	64.050
27	12.880	14.120	16.150	18.110	26.340	36.740	40.110	44.140	46.960	55.480
28	13.560	14.850	16.930	18.940	27.340	37.920	41.340	45.420	48.280	56.890
29	14.260	15.570	17.710	19.770	28.340	39.090	42.560	46.690	49.590	58.300
30	14.950	16.310	18.490	20.600	29.340	40.260	43.770	47.960	50.890	59.700
40	22.164	23.838	26.509	29.051	39.335	51.805	55.759	60.436	63.691	73.402
50	29.707	31.664	37.689	37.689	49.335	63.167	67.505	72.613	76.154	86.661
60	37.485	39.699	43.188	46.459	59.335	74.397	79.082	84.580	88.379	99.607
70	45.442	47.839	51.739	55.329	69.334	85.527	90.531	96.388	100.425	112.317
80	53.539	56.213	60.391	64.278	79.334	96.578	101.880	108.069	112.329	124.839
90	61.754	64.634	69.126	73.291	89.334	107.565	113.145	119.646	124.116	137.208
100	70.065	73.142	77.929	82.358	99.334	118.498	124.342	131.142	135.807	149.449

The Tanner k test

B.3

The Tanner *k* test can be used to show how the accident numbers at a site change relative to control data.

For a given site or group of similarly treated sites, let:

a = before accidents at site
b = after accidents at site
c = before accidents at control
d = after accidents at control

then:

$$k = \frac{b/a}{d/c}$$

or, if any of the frequencies are zero then ½ should be added to each, ie:

$$k = \frac{(b + \frac{1}{2}).(c + \frac{1}{2})}{(a + \frac{1}{2}).(c + \frac{1}{2})}$$

If $k < 1$ then there has been a *decrease* in accidents relative to the control;
if $k = 1$ then there has been *no change* relative to the control; and
if $k > 1$ then there has been an *increase* relative to the control.

The percentage change at the site is given by:–

$$(k\text{-}1) \times 100\%$$

Example

Let us assume that the table below gives the annual injury accident totals for a priority T-junction in a semi-urban area which had Stop signs on the minor road originally, but where a roundabout was installed three years ago. The control data used are accidents on all other priority junctions in the Authority over exactly the same 3-year before and 3-year after periods.

Injury accident totals in 3-year periods at treated site and controls

	Site	*Control*	*Total*
Before	20 (a)	418 (c)	438 (g)
After	6 (b)	388 (d)	394 (h)
Total	26 (e)	806 (f)	832 (n)

Using the notation and formula above,

$$k = \frac{6/20}{388/418} = 0.323$$

Therefore, as $k < 1$ there has been a decrease in accidents relative to the controls of:

$$(k - 1) \times 100\% = 67.7\%$$

The Chi-Squared test

B4

This test can be used to determine whether the change in accidents was produced by the treatment or whether this occurred by chance. This test thus determines whether the change is statistically significant. The test is based on a table showing both the observed values of a set of data (O) and the corresponding expected values (E). The chi-squared statistic is then given by:

$$\chi^2 = \sum_{i=1,k=1}^{n,m} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where O_{ij} is the observed value in column j, row i of the table
E_{ij} is the expected value in column j a, row i of the table
m is the number of columns
n is the number of rows

A chi-squared table (as on page B.2-3) is then used to look up this value which shows the probability that the 'expected' value and the 'observed' values are drawn from the same population. The number of degrees of freedom is also required and this is given by:

Degrees of freedom, υ = (n-1)(m-1).

For a site accident evaluation, where its accidents are compared in similar periods before and after treatment with a set of control sites for the same periods, we have a 2 by 2 contingency table (2 columns and 2 rows with degrees of freedom =1). For the test to be valid the value of any cell of the table should not ideally be less than 5. However, when testing an individual site for accidents then this situation can, of course, be quite common and so a slight modification (known as Yates' correction) is normally applied.

Example
Consider the same example as given in Appendix B3:

Injury accident totals in 3-year periods at treated site and controls

	Site	*Control*	*Total*
Before	20 (a)	418 (c)	438 (g)
After	6 (b)	388 (d)	394 (h)
Total	26 (e)	806 (f)	832 (n)

For such a 2x2 table, a special simplified formula can be used for chi-squared which, using the notation from the above table, is:

$$\chi^2 = \frac{\left(|ad - bc| - \frac{n}{2}\right)^2 .n}{efgh}$$

Its value is then compared with values in the Chi-squared table (page B-7) with degrees of freedom, $\upsilon = 1$, and if it is just greater than a particular value it is said to be statistically significant at at least that percentage level.

$$\chi^2 = \frac{\left(|\,20 \times 388 - 6 \times 418\,| - \frac{832}{2}\right)^2 \times 83}{26 \times 806 \times 438 \times 394}$$

$$\chi^2 = 5.38$$

Now looking at the chi-squared distribution table (page B-7) and the first line (one degree of freedom, υ =1), the value for chi-square of 5.38 lies between 3.84 and 5.41. This corresponds to a value of significance level (on the column header line) between 0.05 and 0.02, which is normally quoted as greater than the lower level, ie. better than the 5% level of significance.

This means that there is only a 5% likelihood (or 1 in 20 chance) that the change in accidents is due to random fluctuation. Another way of stating this is that there is a 95% (100%-5%) confidence that a real change in accidents has occurred at the junction.

The 5% level or better is widely accepted as the level in which the remedial action has certainly worked, though the 10% level can be regarded as an indication of an effect.

For groups of sites that have been given the same treatment, these can be grouped together and analysed using the chi-squared test as for a single site. This will enable the overall benefit to be evaluated, and any specific sites can be analysed separately.

Test for statistical significance between two proportions

B.5

This test is used to determine whether proportions (of accident types, or of any other characteristic) in a study area are significantly different from the proportion in a control area. The null-hypothesis tested is that the proportion from the sample is the same as the proportion from the control, and the test tells us if we can reject this hypothesis.

There are two situations to consider, firstly where the study area is not contained within the control area and secondly where it is within the control area.

Suppose that we are interested in the proportion of all accidents area that involve serious injury within a study as compared to a control area. We test the hypothesis that the proportions are the same. If the number of all accidents in the study area is n_s and in the control area is n_c, and we observe m_s serious accidents in the study area and m_c in the control area, then:

1. Study area not within control area

The proportion in the *Study* area is given by: $p_s = m_s / n_s$,
and the proportion in the *Control* area by: $p_c = m_c / n_c$
and the overall proportion in the *Total* area (both study and control areas) by:

$$p = (m_s + m_c) / (n_s + n_c)$$

The test statistic '**t**' is calculated by: $\mathbf{t} = (p_s - p_c) / (p(1\text{-}p) (1/n_s + 1/n_c))^{1/2}$

with $(n_s + n_c - 2)$ degrees of freedom. If the degrees of freedom are greater than 120, and **t** is greater than 1.96 then we can be 95% sure that the two proportions are from different populations.

2. Study area within control area

Suppose the study area is a local authority area and national data are being used as a control. Then, for the purposes of this test, the *Study* accidents need to be excluded from the *Control* and the numbers of accidents in the *Control* area is calculated as 'the *Total* (national) accidents – *Study* accidents'.

The proportion in the *Study* area is given by: $p_s = m_s / n_s$

and the proportion in the *Control* area by: $p_c = (m_c - m_s) / (n_c - n_s)$

and the overall proportion in the *Total* area by: $p = m_c / n_c$

The test statistic '**t**' is calculated by: **t** = $(p_s - p_c) / (p(1\text{-}p) (1/n_s + 1/(n_c - n_s)))^{1/2}$

with $(n_c - 2)$ degrees of freedom. If the degrees of freedom are greater than 120, and **t** is greater than 1.96 then we can be 95% sure that the two proportions are from different populations. (If n_c is large compared to n_s, then we can ignore the fact that the study area is within the national area and use method 1).

Example

Suppose that we are interested in whether the proportion of accidents at rural junctions in the study area is different from the proportion nationally. Then consider the following (fictitious) data:

	Rural junction accidents	*All Rural accidents*	*Proportion at junctions*
Total accidents nationally	32,000	80,000	0.400
Study area	3200	7750	0.4129

Since rural junction accidents are included within all rural accidents, approach 2 is the appropriate test. The null-hypothesis is that the proportion of rural accidents that are at junctions in the study area is the same as the proportion of accidents elsewhere in the country that are at junctions.

The proportion in the *Study* area is given by: p_s = 3200/7750=0.4129
and the proportion in the *Control* area by: p_c = (32,000-3200)/(80,000-7750)=0.3986
and the overall proportion in the *Total* area by: p = 32,000/80,000=0.400

The test statistic '**t**' is calculated by:

$$\mathbf{t} = (0.4129-0.3986)/(0.4*(1-0.4)*(1/7750+1/(80,000-7750)))^{1/2}$$
$$= 2.44$$

with (80,000-2) i.e. 79,998 degrees of freedom

So since the number of degrees of freedom is greater than 120 and **t** is greater than 1.96, we can be at least 95% sure that the proportion of accidents at junctions in our rural study area is greater than the proportion at junctions on other rural roads. Therefore we would recommend that further investigations are carried out to try and explain this result (see Barker et al (1999) for a more detailed explanation of how to interpret the result).

Regression-to-the-mean correction

B.6

To correct for the regression-to-the-mean effect it is necessary to estimate the true underlying accident rate. Several statisticians have proposed ways of doing this, eg. Hauer (1992) extended the Empirical Bayes' model to estimate the true underlying accident rate and then based the evaluation on this rather than the raw data. However, an approach that is simpler to apply for a single site was described by Abbess et al (1981), in which they adjusted the data to correct for biases using assumptions about the distribution of accidents over a period of years.

Accident data must be gathered for similar sites to the treated site over the same time period: the control sites. Using this full dataset the mean number of accidents, *a*, and the variance of accidents *var* (*a*) are calculated. The regression-to-the-mean effect, R (in per cent) was shown to be given by the following formula:

$$R = \left(\frac{(A_t + A)\, n}{(n_t + n) A} - 1 \right) .100$$

where A = the number of accidents at the site over a period of n years

$$A_t = \frac{a^2}{(var(a) - a)}$$

$$n_t = \frac{a}{(var(a) - a)}$$

A_t and n_t are the estimates of the parameters of the statistical distribution showing the true underlying accident rates, ie. the probability distribution of the accident rate before any data are available. The main assumption is, therefore, that the study site with a particular accident history will behave in the same way as the set of all similar sites with the same accident history.

Example

Let us consider a junction, which has had an average of 15 accidents per year over the past 5 years. The site was widened, large new junction signing, splitter islands and STOP signs installed, after which the site has averaged 10 accidents per year over a similar period.

To correct for the regression-to-mean effect, we need to select similar uncontrolled junction sites with similar traffic flows. If all these sites have produced a mean, *a*, of 12.6 accidents per year with a variance, *var(a)*, of 2.91, then using the equation above, the input values are:

$n = 5$ (years)
$A = 75$ (accidents)
$A_t = 12.62 / (2.91 - 12.6) = -16.38$
$n_t = 12.6 / (2.91 - 12.6) = -1.3$

Thus the Regression effect:-

$$R = \left(\frac{(-16.38 + 75)5}{(-1.3 + 5)75} - 1 \right).100$$

$$= 5.2\%$$

That is, during the after period we would expect that if nothing were done to the site, the accidents would reduce by 5.2 per cent, or to 14.25 accidents per year. Thus it is the figure of 14.25 accidents per year that should be compared with the 10 accidents per year that actually occurred to determine whether the reduction in accident frequency due to the improvements is statistically significant.

Appendix C

County Surveyors' Society & Highways Agency
Monitoring Of Local Authority Safety Schemes (MOLASSES)

DATA INPUT FORM FOR ROAD SAFETY ENGINEERING SCHEMES

This form is intended for passing information to the MOLASSES database about the effectiveness of engineering safety schemes. The MOLASSES database was set up for Local Authority safety schemes but has now been expanded to include Highways Agency schemes, thereby increasing the size of the database and its range of activity.

For a Highways Agency Scheme to be included in the database it must be predominantly a safety scheme and cost under £1 million, but this figure should exclude any secondary work, such as moving services etc, or traffic management costs. **It is the responsibility of the Agents, not the Route Manager, to submit the data.** The aims of the MOLASSES project are:

- to assess the effectiveness of different treatments in relation to specific accident problems;
- to give individual authorities a better idea of the effectiveness of different types of schemes;
- wherever possible, to provide information in response to specific enquiries from authorities.

This form indicates the type of information that is collected on each scheme. Ideally, we would like as much information as possible but, for a scheme to be included in MOLASSES, the basic information requirements are;

- Total 'before'/'after' accidents with dates of monitoring periods. If you have less than 3 years 'after' data leave Sections 6.8 to 6.13 blank. We will ask you to provide 'after' data 3 years after the completion of a scheme, when an appropriate form will be sent to you.
- A brief description of the type of scheme.
- Its location by grid references and/or junction names,
  - for link/route scheme(s) – length of scheme(s) in metres,
  - for area-wide scheme(s) – area covered by grid references.
- Its cost.
- Your reference number, or similar identification method, for the scheme.

The form can be used to report the results for individual sites, or groups of sites. However, if the nature of the sites or the treatments vary, it is better to use separate forms for each one. You may wish to use these forms as a basis for your own records. If your safety scheme data is stored electronically, please get in touch with Ryszard Gorell at the address shown below; MOLASSES is very flexible and data can be accepted in a wide variety of formats.

Please note that information about your unsuccessful schemes is as important as information about the successful ones!

When forms are complete, please check carefully and return to:

Ryszard Gorell
Room C2024, TRL Limited
Old Wokingham Road
CROWTHORNE
Berkshire. RG45 6AU

Telephone: 01344 770636
Fax: 01344 770356
E-mail: rgorell@trl.co.uk

Thank you for your help.

Please turn over:

MOLASSES DATABASE INPUT FORM

Version 5 *TRL reference number (TRL use only):*

Section 1: Details of Agency Supplying Information

1.1 Name of person to contact: ____________________

1.2 Name of agency: ____________________

1.3 'Phone number of agency: ____________________

1.4 'Fax number of agency: ____________________

1.5 Address of agency: ____________________

____

____

____

1.6 Your reference number for this scheme/group of schemes:

____

1.7 Type of agency *(Please tick one box):*

1 DETR	☐	6 District Council	☐
2 Regional Council	☐	7 Borough Council	☐
3 County Council	☐	8 Private consultant	☐
4 London Borough	☐	9 TRLab	☐
5 Metropolitan District	☐	10 Agent *(please specify area)*	☐

0 Other (please specify) ____________________

Section 2: Type of Scheme(s)

Please answer all the following questions where relevant

2.1 Number of sites covered by this report: ____________________
(if not single site scheme)

2.2 Category of safety scheme or plan (please tick **one** box):

1 Single site scheme	☐
2 Group of individually tailored schemes	☐
3 Mass action plan, one treatment only	☐
4 Route action plan	☐
5 Area scheme	☐
6 Traffic calming scheme	☐
7 Other, please specify and complete all questions that appear relevant	☐

____

2.3. Existing site type (please tick **one** box):

	No of approaches 3	4	5+
Signal controlled jct	1 ☐	2 ☐	3 ☐
Priority junction	4 ☐	5 ☐	6 ☐
Conv roundabout	7 ☐	8 ☐	9 ☐
Mini-roundabout	10 ☐	11 ☐	12 ☐
Grade sep intersection	13 ☐	14 ☐	15 ☐

Pedestrian refuge	16 ☐	Zebra crossing	17 ☐
Pelican crossing	18 ☐	Traffic sig X phase	19 ☐
Cycle crossing	20 ☐	Bend	21 ☐
Other (please describe)	22 ☐	____________________	

Section 3: Location of Site(s)

3.1 Grid references (if available): ____________________

3.2 Route number(s): ____________________

3.3 Place name: ____________________

3.4 Further details of location (if necessary for identification):

____

Section 4: Site characteristics

4.1 Please estimate the following and tick box if appropriate:

(i) AADT (Average Annual Daily Total) veh flow		(ii) Pedestrian flows:	
1 Less than 5,000	☐	1 Very light	☐
2 5,000 to 9,999	☐	2 Light	☐
3 10,000 to 19,999	☐	3 Medium	☐
4 More than 19,999	☐	4 Heavy	☐

4.2 Is the site(s) in a built-up area?:
Yes/No *(delete as appropriate)*

4.3 Enter lowest speed limit on any part of the site(s) (mph):

____

4.4 Enter highest speed limit on any part of the site(s) (mph):–

____

Section 5: Treatment details

5.1 Please summarise your diagnosis of the problem:

____

____

5.2 Total works costs for all site(s): £ _______________

5.3 Source of funds *(tick box)*:

Highway Authority Revenue: Yes ☐ No ☐

If Yes, approximate percentage: ______________ %

Central Government Funding: Yes ☐ No ☐

If Yes, approximate percentage: ______________ %

Other: Yes ☐ No ☐

(please specify): __________________________

If Yes, approximate percentage: ______________ %

5.4 Please give a brief description of the treatment:

____

____

5.5 Please specify the type of accident(s) at which the treatment is aimed (TARGET accs)

Please tick all boxes that apply.

1 Vehicle/pedestrian conflict ☐
2 Cyclists ☐
3 Motorcyclists ☐
4 Overshoot ☐
5 Restart ☐
6 Shunt, both vehicles moving ☐
7 Shunt, both vehicles stationary ☐
8 Loss of control on a bend ☐
9 Loss of control not on a bend ☐
10 Overtaking ☐
11 Stopping ☐
12 Changing lane ☐
13 Turning right ☐
14 Turning left ☐
15 U-turn ☐
16 Excessive speed ☐
17 Other (please specify): ☐

____

5.6 Please tick the appropriate boxes to indicate the treatment(s) used in the scheme:

Examples of how to use these treatment codes:

Example 1: Addition of a separately signalled right turn at a set of signals would be coded as 1.2.5

Example 2: Introduction of road humps and new surfacing on a link would be coded as 7.1 and 7.6

Example 3: An area-wide scheme that included all the features described for link schemes would be coded as 9.0-9.9

Example 4: An area-wide scheme that included all the features described for link schemes, and general schemes, would be coded as 9.0-9.35

1 Signalised junction

1.1 New signals ☐
1.2 Modifications to signals ☐
1.2.1 Addition of ped phase/stage ☐
1.2.2 Mods to ped phase/stage ☐
1.2.3 Addition of early cut-off ☐
1.2.4 Modification of early cut-off ☐
1.2.5 Separately signalled right turn ☐
1.2.6 Closely associated secondary signals ☐
1.2.7 Geometric improvement (inc refuges) ☐
1.2.8 Conspicuity improvement ☐
1.2.9 Timing/linkingimprovement ☐
1.2.10 Red light cameras ☐
1.2.11 Gantry signals ☐
1.2.12 Right turn ban ☐
1.2.13 Anti-skid surfaces ☐
1.0 Other (please specify) ☐

____

2 Roundabout

2.1	New conventional roundabout	☐
2.2	New mini-roundabout	☐
2.3	Modifications to conv rdbt	☐
2.3.1	Entry geometry	☐
2.3.2	Circulatory geometry	☐
2.3.3	Exit geometry	☐
2.3.4	Signing	☐
2.3.5	Visibility	☐
2.3.6	Yellow bar markings	☐
2.3.7	Signalise	☐
2.3.8	Anti-skid surfaces	☐
2.3.0	Other *(please specify)*	☐

2.4	Modifications to mini-roundabout	☐
2.4.1	Entry geometry	☐
2.4.2	Circulatory geometry	☐
2.4.3	Exit geometry	☐
2.4.4	Signing	☐
2.4.5	Visibility	☐
2.4.6	Yellow bar markings	☐
2.4.7	Signalise	☐
2.4.8	Anti-skid surfaces	☐
2.4.0	Other *(please specify)*	☐

3 Priority junction

3.1	Geometric improvement	☐
3.1.1	Right turn ban	☐
3.2	Central refuges in side-road	☐
3.3	Visibility	☐
3.4	Signing	☐
3.5	Road markings	☐
3.6	Anti-skid surfaces	☐
3.0	Other (please specify)	☐

4 Bend

4.1	Re-alignment	☐
4.2	Visibility	☐
4.3	Safety fence	☐
4.4	Signing	☐
4.5	Kerbing	☐
4.6	Anti-skid surfaces	☐
4.7	Speed camera technology	☐
4.0	Other *(please specify)*	☐

5 Pedestrian facility

5.1	New zebra	☐
5.2	New pelican	☐
5.3	Modifications to zebra	☐
5.3.1	Conspicuity	☐
5.3.2	Relocation	☐
5.3.3	Safety barriers	☐
5.4	Modifications to pelican	☐
5.4.1	Conspicuity	☐
5.4.2	Relocation	☐
5. 4.3	Safety barriers	☐
5.4.4	Signal linking	☐
5.4.5	Split pelican	☐
5.5	Pedestrian refuges	☐
5.6	Promontory	☐
5.7	New puffin	☐
5.8	Anti-skid surfaces	☐
5.0	Other *(please specify)*	☐

6 Cycle schemes

7 Link calming

7.1	Road humps	☐
7.2	Chicanes – 1 way working	☐
7.2.1	Chicanes – 2 way working	☐
7.3	Plateaux	☐
7.4	Four-way give-way	☐
7.5	Gateways	☐
7.6	Surfacing	☐
7.7	Sheltered parking	☐
7.8	Throttles/narrowings	☐
7.9	Rumble strips	☐
7.10	Thumps	☐
7.11	Cushions	☐
7.0	Other *(please specify)*	☐

Link general

7.20	Carriageway markings	☐
7.21	Surfacing	☐
7.22	Signing	☐
7.23	Signs and markings	☐
7.25	Other Traffic Regulation Orders	☐
7.26	New lighting	☐
7.27	Improved lighting	☐
7.28	Publicity	☐
7.29	Drainage	☐
7.30	Central reservation barrier	☐
7.31	Anti-skid surfaces	☐
7.32	Speed camera technology	☐
7.33	Speed limits	☐
7.34	Island channelisation	☐
7.35	Safety fencing	☐
7.99	Other *(please specify)*	☐

8 Route calming

8.1	Road humps	☐
8.2	Chicanes – 1 way working	☐
8.2.1	Chicanes - 2 way working	☐
8.3	Plateaux	☐
8.4	Four-way give-way	☐
8.5	Gateways	☐
8.6	Surfacing	☐
8.7	Sheltered parking	☐
8.8	Throttles/narrowings	☐
8.9	Rumble strips	☐
8.10	Thumps	☐
8.11	Cushions	☐
8.0	Other *(please specify)*	☐

Route, general

8.20	Carriageway markings	☐
8.21	Surfacing	☐
8.22	Signing	☐
8.23	Signs and markings	☐
8.24	Parking restrictions	☐
8.25	Other Traffic Regulation Orders	☐
8.26	New lighting	☐
8.27	Improved lighting	☐
8.28	Publicity	☐
8.29	Drainage	☐
8.30	Central reservation barrier	☐
8.31	Anti-skid surfaces	☐
8.32	Speed camera technology	☐
8.33	Speed limits	☐
8.34	Island channelisation	☐
8.35	Safety fencing	☐
8.99	Other (please specify)	☐

9 Area-wide traffic calming

9.1	Road humps	☐
9.2	Chicanes – 1 way working	☐
9.2.1	Chicanes – 2 way working	☐
9.3	Plateaux	☐
9.4	Four-way give-way	☐
9.5	Gateways	☐
9.6	Surfacing	☐
9.7	Sheltered parking	☐
9.8	Throttles/narrowings	☐
9.9	Rumble strips	☐
9.10	Thumps	☐
9.11	Cushions	☐
9.0	Other *(please specify)*	☐

Area-wide general

9.20	Carriageway markings	☐
9.21	Surfacing	☐
9.22	Signing	☐
9.23	Signs and markings	☐
9.24	Parking restrictions	☐
9.25	OtherTraffic Regulation Orders	☐
9.26	New lighting	☐
9.27	Improved lighting	☐
9.28	Publicity	☐
9.29	Drainage	☐
9.30	Central reservation barrier	☐
9.31	Anti-skid surfaces	☐
9.32	Speed camera technology	☐
9.33	Speed limits	☐
9.34	Island channelisation	☐
9.35	Safety fencing	☐
9.99	Other *(please specify)*	☐

Section 6: Evaluation of effectiveness:

6.1 "Before" period start date:

6.2 "Before" period end date:

6.3 Date of completion :

6.4 "After" period start date:

6.5 "After" period end date :

6.6 Total "before" accidents for all sites covered by this report:

6.7 Total "before" TARGET accidents (ie; the particular accidents at which the treatment is aimed. Please use the appropriate numbers from Question 5.5 if possible), if known:

6.8 Total "after" accidents for all sites covered by this report:

6.9 Total "after" TARGET accidents:

6.10 Apparent overall percentage change in accidents,ie: ((average annual after/average annual before)x100)-100%

6.11 How would you rate the effectiveness of the scheme on a scale from 1, very effective, to 5, not at all effective? *(please circle the appropriate number)*:

1 2 3 4 5

6.12 Please give any brief general appraisal of the effectiveness of the scheme(s), drawing attention to any difficulties it would be helpful to warn others about (continue on a separate sheet if necessary):

Section 7: Additional comments:

We would be interested to know about additional comments you may have, please put them here (continue on a separate sheet if necessary):

Department for Transport

Product code 01PRSD0457