TOWARDS SAFER ROADS IN DEVELOPING COUNTRIES

A Guide for Planners and Engineers

TRANSPORT RESEARCH LABORATORY

OVERSEAS DEVELOPMENT ADMINISTRATION

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Abbreviations and Acronyms

AADT	***Annual Average Daily Traffic***
ADB	***Asian Development Bank***
CBD	***Central Business District***
EAN	***Equivalent Accident Number***
GNP	***Gross National Product***
HGV	***Heavy Goods Vehicle***
HMSO	***Her Majesty's Stationary Office***
IBRD	***International Bank of Reconstruction and Development (World Bank)***
MAAP	***Microcomputer Accident Analysis Package***
NRSC	***National Road Safety Council***
ODA	***Overseas Development Administration***
OECD	***Organisation for Economic Cooperation and Development***
PRSC	***Provincial Road Safety Council***
PSV	***Public Service Vehicle***
RoSPA	***Royal Society for the Prevention of Accidents***
SCRIM	***Sideways Force Coefficient Routine Investigation and Measurement***
SMV	***Slow Moving Vehicle***
TRL	***Transport Research Laboratory***
UK	***United Kingdom***
UN	***United Nations***
UNDP	***United Nations Development Programme***
USA	***United States of America***
WHO	***World Health Organisation***

PREFACE

(a) Scope and Philosophy of Approach

This document outlines the different stages involved in planning and designing road networks and introduces safety conscious design principles so that professionals and decision-makers in developing countries can be given some practical guidance on how to make their road networks safer. Guidance on "Accident Prevention" is given by highlighting the key, safety-related factors which need to be incorporated when planning, designing and operating road networks. Advice is also given on "Accident Reduction" by showing how hazardous locations can be analysed and what types of countermeasures can be used to reduce accidents at such locations.

This Guide draws heavily upon existing geometric and traffic engineering design practices in a number of developing and developed countries. The main reference documents used in preparing the Guide are listed in Appendix A. Extracts have been taken freely from such documents and, where necessary, these have been amended and modified for application in developing countries. Due acknowledgement has been given where substantial portions of text or diagrams were adapted for use in this document but the authors also acknowledge a debt of gratitude to the many other publications consulted during the preparation process.

The document is intended only to highlight the key elements of planning. design and operation of road networks which influence road safety. It is based in part, on the experiences and standards in use in the developed countries and, in part, on the extensive practical experience of a very large number of professionals with direct experience of working and living in developing countries. The Guide does not, therefore, rigorously follow the design standards of the industrialised countries. It draws heavily upon the accumulated knowledge and expertise of professionals with direct practical experience of working on road or traffic related projects in the developing world.

(b) Aims

The general aim of this Guide is the promotion of safer road planning and design practices in developing countries. The specific objectives of the Guide are:

(i) to bring safety to the forefront of the minds of planners and engineers practising in developing countries and to bring to their attention important details of design affecting road safety that they might otherwise overlook or consider insignificant;

(ii) to act as an introduction for policy-makers in developing countries and aid agencies to the wide range of issues in highway planning and design that can affect road accident rates and the mitigating actions which can be taken to reduce the number and severity of road accidents;

(iii) to bring together in a single document the joint experience of the Overseas Unit, TRL and those UK consultants who have had significant developing country experience in road safety and traffic engineering, together with relevant material from standards, guidelines and design guides of developed countries to act as a first source of information for professionals in developing countries;

(iv) to act as a source of ideas for new designs and countermeasures so that hazardous locations in developing countries can be made safer; and

(v) to stimulate evaluation of and research into road safety countermeasures in developing countries so that the most effective can be identified.

(c) The Need for Guidance and Advice

Since almost all countries of the developing world suffer from lack of financial resources it is essential that the scarce resources which are available are not wasted. Many countries also suffer from absence of adequate technical resources and expertise to ensure that only safe roads are built. The absence of systematic checking of the road safety Implications on new or rehabilitated road networks may be worsening the situation in many countries by increasing the incidence of unsafe roads because additional specific safeguards to overcome the types of operational deficiencies, common in developing countries, are rarely incorporated into the design processes.

Often, too few trained professionals are available. There are often gaps in knowledge and they may not always be familiar with recent developments and techniques. Consequently, there is a need to amalgamate and distil the collective knowledge and experience of the industrialised countries and, particularly, of individuals with extensive experience of working in developing countries to create an easily accessible source of reference and advice on how to overcome existing problems and how to avoid future road safety problems.

(d) Potential Users

This document is intended for use by engineers, planners, traffic police officers and other professionals responsible for road networks in developing countries. It can also act as a basic source of reference for politicians, aid agency officials and other decision-makers so that they are at least familiar with the key elements and constraints relating to the planning, design and operation of highways. Many roads in developing countries would not be built without Aid funding so aid agencies have a particularly heavy responsibility to ensure that such aid-funded roads incorporate the basic safety features outlined in this document. The main principles are summarised and encapsulated in the road safety checklists which are included as Chapter 7.

(e) Structure and Contents

This document consists of a number of parts each containing one or more chapters, followed by a number of Appendices. The Guide is arranged as follows.

PREFACE

The Preface provides a brief guide to the scope and use of the document and discusses its main aims, potential users and structure.

PART I: Introduction (Chapters 1 and 2)

This includes an introduction to the scale and nature of the road safety problem in developing countries. After discussing present practices in developed and developing countries it indicates the lessons which may be learned from the experiences of developed countries. This section then discusses the inter-relationships affecting road safety and the institutional arrangements necessary if the problem is to be tackled effectively in the developing world.

PART II: Planning and Design (Chapters 3 and 4)

This section discusses how accident prevention can be achieved through better planning and design of roads in developing countries. It gives practical advice to planners, engineers and policy-makers on the key elements influencing road safety at each stage of the development cycle. Considerable freedom exists when planning and designing new roads and it may be possible to introduce significant improvements in road safety terms at minimal cost if such issues are given sufficient attention at an early stage.

PART III: Operations and Countermeasures (Chapters 5 and 6)

This section provides advice on accident reduction on existing roads and how this can be achieved through better operation of roads and implementation of low cost countermeasures at locations where abnormally high numbers of accidents occur (i.e. accident blackspots). It includes specific examples of countermeasures and indicates the approaches which may be most suitable for application in the developing world. Such countermeasures are applied to existing roads and consequently normally only involve minimal changes to the basic structure or alignment.

PART IV: Road Safety Checklists (Chapter 7)

This section presents basic checklists which can be used to verity that safety has been properly taken into account in the planning and design of existing or proposed road infrastructure. It is intended to reduce the chances of unsafe road networks being constructed.

PART V: (Appendices A to C)

This section comprises the Appendices. These include a list of main references and guidance on where to get them, information on other useful background documents and brief details about the TRL microcomputer-based accident data system for developing countries.

(f) Sources of further in formation

The key publications listed in Appendix A are those which the authors consider to be most relevant to readers' likely needs and which provide additional information about many of the topics included here. Many of these publications may not be readily accessible to overseas readers so a list of the organisations producing them is given in Appendix A. Some of the publications are free but others require payment. Documents can be ordered by mail through reputable technical bookshops or from the addresses listed. The listing of useful UK documents provides an additional list of potentially relevant documents which may be of interest to individual readers seeking specific areas of knowledge or information. These are the main road safety related advice notes and guidelines issued to British road engineers by central government in the UK

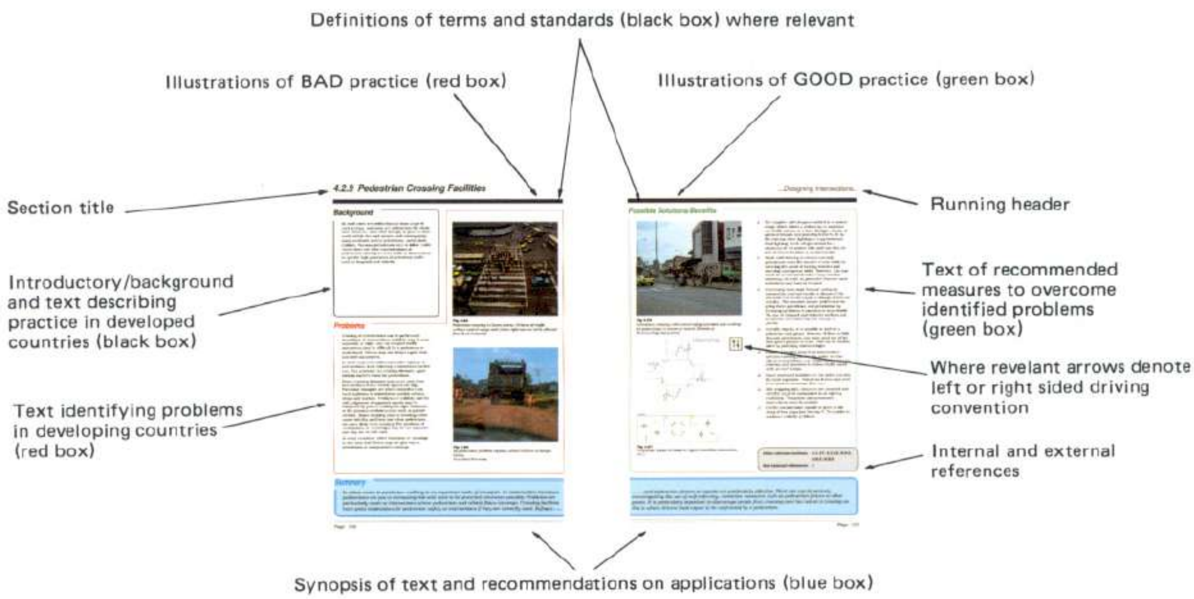
(g) Guidance on Use of Document

The document has been written as a number of free-standing sections which have been internally cross-referenced. It also has a comprehensive index. Those interested in a particular topic, e.g. road hierarchy, can refer to that particular section and can find all the key elements and internal and external references which need to be considered when examining that particular issue (internal references direct the reader to other relevant sections within this document and external references direct the reader to documents listed in Appendix A). Those interested in topics which do not merit a whole free-standing section can use the index to locate relevant sections of text. In this way the reader can readily find specific guidance/information on the areas of direct interest to him without necessarily reading through the whole document to get relevant information. It is, however, recommended that the document is read through cover to cover at least once so that the reader becomes familiar with the contents and their location. Thereafter the document can be used largely as a reference book for specific advice/information as required.

Chapters comprise a short introductory overview, followed by a series of 2-page sections describing key elements of planning, design or operation. wherever possible, a standard format of presentation has been adopted for such sections. This is shown diagrammatically below.

As a consequence of the desire to have self-standing sections for easy access by the reader, a certain amount of repetition/duplication becomes unavoidable on topics which are closely related. The benefits from the format adopted are, however, considered to outweigh this minor disbenefit.

Road safety checklists have been provided as a free-standing chapter These are to be used to check that proposed infrastructure schemes do not inadvertently include dangerous features which could be avoided through better planning or design. If the answer to any of the questions in the checklist is no, the reader is referred to the relevant sections for further information on how road safety deficiencies can be rectified or minimised.



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PART I

INTRODUCTION AND BACKGROUND

1. ROAD SAFETY PROBLEMS IN DEVELOPING COUNTRIES

1.1 Scale and Nature of the Problem

It has been estimated that over 300,000 persons die and 10-15 million persons are injured every single year in road accidents throughout the world. Detailed analyses of global accident statistics by the UK Transport Research Laboratory (TRL) and others indicate that fatality rates per licensed vehicle in developing countries are very high in comparison with the industrialised countries. Fatality rates (with respect to vehicle numbers) in the developing world, particularly in African countries, can often be 20 to 30 times as high as those in European countries (Figure 1.01).

Furthermore, whereas the situation in most industrialised countries appears to be improving (in terms of actual numbers of persons killed as well as the accident rates), many developing countries have, in recent years, faced a worsening situation. An indication of the growth of road accident deaths in developing countries can be seen from Figure 1.02 which shows the percentage change in deaths over the 17 year period 1968-1985 in a number of African and Asian countries and also a group of developed countries. Between 1968 and 1985 the number of deaths increased by over 300% in African countries and by over 170% in Asian

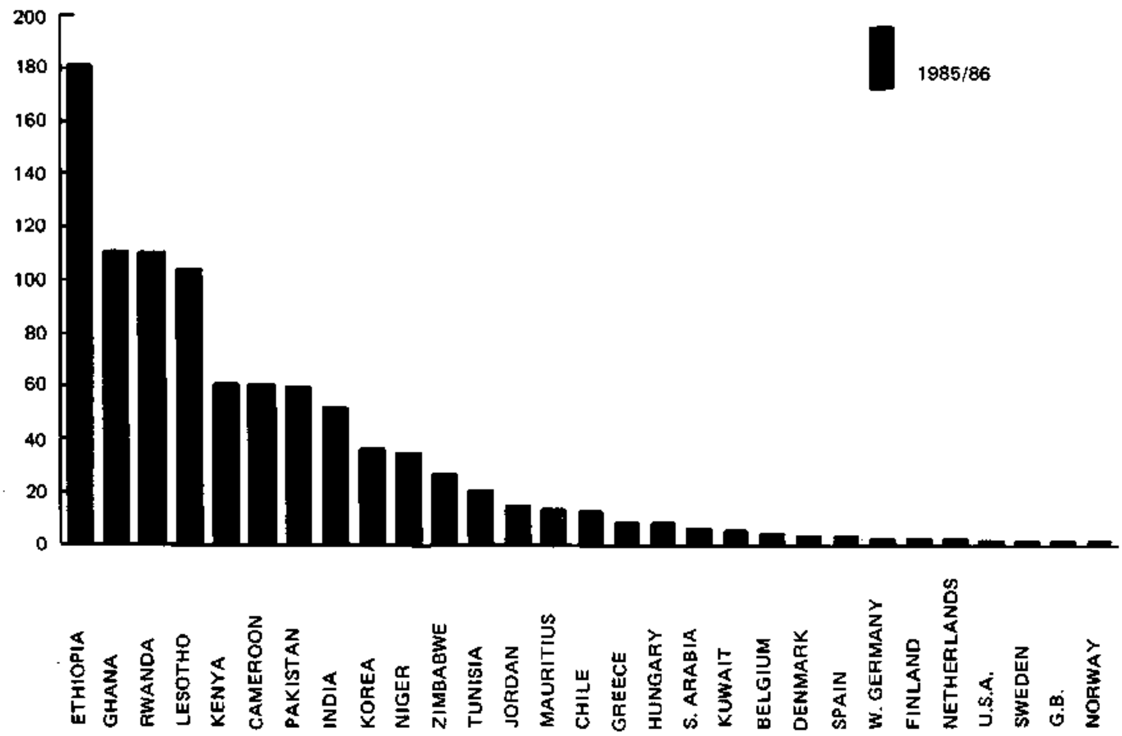


Fig 1.01
Road accident fatalities (deaths per 10,000 vehicles) in selected countries, 1985/86

countries. Conversely, in the developed countries over the same period, the number of persons killed actually declined by 25%.

Road accidents have been shown to cost around one per cent of these countries' annual gross national product (GNP) - resources which they can ill afford to lose. Since, in many cases, replacement vehicle parts, medicines and hospital equipment all have to be imported to such countries, these losses to the economy can often include a significant foreign exchange element.

Studies by the TRL Overseas Unit in collaboration with the World Health Organisation also show that road accidents rank surprisingly high as a cause of death in developing countries. For the 5-44 year age group, road accidents are commonly the second highest cause of early death. Improving health care and gradual reductions in the traditional infectious diseases have resulted in road accidents becoming increasingly more important as a cause of death and they now represent a growing public health problem in the developing world.

The nature of the problem in developing countries is, in many instances, very different from that found in industrialised countries. For example, the proportions of commercial and public service vehicles involved are often much greater. In Indian cities buses are involved in around 25 per cent of all injury accidents while the equivalent figure for Britain is under four per cent. Commercial vehicle occupants in Kenya contribute to 16 per cent of all road accident casualties while the equivalent figure for most developed countries is under five per cent. Pedestrians, cyclists and slow-moving vehicles are often not well catered for and pedestrians, in particular, are often exposed to unnecessary dangers. Not surprisingly, they often constitute the road user group appearing most frequently amongst those injured and killed in road accidents.

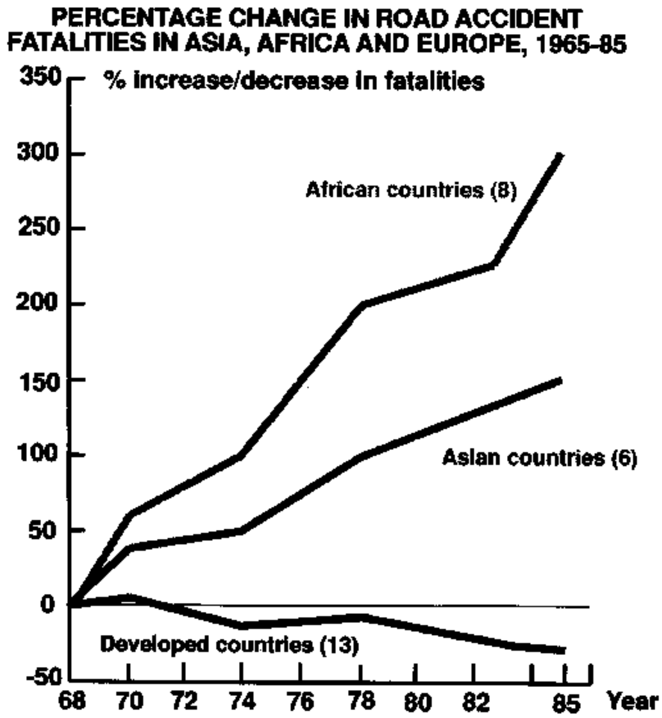


Fig 1.02
Percentage change in road accident fatalities in Asia, Africa and developed countries 1968-85

1.2 Road Safety and Highway Design Practices in Developing Countries

Growth in urbanisation and in the numbers of vehicles in many developing countries has led to increased traffic congestion in urban centres and increases in traffic accidents on road networks which were never designed for The volumes and types of traffic which They are now required to carry. In addition, unplanned urban growth has led to incompatible land-uses, with high levels of pedestrian/vehicle conflicts. The drift from rural areas to urban centres often results in large numbers of new urban residents unused to such high traffic levels. As a result, There has often been a severe deterioration in driving conditions and a significant increase in the hazards to and competition between different classes of road users of the road system. In addition, The inherent dangers have often been made worse by poor road maintenance, badly designed intersections and inadequate provision for pedestrians. All of these have contributed to the serious road safety problems now commonly found in developing countries.

Highway design standards in many developing countries tend to be either outdated (often dating to colonial times) and no longer relevant, or else simply too direct a translation from overseas without appropriate modification for The particular needs of the developing country. The standards usually ignore pedestrians, other non-motorised traffic and motor cycles. Unfortunately, such standards may often be too high, costly or require excessive maintenance for The countries to afford. In such circumstances, The emphasis tends to focus upon the constructional rather than the operational aspects. Engineers will typically concentrate on construction details of drainage, for example, rather Than on how the type of drainage channel chosen may affect road safety. Important operational elements such as road signs or pedestrian facilities are too often left for later addition "if and when time or money permits", while The builders move on to the next construction project. It is rare for the additional time and money ever to be found. As a result, road designs which would be safe in the operational environment of industrialised countries often become unsafe under the operational conditions which exist in developing countries. Little effort is made to modify designs or to add additional features to compensate for the operational deficiencies likely to occur in the developing world. Few efforts are made to quantity potential problems which are specific to developing countries. This is exemplified by The fact that the authors know of no major rural highway project in a developing country in which actual or potential pedestrian flows along The route have ever been formally surveyed - yet it is well known That in many developing countries such pedestrian flows can often be very high as The roadway also becomes the main footpath linking communities.

Even where such elements have been included, The shortages of trained professionals and the limited resources devoted to maintenance organisations often means That overgrown footpaths and damaged traffic control facilities such as road signs and traffic signals are often left unrepaired. Efforts should therefore be made from the planning stage to use solutions which require minimal maintenance (e.g. roundabouts instead of traffic signals). More generally the institutional developments necessary to ensure maintenance capability have usually not kept pace with road building. The result is that roads are often badly in need of maintenance, traffic signing is often inadequate, facilities for pedestrians are poor and guidance to drivers via channelisation or other control measures is rarely available. These general deficiencies in The operational and control aspects of The road systems are made worse by the fact that drivers are rarely adequately trained and tested, traffic law enforcement is ineffective and drivers' behaviour in respect of compliance with regulations is frequently very poor. The net result of these inadequacies is the very high incidence of road accident casualties and fatalities.

1.3 Lessons to be Learned from more industrialised Countries

The OECD countries (which includes all of the most industrialised countries) have achieved considerable success in tackling their road safety problems over the last 25-30 years. Although improvements were achieved through the application of road accident countermeasures in various sectors, one of the most consistently successful and cost-effective areas of investment has been the field of road planning and traffic engineering. Gradual elimination of the most hazardous locations on road networks and the adoption of safety-conscious approaches to the design and planning of new road networks have contributed greatly towards improving traffic safety. Even though the eventual solutions may differ, the approaches and systematic methods used in industrialised countries are readily applicable to the developing world.

In some respects developing countries are fortunate in that theft road networks are usually still at an early stage of development. They also have the added advantage of being able to draw upon the experience of the developed countries which have already passed through similar stages of development, albeit more slowly. Adoption of proven strategies from industrialised countries (such as 'accident blackspot elimination and more safety-conscious design and planning of road networks) offer unparalleled opportunities to make significant and lasting improvements to road safety. They should be given urgent consideration by responsible authorities. Sadly, many developing countries continue to repeat the mistakes of the industrialised countries, e.g. many still permit linear development with direct access from frontage properties along major roads even though this is known to lead to safety problems.

One thing that all industrialised countries have found to be of crucial importance in their efforts to improve safety is the availability of good, accurate and comprehensive accident data, so that the problem can be properly defined and suitable remedial measures devised. Consequently, before developing countries can emulate industrialised countries it is essential that good accident data systems are established.

In order to maximise the impact which engineering can have upon safety problems, it is necessary to apply measures at various stages in the development of road networks. By incorporating good design principles from the start it is possible to avoid many problems simply by planning and designing new roads in a safety-conscious manner. Even where this has not been done, it may still be possible (although more expensive) to improve existing roads by subsequent introduction of safety or environment-related measures, e.g. selective road closures or road humps to reduce speeds, or by prohibitions on heavy goods vehicles in residential areas.

Finally, it is possible to identity hazardous sections of the road network so that appropriate remedial measures can be undertaken to reduce the likelihood and severity of accidents at those locations. This has proven to be one of the most cost-effective ways of improving road safety in industrialised countries.

These methods offer scope to improve safety through their influence on driver behaviour, traffic speeds, route choices and so on. These approaches are discussed in depth in later sections of this document. However, there may be valid reasons (such as behavioural and traffic type differences) why methods which are proven to work well in industrialised countries may be less effective in a developing nation. Thus the need for evaluative research is stressed whenever new methods are introduced (see Section 6.5).

2. INSTITUTION FRAMEWORK

2.1 Inter-relationships between Land-use, Transport and Road Safety

Land-use and transport planning can have fundamental effects upon road safety, both in the short and long term. These not only create the conditions and environment for today's traffic but often impose the framework within which future traffic (which may be very much higher) has to operate. It is, therefore, essential to ensure that those involved are fully aware of the road safety consequences and implications of their proposals and that efforts are made to ensure that insensitive planning does not create additional road safety problems or hazards for future years.

In many developing countries, the absence of strong inter-agency relationships and linkages which are necessary to avoid road safety problems being created, together with poorly defined and fragmented responsibilities, often result in inefficient use of road space and transport resources. Professionals in different ministries often work independently of each other - despite the fact that their respective work impinges upon each others activities. Responsibilities in some areas may overlap or be duplicated while in other instances, there may be no organisation at all responsible.

Advertisers, developers and builders frequently appear unconstrained in placing advertising hoardings, accesses and even buildings very close to the road with little or no reference to those responsible for that road. Such hazards and the informal markets which also tend to spring up on sections of the road can cause road safety problems when traffic levels increase.

Land-use planning, traffic planning and operations require control and coordination, if they are to contribute to the development of safe transport systems. In the industrialised countries, efforts are made to achieve this through development control and by circulating planning proposals to other relevant departments for comment.

Unfortunately, in developing countries administrative procedures can be ponderous and time-consuming and there may be shortages of professionals with specialist skills. In such circumstances, it is important to clarify responsibilities between different agencies and to establish clear cut lines of responsibility between central and local agencies. In smaller countries, it may even be necessary initially to concentrate resources in a central agency which can then provide advice to others. This may be particularly important where the local councils, who may not have adequate technical and planning expertise, serve as the only planning authority.

It is essential that land-use planners understand the traffic and safety implications of their proposals before schemes are finalised. This should be done by circulating the plans for comment to fellow professionals responsible for traffic and road safety (perhaps via a coordinating Traffic Committee). Planners should also use checklists (see Road Safety Checklists, Chapter 7) to ensure that there are no major aspects affecting road safety which have been missed inadvertently during the planning stages.

2.2 Interdependence between Enforcement, Environment and Education

In industrialised countries the multi-disciplinary nature of the problem is now accepted and a large number of organisations are involved in the efforts to improve road safety. Each takes the necessary actions within its respective area of responsibility. Police seek to influence drivers' behaviour through enforcement of traffic regulations, engineers try to create safer roads and educationalists try to train and inform road users about potential dangers on the road and on the ways to avoid them. Such efforts in developed countries are normally coordinated so that they can have maximum effect.

In developing countries, by contrast, road safety responsibilities are often more confused and fragmented and very little coordination occurs. Where a single agency is supposed to be responsible for improving road safety it may have little or no contact with the various other agencies which can influence the road safety situation and little or no powers of implementation in other fields. The problem can only be tackled effectively through coordinated action aimed at reducing the deficiencies in each of the main areas affecting road safety. Efforts should be made to get the key agencies to collaborate so that they reinforce each others' efforts.

Without enforcement many traffic schemes may become unworkable or unsafe but conversely, if those same traffic schemes are not designed to be as 'self enforcing' as possible (e.g. raised channelising islands at junctions to force drivers along particular paths) the enforcement demands may become too high and impossible to police. This will make the schemes unworkable and unsafe. Education, information and training can also play a role by teaching drivers better and safer road behaviour and informing them about the meanings of road signs and markings. If drivers are unaware of the meanings of road signs and markings, they are unlikely to obey them. Conversely, if there is no guidance to drivers through road markings, signs or traffic islands it may be more difficult or even dangerous for them to carry out the required manoeuvres and the police may find it more difficult to enforce them. Whilst a better road environment will not guarantee safe behaviour, it is even less likely to occur if inadequate guidance and information is available to the driver and if the road itself is not designed to minimise risks of accidents to road users (e.g. through channelisation).

Consequently, very strong inter-relationships exist between enforcement, environment and education. Although deficiencies in one can sometimes be compensated for by additional strengthening of the others, the general aim should be to have each contributing fully to the improvement of road safety. This will require appropriate institutional arrangements to be made, as discussed below.

2.3 Institutional Arrangements

For road safety matters to be dealt with efficiently and effectively it is necessary for there to be adequate funds and organisations capable of carrying out and coordinating such activities so that the impact of individual efforts is maximised. Hence road safety should, wherever feasible, have its own protected budgets. In the engineering area, for example, this could be tree to five per cent of the roads budget. This would ensure that there is no delay or interference in implementing urgently needed road safety improvements and would allow establishment of procedures for consultation and for checking proposed schemes to ensure that they will not be unsafe.

In some of the more industrialised countries, road safety activity is encouraged by having statutory responsibility placed upon each highway authority to improve road safety on its road network, by having a specialist traffic police force and by having continuous road safety publicity/propaganda campaigns and activities undertaken by full-time road safety officers (sometimes employed by the highway authority). Coordination can be done by having traffic committees at local level to discuss all new proposals so that all key parties have an opportunity to consider the implications and problems from theft own point of view.

Experience in other countries indicates that to improve road safety in particular, it is often beneficial to have a National Road Safety Council (NRSC) to coordinate and promote road safety matters nationally and Provincial Road Safety Committees (PRSC) to carry out similar activities at a local level. All key government and relevant non-government organisations should be represented on the NRSC and members should meet regularly (e.g. every month) to discuss road safety activities. To be effective, such an NRSC requires its own small operating budget and a small (perhaps 2 or 3 persons) permanent secretariat to work full-time in following up and implementing decisions of the Council.

Typical areas where improvements may be needed in developing countries include:

- Accident data collection and analysis
- In Highway engineering improvements at accident blackspots
- In Vehicle testing/inspection
- In Driver training/testing
- In Traffic education of children
- In Publicity/propaganda
- In Traffic Police enforcement
- In Road safety research
- In Traffic and highway design standards
- In Emergency medical services
- In Road safety legislation

In recent years the World Bank and other aid agencies have recognised the importance of such activities and are now increasingly more willing to finance improvements and to assist governments to tackle theft road safety problems. Such improvements are normally undertaken as part of comprehensive road safety improvement programmes coordinated and perhaps even initiated by the Ministry responsible for road safety in a country. Advice on such comprehensive programmes is, however, outside the scope of this document which relates only to safer planning, design and operation of roads.

2.4 Areas of Influence for Engineers and Planners

Although, as earlier sections have shown, many organisations can influence road safety, engineers and planners play a particularly important role. They create the road network and road environment which present and future road users have to use. They can thus have a fundamental influence on driver behaviour. By adjusting the design of the road and road networks to accommodate human characteristics and to be more "forgiving" if an error is made they can make major contributions to road safety. when confronted with a traffic system there are three basic problems which the engineer/planner has to resolve. These are:

(a) Competing demands for space between “moving” and “access” traffic

The first problem of competing demands for the available road space occurs because of the need to allow for faster, through traffic movement (movement function), while at the same time accommodating slower local traffic on the road network (access function). The techniques used can range from segregation of functions and parking controls (for through routes) to partial closures and the use of shared surfaces (for access roads). Engineers can reduce conflicts, particularly those between pedestrians and vehicles, by appropriate design of road networks so that roads intended primarily for movement (e.g. motorways and expressways) are designed for that purpose, while roads intended for access (e.g. residential roads) have an environment suited to that function.

(b) Accommodating human characteristics in system design

Drivers tend to overestimate their own ability and the capability of their vehicles to react in sufficient time to avoid problems (e.g. they often drive too close to vehicles in front). It must also be understood that drivers drive on "expectancy" and anything out of the ordinary must be clearly indicated whether it is roadworks or a sudden bend after a long straight section. Decision points must also be simplified and confusing, overcrowded signs avoided by splitting the information into two or more signs so as to simplify the driving task.

There are many characteristics of road design which influence drivers and one of the primary functions of traffic engineering is to impart information to the driver in a suitable format and in sufficient time for him to take the necessary action for safety. Road geometry and the many associated design variables, (such as width or alignment) all influence how and what road users see, so again the engineer is in a position to influence road users through appropriate design. Distant views and parallel features (kerbs, buildings, lamp columns etc) will tend to induce higher speeds than more random arrangements. Creating the appropriate environment can therefore provide the necessary perceptual cues to modify driver behaviour and have significant beneficial results, such as reduced vehicle speeds. In developed countries, this is now often done deliberately in residential areas (e.g. by decreasing road width, deliberately introducing sharp curves, building road humps or rumble strips). It is not, however, always possible to influence drivers sufficiently by design alone. Other measures also need to be applied and these can range from improving the information available to the driver (e.g. through delineation of the road ahead) so that he is given advance warning of hazards ahead, to the provision of "recovery zones" so that even if the driver makes an error of judgement, there are still possibilities for him to regain control before an accident occurs.

(c) Adjusting the traffic mix

Any measures which simplify the traffic situation will improve traffic safety. Consequently, the segregation of slow or vulnerable road users from faster vehicles will be beneficial and measures such as pedestrian only streets, cycle routes and pedestrian segregation, can all improve traffic safety. Prohibition of animal drawn vehicles from certain roads, exclusion of heavy goods vehicles or extraneous through traffic from residential areas, banning street traders at locations where they displace pedestrians from the footway, banning of rickshaw or trishaw parking at key junctions, provision of separate areas for trading and rickshaw parking, regulating taxi pick up/set down points, all help to reduce the diversity of traffic and hence aid traffic safety.

2.5 Opportunities for intervention to improve Road Safety

In order to tackle safety problems effectively via engineering, it is necessary to apply measures at various stages in the development of road networks. By incorporating good design principles from the start it is possible to avoid many problems simply by planning new roads in a safety-conscious manner; for example, widening through roads at T-junctions to permit protected turns. Furthermore, incorporation of safety features (e.g. channelisation or guardrails) during the design and construction phases can usually be undertaken at lower cost whilst roads are being built and can make the road environment more “forgiving”, when a driver makes an error.

Even where the opportunities to intercede at the planning and design stages have not been taken, it may still be possible (although more expensive) to anticipate future problems and to improve existing roads by the introduction of safety or environment related measures, such as road humps to reduce speeds or lorry gates to prohibit heavy goods vehicles from residential areas. It is also essential to identity hazardous sections of the existing road network so that appropriate remedial measures can be undertaken to reduce the likelihood and severity of accidents at those locations.

The opportunities for intervention by engineers and planners can be summarised as:

- Safety conscious planning of new road networks and new developments;
- Incorporation of safety features in the design of new roads;
- Improvement of safety aspects of existing roads to avoid future problems; and
- Improvement of known hazardous locations on the road network.

On any network, because of the historic development of road systems. all four approaches will be necessary and in use at any one time. They will need to be applied continuously because of the constant development of new solutions and approaches and the fact that the road networks and traffic using them are themselves in a constant state of development. This process can be termed "safety conscious planning, design and operation of roads" and is outlined below and described in detail in the remainder of this document. The balance of resources devoted to each will depend heavily upon local circumstances in terms of the types of problem, the availability of skilled staff and budgetary constraints.

2.6 Safety Conscious Planning, Design and Operation of the Road Network

Various road safety strategies and countermeasures have been used in developed countries at different stages of network development. This method of seeking to prevent road accidents has been termed by the authors safety conscious planning, design and operation of roads. The key features at each stage are summarised below.

Planning

…has a profound effect upon the level of road safety and can have a major impact upon pedestrian accidents in particular. Sensitive planning of residential areas and highway networks can ensure that trough traffic is rerouted to more suitable roads and that the right soft of environment is created for the road users likely to use each type of road. Guidance on how road network and development/land-use planning can influence road safety is given in Chapter 3.

Geometric design

…normally seeks to ensure uniformity of alignment and maximum levels of safety and comfort for drivers using the road, within given economic constraints. Compromises are inevitable to achieve an acceptable solution and not all objectives can be fully met. Often, however, it is possible to improve road safety characteristics markedly at little or no extra cost, provided the road safety implications of design features are considered at the design stage. Chapter 4 discusses the key safety related aspects which should be considered when detailed design of roads is being undertaken.

Traffic management

…of the network approaches have been developed in industrialised countries to tackle the problems of road safety and congestion on existing road networks. Although many of these traffic management measures are aimed primarily at reducing congestion or improving traffic circulation, there are often associated benefits in terms of general traffic safety. In addition, potential future problems can often be avoided through early application of such preventive measures. Guidance on how road safety can be improved by such measures on existing roads is given in Chapter 5.

Systematic identification and treatment of hazardous locations

…has proven to be successful in many countries. Although the countermeasures used may need to be different to reflect the differing social, cultural and economic circumstances of the country concerned, the systematic methods and techniques for identifying blackspots and analysing the problem are directly transferable to the developing world. Chapter 6 outlines the processes necessary to identity and analyse hazardous locations and provides some practical examples and guidance on the types of approaches and countermeasures which may be applicable.

Unfortunately, in developing countries, the road environment is often inadequate to guide the driver safely through the system and, in the past, roads were often constructed with little or no consideration given to the traffic safety implications of alternative solutions. Engineers and planners in developing countries now have considerable opportunities to intervene in improving road safety. Safety conscious planning, design and operation of the road network as advocated in this document offers them the means to do this.

PART II

ACCIDENT PREVENTION THROUGH BETTER PLANNING AND DESIGN OF ROADS

3. PLANNING ROAD NETWORKS

3.1 Introduction

Urban areas contain a complex interaction of land-uses and activities. Newer cities with strong planning controls may have fairly well defined residential, shopping or industrial areas. Elsewhere a great mix of land-uses may exist side-by-side, sometimes in conditions of extreme conflict. Different land-uses place differing demands upon the highway network. Therefore, it follows that any transportation policy or action must take account of land use patterns, economic and social activity and will depend on the physical, social and economic characteristics of a given area for success. Account must also be taken of the regional and national transport framework within which local plans must operate since travel in any given area will include some proportion of longer distance journeys.

This section examines how the careful planning of different types of roads and their environments can create safer conditions for all users whilst, at the same time, creating more efficient networks. Roads can be classified according to the function they serve. For example, arterial roads are the main strategic arteries for moving traffic between different parts of a country, region or city and these are fed by district collectors I distributors which are in turn fed by local collectors/distributors. These, in turn, serve as links to access roads. In urban areas the function of the road often depends largely upon its traffic volume and width. Hence the arterial roads are normally primary distributors and local distributors are normally 'collector' roads in urban areas (see Figure 3.1).

The safety aspects of networks and new proposals can be checked by submitting them to a safety audit, which is a systematic procedure for safety checking of proposed schemes (see Chapter 7). The features of most influence on road safety when planning networks are: road hierarchy, access control and land-use planning. The key safety principles associated with each of these are included in the following list.

Road hierarchy

- ❑ The roads in a network should be clearly categorised into those which are primarily for movement and those which are primarily for local access.
- ❑ There should be clear, unambiguous priority indicated at each intersection so that the traffic on the more important road is always given precedence over that from the less important road.

Land-use

- ❑ Traffic and safety implications of all development proposals should be thoroughly examined before approval is given.
- ❑ Land-uses should be distributed to minimise road traffic and pedestrian conflicts.
- ❑ The need for travel by vehicle should be minimised by locating shops and schools within walking distance of homes.

Access control

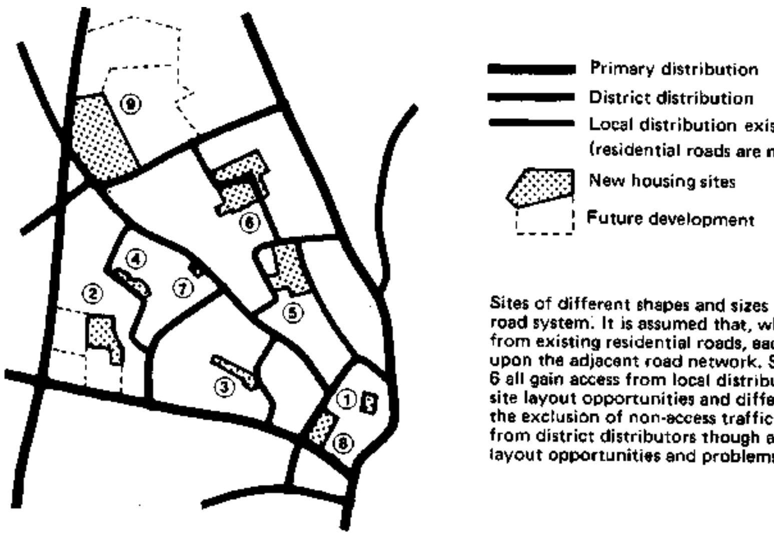
- ❑ On new roads of district distributor level or higher, direct frontage access should only be permitted in exceptional circumstances.
- ❑ The number of direct accesses onto main roads should be minimised and service roads or collector roads used to bring traffic to a single T-junction at the main road.

- No accesses should be permitted at potentially dangerous locations (e.g. at road intersections or on bends with poor visibility).

- In all cases each class of road should intersect only with roads in the same class or one immediately above or below it in the hierarchy.

Adoption of such basic principles enables safety to be incorporated at the planning stage. Checklists for road safety in planning are included in Chapter 7.

Possible Solutions/Benefits



Sites of different shapes and sizes in different places in an urban road system. It is assumed that, while Sites 1 and 2 both gain access from existing residential roads, each will make a different impact upon the adjacent road network. Similarly, while Sites 3, 4, 5 and 6 all gain access from local distributors, each presents very different site layout opportunities and different problems; for instance, with the exclusion of non-access traffic. Sites 7, 8 and 9 each gain access from district distributors though again, each presents different layout opportunities and problems.

Fig 3.01
Illustrative road hierarchy
(ref 10)

Fig 3.02
Well planned local network in Australia segregating access and movement functions
(ref 6)

3.2 Land Use Planning and Zoning Background

Background

Traffic patterns are primarily determined by the location of dwellings in relation to places of employment, services and recreational areas. They are also influenced by the general affluence of the population and the availability of motorised transport.

In developed countries the freedom of movement that motorisation has produced has resulted in a broadening of choice of where to live or work while, at the same time, encouraging concentration of economic activities in towns and cities.

Land-use in urban areas changes continuously. Consistent control of such changes is an effective way to promote the basic aims of traffic planning and to achieve improvements in road safety. In many countries zoning is used to designate different areas for different land uses in order to segregate incompatible or conflicting uses and the types of traffic they generate.

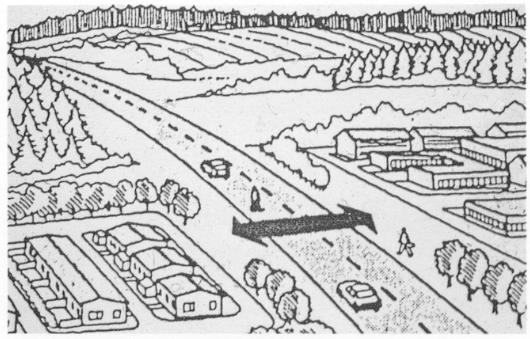


Fig 3.03
Residential area is separated from school and working places by a major road. Workers and students have to cross the road

Problems

Each type of land use has its own traffic characteristics and this can lead to problems. In terms of vehicular traffic, industrial, manufacturing and commercial premises will require access by heavy goods vehicles. Shops and offices also require access by delivery and service vehicles but in terms of volume, most of their demand is from workers and customers. In many residential areas the private car will be the dominant vehicle type but greater importance must be given to pedestrians.

A road will affect the environment through which it passes and will attract activity. If a road Is provided to satisfy a given set of circumstances and Inadequate development control is applied to its surroundings, it Is likely that a whole new set of circumstances will gradually develop. This will create conflicting demands which are incompatible or which cannot be accommodated easily on the road in question.

In developing countries particular problems occur due to lack of development control with squatter areas and shanty-towns developing around industrial areas and along busy major routes. These can often encroach right up to the road edge, creating hazardous conditions for pedestrians and passing traffic (eg Figs. 3.03 and 3.04).

Fig 3.04
Mixed land-use Choosing, trading and manufacturing along this arterial road) creating conflict between the demands for access and movement in Indonesia
(TRL)

Summary

Developed countries have experienced the effects of motorisation on land-use and traffic safety. The control of both land-use and traffic is vital to successful planning. Different land-uses give rise to different sets of traffic patterns and traffic composition and often these can be incompatible. Ideally a road should serve a narrow range of traffic types, which usually means segregating different…

Possible Solutions/Benefits

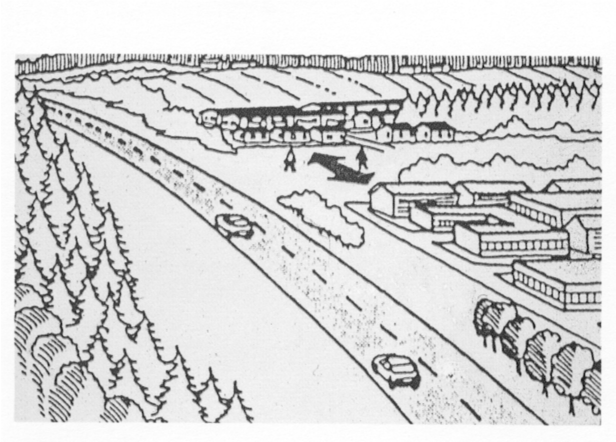


Fig 3.05
All development on the some side of the major road removes the need for regular crossings
(ref 7)

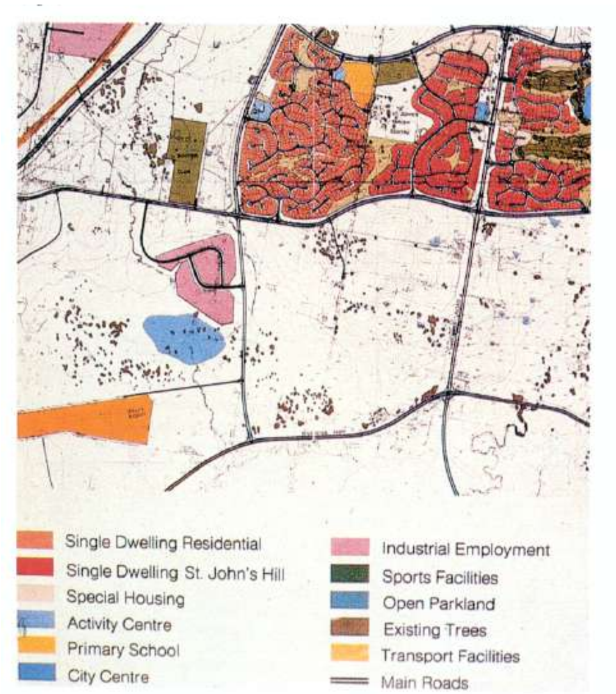


Fig 3.06
Well segregated land-uses in Australia, note road hierarchy
(ref 6)

Planning and design for traffic needs depends ultimately upon the land-uses which are being served. Therefore, the control of both is vital. Wherever possible, incompatible uses should be segregated so that techniques can be applied to direct major traffic flows onto the most suitable routes. A city street will differ from a rural road both functionally and in scale. However, the same principles of segregating, minimising and clearly defining conflicting uses apply throughout.

In terms of land-use planning the key principles to adopt are:

- Development and implementation of a zoning plan to separate out incompatible and conflicting land uses and the traffic they generate;
- Strong planning regulations to influence the location of new development and to control access arrangements and parking;
- Land-uses should be planned with the aim of minimising travel and maximising accessibility to public transport;
- Residential development should be separated from heavy industry and major commercial uses;
- Activities which generate substantial traffic should be located adjacent to roads most suited to the types of traffic expected (e.g. if a primary school generates many cycle or pedestrian trips, then It should be capable of being reached directly via a network of cycleways/footpaths as in Fig. 3.05);
- Light industry and service establishments can be sited adjacent to residential areas but vehicular access should not be via the residential streets.

As well as occasional access for large vehicles for purposes such as removals, deliveries, refuse collection and emergencies, public buildings result in a variety of significant vehicle movements. Sport and recreational facilities also attract significant traffic but this tends to be characterised by fluctuations and peaked demands. All of these land-uses require access to appropriate facilities by public transport and pedestrians.

Other relevant sections: 3.3-3.5, 3.6.1 - 3.6.4
Key external references: 1, 6,7

…..*land-uses in terms of their connections to the road network and restricting their spread to pie-specified parts of towns. In practice it is often necessary to develop a comprehensive set of measures, such as speed and parking restrictions together with other measures such as lorry bans to achieve overall improvements in road safety and to create safe environments for all road users.*

3.3 Road Hierarchy/Network Design

Background

Developed countries define road networks as a hierarchy in terms of road types, according to the major functions the roads will serve. The main basis for classification is whether the road is to be used primarily for movement or for access. Roads can be categorised according to their function or according to their operational characteristics and Table 3.01 overleaf shows how these overlap.

Road planning arid design can have a profound effect on the level of road safety in a country. Layouts of roads in residential areas can have a major impact on pedestrian accidents. Grid layouts, because of the large numbers of crossroads, are less safe than those networks based on principles of segregating functions of movement and access and keeping extraneous traffic away from pedestrians. Good network design within an overall hierarchy enhances safety.

Fig 3.07
Pedestrian/vehicle conflict in Indonesia as a result of inadequate definition of road hierarchy i.e. schools and offices located along a primary distributor
(TRL)

Problems

Typical problems which arise, in the absence of a clearly defined road hierarchy, include:

- Congestion occurs with slow and fast vehicles using the same road and inadequate provision for frontage access activities in locations where high pedestrian activity occurs (e.g. shopping streets).
- Through traffic passing through residential and shopping areas incurs economic losses due to delays and creates hazards on roads not suited to carry such traffic.

The adoption of a road hierarchy in an urban area that later expands beyond its bounding roads can mean that the distributor roads initially designed to surround an area and offer external access no longer do so. This can have expensive consequences in trying to maintain segregated routes across the major distributors as travel patterns expand across the former boundary.

It is unlikely that new road plans can be made without there being some form of network, however unsuitable, already in existence. Consideration often has to be given to modifying or improving an existing network by applying modern standards and approaches.

Gridiron network

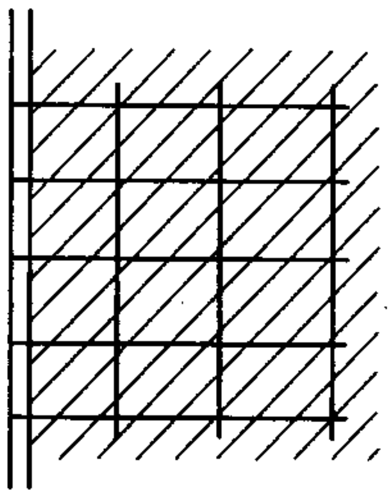


Fig 3.08
Grid-iron network which does not separate access and movement functions
(ref 7)

Summary

Most developed countries classify and manage roads according to the junctions which the roads will serve as this creates safer, more efficient road networks. The number, types and spacing of intersections permitted can thus be kept consistent with the type and nature of traffic expected to use that road. Hierarchical layouts which utilise the natural barriers formed by major roads to

Possible Solutions/Benefits

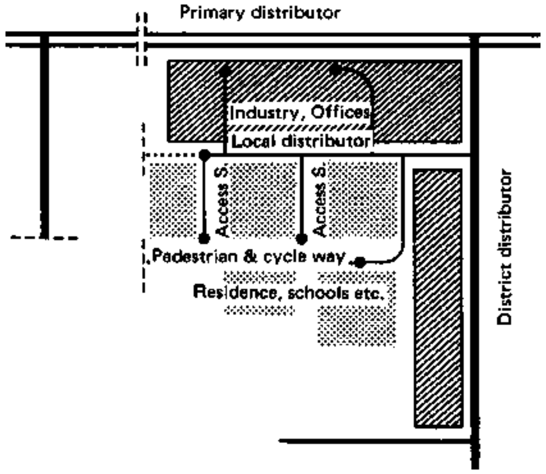


Fig 3.09
Schematic hierarchy of roads
(ref 7)

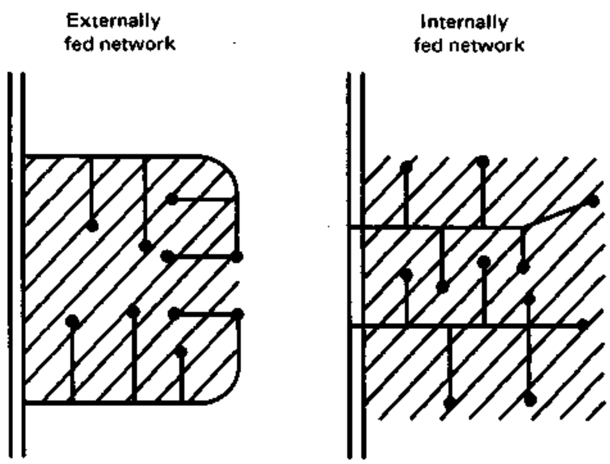


Fig 3.10
Externally and internally fed networks which separate access and movement functions
(ref 7)

Designation of a hierarchy such as that shown in Table 3.01 (overleaf) can help clarify policies concerning the highway aspects of individual planning decisions on properties served by the roads concerned. Furthermore, specific planning criteria could be developed and applied according to a road's designation in the hierarchy. It is, however, important to ensure that roads are assigned to the appropriate level in the hierarchy on the basis of their proposed (or desired) functions rather than their existing functions which may not be the same as those required for safe operation. Key points to consider are:

- Within the hierarchy, networks should be planned such that areas are separated into self-contained zones (often referred to as neighbourhoods, cells or environmental areas). The size and scale of these zones will depend upon the importance of the road bounding them. Within these areas all non-essential traffic should be excluded. It should be possible to carry out most daily trips to shops and schools wholly within the area.

- The natural barrier of main routes can be used to segregate and contain incompatible uses and to reinforce local identities. The network can be such that traffic can enter zones from an external or internal system (see Fig. 3.10). The external system reinforces this natural barrier and offers the safest network when well planned. Existing grid-iron networks should be closed off or restricted to create internally or externally fed systems.

- Each class of road should clearly convey to the road user its role in the hierarchy in respect of both traffic volume and speeds attainable. This can be achieved by appearance and related design standards (Table 3.02 overleaf).
- Each road should intersect only with roads in the same class or one immediately above or below it in the hierarchy. In that way anyone using the network has a clear impression of the graduated change in conditions between the low speed access roads and the segregated, higher speed "through routes' at the top of the hierarchy.

Other relevant sections: 3.4, 3.5
Key external references: 1, 6, 7, 10

...contain well planned community activities can signiftcantly reduce accidents. Even well established layouts with a grid-iron layout can be modifted to make them safer by concentrating through traffic onto the main roads while leaving local roads to serve only local traffic at low speed. Roads should only intersect with roads at the same level, or one level higher or lower in the hierarchy. Priority should be clearly marked at each intersection so that the major road traffic always has precedence.

3.3 Road Hierarchy/Network Design (cont)

	Pedestrian Streets	Access Roads	Local Distributors	District Distributors	Primary Distributors
Predominant Activities	Walking Meeting Trading	Walking Vehicle access Delivery of goods and servicing of premises Slow moving vehicles	Vehicle movements near beginning or end of all journeys Bus stops	Medium Distance Traffic to primary network Public transport services All through traffic with respect to environmental areas	Fast moving long distance traffic No pedestrians or frontage access
Pedestrian Movement	Complete freedom Predominant activity	Considerable freedom with crossing at random	Controlled with channelised (e.g. zebra) crossings	Minimum pedestrian activity with positive measures for their safety	Nil-vertical segregation between vehicles and pedestrians
Stationary Vehicles	Nil except for servicing and emergency	Some, depending on safety considerations	Considerable if off highway facilities not provided	Some depending on traffic flow conditions	Nil
Heavy Goods Vehicle Activity	Essential servicing and frontage deliveries only	Residential: related activities only Other areas: delivery of goods and services	Minimum through trips	Minimum through trips	Suitable for all HGV movements especially through trips
Vehicle Access To Individual Properties	Nil except for emergency vehicles and may include limited access for servicing	Predominant activity	Some to more significant activity centre	Nil apart from major centres i.e. equivalent to local distributor level of vehicle flow	Nil apart from sites of national traffic importance
Local Traffic Movements	Nil but may include public transport	Nil	Predominant activity	Some - only a few localities may be severed, junction spacing important	Very little - junction spacing may preclude local movements
Through Traffic Movements	Nil	Nil	Nil	Predominant role for medium distance traffic	Predominant role for long distance traffic
Vehicle Operating Speeds/Speed Limits	Less than 5 miles/h (8km/h) (vehicles enter on sufferance)	Less than 20 miles/h (32km/h) with speed control devices	Subject to 30 miles/h (48km/h) limit but layout should discourage speed	Subject to 30 or 40 miles/h (48/64km/h) limit within the built-up area	More than 40 miles/h (64km/h) depending on geometric contraints

Table 3.01
Designation of a hierarchy for urban roads in the UK (ref 1)

	By-pass Roads		Primary Distributors		District Distributors	Local Distributors	Access Roads
Number of lanes	≥ 2+2	2	≥ 2+2	2	≥ 2	2	1....2
Design speed (kph)	110	100	90-70	70-50	60-50	50-40	40-20
Access Control	full	full	full	full	full-partial	partial	none
Minimum junction distance	1.5 km	1.5 km	0.5 km	0.3 km	0.2 km	50 m	-
Parking	no stopping		no parking		no parking	exceptionally	short time
Pedestrian traffic along road	only on separate walkways		only on separate walkways		separate walkways/ pavements	footpaths	mixed traffic
Crossing pedestrian traffic	grade separated		grade separated or signalised		signalised or level crossings	-	level crossings
Minimum width of median island (m)	6.5	4.0 -1.8	-		1.6	1.2	-
Road reserve (m)	60	50	50	40	30	20	20-8
Stopping sight (m)	180	200	130-90	90-60	75-60	60-40	40-20
Bus stops	separated from main road		laybys		laybys	layby on road	-
Design volume (veh/day)	35,000	12,000	40,000	15,000	15,000	6,000	-
Lane width (m)	3.6-3.4	3.6-3.5	3.4	3.5	3.4-3.2	3.2	3.2....2.5
Shoulder width (m)	2.0	2.0	1.0-0.5	1.5	1.0	0.5	0.25
Minimum radius (m) Horizontal curve	1,000	1,100	600	350	180	130	50
Vertical curve	10,000	12,000	2,500	1,500	1,100	800	200
Maximum gradient on links	5	5	6	5	7	8	10
Maximum gradient at junctions	3	3	4	4	5	5	6

Table 3.02
Road characteristics relative to a hierarchy (ref 7)

3.4 Route Planning through Existing Communities

Background

When roads are rehabilitated or new roads are being built in developed countries, specific efforts are made to minimise the disbenefits to communities along the road so that through traffic as it passes through the community, does not cause problems or dangers to pedestrians and local traffic. This can range from provision of bypasses around communities to countermeasures aimed at reducing speeds of through traffic as it passes through the community where a bypass cannot be justified economically.

Fig 3.11
High speed interurban traffic causes danger to pedestrians and local traffic as it passes through small communities, Ghana (Ross Silcock Partnership)

Problems

In developing countries little consideration is given to the safety implications when roads are rehabilitated. It is commonplace to find existing rural roads upgraded to permit higher speeds and for such roads to continue along existing alignments straight through rural communities and trading centres. Because of higher speeds, this causes considerable additional danger to local traffic and pedestrians in the area.

Even the construction of new roads with bypasses around such small communities often does not solve the problem. Inadequate access and development control often result in the spread of commercial activities to the new road, leading to conflicts between through traffic and local traffic.

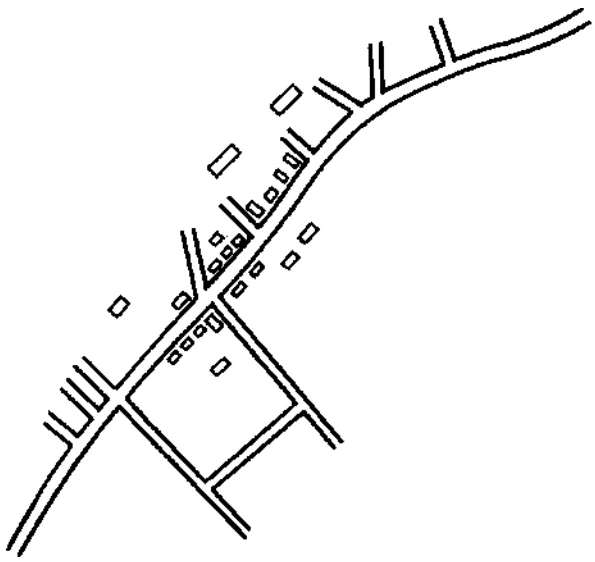


Fig 3.12
Existing interurban road results in considerable conflict between through traffic and local traffic in a Korean village (Ross Silcock Partnership)

Summary

Through traffic either needs to be separated from local traffic by the provision of bypasses, or its speed should be reduced as it passes through locations where large numbers of pedestrians and local traffic can be expected. Where bypasses can be justified, the old road should be deliberately down-graded and access to the community bypassed should be via spur roads. Where a bypass cannot be ....

Possible Solutions/Benefits

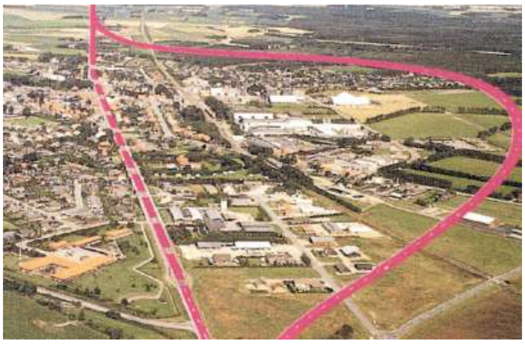


Fig 3.13
Potential solutions are either to moue through traffic to a bypass or to slow speeds of through traffic as it passes through built-up areas
(Road Directorate & Anders Nyvig A/S, Denmark)

When planning new routes or rehabilitation schemes efforts should be made to remove through traffic onto bypasses away from local traffic, thereby not only reducing delays and congestion to the through traffic but also creating safer environments on the roads from which such traffic is removed. Where a bypass can be justified the most important considerations are:

- The opportunity should be taken to reinforce the road hierarchy by down-grading the old road to discourage through traffic.
- Access to the bypass should be restricted to only a few points where safe intersections and spur roads can be provided to link to the existing network. Direct access from frontage land should not be permitted.
- Provision should be left for future expansion or development of the community but such developments should be served by service roads and spur roads.

Where a bypass cannot be justified, countermeasures should be implemented to slow down the speeds of through traffic as it passes through the community or trading centre as follows:

- Warning signs and rumble strips can be used to alert drivers about speed reducing devices ahead.
- A series of road humps increasing in height from 40 mm to around 80 mm can be used gradually to slow down traffic in areas where pedestrians predominate.
- Chicanes and road narrowing can be used to induce lower speeds as traffic passes through the community.
- In order to alert drivers to the fact that they are entering a community, it is generally regarded that some form of gate on the approaches is beneficial (eg chicane, substandard curve, tree lining or even a non-rigid gate structure).

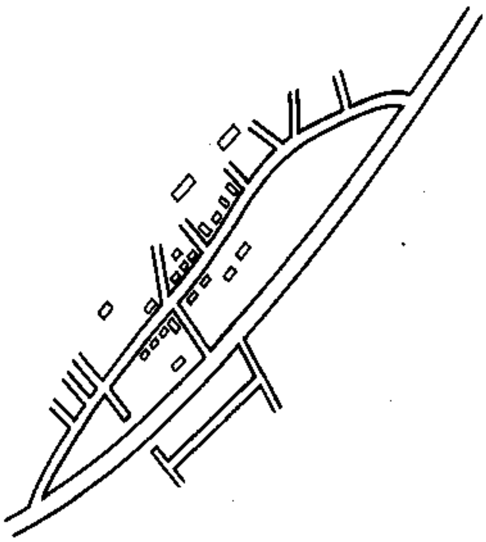


Fig 3.14
A bypass removes through traffic from the village in Fig 3.12. Note limited access points onto new road
(Ross Silcock Partnership).

Other relevant sections: 3.3 4.2.9
Key references: 1,6,7

……justified efforts must be made to reduce the speeds of through traffic as it passes through the built-up area. Warning signs and rumble strips can be used to alert approaching drivers. Road humps and raised pedestrian crossings can be used to reduce speeds at locations where large numbers of pedestrians congregate. When rehabilitating roads, efforts must be made to ensure that unsafe conditions are not created as a result of the increased speeds now possible on the improved road.

3.5 Roads in the Hierarchy
3.5.1 Primary Distributors (Major Arterials)

Background

These roads are the longer distance transport routes for motorised traffic. They provide the transportation link between districts and regions as well as for intercity and main urban traffic. Therefore, they need to cover a range of movement functions dependent upon the location of the road and its surroundings. Their primary function. however, is movement, not access.

Fig 3.15
Multi-purpose primary route in Indonesia with conflicts caused by variable road width, mixture of traffic types and frontage access
(Mott MacDonald)

Problems

By necessity primary distributors pass through urbanised areas and link individual settlements of varying size. Whilst their main role is to carry longer distance motorised traffic, there will be situations where these roads also provide the main route for local traffic. This will often include slow moving animals or pedestrians. In very isolated areas it may be the only road available for motorised traffic. The need for certain vehicles to stop (e.g. buses) may be unavoidable and bus-bays may need to be provided at suitable locations

Due to its relative attractiveness, the growth of development along such roads is inevitable. This can increase road safety problems when stopping, turning, servicing and pedestrian movements become more frequent

The rate of expansion of isolated communities along a road can rapidly reduce the effectiveness of a nationally or regionally important route as a result of the local traffic activities overwhelming the road. Its overall role in the road hierarchy then becomes confused. Once intense development has been allowed it is very difficult to achieve improvements without major reconstruction on a new alignment

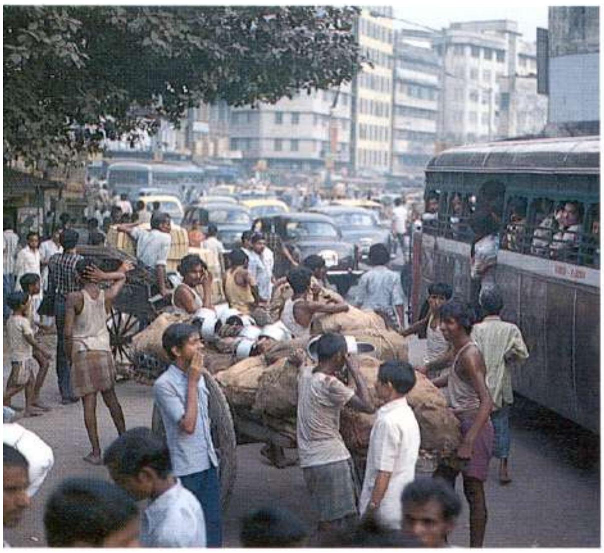


Fig 3.16
Severe conflict between pedestrians, non-motorised vehicles and other traffic on a major urban road in India
(Ross Silcock Partnership/

Summary

Primary distributors are the main longer distance traffic routes and are the most important and best known roads in a given area. They will be required to accommodate a variety of vehicle types with different speed and access requirements but the needs of mooing traffic must always predominate. All adjacent development should be strictly controlled and segregated from the highway as ....

Possible Solutions/Benefits

Fig 3.17
Primary distributor in Indonesia with limited access and well set back frontage development reduces conflicts
(Mott MacDonald)

Fig 3.18
Primary distributor in Papua New Guinea. Dual carriageway and no frontage access
(TRL)

Primary distributors need to be clearly identified as the main transport routes within an overall hierarchy. This needs to be done as soon as possible and once the route is known, a road reserve should be made to prevent buildings and development too close to the line of the road. In highly urbanised areas such a road is likely to be of a dual carriageway standard, but as the road passes into a more rural setting and traffic flows decrease, standards may be lowered. This will depend upon traffic flows but emphasis should always be on maintaining through traffic. Local access traffic should be accommodated off the primary distributor if at all possible.

The main elements to consider when planning primary distributors include:

- ❑ No frontage access;
- ❑ Development set well back from the highway;
- ❑ All access to premises provided via district or local distributors;
- ❑ Number of intersections to be minimised;
- ❑ Suitable at-grade channelised intersections for minor flows;
- ❑ Pedestrian and slow-moving vehicles clearly segregated wherever possible;
- ❑ On-road parking opportunities discouraged;
- ❑ Where necessary parking/stopping to be provided clear of main carriageway;
- ❑ Bus-bays to be provided at regular intervals; and
- ❑ Grade separated intersections for extremely high flows.

If the road passes through an existing settlement where lack of control has allowed the road to become deficient in any of the above elements, accidents are likely. If these elements cannot be re-established efficiently through suitable countermeasures, then the creation of a new route may have to be considered, with suitable controls (i.e. development control and road hierarchy standards) being enforced from the start to prevent recurrence.

Other relevant sections: 3.3, 3.4, 3.5
Key external references: 1, 6, 7

................encroachment from adjacent sites can quickly destroy the efficiency of a national or regional route. Intersections and other potential conflict locations should be minimised. Local access needs should be accommodated on other parts of the network and of *road bus-bays should be provided along the road at regular intervals. On-road parking should be discouraged*

3.5.2 District Distributors (Minor Arterials)

Background

These roads form the next level below Primary Distributors in a road hierarchy. The needs of moving traffic still predominate but they also contribute to access requirements. Although they may carry a large proportion of longer distance traffic this is only as one of the main distributors to and from the national network.

It is generally accepted that vehicle speeds will be lower (around 50-60 km/h) than on primary distributors and that a relaxation of access control can be permitted. However, they are still important traffic routes and segregation should be maintained wherever possible.

Fig 3.19
Street trading on a district distributor in Zimbabwe forces pedestrians onto road
(Zimbabwe Traffic Safety Board)

Problems

Whilst these roads should not generally form part of the longer distance route network, they are nevertheless important links to it. Therefore, particularly in urban areas, they can be subject to high concentrations of commercial and/or commuter traffic. High capacity requirements may be necessary for short periods.

As such roads are likely to form the boundaries between individual communities (see section 3.4) two problems arise for pedestrians. The first is that of using the road as a main link, either on foot or by public transport. Secondly, at some point, it will have to be crossed. Frequently, this is at bus stops or road intersections where the main traffic flow already has to contend with a number of conflicts and to react to a range of information. Pedestrians will tend to cross where there is a concentration of local services or a particular attraction. Paratransit stopping places also often cause disruption to other traffic on such routes.

District distributor roads, particularly in urban areas, tend to have the worst accident potential at intersections or where parking and roadside development encroach upon the highway.

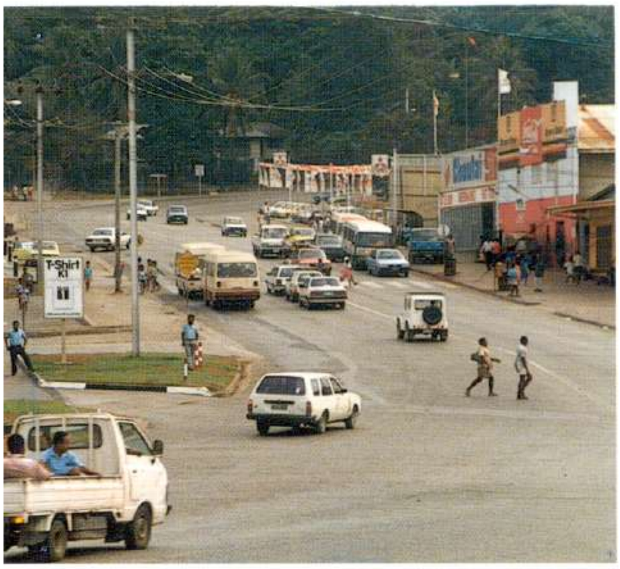


Fig 3.20
Frontage access and pedestrian/vehicle conflicts on distributor in Papua New Guinea
(TRL)

Summary

District distributor roads distribute traffic between residential areas, industrial areas, town centres and the primary network. Such roads are established to channel large traffic movements off the local roads, therefore the needs of mooing traffic still predominates. They need to be planned and designed in a similar manner to primary distributors but the standards can be lower, reflecting ....

Possible Solutions/Benefits

Fig 3.21
Protected footway on a district distributor in Kenya (Ross Silcock Partnership)

Fig 3.22
Vehicle barrier in Ghana prevents direct access and provides protected footway. However, note unsafe, exposed end post (TRL)

District distributors need to be identified as main traffic routes in much the same way as the primary, longer distance routes. However, the standards to be applied can be relaxed in recognition of their reduced importance as traffic routes.

The main elements to consider when planning district distributors include:

- No frontage access;
- Development set back from the highway;
- Most development to be given access via intersections with local distributor roads:
- In exceptional circumstances large individual developments may have direct access, provided a high standard of intersection is provided;
- All intersections will normally be at-grade;
- Turning traffic should be separated out from the through traffic;
- Separated pedestrian/cycleways remote from the carriageway;
- Pedestrian crossing points should be clearly defined and controlled;
- Parking on the road should not be permitted or necessary;
- Bus stops and other loading areas (only permitted in exceptional circumstances) should be in separate well designed laybys: and
- Regular stopping places for paratransit vehicles (ie private, non corporately run public transport operating vehicles smaller than buses) should be identified and safe stopping places established.

Careful consideration of the design and frequency of intersections on these roads and the needs of pedestrians/non-motorised traffic is particularly important if road safety is to be improved.

Other relevant sections: 3.5, 3.4, 3.5
Hey external references: 1, 6

....their reduced importance. Intersections and pedestrian and cyclist crossing points need to be given careful consideration to improve standards of road safety. Safe stopping/parking places for paratransit vehicles often need to be established in urban areas along such roads. Parking on the road should not be permitted or be necessary. Whenever possible, turning traffic should be separated out from through traffic.

3.5.3 Local Distributors (Collectors)

Background

Local distributors are the main 'collector' roads within any zone or area. They serve to feed traffic onto and off the main road network at the beginning and end of journeys. They include all the important link roads in an area but will be characterised by an absence of through traffic. Local distributors are the level at which the needs of moving traffic starts to be of less importance than the needs of local traffic and access.

In urban areas they will serve residential and commercial property along their frontage. Street development will be adapted to the existing building pattern, with non-motorised traffic moving parallel to motor routes, on footways and along the slow lane. In rural areas where only scattered individual developments exist, the local distributor may be the important local connection and have a mix of residential and light industrial/ agricultural traffic.

Fig 3.23
No pedestrian facilities on this local distributor in Indonesia (TRL

Problems

Local distributor roads need to carry local traffic while providing for access to the busier commercial and industrial areas. They will invariably have loading and parking taking place within the highway, particularly in older areas. This can cause congestion at such locations and create a serious hazard, especially as these routes can also concentrate pedestrian movements. Community buildings, schools and shops are often located on or near local distributors. Such buildings need to provide for the local community which surrounds them, but they also need to be serviced by traffic from outside the area. Public transport and paratransit vehicles also use these roads to penetrate residential areas and this is essential if an adequate service is to be provided. This, however, increases the likelihood of pedestrian movements and vehicle/pedestrian conflict.

Fig 3.24
Long, straight and wide local distributor encouraging high speeds in the UK
(TRL)

Summary

Local distributors are the main 'collector' roads within an area serving transport, recreation, shopping and other access needs. They allow Limited frontage access and give equal importance to motorised and non-motorised traffic. Such roads can carry a ml of residential and commercial traffic but this should be only local traffic. All through traffic should be routed through an ....

Possible Solutions/Benefits

Fig 3.25
Local distributor in Papua New Guinea. Note well separated footways but too many, closely spaced crossroads
(TRL)

Fig 3.26
Local distributor in the UK where carriageway has been narrowed by protected parking to reduce speeds. Note well separated footway
(TRL)

The main function of local distributors is access. Vehicle speeds should be kept low. Frontage access may be allowed but individual vehicle accesses should be avoided from adjacent buildings, except where large traffic generators exist.

These roads will be within or close to residential areas and traffic needs to be aware of pedestrians, especially young children. Adjacent areas alongside such roads can become play areas unless careful consideration is given to ensure that open areas between routes do not develop in that way.

The main points to consider are:

- The road is only for local traffic: through traffic is adequately accommodated on an alternative, more direct main road;
- Where possible, an industrial traffic route should not pass through a residential area;
- Vehicle speeds should be kept low so long straight roads should be avoided;
- Parking is allowed, but alternative off-road provision should be made if possible;
- Non-motorised traffic is of equal importance to motor traffic and separate routes should be provided if possible;
- Where non-motorised traffic needs to use a local distributor it should be separated from motorised traffic;
- Dependent upon traffic flows the road width can be varied to provide for parking or to give emphasis to crossing points;
- Bus stops can be located on the carriageway but should be near well defined crossings; and
- Through-movements should be made awkward and inconvenient to discourage them.

Other relevant sections: 3.2, 3.3, 3.4, 3.5, 3.6
Key external references: 1, 6, 7

................alternative more direct route. To keep speeds low, long straight roads should be avoided and through movements should discouraged by making them awkward and inconvenient. -Parking is allowed but off-road parking should be provided wherever possible. Proximity to residential areas means that adjacent areas and road verges can become play areas for children unless action is taken to prevent this.

3.5.4 Access Roads (Local Roads)

Background

As the name implies, these roads are for access only and are primarily for residential uses (industrial access should normally occur from a road of at least local distributor standard). These are ultimately the streets on which people live. Consequently, safety, security, social and environmental concerns are of primary importance. Access roads therefore need to provide only for essential access and designs should cater only for minimum traffic. It is far better to have many, short access ways linked by local distributor than a few long access roads.

On access roads, the needs of the non-motorised user predominate and children will often play in the street. It should be clearly indicated that the vehicle is an intruder into these areas and that low vehicle speeds are demanded.

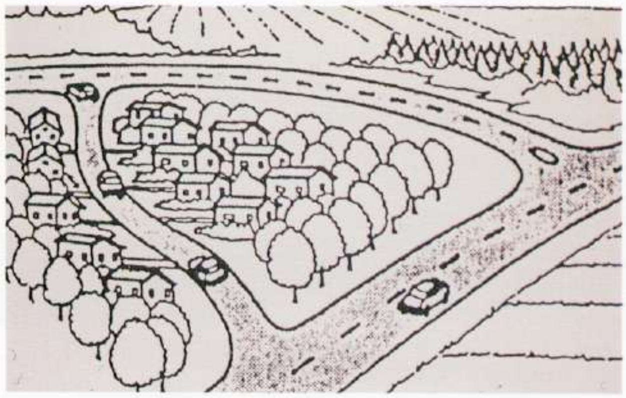


Fig 3.27
Bad road network design attracts through traffic onto access road
(ref 7)

Problems

Access roads are often used as unsupervised play areas by children. The risk of potential conflict with vehicles is, therefore, at its greatest. The need for vehicles to give priority to pedestrians must be continually reinforced within the street design.

In older, urban areas, where population density is high, existing streets are often long and straight and on-street parking leads to danger for pedestrians (especially children) crossing the road.

Even in the least trafficked areas, provision will need to be made for large delivery or emergency vehicles, even if only on an infrequent basis. This requires the road geometry to be capable of accommodating such vehicles. These large vehicles require much greater clearances than general light traffic so there is often a tendency for the speeds of cars on such roads to be higher than desired.

One-way traffic systems are often used in converting 'grid-iron' street patterns to access-only streets. However, they should be used with care as drivers easily become accustomed to not having the risk of traffic opposing them and thus increase speed, sometimes unwisely.

Fig 3.28
Children exposed to risk playing on long, straight residential road in the UK
(TRL)

Summary

Access roads are the roads used for the first or last parts of any non-commercial journey and are closest to where people line. The road will often fulfi1 a number of other social functions besides access. The presence of young children playing will be quite common so the needs of the non-motorised user will predominate. The vehicle, therefore, needs to be treated as the intruder …………,

Possible Solutions/Benefits

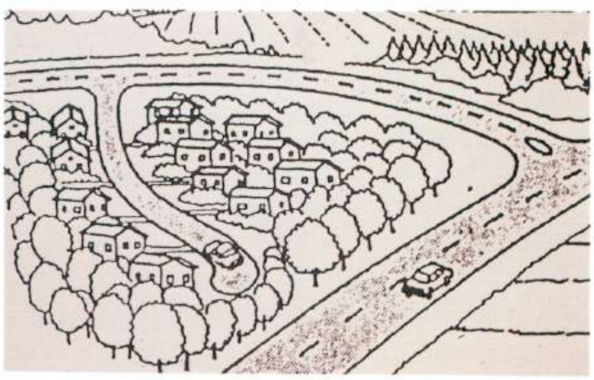


Fig 3.29
Good road network design deters through traffic from using access road
(ref 7)

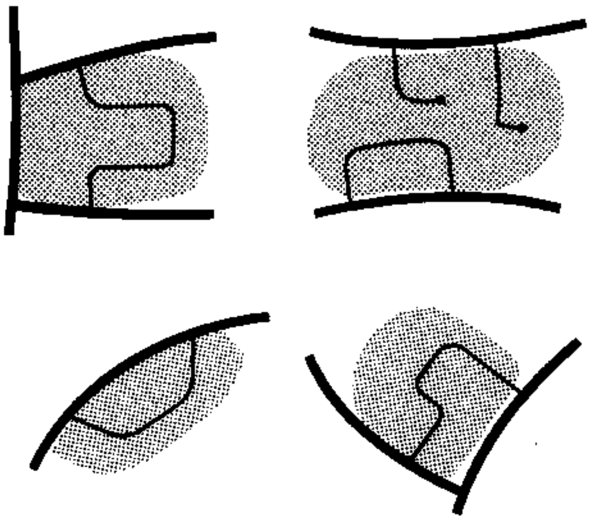


Fig 3.30
Examples of good layouts where through traffic is unlikely to use access roads
(ref 10)

Safety and a sense of security on access roads are dependent upon the frequency and seriousness of conflict, type and density of development and the type of activities being pursued. As a consequence, design standards may vary but the important elements to consider for access roads are:

- Vehicle flows to be kept to a minimum;
- All unnecessary traffic eliminated;
- Vehicle speeds to be kept low by careful and deliberate inclusion of obstructions to create meandering alignments;
- Access roads kept short where possible;
- Culs-de-sac and loop roads to be used wherever possible to deter through traffic;
- Intersections to be three rather than four leg and kept compact to aid pedestrian movement;
- Pedestrians and vehicles can 'share' space;
- Carriageway width can be reduced to emphasise pedestrian priority;
- Entrance/exit points of access streets should be clearly identified by threshold treatments, e.g. changes in geometric layout, landscaping, building development or even gateways and signing:
- Parking and stopping within the street is permitted although adequate provision should be provided within individual properties or separate garage areas;
- Use of fully mountable kerbs for vehicles may enable reduced road width and reduced standard alignments to be used by emergency and service vehicles, or for occasional parking: and
- Firepaths (emergency accesses for fire engines) can be kept clear by using diagonal closures to eliminate parking spaces or by ensuring other nearby owners gain access by the same route so that they keep them clear.

Other relevant sections: 3.3, 3.5, 3.6
Key external references: 1, 6. 7. 10

..................and its speed should be kept to a minimum by whatever means necessary. The use of loop roads and cull-de-sac to deter extraneous traffic and of `threshold' treatments (e.g. special entry gates) to let motorists know they are entering a pedestrian priority area with access roads free from all but minor, essential traffic can contribute towards safe, secure environments in such areas.

3.5.5 Pedestrianised Areas/Routes

Background

These are areas from which all motorised vehicles are excluded. In their broadest sense they would include all routes where non-motorised traffic has sole priority. This would include purpose-built footpaths and cycleways that often form a totally separate network to that for motorised traffic in residential areas.

Fig 3.31
Severe pedestrian/vehicle conflict on central area shopping street in India
(Ross Silcock Partnership)

Problems

In order to provide for a separate non-motorised traffic network, motor vehicles will need to be denied access to certain areas. Where they have a need to service premises used by large numbers of pedestrians, alternative access arrangements will need to be devised. At times it may be necessary for vehicles to enter pedestrianised areas (e.g. for emergencies and cleansing). The design, therefore, has to be capable of accommodating their occasional entry.

The provision of a separate, non-motorised network can be expensive, not only because of the need to segregate all crossings with the major road network but because a high standard of provision is usually necessary. Pedestrians and cyclists are much more exposed and hence more aware of their surroundings than drivers. For segregated networks to operate, they generally need to be cleaner, drier and more pleasant than the alternative, as well as being more direct.

Non-motorised traffic will generally use the most direct route to get to its destination. Any attempt at diversion will be resisted. Even very good segregated pedestrian facilities (e.g. bridges, subways) can sometimes be left unused because they are too far from the direct route.

Shopkeepers and other commercial concerns also often have fears about the diversion of traffic away from streets to be pedestrianised as they think this may result in loss of business from passing traffic.

Fig 3.32
Heavily congested pedestrian/trishaw route in Indonesia with poor drainage and no protection for pedestrians
(Ross Silcock Partnership)

Summary

Total segregation of motorised and non-motorised traffic is a good way to improve road safety. It reduces or eliminates conflicts. Pedestrian routes need to be more direct and attractive than alternative motor roads otherwise they will not be used. Pedestrian and cycle networks should cover a whole area, or at least link all the important attractors/generators of pedestrian ....

Possible Solutions/Benefits

Fig 3.33
Pedestrian street in India where motorised vehicles are excluded by volume of people
(Ross Silcock Partnership)

Fig 3.34
Pedestrianised street in China. Note vehicles excluded for certain times of day
(Ross Silcock Partnership)

Pedestrian routes or areas should not be planned in isolation because motor traffic still has to be accommodated somewhere. In planning new pedestrian networks and areas the key points to consider are:

- Residential, industrial and commercial areas should be linked by footpaths providing the most direct and pleasant route between destinations. Use of trees to provide shade can encourage use;
- Any deviation from a direct route should be more attractive than a less safe option;
- All crossings with main routes should be grade separated wherever possible and if not possible additional at-grade facilities (e.g. refuges) should be provided to minimise crossing problems;
- Vertical rerouteing (via overbridge or underpass) is much less attractive to pedestrians than at-grade facilities;
- The vertical and horizontal alignments of pedestrian routes can include much steeper gradients and sharper bends than for a motor road;
- Open aspects need to be maintained, particularly at intersections and underpasses;
- In shopping and commercial areas priority needs to be given to pedestrians;
- Where motor vehicles are displaced adequate capacity (for loading, parking and movement) needs to be available elsewhere on the surrounding roads but such facilities should always be within easy walking distance;
- If no alternative provision can be made for motor traffic, consideration may be given to pedestrianisation by time of day, i.e. vehicle access allowed only when pedestrian flows are light (e.g. very early in the morning or late at night);
- Connections to bus stops, parking areas and stations are vital and should be convenient; and
- All pedestrianised areas must have provision for access of emergency and refuse collecting vehicles.

Other relevant sections: 3.5.4, 4.1.19, 4.2.9, 6.9
Key external references: 1, 6, 10, 11

...................traffic (e.g. schools, shops, residential areas and parks/ recreation areas). They should be lined where possible with shade-trees. Routes can follow an entirely different layout to the motorised network but it will be necessary for the two to meet and/or cross at carious points. At such locations special arrangements, such as pedestrian crossings or footbridges, will need to be incorporated.

3.6 Traffic Planning for Different Land uses
3.6.1 Residential Areas

Background

Residential roads are the prime locations where vehicles and pedestrians interact and where the movement function fulfils an increasingly minor role amongst the most important service and domestic activities.

In older developed areas, road traffic problems have gradually increased and many towns are currently affected by road safety problems. Whilst the car is increasingly necessary to gain access to the widest choice of surrounding facilities, accommodating its movement and storage often takes up the majority of the road space, which inevitably has to fulfil other functions for the majority of the time in residential areas.

Fig 3.35
Residential buildings with direct access onto distributor road in Saudi Arabia
(MVA Consultancy)

Problems

The overall layout of residential areas will largely depend upon the density of development and the location of access to other parts of the overall network for both pedestrians and vehicles. In large developments the amount of traffic generated within the area can result in hazards and the presence of through-traffic just adds to difficulties. Ideally the road user should be able to identify a street's function by its character. An inadequate design layout can create both hazards and unnecessary congestion.

In developing countries there is rarely any attempt made to segregate residential areas from other activities. It is not uncommon to see light industry, workshops, overnight lorry parking (often with hazardous loads) all occurring within residential areas.

Through traffic often passes through such areas and few efforts are made to create safer environments for the large numbers of pedestrians (especially children using the streets for play) and other social activities.

Fig 3.36
Children playing in long straight residential street in Pakistan, exposed to potential danger from traffic
(TRL)

Summary

Residential areas need to be designed to increase pedestrian safety. Unnecessary usage by through traffic, particularly heavy vehicles, creates additional road safety hazards. Ideally the road user should be able to identify the street function by its appearance and layout. Threshold treatments at entry points to residential areas can be used to tell the driver he is entering a ....

Possible Solutions/Benefits

Fig 3.37
A Yuzuriha Street in Japan where pedestrians are given priority and speed reducing devices are used
(City of Osaka)

Fig 3.38
Residential street in the Netherlands, clearly identified as a play street with priority for pedestrians
(TRL)

In order to provide a safe environment for vehicles and pedestrians:

- Residential roads longer than 100 metres should be meandering and should have tight horizontal curves to encourage low speeds;
- Non-access traffic needs to find it impossible, or highly inconvenient, to use residential roads as a short cut;
- Pedestrians must be given priority, especially close to buildings and in play areas;
- Direct access to dwellings should be provided from access ways rather than distributor roads;
- Where dwellings have vehicular access onto distributor roads, alternative pedestrian access should be provided via segregated footpaths onto access ways;
- Pedestrians should be segregated wherever possible and crossings of traffic routes should be convenient and safe;
- Parking should be ample and convenient but located away from areas where children play;
- Drivers need to be made aware of the priority for pedestrians on entry and throughout the area by the overall geometry, surface texture and threshold treatment as they enter the area;
- Large developments should be sub-divided to minimise traffic on internal roads;
- Existing grid-iron networks should be modified by closures or restrictions to create internally or externally-fed systems (see Section 3.3);
- Inter-visibility between drivers and pedestrians should be sufficient to minimise the risk of accidents; and

Other relevant sections: 3.3, 3.4, 3.5.5
Hey external references: 1, 6, 7, 10

.... .residential area. Conditions in residential areas should be such (because of road narrowing, cull-de-sac and loop-roads) that low vehicle speeds predominate, and priority should be given to pedestrians. Non-essential, inappropriate and through traffic should be minimised in such areas. Overnight parking of commercial vehicles, especially those carrying hazardous loads, should be actively discouraged.

3.6.2 Industrial Areas

Background

Industrial areas are very important to the economies of most countries and it is necessary for them to be provided with safe, efficient links to national and international markets for both raw materials and finished goods. In most instances, these links are by road because of the ease and flexibility of movement which they offer. However, certain types of bulk freight and loads can sometimes be transported more easily and cheaply by rail, ship or air. Industrial developments in the more industrialised countries are often sited to take advantage of such transhipment opportunities.

Fig 3.39
Inadequate access to industrial area in Kenya
(Rendell Palmer Tritton)

Problems

Whilst it is practical for large industrial premises to have their own access road with all parking, loading and administrative functions undertaken within a secure site clear of any other traffic movement, this is often not feasible for small factories or individual workshop units. In those instances loading, parking and even the building entrance itself may be on an open forecourt alongside the highway. In these circumstances, indiscriminate use can result in activities overspilling into the adjacent highway. This is most common with parking and manoeuvring of heavy delivery vehicles and can soon cause danger to main road traffic and congestion to all users. Such sites are common along the roads of many developing countries.

Industrial estates are primarily concerned with the manufacture and movement of goods. However, workers are required and their journey to work has to be catered for. In developing countries, large volumes of workers may walk between home and work, so footpath networks may be required. As large vehicles are important in such areas it is necessary for intersections in their vicinity to accommodate large turning circles. Wide crossings, unsuitable for easy negotiation by pedestrians, usually result from such efforts to assist goods vehicles.

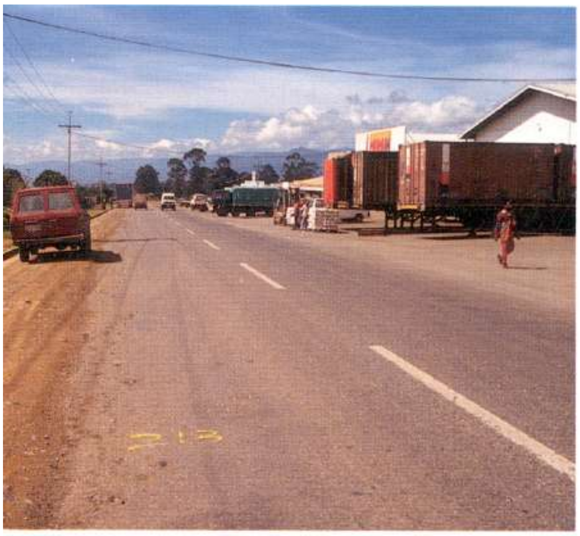


Fig 3.40
Industrial area with direct frontage access onto a national primary route in Papua New Guinea causing conflicts with through traffic
(TRL)

Summary

Industrial areas have to cater for significant numbers of people and vehicles, requiring substantial parking/loading areas and they need road layouts capable of accommodating large, heavy vehicles. Such traffic creates congestion and safety problems. The road networks should make access to the national transport networks as easy and safe as possible. Separate, shaded ....

Possible Solutions/Benefits

Fig 3.41
Well laid out industrial area in the UK. Note separate parking and loading facilities for each commercial unit (ref 1)

Land intended for industrial use should be clearly identified in Development Plans and most large developments should be sited on the urban fringes. They must be physically separated from residential or similar land uses where the presence of high traffic levels or heavy goods vehicles will not be tolerated.

In locations where industries already exist amidst residential areas and such segregation is not possible, serious consideration needs to be given to relocation as a long term aim. As an interim measure, it may be possible to design measures, as part of an areawide traffic management scheme, to restrict the undesirable effects of existing industrial activities and to limit heavy vehicles to selected roads.

The important factors to consider for the layout and design of industrial estates are:

- Land zoned for industrial purposes should have access directly from the district distributor network whenever possible;
- Each site should have sufficient off-road parking and loading areas to accommodate all its operational, staff and visitor requirements within the site boundary;
- Roads and footpaths should provide a safe and efficient means of access for workers, visitors and the range of vehicles which can be anticipated when a number of different industries are grouped together;
- The internal circulatory system (to at least local distributor standard) should ensure that no traffic queues form on the network in normal circumstances; and
- Networks of safe cycle/footpaths should be created between the industrial area and the main areas where employees live.

Other relevant sections: 3.2, 3.3, 3.5
Key external references: 1. 6, 7

................footpaths and cycleways linking residential and industrial areas should be provided wherever feasible because of the very much larger proportions of workers who walk or cycle to work in developing countries. Industrial sites should have sufficient off-road parking and loading areas so that delays and danger to main road traffic can be minimised and should be given access directly from the district distributor network wherever possible.

3.6.3 Commercial/Retail Areas

Background

Commercial and retail areas can vary from isolated stalls or street sellers to major shopping centres and office developments covering large areas of land. Consequently their transport needs can be very mixed. In developed countries cities increasingly try to avoid the congestion of a single Central Business District (CBD) and develop specific commercial or retail parks at the edges of towns. These offer ample parking and efficient links with both the public and private transport networks. In more rural areas the scale of operation is much smaller and may be restricted to market days, but even those activities require adequate provision for safe and efficient movement of traffic.

Fig 3.42
Illegal obstruction of footway in Zimbabwe by goods vehicle delivery
(Zimbabwe Traffic Safety Board)

Problems

Delivery vehicles servicing commercial/retail premises often occupy space (which could otherwise be used for short term customer or visitor parking), or even double park, obstructing the flow of through traffic. Accident risks are also increased with such deliveries and their need for access can also prevent full pedestrianisation.

There are also often instances where commercial activities spring up at locations where cars regularly slow down. Hawkers weave in and out of cars selling their produce causing further vehicle delays. Traffic speeds drop and more hawkers are attracted to the now more slowly moving traffic, resulting in further congestion and danger to all involved.

Commercial activities often overspill from adjacent stalls and encroach onto the verge and even the inside (slow) lane, causing more disruption and danger.

In rural areas on primary distributors, truckstop locations and trading posts often create unexpected hazardous locations. Often with several hundred metres of ribbon development along each side of the road, such places become accident blackspots as crossing pedestrians, parked vehicles, slowing and accelerating vehicles come into conflict with fast moving through traffic.

Fig 3.43
Poorly maintained and congested footways in India
(Atkins Planning)

Commercial and retail areas can nary in size and scale from individual stalls and street sellers, to isolated trading centres along major rural roads to large purpose-built developments in town centres or at the edges of a town. However, they cannot function effectively without adequate provision for the safe and efficient movement of both people and goods. Adequate space must be provided for ......

Possible Solutions/Benefits

Fig 3.44
Layby for roadside stalls off the main road separates stopped traffic from through route in Indonesia (TRL)

Fig 3.45
Shopping area separated from main road and a service road provided for access in Zimbabwe (Zimbabwe Traffic Safety Board)

Retail and commercial areas should be serviced from the local and national distributor network to provide a high level of access for all concerned. It is beneficial to provide separate access points for customers and service vehicles, or to segregate them as early as possible. This minimises conflict and allows distinct circulatory systems.

Where such areas take the form of street trading it is essential that adequate space is provided clear of the main highway. Off-street parking space should be available for customers to stop.

The main points to consider in the planning of such areas are:

- All commercial and trading areas should be away from the through traffic network. If alongside, then service roads should be provided to service the development;
- Rear servicing separate from pedestrian access should be provided whenever possible;
- Adequate parking and loading facilities for operational use should be provided within the site of individual premises if possible;
- Visitor and customer parking should be provided off the road, possibly on a communal basis;
- On-street parking should be discouraged and only permitted where it does not obstruct general traffic movements or conflict with pedestrians;
- Good public transport provision to and within such areas can effectively reduce overall parking demand; and
- When rural main roads in developing countries pass through "trading centres" it may be necessary to reduce speeds by physical measures such as road humps and raised pedestrian crossings to protect pedestrians and shoppers.

Other relevant sections: 3.2, 3.3, 3.5, 3.7
Key external references: 1, 6, 7

……all trading activities to take place off the highway and, if necessary, physical barriers should be used to prevent encroachment onto the roadway. The conflicting requirements of workers, customers and deliveries have to be separated. When rural interurban roads pass through isolated `trading centres' speed reducing devices may need to be used to protect pedestrians.

3.6.4 Recreational/Tourism Areas

Background

As countries develop, people increasingly find time for leisure and recreational activities. This leads to demands for sport and recreation centres and leisure parks in addition to major facilities for spectator sports.

Where tourist or leisure related activities are encouraged and have become a necessary part of the economy, safe access to them and appropriate parking facilities at them can form an important part of their success.

Fig 3.46
Unsigned and uncontrolled access to sports stadium in Zimbabwe
(Zimbabwe Traffic Safety Board)

Problems

Recreational facilities fall into two basic categories, those which focus on a particular building or facility (e.g. a stadium) and those which are areawide (e.g. a beach or park).

Although the scale of the individual centre or stadium will vary widely, the leisure activity is usually concentrated into a confined area. However, depending upon its size and activities, it can generate a considerable amount of traffic when it is in use. Special traffic management schemes may need to be implemented on surrounding roads on days when such stadia are in use (e.g. in Karachi, international cricket matches generate huge amounts of pedestrian and vehicular traffic).

The other category of activity is areawide, where people are attracted into an area because of the availability of a particular type of recreation, e.g. coastal beaches or game parks. In this latter case, although the activity may be spread out, there are nevertheless likely to be concentrations of traffic around recognised starting points or main entries into an area. Major congestion and road safety hazards can often be created by vehicles, particularly buses, double parking or parking on pavements near to the main entry points.

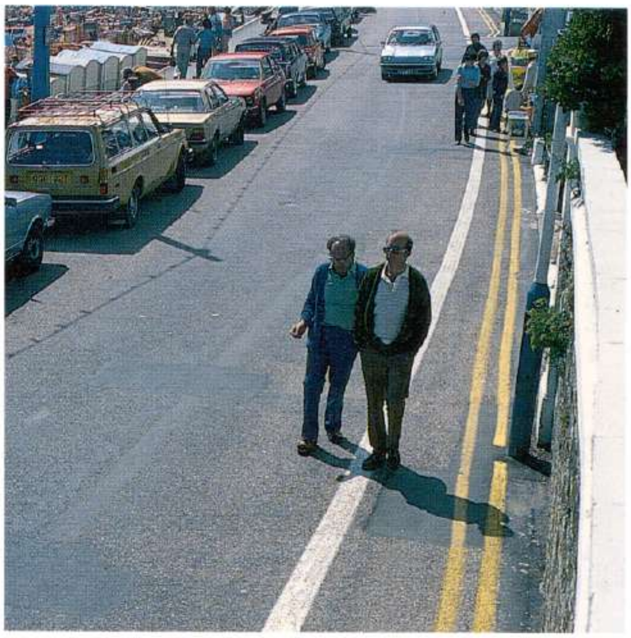


Fig 3.47
Inadequate pedestrian protection and kerbside parking along this UK seafront have led to many accidents
(TRL)

Summary

When recreational facilities are planned, the safety and quality of their access and parking provision must be checked. Irrespective of the type and scale of activity proposed, only those who enjoy that activity may find it useful. People lining in the immediately surrounding area, may well regard it as an unnecessary intrusion and a danger. Unless off-street parking for ....

Possible Solutions/Benefits

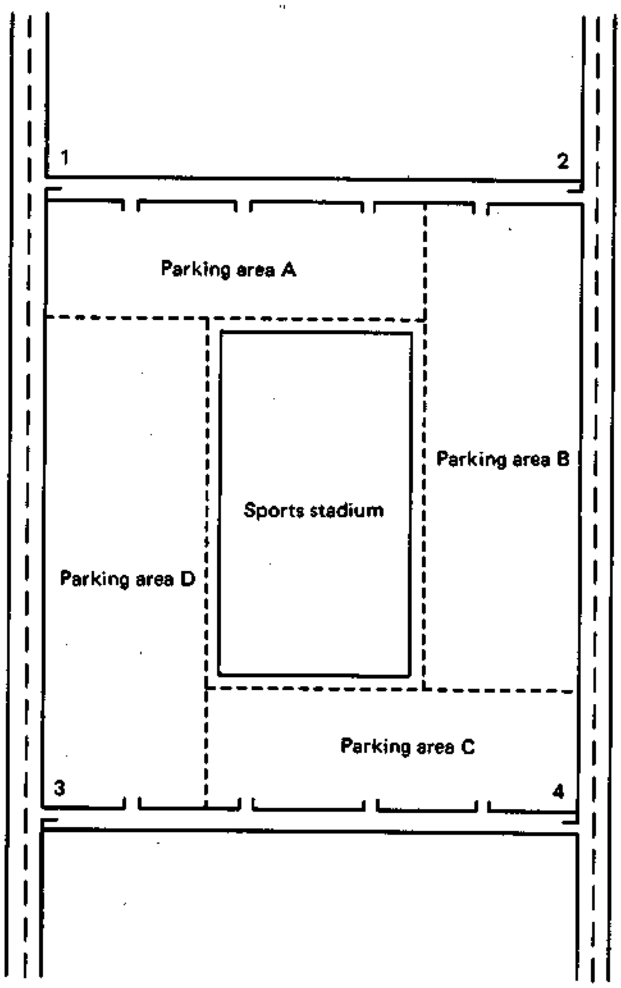


Fig 3.48
Parking provision at a sports stadium. Note access to car parks off side roads. Special arrangements need to be made at T-junctions 1-4 when stadium is in use. Internal circulation allows all car parks to be reached.

When planning recreational facilities which are not in use continuously, consideration should be given to sharing facilities (such as parking spaces) with more general uses (e.g. large stadia car parks used for markets or overnight lorry parks when not in use for the stadia). It is important to ensure in such circumstances that the many uses do not coincide, or if they do that there is adequate provision to serve all users.

The main considerations to bear in mind are:

- All recreational generators should be given access from local or district distributor roads, depending on their scale;
- Recreational land uses should be separated from residential areas, but they may be on the fringes provided recreational traffic is directed away from dwellings;
- Certain recreational uses may be acceptable within commercial or industrial areas, although this should be done with care;
- Adequate provision of public transport is essential;
- All participant and spectator parking should be provided separately within or near each facility and be sufficient to accommodate peak demands;
- Pedestrian routes between entrances/parking areas and venues should be free of vehicular traffic and clearly signposted;
- Where events necessitate use of public highways they should be clearly segregated from general traffic (periodic closures may be justified);
- Service areas and facilities should be segregated from general traffic and if possible should operate at different tunes to public use; and
- Certain facilities such as car parks could be shared with other users.

Other relevant sections: 3.2, 3.3, 3.5
Key external references: 1, 6

................spectators/visitors is provided, major congestion and road safety hazards can be created by vehicles, particularly large buses, double parking or parking on pavements and roads forcing pedestrians onto the road. Special temporary schemes should be devised for traffic management use on days when major events are held at national stadia. Consideration should be given to sharing facilities such as parking with other users.

3.7 Development Control/Encroachment

Background

Planning is a constantly changing process. The difficulty is to control the degree of change so that the various inter-related elements can still operate efficiently. In land-use terms this is usually achieved (with varying degrees of success) through the control of existing or new development and prevention of uncontrolled parking, illegal accesses and spread of unauthorised commercial activity.

Fig 3.49
Encroachment by street traders in Pakistan reducing available road width significantly
(TRL)

Problems

When roads are planned or constructed it is usually with the expectation that particular land-uses will be serviced by the road. However, land-uses change over time and if these are incompatible they can have a dramatic effect on the efficiency of a road. For example, residential or commercial units with unauthorised direct access onto major transport corridors cause danger to residents and to through traffic.

It is not just changes of use that can be problematical. Often, perfectly acceptable uses outgrow their location or change their operating system and require new demands to be met by the highway network. When all activities cannot be contained within a particular site it inevitably spreads onto adjacent land and this, in many cases, is the transport corridor.

It is vital that the access and development control is retained if overall road safety is to be preserved, e.g. roads designed as bypasses must not be allowed to develop ribbon developments along either side with numerous access points. Turning and emerging vehicles from unauthorised accesses can significantly increase the risk of accidents at such locations.

Fig 3.50
Encroachment of market stalls into road intersection, using traffic signal to support buildings. Nigeria
(Ross Silcock Partnership)

Summary

Effective land-use planning is dependent upon strict rules to control development and enforcement when those rules are broken. Unauthorised buildings and advertising hoardings encroaching onto the road or causing obstructions can create additional dangers for road users and need to be prevented. This can only be done by rigorous enforcement and the forced removal of such ....

Possible Solutions/Benefits

Fig 3.51
Wide, segregated pedestrian footway in Singapore with good enforcement against illegal street trading
(TRL)

Fig 3.52
Absence of encroachment and footway outside shops in Kuwait allows pedestrians to pass unhindered
(Ross Silcock Partnership)

Any planning and design process must incorporate a degree of flexibility to allow for growth and the development of activities or uses that were unforeseen earlier. However, this does not mean that all changes should be permitted. Those involved in planning and design must be aware of the scale of change that can take place and to what extent this can be controlled. Similarly, they should be aware of the implications that relaxation of control can have on the various elements of infrastructure provision, and their safe and efficient operation.

The main points to consider are that:

- Strict control of roadside hoardings and advertisement boards is required;
- Land-use and highway requirements change over time so some spare capacity should be designed into road networks to enable such changes to be accommodated without detrimental effects safety;
- Building regulations should include 'building line' specifications to control roadside development;
- If development control standards permit the growth of activities to encroach onto the transport corridor, additional countermeasures may be required to maintain a safe level of service to the community as a whole;
- Strong development control can only prevent encroachment onto roads if there are alternative locations for commercial activities to be undertaken; and
- Unauthorised development such as roadside advertising boards, illegal accesses and market stalls which create unsafe traffic conditions should be removed as soon as possible and the sites monitored to prevent their reappearance.

Other relevant sections: 3.2, 5.6
Key external references: 1, 6, 7

............unauthorised activities. However, unless suitable alternative sites are provided nearby where such activities can be relocated, it is quite likely that the unauthorised activities and buildings will be re-erected within a short time of their removal. Inadequate development control and failure to prevent unauthorised access can quickly reduce the integrity of a route and create unsafe road conditions.

3.8 Public Transport

Background

Public transport can make a significant contribution to travel patterns and can provide for the movement of large numbers of people while occupying a relatively small proportion of the road space. It also offers a service to the community at large by providing travel opportunities to those without private motor transport to meet work, social and recreational needs. In the developing world, public transport modes provide for the majority of motorised journeys. By locating activities and functions in such a way as to facilitate the use of public transport the number of road accidents can be reduced and the overall safety and efficiency of the road network improved.

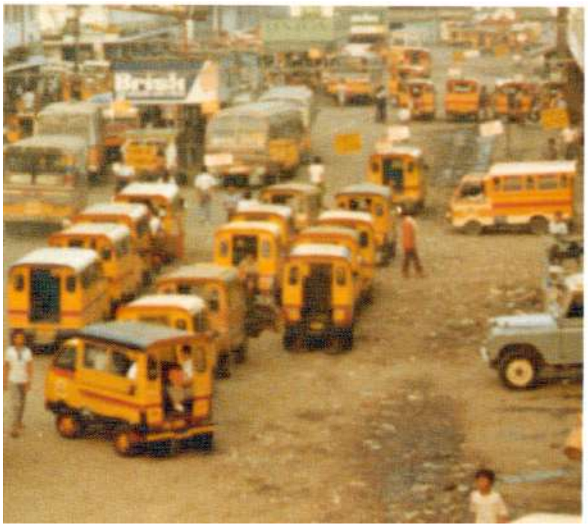


Fig 3.53
Inadequate, on-street terminal for paratransit services in Indonesia
(Mott MacDonald)

Problems

From a road safety viewpoint public transport routes should be designed to allow convenient access without increasing pedestrian/vehicle conflicts. Large buses are not desirable on access roads, yet if they are kept away from residential areas this increases the inconvenience to users and results in pedestrians being attracted to the more major transport routes. Conversely, if roads suitable for large buses are provided in residential areas, they may attract other undesirable traffic (e.g. HGVs and through traffic).

Taxi and paratransit vehicles often stop indiscriminately to pick up or discharge passengers and this often occurs at intersections. This causes delays and dangerous conditions at such locations.

In many developing countries, wooden bodies are bolted onto vehicle chassis to make public transport vehicles. When such vehicles are involved in an accident, very serious injuries can be sustained. The shortage of public transport vehicles also often results in gross overloading of all types of public transport vehicles at peak times. If and when an accident does happen, the numbers of persons injured can often be very high.

Fig 3.54
Inadequate bus facilities cause passengers to attempt to board at unsafe location on major route in Nigeria
(Ross Silcock Partnership)

Summary

Well designed and operated public transport can contribute to the safety and operating efficiency of the road transport network. Regulating authorities for public transport have a particular responsibility to ensure that vehicles are safe and roadworthy and that drivers and operators are appropriately qualified as public transport is the only option for many travellers. Routes should ....

Possible Solutions/Benefits

Fig 5.55
Bus stop adjacent to pedestrian/cycleway gives good access for passengers in China
(J Cracknell)

Fig 3.56
Well defined bus lane in Japan with good access for passengers.
(J Cracknell)

The main factors influencing road safety in terms of public transport are:

- Interchanges should be close to their users. Bus and paratransit stops should be near to residences to minimise walking distance and major interchanges should have direct pedestrian links segregated from motorised traffic;
- Public transport routes should generally follow main traffic routes and boarding points should be adjacent to and beyond intersections and linked with other parts of the general traffic network - particularly footpaths;
- Wherever possible public transport vehicles should be provided with clearly marked passenger pick-up points preferably off the through-traffic carriageway;
- Segregated lanes should be provided for public transport in areas of congestion, providing that overall capacity is not restricted to the extent that total delays are increased:
- Cement/concrete should be used in construction of bus bays to minimise maintenance problems resulting from leaking oil and fuel which softens blacktop roads;
- Public transport and paratransit vehicles should undergo frequent (6 monthly) road worthiness checks to ensure they are safe; and
- Public transport operators and drivers should be required to meet minimum criteria before being licensed to operate or drive public transport vehicles.

Other relevant sections : 4.1.16, 5.13
Key external references : 1, 6

.............be planned to serve all major needs. Bus bays should be provided beyond intersections and boarding points should be conveniently located and linked to pedestrian networks. Bus bays and standing areas should be constructed in concrete to minimise maintenance problems due to the softening effects of leaked oil and fuel. Such bays should be located clear of the through route.

4. DESIGNING FOR SAFETY

4.1 Link Design

4.1.1 Introduction

Background

Safety must be given special attention at the initial design stage of any road or intersection. This section of the Guide deals with the accident risks associated with such designs for both urban and rural situations.

It will often be possible at the initial design stage to develop designs or to incorporate at little cost safety features which will reduce accident risk substantially. In all such circumstances, safety features should be incorporated. In other situations, the cost of the primary safety feature, such as increasing curve radii for a road in mountainous terrain, may be prohibitively high. Reliance in such circumstances may then need to be placed on secondary safety features, such as the provision of signs and guard rails. Final decisions will be based largely on financial and economic criteria and available research evidence, such as that incorporated into TRL Overseas Road Notes 5 and 6 for interurban roads (ref. 4). However, whatever the decision, *it is very important that safety considerations are carried forward throughout the complete design and construction process.*

Whilst this section is concerned with the effectiveness of the final designs, the design process should also include decisions and recommendations as to how traffic will be safely controlled during the construction process. This should include signs and their placement for each stage of construction, together with details of how the interactions between construction and other traffic will be handled. In general, good design will result in a driving task which is clear, simple and consistent. Use of these principles will automatically result in a driver being led along a road or through a conflict situation such as an intersection, in an efficient and safe manner. The driving tasks will be the result of the effects of a combination of geometry, road signs and markings and clear priorities should be presented to the driver. Even if a driver makes a mistake the design should enable a driver either to recover without accident, or minimise severity should an accident occur.

Evidence of the effects of different design parameters on accident rates in developing countries is scarce and, whilst much research is under way, it is essential that the collection and analysis of accident information continues to be undertaken in order that the guidance contained here may be refined to represent local circumstances.

Interurban Roads

Interurban roads can range from single-lane rural roads to multi-lane dual carriageways. Geometric design characteristics and construction standards will depend on factors such as traffic flow and terrain, and the main accident problems and related safety features will also vary substantially.

Within the following sections of the Guide, emphasis has been placed on single carriageways, as interurban dual carriageway roads are less common and usually less of a problem in developing countries. Where dual carriageways are to be found, they will usually have been designed on the basis of selected developed country standards. Such standards will normally include safety considerations.

The design process recommended in Overseas Road Note 6 (ref. 4) incorporates safety considerations based on assumptions of consistency of design elements with speed (see Fig. 4.01). More direct safety considerations may be incorporated as shown. (It is to be noted that the safety considerations should be carried forward from this design stage to final implementation.) The emphasis within Overseas Road Note 6 is on economic optimisation. Road safety can only be included in the economic evaluation process if there are predictive relationships for accident rates, and accidents can be given specific economic values. Unfortunately, in most developing countries such information is not yet available. Thus, for the present, safety should be assessed by consideration of appropriate checklists or audits at the stage indicated in Fig. 4.01. (Safety Checklists are given in Chapter 7 of this document.)

Urban Roads

In urban situations, accidents are largely caused by interactions between the movements of conflicting streams of traffic and between the different road user groups. The safety emphasis has thus been placed on clear segregation and prioritisation. Conflicts between road users are reduced where possible, whilst elsewhere, priorities are identified in an obvious and positive way.

Pedestrian accident rates tend to be very high in the developing countries often due to pedestrians choosing to cross at unsuitable places along a road. As well as providing adequate safe crossing places, enforcement and education of the public are also generally required.

At the design stage, it may be possible to introduce large scale traffic management schemes, incorporating one-way systems which will reduce conflicts and accidents. As with interurban roads, checklists and audit systems should be used at the initial design stage and be carried forward to implementation. Studies to compare the accident conditions in the before situation with that afterwards should be made where possible to refine design and control features, and to identify their effectiveness for application elsewhere.

Possible Solutions/Benefits

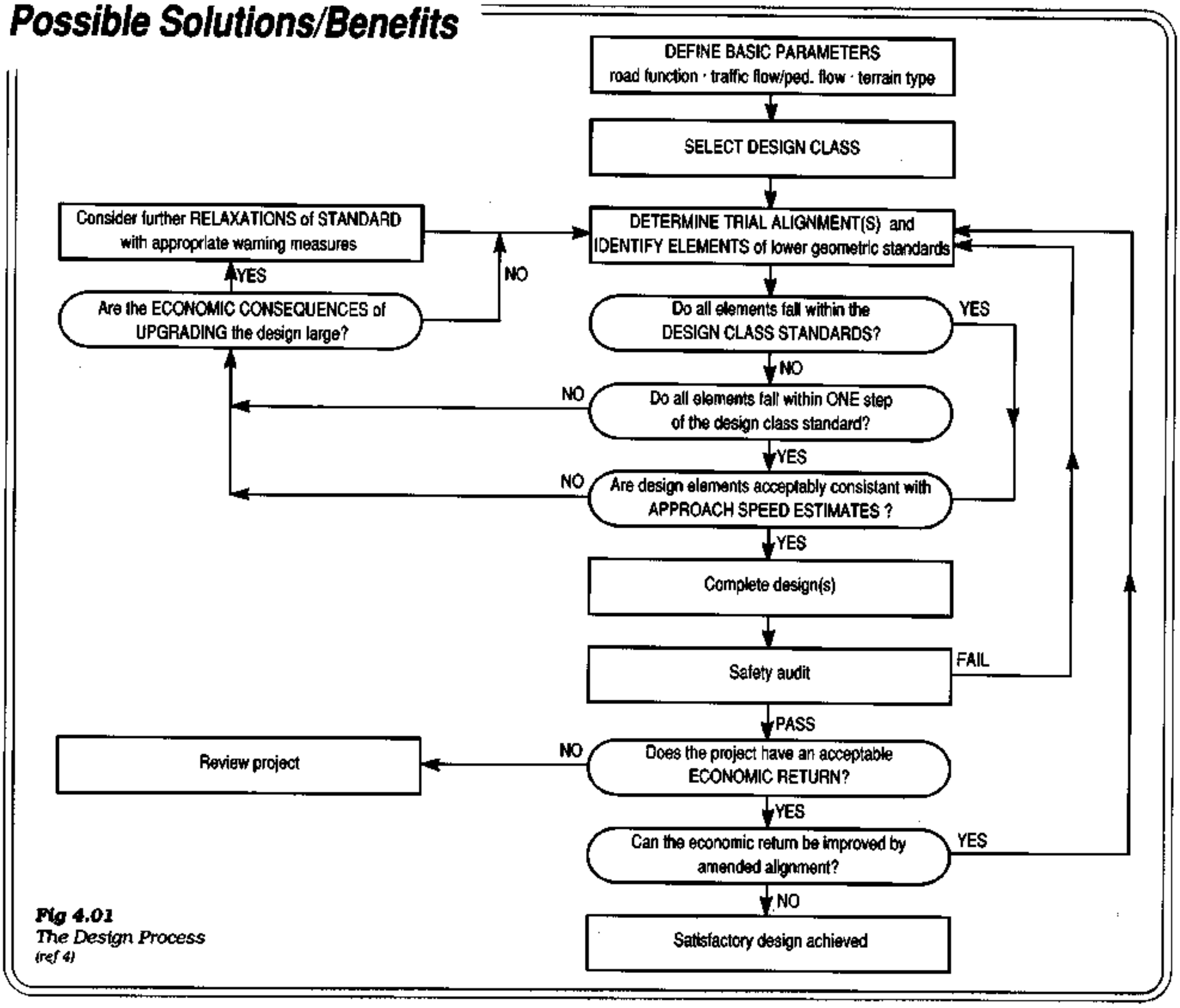


Fig 4.01
The Design Process
(ref 4)

4.1.2 Design Parameters and Speed

Background

The speed of a vehicle travelling along a road will vary with vehicle type and condition, driver characteristics, road geometry and the presence of other road users and speed controls.

In light flow conditions on rural roads, the successive geometric features presented to a driver should be consistent. This consistency is usually achieved through the concept of 'design speed'. In most current standards, the speeds used for the estimation of design parameters, such as sight distance, are closely related to actual speeds. This is crucial for safe design. There are many relationships to predict vehicle speeds from known geometry. The 85th percentile speed of light vehicles is commonly used as a basis for design, i.e. the speed exceeded by only 15 per cent of the vehicles.

In Overseas Road Note 6 (ref. 4), Design Class Standards are used which link road function, traffic flow and geometry in order to develop an economic design. Consistency is ensured by comparing estimates of actual speeds with those inherent in each of the Design Class Standards. If the design is found to be inadequate on the basis of this comparison, a new alignment is adopted and the process repeated (see Fig. 4.01).

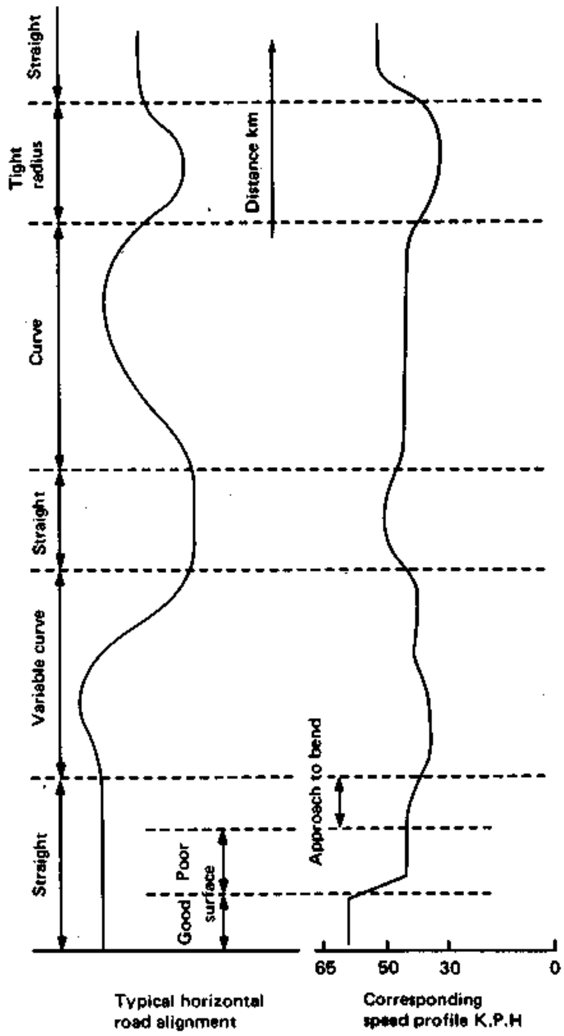


Fig 4.02
Schematic relationship between speed and horizontal curvature

Problems

Drivers on a road will travel with a speed profile which reflects the predominant geometric features of the road, and the rigid application of a set of speed related design standards will not necessarily result in a 'safe' road. For example, if the terrain allows a road to be built to curvatures substantially above the minimum for the design speed, the application of minimum standards at any single location will result in a substantial apparent reduction in standard to the driver, and create a potential accident blackspot at that location.

Relationships between speed, geometry and accidents are generally poorly understood, and the effects of interaction between different design features is difficult to predict: e.g. is a straight narrow road more or less safe than a tortuous but wide road?

Summary

It is important that the elements of design standards which are based on speed assumptions reflect the actual speeds of vehicles and hence relate to drivers' expectations. Where no suitable equivalent local data exists, it is recommended that the speed estimating relationships in Road Note 6 (ref. 4) are used. Consistency is the key issue, with higher standards being justified by the road user ....

Possible Solutions/Benefits

ROAD FUNCTION	DESIGN CLASS	TRAFFIC FLOW* (ADT)	SURFACE TYPE	WIDTH (m)		MAXIMUM GRADIENT (%)	TERRAIN/DESIGN SPEED (km/h)		
				CARRIAGE-WAY	SHOULDER		MOUNTAINOUS	ROLLING	LEVEL
	A	5,000 -15,000	Paved	6 5	2 5	8	85	100	120
Arterial	B	1,000 - 5,000	Paved	6.5	1 0	8	70	85	100
	C	400 -1,000	Paved	5 5	1.0	10	60	70	85
Collector	D	100 - 400	Paved/Unpaved	5 0	1.0+	10	50	60	70
Access	E	20-100	Paved/Unpaved	3 0	1.5+	15	40	50	60
	F	< 20	Paved/Unpaved	2.5/3 0	Passing places	15/20	N/A	N/A	N/A

* *Two-way flows recommended to be no more than one Design Class step in excess of first year ALT*
\+ *For gravel roads the shoulders would not normally be gravelled except for class D if shoulder damage occurs*

Table 4.01
Road standards for developing countries proposed in ref 4

REDUCTION IN SPEED DUE TO ROAD WIDTH

Width (metres)	≥5.0	4.5	4.0	3.5	3.0	2.5
Reduction in speed (km/h)	0	4	7	11	15	19

REDUCTION IN SPEED DUE TO ROAD TYPE AND CONDITION

Road	Reduction in speed (km/h)
"Good" paved	4
Pot-holed paved	6
"Good" gravel	5
"Average" gravel	8
Corrugated	15

Table 4.02
Expected reductions in 85th percentile free speed from that measured on flat, straight, smooth and wide section of road due to width reduction and road deterioration (ref 4)

- Use comprehensive design standards which *link* individual design elements to best estimates of actual speeds. Several empirically based relationships exist which link speed to geometry, such as those given in Overseas Road Note 6 for developing countries (ref. 4).
- The linkages between design standard speeds and estimated actual speeds should form part of the design process, as shown in Fig. 4.01.
- Drivers must not be presented with the unexpected. This concept may be incorporated in standards and the emphasis must be on maintaining continuity or giving adequate warning where this cannot be done. For example, drivers will expect more tortuous roads in mountainous conditions, and actual and design speeds will be lower.
- In urban areas, speed limits will apply, and design parameters will be closely linked to speed limits. Care should be taken to note that the character of the road will often influence drivers' speeds more than an arbitrarily low speed limit so features of the road must be designed to induce the required speeds.

Other relevant sections: 4.1.2, 4.1.4, 4.1.4-9, 4.1.11)
Hey external references: 1, 4

............savings available at higher flows from straighter, less hilly alignments. The design table shown above is recommended as a basis for the design of interurban roads. Relaxation of standards are acceptable, provided drivers are adequately warned, through additional signing and road markings, and the relaxations should be appropriately linked to stepped reductions in design speed.

4.1.3 Sight Distance/Visibility

Background

A driver needs to see in order to stop safely to avoid colliding with a stationary object on the road. This sight distance will depend on the approach speed of the vehicle and the assumed driver's eye and object heights. In addition to a safe stopping distance, it is also necessary periodically to provide sections of extended sight distances to permit overtaking opportunities.

Sight distance criteria may be introduced other than for safe stopping, and these include manoeuvring sight distance, in which a driver may not be able to stop, but may have sufficient time to manoeuvre round an obstruction.

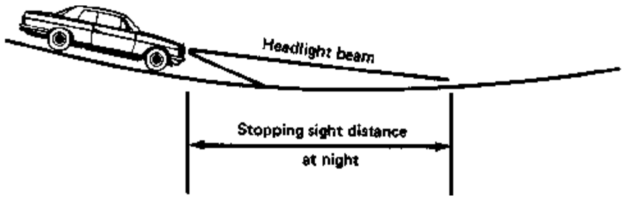


Fig 4.03
Stopping sight distance on sag curve at night

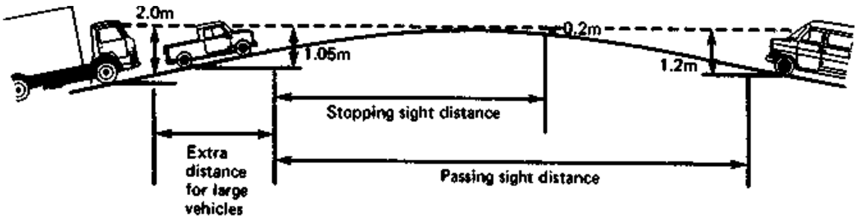


Fig 4.04
Stopping sight distance on crest curve

Problems

Sufficient stopping sight distance must always be available for drivers to stop their vehicles when faced with an unexpected obstruction in the carriageway. The effects of a driver hitting an object (e.g. which might have fallen off a lorry) or water at speed, or whilst braking, can be extremely serious.

Due to the generally higher levels of poorly maintained vehicles in many developing countries the braking capabilities are often extremely variable and driver training and testing may be poor. Hence, calibration based on stopping distances in industrialised countries may be unreliable. Trucks and buses, because of their greater weight, generally require a greater distance to stop than cars. However, bus and truck drivers are approximately one metre higher above the road than car drivers and can thus often see further ahead. Therefore, extended stopping sight distances for buses and trucks are not required except, perhaps, when horizontal sight distance restrictions occur at the end of along downgrade, or where the inside edge of a horizontal curve is bounded by a high vertical barrier such as a hedge or a fence. Sight distances may be substantially reduced due to growth of untended vegetation.

Fig 4.05
Poor sight distance on a curve in Indonesia. Note also U-type drain which poses potential hazard
(TRL)

Adequate sight distances should be available along the full length of a road for vehicles to be able to stop safely. In view of the greater likelihood of there being objects on the road (e.g. having fallen from other vehicles) in developing countries, an object height of 0.2 metres should be used. Where there is the possibility of standing water on the road, it may be advisable to have a zero object ....

Possible Solutions/Benefits

DESIGN SPEED (km/h)	STOPPING SIGHT DISTANCE (m)	MINIMUM SAFE OVERTAKING SITE DISTANCE (m)*
Two lane		
120	230	590
100	160	430
85	120	320
70	85	240
60	65	180
50	50	140
40	3	N/A
30	25	N/A
Single lane		
60	130	
50	100	
40	70	
30	50	

** Values assume an overtaking vehicle may safely abandon the manoeuvre if an opposing vehicle comes into view*

Table 4.03
Minimum recommended sight distances
(ref 4)

Fig 4.06
Good sight distances on road in Kenya. Note wide shoulder and shallow slope to drainage ditch reduces hazard
(TRL)

- For stopping sight distance an object height of 0.2 metres and an eye height of 1.05 metres are recommended. Where standing or running water may occur on the carriageway (e.g. a ford) a zero object height should be used.

- Overtaking sight distance should be available between points 1.05 metres above the centre of the carriageway forming an envelope of visibility, and should be checked in both the horizontal and vertical planes. Long sight distances are desirable to permit overtaking, avoid frustration and the need for dualling.

- Suitable sight distance may be achieved by increasing the radii of horizontal and vertical curves, widening verges, and benching to allow visibility outside the road width. If sight distance requirements are satisfied in the 'worst' case, i.e. when both the vehicle and the object are located on the inside lane of the curve, there will always be adequate visibility for a vehicle on the outside of the curve.

- On single lane roads, the sight distance must be sufficient for two vehicles approaching each other at the design speed to stop before they collide, i.e. twice the standard stopping sight distance.

- There will normally be some sections of road, such as on bends and summit curves, where there is insufficient sight distance for safe overtaking; these may be designated 'non-overtaking' sections and should be clearly marked as such. Adding an overtaking lane at hillcrests may be a cheaper solution than increasing vertical curve radius. If sharp, low-radius bends are replaced with longer bends in rolling terrain, the remaining overtaking opportunities may be inadequate. To increase the opportunities, shorter sharper curves can be used, provided this is done consistently along the route and does not result in approach speeds which are too high.

Other relevant sections: 4.1.2, 4.1.4-8, 4.2.5, 6.8.8
Key external references: 1, 4

.........height, although this will very substantially increase the sight distance requirements and the cost of provision. There should be a clear signing and marking system to indicate locations where sight distance is inadequate for safe overtaking.

4.1.4 Horizontal Curvature

Background

Horizontal curves should be designed so that they can be negotiated safely by approaching vehicles (see Section 4.1.2). For higher speeds and tighter radius curves, the sideways friction developed between a vehicle's tyres and the road surface will need to be greater. Consistency of design is achieved by relating approach speed to acceptable levels of sideways friction for any horizontal curve. For economic and environmental reasons, curvature standards may be relaxed, the extent of relaxation depending on local circumstances and the degree to which additional measures such as signs and road markings are introduced to reduce approach speed and thus offset the potential increase in risk.

Design speed (km/h)	120	100	85	70	60	50	40	30
Side friction factor	0.15	0.15	0.18	0.20	0.23	0.25	0.30	0.33
Longit.friction factor	0.35	0.37	0.40	0.43	0.47	0.50	0.55	0.60

Table 4.04
Design speed and friction factors
(ref 4)

DESIGN SPEED (km/h)	STOPPING SIGHT DISTANCE (m)	MINIMUM CURVATURE VALUES HORIZONTAL (m)	
		PAVED (10% SUPERELEVATION)	UNPAVED (ZERO SUPERELEVATION)
Two lane			
120	230	450	-
100	160	320	-
85	120	210	-
70	85	130	190
60	65	85	125
50	50	60	80
40	35	30	40
30	25	15	20
Single lane			
60	130	85	125
50	100	60	80
40	70	30	40
30	50	15	20

Table 4.05
Design speed/curvature relationship
(ref 4)

Problems

Unexpectedly tight horizontal curves can lead to accidents as drivers try to negotiate them at too high a speed. A similar situation may occur on horizontal curves at other hazardous situations, such as on steep gradients or long straights where drivers are encouraged or misled by the approach geometry to be travelling at excessive speeds. The sight distances associated with larger radius curves may also encourage drivers to overtake when it is unsafe.

On narrow carriageways, vehicles may cross into the path of an approaching vehicle on tight curves, or onto shoulders and pedestrian areas. On gravel roads in particular, the loss of super-elevation in the cross-sectional profile through lack of maintenance, may result in the effects of a horizontal curve being more severe than as designed.

Fig 4.07
Poorly signed and delineated curve approaching bridge in Papua New Guinea. Road bends through 90° to right (TRL)

Summary

Where possible, the horizontal curvature of a road should be consistent with speed requirements. If a relaxation in standard is necessary for economic or environmental reasons, clear signs, markings and other warning devices should be introduced to make the driver aware of the potential problem ahead and to guide him through the hazard. Good design should not encourage excessive ....

Possible Solutions/Benefits

Fig 4.08
Mountain road in Jordan showing appropriate design in difficult conditions
(Rendel Palmer & Tritton)

Fig 4.09
The substandard bend of Fig 4.07 after low-cost treatment of chevron board and bar line road markings
(TRL)

- ❑ In general, horizontal curves should either be designed geometrically so that they can be safely negotiated by the driver of an approaching vehicle, or the driver should be adequately warned of the need to reduce speed.

- ❑ At the design stage, the geometric solution to reduce the hazard of an unexpectedly tight horizontal curve is to increase the radius of the curve. Alternatively, a range of simple and inexpensive techniques exist to warn drivers of a potentially hazardous tight horizontal curve which cannot be re-aligned for financial or environmental reasons. Special treatments should be specified and carried forward to the design and construction phases. These may include safety barriers or the removal of obstructions to reduce accident severity.

- ❑ Potentially unsafe overtaking on curves with inadequate sight distances should be prevented by signs, road markings or physical barriers. (Additionally, positive signing or markings may be introduced to inform drivers of safe overtaking opportunities. Shorter, sharper curves with longer straight sections for overtaking may be better.)

- ❑ On gravel roads an acceptable cross-sectional profile with appropriate camber should be maintained. Where adequate maintenance is considered to be unlikely, it may be better to design the road curvature on the assumption of a level cross-section.

- ❑ Clear centre line markings should be introduced wherever possible. Edge of carriageway markings should be introduced to differentiate carriageway from shoulder.

- ❑ Large radius horizontal curves may be introduced on otherwise straight alignments to relieve driver monotony and to enable drivers to make better judgements of approaching vehicles' speed. Care must be taken, however, to ensure that unsafe overtaking is not encouraged.

Other relevant sections: 4.1.2, 4.1.7, 4.1.11
Key external references: 1, 4

..................speed, but nonetheless should provide requent overtaking opportunities. It is particularly important not to introduce a flowing design with sight distances well in excess of safe stopping sight distances, yet below safe overtaking standards. Horizontal curvature should be coordinated with other design features. Safety should be considered at an early stage of design to identify possible hazardous locations and alternative solutions.

4.1.5 Transition Curves, Superelevation and Pavement Widening

Background

Simple circular horizontal curves are normally used for road design. In order to facilitate the gradual transition of steering from straight sections of road to the curves, transition curves are often provided. The characteristic of a transition curve is that it has a constantly reducing radius, as in a spiral.

Superelevation is often applied over the length of a circular curve to reduce the sideways frictional requirements between the tyres and road surface and to increase comfort. In such situations, the transition curve length may be used to introduce the superelevation (Fig. 4.11).

The widening of traffic lanes is often necessary on lower radius curves to allow for the offset of the rear axles of heavy vehicles following a smaller radius curve than the steering axle.

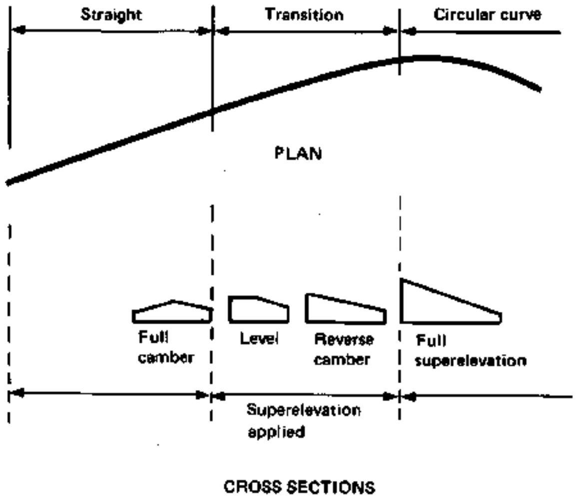


Fig 4.10
Transition curve and superelevation

Problems

Too high a superelevation will result in the possibility of stationary, slow moving vehicles sliding sideways or, in extreme cases, overturning. Too low a superelevation may result in standing water on the carriageway.

The application of superelevation with a very low rate of rotation of the carriageway over a long transition section may result in 'flat spots' with inadequate drainage.

Without adequate superelevation or removal of adverse camber, the friction required between the tyre and road surface will be much greater, and the risk of an accident higher. Such a situation will encourage drivers to use the centre of the road, or the inside lane, irrespective of direction. This situation is frequently evident on gravel roads, where a lack of adequate maintenance can lead to a loss of profile.

Long transition curves can be deceptive and drivers may enter such curves at speeds that they are unable to sustain safely as the radius reduces.

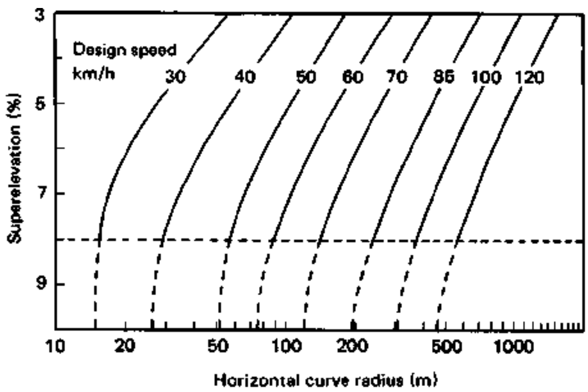


Fig 4.11
Superelevation design curves
(ref 4)

Summary

Transition curves provide a useful role in enabling drivers to moue safely from straight-ahead to circular motion round a curve. The transition length is also useful in introducing superelevation, the removal of adverse camber and lane widening. Care should be taken to ensure that the resulting edge profile shows a consistent aspect to the driver, and there are no inadequately drained ....

Possible Solutions/Benefits

Curve Radius (m)	20	30	40	60
Increase in width (m)	1 50	1 00	0.75	0 50

Table 4.07
Recommended widening on curves on two lane roads (ref 4)

Curve Radius (m)	<50	50-149	150-299	300-400
Increase in width (m)	1.50	1.00	0.75	0 50

Table 4.06
Recommended widening on curves on single lane roads (ref 4)

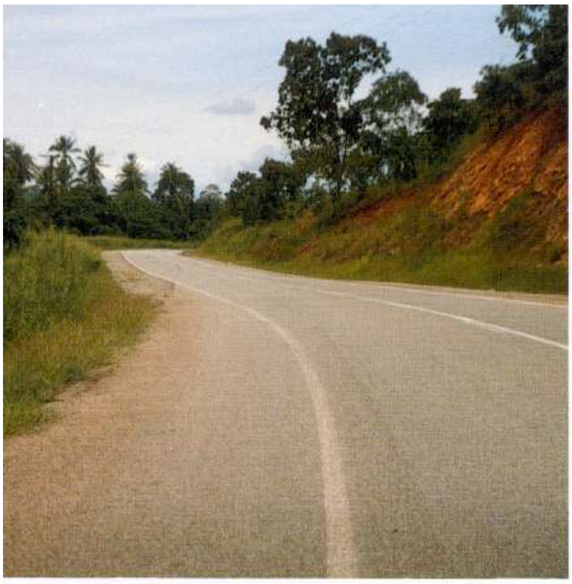


Fig 4.12
Superelevation on road in Papua New Guinea (TRL)

- A maximum superelevation of eight or ten per cent will generally eliminate overturning and sliding problems (ref. 4).
- The introduction of superelevation and curve widening, where the radius is less than a specified minimum for each design speed, will minimise the intrusion of vehicles on to the adjacent lanes, tend to encourage uniformity of speed, and increase vehicle safety at the curves. This consistency is achieved by using minimum acceptable side friction factors between the tyres of a vehicle at the design speed and the road surface. Acceptable friction factors vary from 0.15 to 0.33, the higher values being used with lower speed, tighter radius curves.
- Transition curves may be inserted between tangents and circular curves to reduce the abrupt introduction of the lateral acceleration, and they may also be used to link straights or two circular curves. The full nature of approaching curves must be evident to a driver. Long transitions which mask a sharp final radius should be avoided. However, transition curves may not be worthwhile on low volume roads where speeds are low; and recent research has indicated that circular curves alone may be safer than those with transition curves. Drivers will always trace their own transitional path wherever there is sufficient carriageway width, and if the road itself is circular they are less likely to be caught out by the bend tightening.
- The length of a transition curve should be the sum of the length required to remove adverse camber and the length needed to increase this crossfall to the full superelevation requirement.
- On roads of lower design classes which have substantial curvature requiring local widening, it may be advisable to increase width over a complete section to offer a more consistent aspect to drivers.
- Drainage conditions should be checked to ensure that combinations of fall along and across the road are adequate to remove water from potential 'flat areas'.

Other relevant sections: 4.1.3, 4.1.4, 4.1.7
Key external references: 1, 4

………areas. Transition curves must not mask the true nature of curves to oncoming drivers. The applications of the above principles are detailed in Road Note 6 (ref. 4) and will prevent intrusion of vehicles onto adjacent lanes and will increase road safety at curves. A maximum superelevation of eight to ten per cent will eliminate most overturning and sliding problems.

4.1.6 Vertical Curves

Background

There are two types of vertical curve: crest curves, which occur on hills, and sag curves, which occur in valleys. The design of vertical curves is based on comfort or visibility criteria and a parabolic function is usually used to connect gradients in the profile alignment.

Sight distance requirements for safety are particularly important on crest curves. The minimum lengths of crest curves are designed so as to provide sufficient sight distances for safe stopping during daylight conditions.

Two conditions exist when considering minimum sight distance criteria on vertical curves. The first is where sight distance is less than the length of the vertical curve, and the second is where sight distance extends beyond the vertical curve. There are relationships to calculate each separately, which include object and eye heights discussed in section 4.1.3.

The maximum vertical accelerations at the top of a crest curve and at the bottom of a sag curve also need consideration. The comfort criterion for sag curves as a result of vertical acceleration, is often taken as the critical design factor.

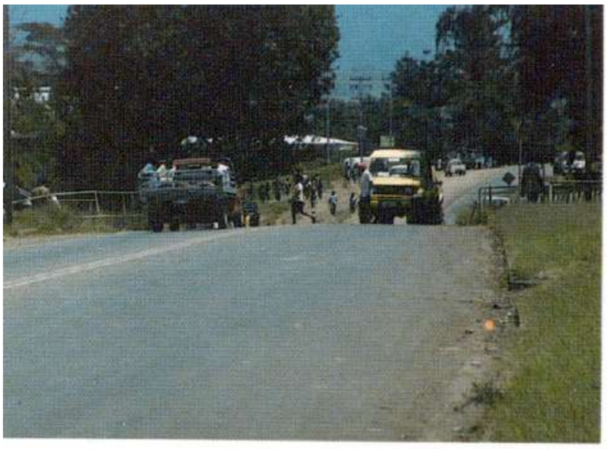


Fig 4.13
Poor visibility due to sag curve in Papua New Guinea (TRL)

Problems

It may be difficult for a driver to appreciate the sight distance available on a crest curve and he may overtake when it is insufficient for him to do so safely. It can be extremely expensive to provide safe overtaking sight distances on crest curves. However, a complete ban on overtaking would be difficult to enforce because of the presence of very slow moving vehicles, the lack of driver discipline in selecting stopping places, and poor maintenance of road markings and signs. Successive short vertical curves on a straight section of road may produce misleading forward visibility.

Although comfort may be a key factor in determining the minimum length of a sag curve, because centrifugal and gravitational forces act together, night-time visibility determined by headlamp beam angle is also important. The night-time visibility concept assumes that headlamp beams also have the necessary range to illuminate an object on the road. This is often far from true, particularly for vehicles in developing countries.

The radii of sag curves at the entries to underpasses and tunnels may be such that sight distance is restricted by the presence of the overhead structure. Long sag curves connecting shallow gradients can lead to drainage problems.

Fig 4.14
Undesirable 'roller coaster road profile in Papua New Guinea. However, note the good use of road markings to indicate no overtaking section
(TRL)

Summary

Stopping sight distances should be provided on all vertical curves, although sight distance requirements for safe overtaking are usually difficult to achieve on crest curves. Drivers should be given adequate warning through signs and road markings. On sag curves, the vertical acceleration which can be tolerated in comfort is often the critical design parameter. Care must also be taken .....

Background (cont)

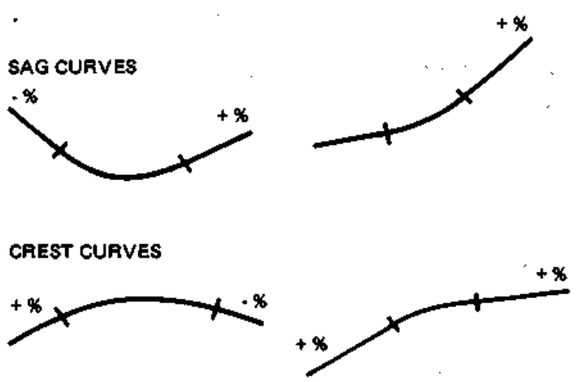


Fig 4.15
Sag and crest curves

DESIGN SPEED (km/h)	MINIMUM CURVATURE VALUES VERTICAL CURVES (m)		
	CREST K TO OBJECT ON ROAD	CREST K TO ROAD SURFACE	SAG K FOR COMFORT
Two lane			
120	120	250	22.6
100	60	125	13.1
85	30	70	8.1
70	60	35	4.8
60	10	20	3.5
50	5	11	2.2
40	3	6	1.3
30	1.5	3	0.7
Single lane			
60	25	20	3.5
50	15	11	2.2
40	7	6	1.3
30	4	3	0.7

Table 4.08
Recommended vertical curvatures
(ref 4)

Possible Solutions/Benefits

- Vertical curves are usually designed as parabolas. The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimum stopping sight distance should be provided in all cases. Overtaking opportunities can be maximised by using small vertical curves allowing longer tangential gradient sections.

- Sag curves should be designed according to comfort criteria, in which a vertical acceleration of 0.05g would be an appropriate maximum on major roads, although this may be relaxed to 0.10g on other roads.

- Profiles with successive short vertical curves (i.e. 'roller coaster' profiles), should be avoided as they are potentially dangerous. Sections of highway composed of two vertical curves in the same direction separated by a short tangent length (i.e. 'broken back' profiles), should also be avoided.

- Care should be taken with long vertical curves connecting shallow gradients, to ensure that the cross-drainage is adequate. Such problems may be particularly acute on sag curves which are associated with horizontal curves which themselves require a change in profile.

- When sag curves are associated with highway underpasses, curve lengths must be chosen to ensure the necessary vertical clearances and to maintain adequate sight distances into the underpass.

Other relevant sections: 4.1.3, 4.1.4, 4.1.7
Key external references: 1, 4

...........to ensure adequate night-time visibility by taking account of the upper limit of headlamp beams. Successive short vertical curves should be avoided, particularly on straight sections of road. Care is needed with drainage, especially on long, shallow sag curves. Lane and edge markings are critical on the vertical curves of surfaced roads. Some local carriageway widening may be beneficial on otherwise narrow pavements.

4.1.7 Combination of Horizontal/Vertical Curves

Background

Horizontal and vertical alignments should not be considered independently. They complement each other and poor design combinations can confuse drivers and lead to potentially dangerous situations. It is extremely difficult and costly to correct alignment deficiencies after the highway has been constructed. Evidence suggests that initial cost savings may be more than offset by the subsequent economic loss to the public in the form of accidents and delays.

Problems

Poor coordination of the horizontal and vertical alignments of a road can result in visual effects which contribute to accidents and are detrimental to the appearance of the road.

An appearance likely to be misinterpreted by a driver may result when horizontal and vertical curves of different length occur at the same location. For example, drivers who judge their approach speeds and lateral locations on the expectation of a single vertical crest curve may be surprised by the later appearance of a short horizontal curve contained within the vertical curve. These situations are particularly dangerous.

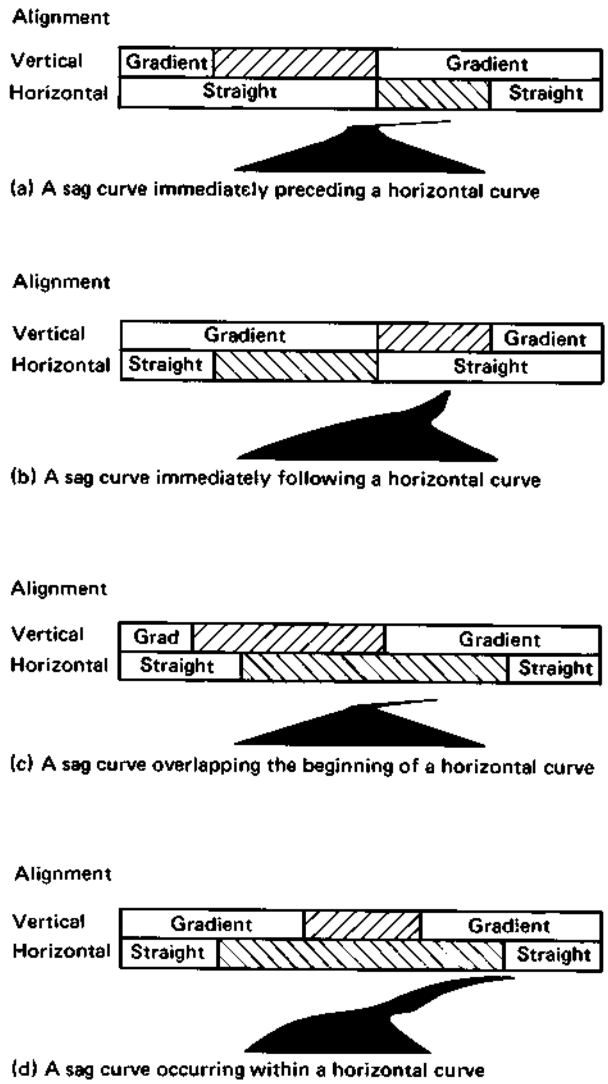


Fig 4.16
Examples of bad combinations of horizontal and vertical curvature
(ref 4)

Summary

Where possible, horizontal and vertical curvature should be so combined that the safety and operational efficiency of the road is enhanced. If horizontal and vertical curves cannot be entirely separated, they should be combined with common changes for intersection points and where possible, should be of the same or similar length. Good coordination should result in the ....

Possible Solutions/Benefits

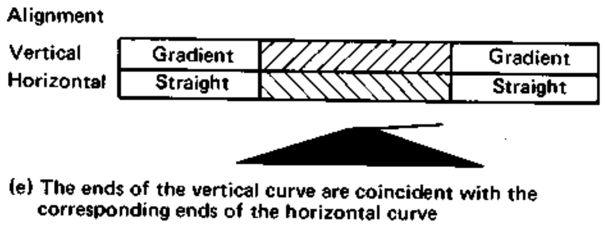


Fig 4.17
Example of good combination of horizontal and vertical curvature
(ref 4)

Fig 4.18
Good combination of curves allows good visibility and consistency in Korea
(Ross Silcock Partnership)

The presentation of misleading information to drivers can be avoided by making coincident all the points where horizontal and vertical curvatures change. Where this is not possible and the curves cannot be separated entirely, the vertical curves should be either contained wholly within, or wholly outside the horizontal curves. Also, horizontal and vertical curves should be of the same length and the chainage of their centres should coincide.

A logical design is a compromise between the alignment, which offers the most in terms of safety, capacity, ease and uniformity of operation, and pleasing appearance, within the practical limits of the terrain and area traversed.

- Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve as drivers will not be able to perceive the horizontal change in alignment, especially at night.
- Sharp horizontal curvature should not be introduced at or near the low point of a pronounced sag vertical curve because the view of the road ahead would be foreshortened.
- Expenditure is often justified to increase the radii of horizontal curves at the bottom of steep grades to allow for vehicles running out of control. Alternative measures include 'escape' lanes where vehicles travelling too fast to turn can be safely stopped.
- At locations where there may be drifting snow or sand, the design should give consideration to characteristics which will reduce the likelihood and extent of material being deposited on the road, e.g. shallow cuttings should be avoided.
- Horizontal alignment and profile should be made as flat as possible at interchanges and intersections where sight distance along both highways is important. Sight distances well above minimum should be provided at these locations, where possible.
- On two-lane roads where combinations of curves are likely, straight sections should be provided with good passing sight distance to provide opportunities for safe overtaking.

Other relevant sections: 4.1.3, 4.1.4, 4.1.6
Key external references: 1, 4

…….....maintenance of safe overtaking opportunities, and the continuity of a consistent appearance of the road profile to the driver. Drivers must be clearly warned of situations which cannot be readily anticipated from the geometric profile seen ahead. In particular, sharp changes in horizontal alignment should not be introduced at or near the bottom of a sag curve or at or near the top of a crest curve.

4.1.8 Gradients and Criteria for Climbing Lanes

Background

Restricted overtaking opportunities and the presence of slow moving vehicles can result in substantial congestion and high accident rates through injudicious overtaking. Congestion effects are greatest on long steep gradients. The situation is worse in many developing countries because of the presence of overloaded trucks and buses with very low power-to-weight ratios, and animal drawn vehicles.

In such circumstances, the provision of an auxiliary climbing lane can be extremely beneficial to enable vehicles travelling up the gradient to overtake safely and efficiently. However, the criteria for introducing and evaluating climbing lanes are complex and involve length and severity of gradient, traffic composition, level of flow and an estimation of the speed differences between the various vehicle groups. Overtaking opportunities on the adjacent sections of road are also significant. If the overall alignment is tortuous with few other overtaking opportunities, the provision of a climbing lane may be particularly beneficial.

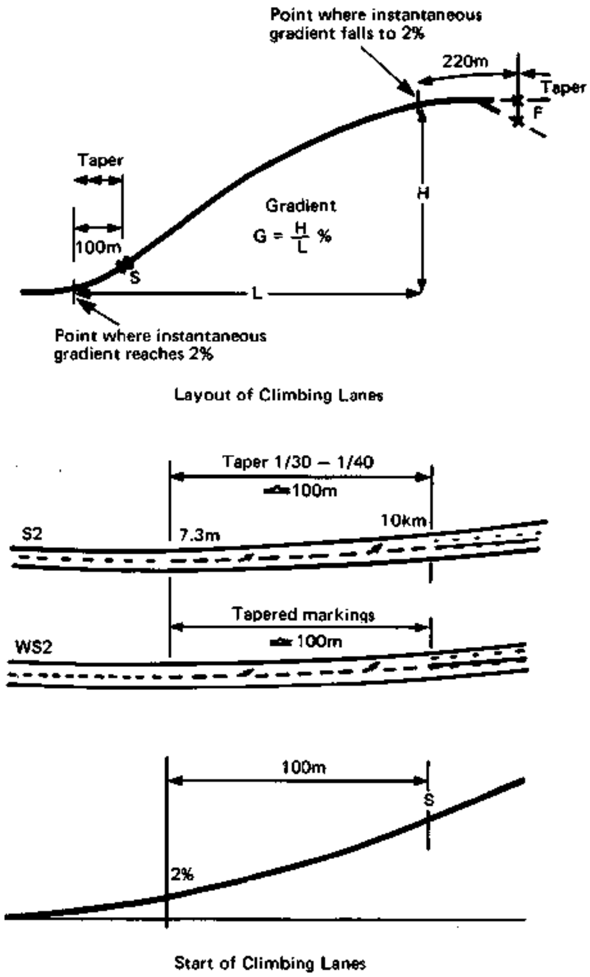


Fig 4.19
Layout of climbing lanes
(UK standards TD9/81)

Problems

Climbing lanes, by the nature of the terrain in which they are installed, will often involve expensive construction, and accurate estimation of the economic benefits is particularly difficult and uncertain.

The provision of a climbing lane on a two-way, two-lane road may encourage vehicles travelling downhill to overtake, resulting in a high accident rate with high levels of severity.

In heavy flows, there may be merging and accident problems when the climbing lane ends and the overtaking and overtaken flows merge.

Summary

As auxiliary lanes, climbing lanes are particularly effective as they operate at locations where the maximum overtaking advantage can be obtained from the relative power-to-weight ratios of light and heavy vehicles. The case for their introduction is largely economic, and relatively high traffic flows are usually needed for their justification. However, even though the extra width of a ....

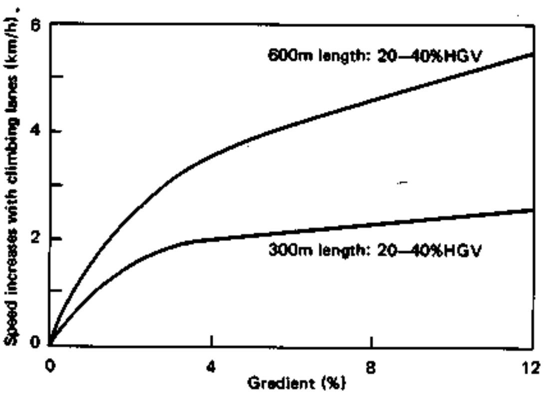


Fig 4.20
Estimated speed increase with climbing lane (ref 4)

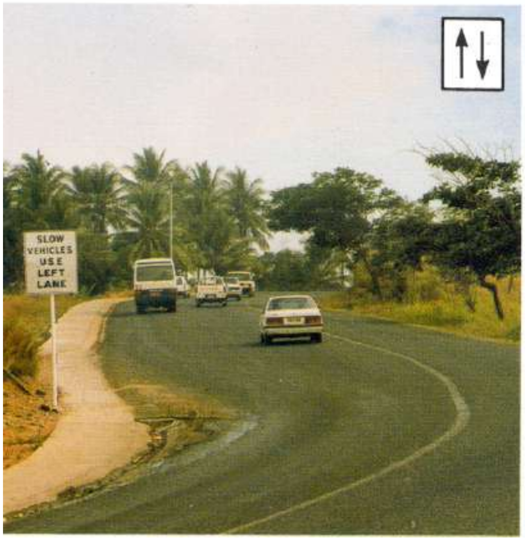


Fig 4.21
Additional climbing lane in Papua New Guinea. Note recent footway. Unfortunately road markings not yet renewed
(TRL)

Possible Solutions/Benefits

- Simple empirical and other models exist which can be used to estimate the effects of introducing climbing lanes. However, these models relate to traffic conditions in developed countries, where the differences in the performance of vehicles in the traffic stream are usually substantially less than in developing countries.
- Simulation models can be used to estimate the effects for a broad range of climbing situations, but are based on time saved rather than vehicle operating cost or accident savings because there is little relevant data. Guidance is given in ref. 4 on the increases in mean speed to be expected.
- Clear signing, road marking and, in some cases, physical barriers are needed to ensure that the absolute right of way of climbing vehicles is safely upheld.
- Climbing lanes should start before the gradient, and end after it, to ensure as small a speed differential as possible between overtaking and overtaken streams to aid safe and efficient overtaking and merging.
- Maximum benefits have been found to be achieved within the first few hundred metres of the start of a climbing lane. Particularly with shorter climbing lanes, it is essential that the start is clearly marked and that heavy vehicles block the remaining traffic for as short a time as possible.
- Although the major benefits of a climbing lane are in terms of values of travel time saving, there is some evidence to suggest that they also result in a reduction in the accident rate. Accident savings may also occur on adjacent sections of road, if the climbing lane reduces levels of frustration and injudicious overtaking on these approach sections.
- In some situations climbing lanes will occur on both sides of a sag or crest curve, serving the two directions of traffic. In these situations the opposing flows must be separated by solid lines and hatched areas may be provided as an additional safety measure.

Other relevant sections: 4.1.3, 6.8.5
Key external references: 1, 4

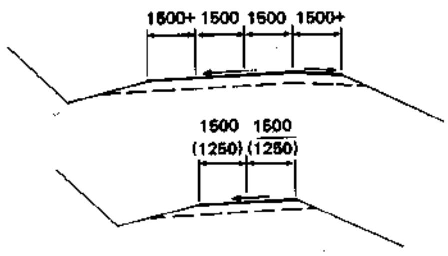
.........lane is required, there may be some situations in which the provision of that is cheaper than having to build in a full overtaking sight distance. There are detailed design differences between the various standards, although an indication of parameters is given in the figures above (based on UK standards). Clear signing and marking is required and it may be appropriate to have physical separation between opposing flows.

4.1.9 Cross Sections

Background

A cross-section will normally consist of the carriageway, shoulders or kerbs, drainage features, and earthwork profiles. It may also include facilities for pedestrians, cyclists or other specialist user groups.

There is some evidence to suggest that widening lane or carriageway width or widening shoulders is beneficial in reducing certain types of accident.



Cross-sections, particularly on roads in built-up areas, are often not uniform. Local developments may encroach onto the carriageway because of a lack of effective planning control. In rural conditions cross-sections may be reduced at drainage structures.

The continuity between the shoulder and the pavement may be broken by a lack of adequate maintenance. This is a particular problem with gravel shoulders on narrow paved roads, where there are frequent intrusions onto the shoulder by heavy vehicles. The resultant 'step' can be substantial and may lead to drivers' loss of control as well as erosion of the surfaced section. The general lack of maintenance may result in a loss of cross-sectional profile and standing water and the associated accumulation of silt can also lead to the loss of control of a vehicle.

Steep side slopes, introduced for drainage purposes, do not allow a driver to recover should he leave the carriageway, and thereby add to the likelihood of an injury accident. Open channel drains can also increase the probability that driver error will result in an accident.

Few rural cross-sections cater for what may be substantial pedestrian, cyclist and animal drawn traffic, and these user groups tend to have to share the carriageway with fast moving motorised traffic.

Few appropriate stopping places are provided for vehicles to stop and park off the carriageway. As well as hindering flow, inappropriate parked vehicles may be a danger to crossing pedestrians.

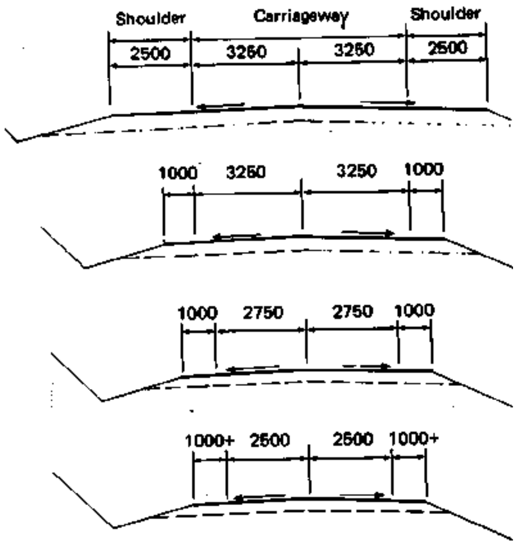


Fig 4.22
Typical cross-sections-rural roads
(ref 4)

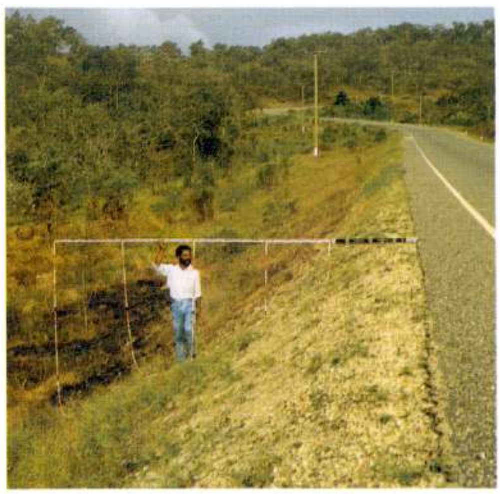


Fig 4.23
Severe unprotected side slopes being surveyed in Papua New Guinea
(TRL)

Summary

Adding extra width to cross-sections can be very expensive, and many safety benefits can be obtained simply by careful design of the cross-sectional profile. The need to maintain the designed cross-sectional profile is particularly important. For rural roads, this is easier if the shoulder is designed and constructed to the same standard as the carriageway. The use of edge of ....

Possible Solutions/Benefits

- The development of cross-sections to cater safely for all road users is a most important aspect of road design and this can be done as follows:

- Cross-sectional standards such as those proposed in ref. 4 should be applied. They incorporate a consistency of approach which links the various cross-sectional elements to other design factors. Encroachment of other activities into the cross-section should be controlled.

- Cross-sectional profiles should be properly maintained. This may be helped by constructing the shoulder to the same standard as the carriageway. Edge of carriageway marking and other delineators will be helpful.

- Open channel drains should be covered where possible or have some physical barrier to separate them' from the carriageway. The physical barrier could consist of a raised kerb or similar structure. In some situations the drainage ditch or kerb will effectively segregate vehicular and pedestrian movements.

- Side slopes should be limited to no more than about 1:6 (1:10 m flat to rolling terrain and 1:4 in mountainous terrain). They should run down to a flat bottomed or rounded ditch for safety. There should be no obstructions to a vehicle's passage in an emergency situation. The outside of horizontal curves require special consideration, and safety barriers may be a more cost effective alternative in some situations.

- The incorporation of a shoulder will give room for parked or stopped vehicles and for manoeuvring in an emergency.

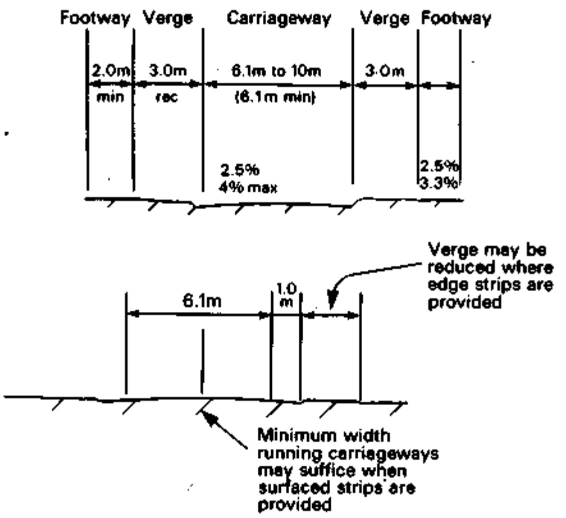


Fig 4.24
Typical dimensions of a two-lane urban road (ref 1)

Fig 4.25
Road in Papua New Guinea with shallow side slopes and rounded drainage ditches improves safety (TRL)

Other relevant sections: 4.1.10-13, 4.1.18-19
Key external references: 1, 4

.........carriageway markings also protects shoulders from excessive wear if they are built to lower standards. The appropriate design of drainage facilities is also particularly significant. Adequate and appropriate consideration should be given to the movements of non-motorised vehicles and pedestrians in the cross-sectional design. Design for and control of parked and stopped vehicles is important.

4.1.10 Drainage

Background

Drainage ditches are an essential part of any road which is not on an embankment and must be incorporated into most highways. These are designed to accommodate the expected rainfall but can often be hazardous to vehicles that run off the road. Adequate attention must therefore be given to the safety considerations of drainage facilities when designing and upgrading highways. Drainage ditches collect and disperse the water from the roadway pavement and the run off from the uphill side of the carriageway. Careful design and location of such ditches can reduce the potential hazard of such structures.

Fig 4.26
Deep V-type drainage ditches in Papua New Guinea leave no room for recovery if a vehicle runs off the road (TRL)

Problems

In developed countries median drains are often covered and designed to be crossed by vehicles because less disciplined drivers will drive across medians rather than making U-turns at the correct locations. However, in developing countries such buried median drains are unsatisfactory because of high cost and because they are often not regularly cleaned out.

Drainage ditches are designed to accommodate expected run-off and in countries where very intense rainfall occurs the ditches may need to cope with very high volumes of water over short periods, (e.g. flash floods in desert areas or monsoon rains in tropical countries). Consequently, they often need to be very deep and steep-sided to accommodate the volume of water but this can result in increased danger to vehicles which run off the road.

Inadequate maintenance and clearing of debris from drainage channels, especially on the uphill side of the carriageway where large volumes of solid material are often washed down into the ditch, can result in water and debris overflowing onto the carriageway. This results in potential danger of collision or aquaplaning of traffic on the road.

In many countries rural roads become the main pedestrian routes between adjacent communities and the absence of pedestrian footpaths forces pedestrians to walk on the road, especially if the drainage ditch is of a type (e.g. deep U or V-type) which cannot be used by pedestrians.

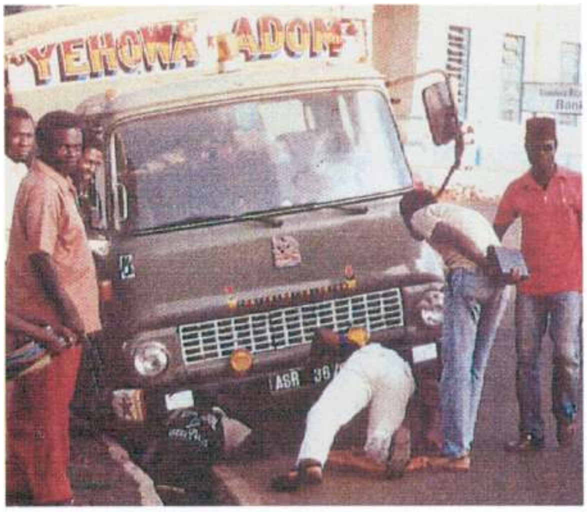


Fig 4.27
Uncovered U-type drainage channels in urban areas of Ghana pose potential hazards to traffic (Ross Silcock Partnership)

Summary

Drainage ditches must, first and foremost, be designed to accommodate the expected rainfall and run-off and are required to prevent structural damage to the road. In countries where f lash, floods or monsoon rains occur these channels may need to be very deep. Unfortunately deep, steep-sided drainage channels can result in increased danger to vehicles which accidentally run off the road.

Possible Solutions/Benefits

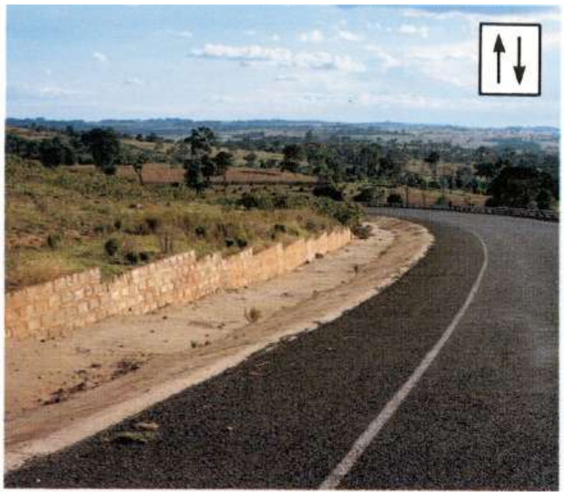


Fig 4.28
Shallow slope to drainage channel gives room for recovery in Kenya
(TRL)

Fig 4.29
Covering drainage channels as In Thailand can reduce the risk of accidents such as shown in Fig 4.27
(JMP Consultants Ltd)

The development of drainage ditches which can cope with expected rainfall levels and yet do not create unsafe conditions for motorists is not an easy task and inevitably a compromise is required. The most important principles to consider are as follows:

- The best possible hydrological study must be made using all available data, including discussions with local inhabitants, aerial photographs of areas upstream and personal reconnaissance (ideally in winter lust after rain when wet channels are clearly visible).
- On long grades, culverts are required at regular intervals to reduce the risk of flow damaging the roadside ditch. Regular turnouts are required on the downhill side of the road.
- Ditches do not need to be watertight and, indeed, it is better if they are not watertight on the side nearest the carriageway. Even in areas of tropical rainfall they will be dry for much longer than they are wet. If the side of the ditch is porous, evaporation takes place rapidly and dries out not only water which has percolated sideways from the ditch into the subgrade but also any which has percolated vertically into the subgrade from cracks in the surface of the pavement.
- Slopes on the side of the ditch nearest the road should be no more than 3:1 and preferably shallower if feasible as this will minimise damage and injury. On the side further from the road, the slope can be as steep as the ground will permit to make it difficult for vehicles to enter the road except at proper access points.
- Where expected volumes of run-off permit L- type and J-type drainage channels these should be used in preference to open U or V-type to minimise danger to vehicles which run off the road and to provide, during dry periods, a safe area for pedestrians to walk. The depth and width of the channel gap on a typical U-type ditch offers no opportunity for the motorist to recover if he should temporarily lose control and no possibility for pedestrians to walk along it.
- Legislation should be introduced which, as well as specifying road widths for particular traffic requirements, also allows adequate space for safe drainage.

Other relevant sections: 4.1.9, 4.1.17, 4.1.18
Key references: 12

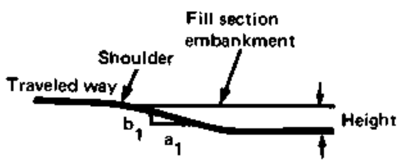
.........Where expected volumes of run-off permit L or J-type drains should be used in preference to U or V-type as, in addition to minimising damage to vehicles running off the road, these provide a safe area for pedestrians to walk on rural roads.

4.1. 11 Safety Fences and Barriers

Background

Many accidents on high speed roads involve vehicles leaving the road and being in collision with hazardous obstacles such as trees, bridge supports or simply rolling down a high embankment. Similarly, a vehicle leaving a lane on the off-side of a dual carriageway runs the risk of collision with an oncoming vehicle.

The risk of these types of accidents can be significantly reduced by the use of guard rails or barriers. The purpose of the barrier is to absorb the impact with as little overall seventy as possible. Barriers and safety fences may also be introduced to protect roadside facilities from vehicle impact.



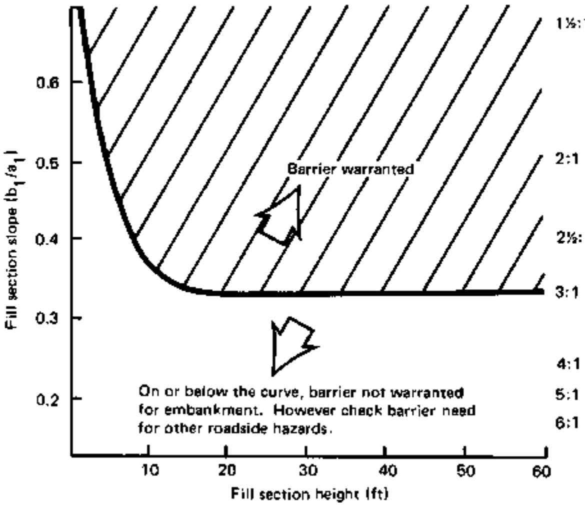


Fig 4.30
Barrier warrant for fill-section embankments as used in the USA
(ref 9)

Safety fences and barriers are used to protect drivers and passengers of vehicles from severe accidents. Problems occur when:

- The principles of design are not fully understood and carried forward to construction, so that a vehicle colliding with the safety fence is not adequately restrained. In such situations, the costs of construction will have been wasted.

- Safety fences are introduced too close to the hazard, terminated too early or the detailing of the ends of the safety fences is poor and introduces a new and severe hazard.

- Barriers and safety fences are subject to minor damage from vehicle scrapes and impacts and will lose much of their safety benefits if they are not properly repaired.

- Barriers and safety fences are installed too close to the edge of a carriageway. Reduction of the effective width of the carriageway increases the likelihood of collision between opposing vehicles, particularly on narrow roads.

- Barriers and safety fences are installed at locations where they are not essential, as this may result in additional accidents.

Fig 4.31
Vehicle impaled on incorrectly terminated barrier, Ghana
(TRL)

Summary

The correct design of safety fences and barriers is important to prevent accidents which otherwise would often be very severe. They should be designed to absorb impact with as little risk of injury to vehicle occupants as possible. They are intended to be placed between the carriageway and the objects which cause severe accidents if struck, such as bridge supports, or to retain vehicles on ....

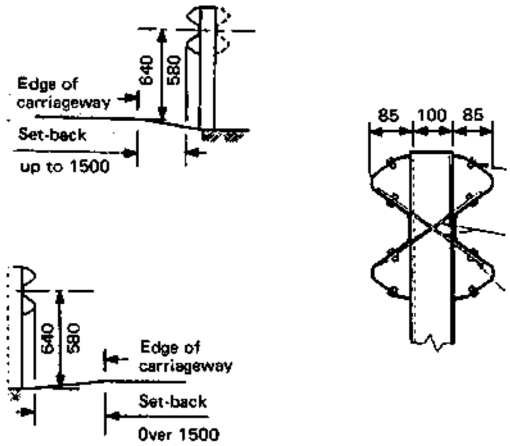


Fig 4.32
Typical barrier dimensions
(UK standards)

Fig 4.33
Guard rail to protect pedestrians on bridge, Papua New Guinea. Note flared barrier end treatment to minimise consequence of impact
(TRL)

Possible Solutions/Benefits

- Where there is space between the guardrail or safety fence and the protected feature, flexible barriers should be used which are held in tension at both ends but are flexible in between. This allows energy absorption by the barrier and therefore leads to less serious accidents. Construction must be to the manufacturer's requirements, as tolerances may be small if they are to be most effective for the range of vehicle types and conditions of impact which may occur.

- Where there is no room for deflection, for example, where width is severely limited by a bridge support, then appropriately designed rigid barriers must be used. These are not suitable for high-speed roads, although some designs will deflect vehicles back onto the carriageway.

- Special attention should be paid to end points of barriers which can themselves be a significant hazard due to the positive anchorage required and their unprotected nature. The easiest solution to this is for the end of the barrier to be buried into the back slope.

- Guard rails and safety fences should be placed sufficiently far from the edge of the carriageway so as not to cause a hazard to vehicles on the carriageway, nor reduce the effective width of the road. For rural roads, the minimum clearance should be 0.5 metres although 1.0 metres would be more desirable. For urban roads, with low speeds the setback may be reduced to 0.33 metres.

- Proper maintenance of barriers is essential if they are to remain effective.

- Warrants for the introduction of guardrails are available in reference TD19/85 and a typical example is shown in Figure 4.30.

Other relevant sections: 4.1.4, 4.1.13, 6.8.7, 6.9.4
Key external references: 1, 9

………high embankments or mountain roads. Their use on high speed roads is justified, but care needs to be taken to detail correctly, particularly at the start and end points. Damaged barriers must be repaired immediately as they can cause serious damage if struck by passing vehicles.

4.1.12 Delineation

Background

Centre and edge lining, especially if reflective, assists in the efficient and safe usage of the carriageway. They allow drivers more easily and accurately to judge their position on the road and are particularly helpful in conditions of poor visibility such as in rain, fog or darkness. This can lead to a reduction in accidents with oncoming vehicles, and with stationary vehicles or obstructions on the shoulder or road side.

Areas of cross hatching may be used to guide drivers away from an obstruction such as a central bollard or sheltered turning lane. Delineation of this sort gives clear guidance to a driver, whilst allowing him to recover from an error by driving on the hatched area if necessary. Reflective road studs and "cats eyes" are commonly used in industrialised countries to delineate the carriageway and give drivers advance warning of changes in alignment ahead.

Fig 4.34
Typical plastic delineator post, Korea.
(Ross Silcock Partnership)

Problems

It is more difficult for drivers to judge their lateral locations on a road where there are no centre line and/or edge markings. A lack of edge definition can increase pavement deterioration due to vehicles driving onto the shoulder and may increase the risk of accidents.

Centre line markings may not be sufficient to deter vehicles from overtaking into an opposing lane, especially in developing countries where driver discipline is often very poor.

Without delineation, drivers may not be aware of the need to locate their vehicles correctly as they approach either an obstacle or a changing traffic situation, such as at an intersection or at the end of a climbing lane.

Delineators which form physical barriers may themselves add to the accident situation if they are poorly designed or located. The presence of physical barriers may also restrict the movements of heavy vehicles/abnormal loads or the ready ability to divert traffic in emergency situations or when there are road works.

Fig 4.35
Hazardous bend, no delineation around bend to guide approaching motorists, Kenya
(Ross Silcock Partnership)

Summary

Delineation of the carriageway using lane markings and small physical barriers can be extremely cost effective in maintenance, traffic operations and safety terms. A large range of measures exist as indicated above, and consideration for their appropriate introduction should be given at an early stage of design. For example, on the interurban roads, markings should be considered as part ....

Possible Solutions/Benefits

Curve radius (m)	Delineator spacing m)
30	5
50	8
100	12
200	20
500	35

Table 4.09
Recommended delineator spacing on curves
(from various national standards)

Fig 4.36
Painting of crash barrier provides delineation around curve, Korea
(Ross Silcock Partnership)

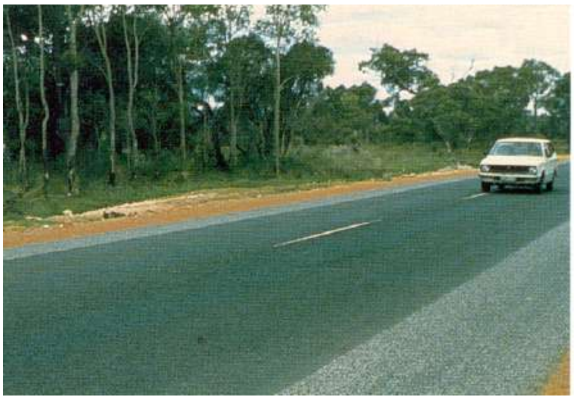


Fig 4.37
Shoulder delineation by use of different coloured surfacing in Australia
(Rendel Palmer & Tritton)

The benefits of delineation are as follows:

- Clearer road markings should be introduced wherever possible as they result in more consistent and, therefore, safer positioning of vehicles in all highway situations. The density and type of marking can also give clues to a driver as to whether or not they can consider overtaking in safety. On dual carriageway roads, and where lanes are added or dropped, delineation can encourage less haphazard movements and hence reduce accident risk.
- Reflective delineator posts and markings are especially useful at night-time. These are typically one metre high and set one metre from the carriageway. Reflectorised raised pavement markers are very effective for centre-line, lane and edge marking.
- Small physical delineators such as rumble strips or raised kerbs can deter drivers from changing lane. They should be used in dangerous situations where drivers will not obey road markings which are difficult to enforce otherwise.
- Edge of carriageway markings may be very cost-effective in reducing shoulder damage and maintenance costs.
- Even with delineation it may be helpful in rural locations to erect advisory maximum speed limit signs on the entry to particularly sharp bends located after long, straight sections of road.

Other relevant sections: 4.1.9, 5.7, 5.8, 6.8.6
Key external; references: 4

..............of the design process. Indeed, early consideration will sharpen the designers' awareness of the overtaking and other opportunities available in the alignment. Reflective delineators are especially useful at night-time in guiding a driver through what might otherwise be a potentially dangerous location.

4.1.13 Roadside Obstacles, Street Furniture & Trees

Background

The presence of roadside obstacles, street furniture and trees have two safety implications. The first is the potential danger of collision, and the second is their obstruction of visibility.

Visibility is important not only to the driver, but also to other road users. A pedestrian's decision to cross a road must be made on the basis of a full appreciation of approaching vehicles. Obstructions caused by trees, for example, may result in a pedestrian making an unwise decision.

There are many situations where good visibility is particularly important and it can be adversely affected by road side obstructions. The most important situations are on bends, the approaches to intersections and on overtaking sections.

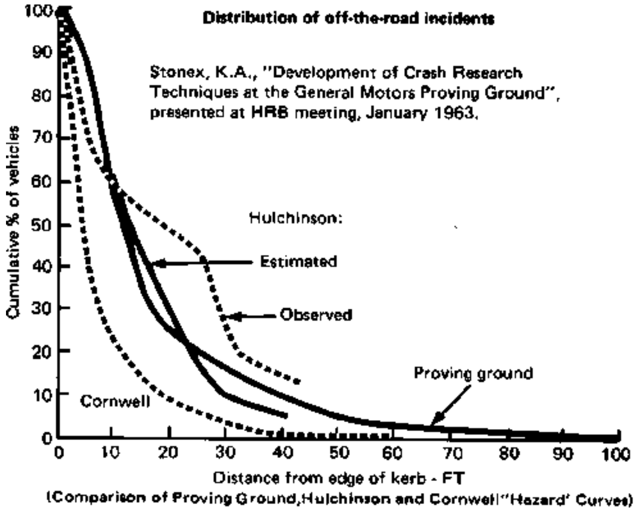


Fig 4.38
Distribution of off-the-road incidents. Note incidence of risk increases with proximity to edge of carriageway

Problems

Problems arise particularly where obstacles are immovable, either due to their very nature such as trees or outcrops of rock, or because they are needed at particular positions, such as road signs and some other street furniture.

Seasonal growth of foliage can cause substantial visibility problems, particularly by obscuring signs and signals.

In hot climates, trees are often planted adjacent to roads in order to provide shade for pedestrians, animals and parked vehicles. They also help combat erosion caused by badly detailed road drainage. Yet such trees are often a mayor source of increased severity in single vehicle accidents on interurban roads.

Unauthorised stalls may be set up immediately adjacent to the edge of the carriageway and these could be a hazard to passing vehicles.

Fig 4.39
Trees too close to carriageway increase danger of collision, Korea
(Ross Silcock Partnership)

Summary

Great care should be taken in the positioning of roadside features which may either obstruct visibility, lead to accidents or increase accident severity. Where obstructions cannot be practically removed, and contribute to hazardous situations, consideration should be given to their replacement by equipment designed to collapse on impact, re-alignment of the road, or the introduction of ....

Possible Solutions/Benefits

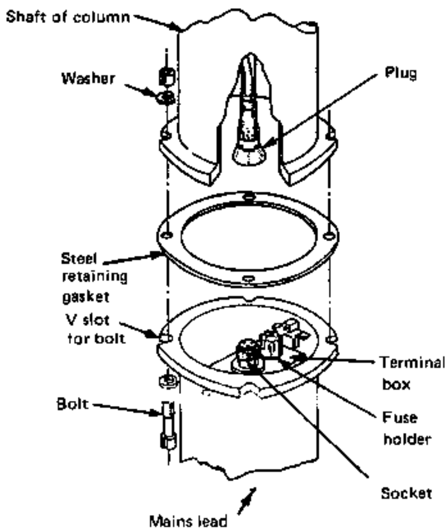


Fig 4.40
Diagram of breakaway joint (under impact) and pull-out electrical connection. Lower cost frangible post can be made by drilling holes around normal solid base
(TRL)

Fig 4.41
Vegetation and shelter well clear of roadside in Papua New Guinea, reduces risk of collision
(TRL)

- ❑ When street furniture is being installed, care should be taken to ensure that adequate visibility is maintained on all approaches.
- ❑ It is permissible for insubstantial structures or those specially designed to collapse on impact such as lamp posts, to be positioned in critical places such as at the approaches to intersections. However, larger objects such as telephone kiosks and large road signs should be positioned outside such areas or protected by a safety fence or barrier.
- ❑ There is a difficult balance to be made between the many benefits from the presence of trees beside a road and their effects on accident severity. Large trees set back five or more metres may provide an acceptable compromise. However, trees should not be planted where they are likely to be struck by a vehicle which leaves the road. Where such trees already exist, they should either be removed or a guard rail placed in front of them to deflect approaching vehicles and absorb the impact energy.
- ❑ Areas in which pedestrians or animals cross the road should be clear of roadside obstructions so that they can be seen clearly by approaching drivers within a safe stopping sight distance. The road user should also have clear views of approaching vehicles in both directions in these areas.
- ❑ Vegetation should be cut back regularly to ensure that sight distances are maintained.
- ❑ Planning controls should be enforced to remove stalls and other similar structures which are too close to the edge of the carriageway.

Other relevant sections: 4.1.11
Key external references: 4, 9

...........barriers. Once a road is completed, care must be taken to ensure that obstacles are not introduced by others subsequently, such as telephone or electricity authorities. Vegetation should be cut back regularly and planning controls should be enforced to prevent stalls and structures too close to the road edge.

4.1.14 Median Barriers

Background

Medians, or central barriers, are used to segregate opposing streams of traffic and to discourage unwise choices of crossing place by pedestrians. The safety implications are that head-on collisions between opposing streams are avoided and that pedestrians are encouraged to use crossing facilities or to choose another, safer point at which to cross.

A distinction should be made between medians used for directional guidance in traffic management, and safety barriers. The latter need to be more substantial as their function is to redirect errant vehicles onto their original course and absorb much of the energy of collision. Safety barrier dimensions are discussed in section 4.1.11. Typically they are of the order of 600 mm or more in height, whereas medians provided for guidance need only consist of a raised kerb or low railing.

Fig 4.42
Poor design of central barrier in Ghana. Note provision of a walking area encourages its use by pedestrians and exposes them to risk
(Ross Silcock Partnership)

Problems

Pedestrians are reluctant to make long detours to find a safe crossing point and in some situations the median barrier merely necessitates a dangerous vaulting or climbing manoeuvre in the middle of the road.

Medians can restrict the movement of traffic if there is a breakdown or if emergency vehicles need to make their way through a traffic jam. The materials used for median barriers can be useful for other purposes and pilferage is a problem in some countries.

End detail is important; as the unprotected end of a median barrier can form a substantial and potentially lethal structure in the centre of the carriageway.

Clear and effective signs are needed, with strict enforcement, to ensure that drivers do not mistakenly - or deliberately - drive on the wrong side of the barrier.

Fig 4.43
Narrow median barrier in Pakistan, separates traffic but creates dangers for pedestrians due to inadequate width
(Ross Silcock Partnership)

Summary

Median barriers are an important safety feature on high speed roads and in some situations can have safety implications for both motorists and pedestrians. They reduce or eliminate the danger of head-on collisions and prevent pedestrians crossing at potentially hazardous locations. Care needs to be taken with access routes for emergency vehicles and for other unexpected events such ....

Possible Solutions/Benefits

Fig 4.44
Concrete median barrier, Hong Kong, separates traffic and deters pedestrian use through good design
(Ken Huddart)

Fig 4.45
Movable concrete block and steel rail barrier in Chula, separates traffic and provides ease of relocation when required
(Ross Silcock Partnership)

- Physical barriers may be used where the effects of vehicles ignoring guidance may lead to severe accidents and where other objectives can be met at the same time. Such barriers are often placed down the centre of wide urban multi-lane roads and incorporate pedestrian barriers. They stop U-turns, a particularly dangerous and disruptive movement and can reduce or even eliminate head-on collisions, depending upon their characteristics. Full width medians with purpose-built crash barriers are unnecessary on low speed urban roads.

- Median barriers can be used to channel pedestrians to safer crossing points, at which special facilities can be provided. In some cases kerbside barriers may also be required to prevent pedestrians attempting to cross by climbing the median. The median barrier may be retained at pedestrian crossing points, but be modified for easy use by pedestrians. A single step of not more than 0.25 metres would be adequate to deter vehicle usage.

- Consideration should be given to the access of emergency vehicles and other vehicles in the case of a breakdown or accident. This can be done by local widening at the intersections or by strategically placed gaps in the barriers.

- Careful end detailing can reduce the hazard formed by the end of the barrier. This may include some form of impact absorbing crash cushion, with road markings and advance warning signs.

- Where barriers are not considered necessary a desirable minimum median width is five metres, but where there is insufficient road space available, a width down to 1.2 metres will at least provide some refuge for pedestrians.

Other relevant sections: 4.1.11, 6.8.7
Key external references: 1, 4

…….as accidents or breakdowns. End details are important as an unprotected end to a median barrier becomes a particularly severe hazard. Where barriers are not considered necessary a desirable minimum median width is 5 metres.

4.1.15 Lighting

Background

Background: The introduction of adequate street lighting can help reduce night-time accidents and is an established accident prevention measure in urban areas in industrialised countries. It is particularly important where there are high proportions of pedestrians, cyclists or other poorly lit road users including animals. Lighting has benefits other than accident prevention and can often be justified as a general amenity with an associated reduction in night-time crime and an improvement in personal security.

Lighting should provide a uniformly lit road surface against which vehicles, pedestrians or other objects are seen in silhouette. The design of the lighting system should relate to the road surface reflection characteristics in order to provide the optimum quality and quantity of illumination. Light coloured surfaces give better silhouette vision than do dark ones.

CATEGORY	AVERAGE LUMINENCE LEVEL L cd/m^2	OVERALL UNIFORMITY RATIO U_0	LONGITUDINAL UNIFORMITY RATIO U_1	EXAMPLES
1	1.5	0 4	0.7	High Speed Roads Dual Carriageway Roads
2	1.0	0 4	0.5	Important rural and urban traffic routes Radial roads Distrct distributor roads
3	0 5	0 4	0 5	Connecting, less important roads Local distributor roads Residential area major access roads

NOTES:
Average luminance (of the road surface) is the average luminance over a defined area of the road surface viewed from a specified observer position (symbol L).
Overall uniformity (of luminance) is the ratio of the minimum to average luminence of a defined area of the roadway (symbol U_0)
Longitudinal uniformity (of luminance) is the ratio of the minimum to the maximum luminance along a longitudinal line drawn through the observer position (symbol U_1)

Table 4.10
Recommended Lighting standards as used in UK (British Standard 5489)

Problems

Urban street lighting is often inadequate in developing countries and, unfortunately, it is expensive to install and maintain.

Without proper maintenance, the resulting inconsistency in lighting can of itself be a safety hazard. Maintenance can be a problem in many developing countries.

Careful attention needs to be paid to the siting of lamp posts as they can be hazardous in the event of a vehicle leaving the road. The column can be a significant visual obstruction at critical locations.

Lighting demands readily available and sustainable electricity. This is generally not available in rural areas in developing countries and many towns also suffer from irregular and low-voltage supplies.

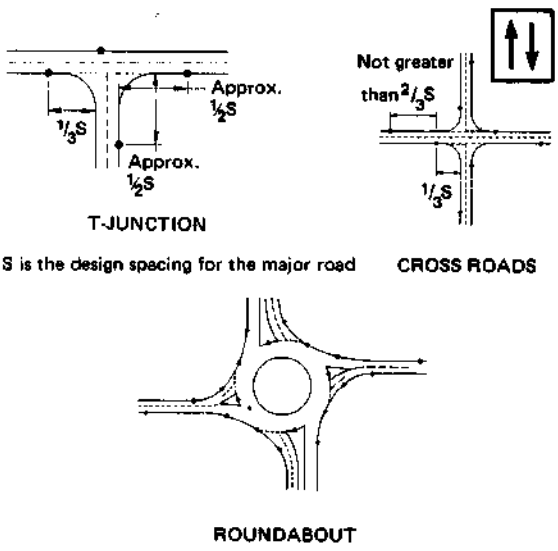


Fig 4.46
Lighting installations at intersections (British Standard 5489)

Summary

Lighting is most appropriate in urban streets, and key locations include intersections and places where pedestrians cross. The level of illumination needs to be consistent and maintenance is most important. Signs and road markings should be visible at night. Where the road layout is at ....

Possible Solutions/Benefits

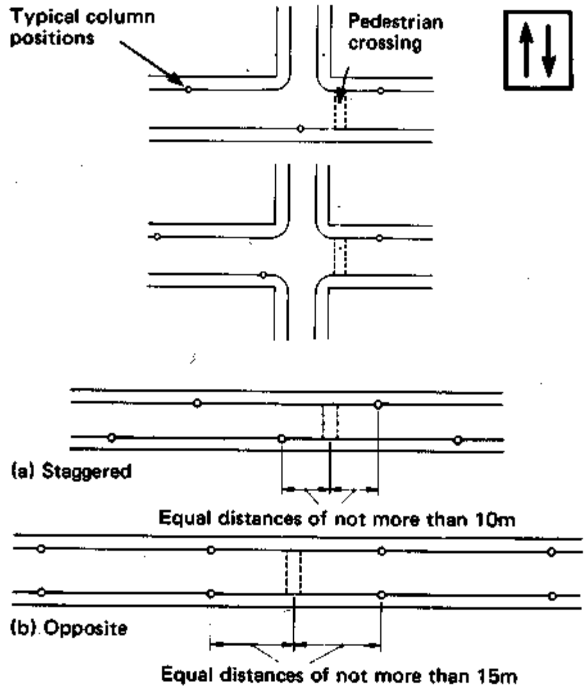


Fig 4.47
Lighting installations at pedestrian crossings (British Standard 5789)

Generally there is a need to improve street lighting especially where there are high pedestrian flows. The most important aspects to consider are:

- Evenness of illumination is important. This requires good design and regular maintenance. A routine maintenance programme should be initiated and all installations inspected on a regular basis.
- Lamp posts should not be sited in positions where they will be a danger to a vehicle leaving the road. If this is not possible, then they should be protected by crash barriers, or designed to collapse on impact.
- Signs and road markings should be visible at night. Where lighting is not feasible, use of reflective material is a useful, cheaper alternative.
- Lighting is most important at key locations such as at sub-standard design sections, at sites where the layout may be unclear, at intersections, and where pedestrians cross.
- Consideration should be given to the use of sodium lighting, particularly at key points, as it is much more efficient than mercury or tungsten lighting.

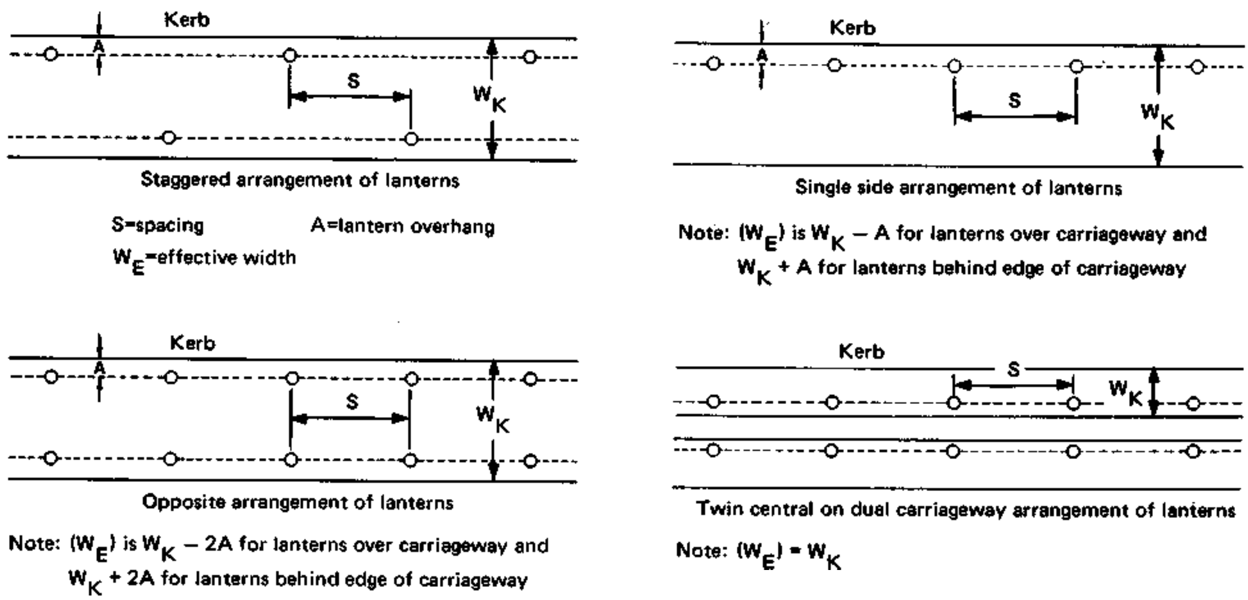


Fig 4.48
Typical street lighting layouts (British Standard 54891

Other relevant sections: 4.1.13
Key external references: 1,17

………..all unusual or where there are large numbers of cycles or pedestrians, lighting is particularly important. If only limited funds are available, efforts should be made to provide lighting on at least the most important routes.

4.1.16 Lay-bys, Bus Stops and Service Roads

Background

Lay-bys and bus stops allow vehicles to stop safely and with the minimum of adverse effects on other traffic. This is best done with a segregated area joined to the main road pavement only at an entry point and an exit point. Vehicles can then stop off the main carriageway without interfering with other traffic and with less risk to passengers getting on or off.

Where major roads are bordered by commercial or residential development, service roads are the safest way of allowing access to property with the minimum effect on other traffic. Also, where a large commercial development is fronted by an informal parking area with uncontrolled access to the carriageway, a significant risk of accidents will often exist.

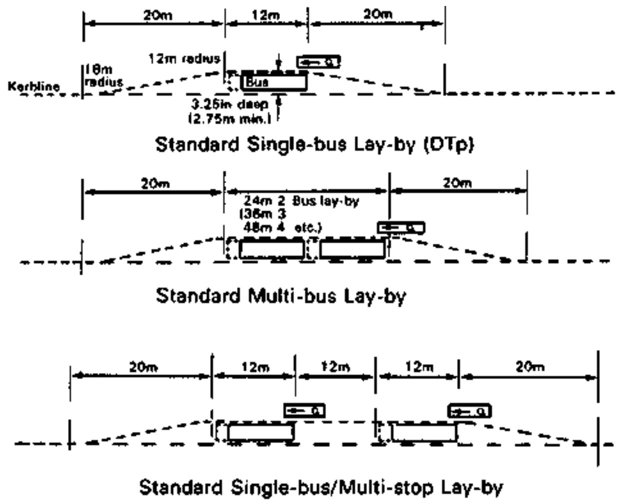


Fig 4.49
Typical dimensions for bus bays in UK. Dimensions need to be adjusted to suit local traffic (ref 1)

Problems

Bus stop lay-bys are often not provided and buses simply stop by the side of the carrriageway. Where lay-bys do exist they can be crowded with waiting passengers and bus drivers tend not to use them. This behaviour is frequently observed on heavily trafficked roads where the driver is more likely to experience difficulty in merging with the main road flow again.

Vehicles stopping at a lay-by or bus stop constitute a temporary obstruction which may obstruct visibility of an important feature. If the lay-by is close to the road, there is also the risk of collision between parked vehicles and those inadvertently straying from the road.

The slower speeds of vehicles entering and leaving a lay-by could cause a hazard to faster moving through traffic, although this is often less hazardous and disruptive than buses stopping directly on the carriageway.

A bus lay-by which has been produced at the expense of the adjacent footway may not be able to be used fully at peak periods because of pedestrian queues and movements.

At existing commercial sites, there may be insufficient room for the construction of a service road, although there may be too many accesses to be compatible with safety.

Fig 4.50
On-road bus stop causes obstruction and creates potential hazard for pedestrians and vehicles, Ghana (Ross Silcock Partnership)

Summary

Lay-bys and bus stops are an essential element in providing for access. By removing stopping traffic from the main carriageway, conflicts are reduced and safety is enhanced. Their positioning is critical, however, and every effort should be made to avoid physical or visual obstruction. They should not be located on the outside of curves, or very close to intersections and should be ....

Possible Solutions/Benefits

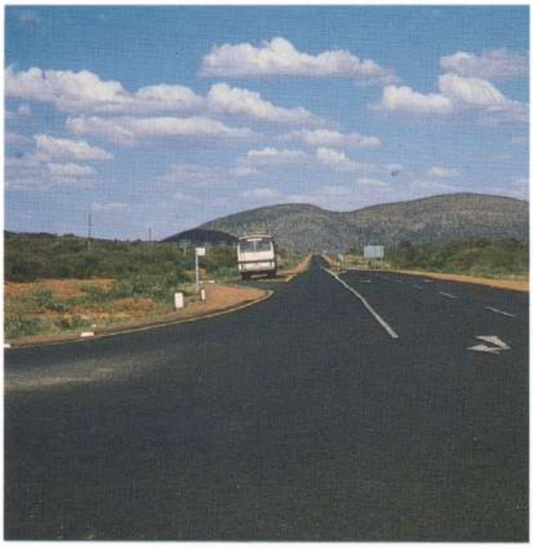


Fig 4.51
Rural bus bay provides safe off-road operation.
Botswana
(TRL)

Fig 4.52
Ample space provided off-road for bus to pickup/drop passengers in Ghana. Note shaded bus shelter
(TRL)

- ❑ Lay-bys should be positioned on straight, level sections of road and should be visible from a good distance in both directions.
- ❑ On rural roads, it is cheaper to provide lay-bys at transitions from cut to fill.
- ❑ Access to a lay-by should be convenient and safe for vehicles and, also for pedestrians in the case of bus stops.
- ❑ Advance warning signs could be erected to alert drivers of the approach to lay-bys, and to the possible presence of pedestrians ahead.
- ❑ Adequate queueing areas should be available so that waiting passengers do not use the road or a dedicated bus lay-by.
- ❑ Where space is limited, it may be possible to link premises using a service road which runs behind the premises and turns to rejoin the main road only when a convenient and safe location is reached. At this point, parking and other potential visual obstructions should be carefully controlled.
- ❑ Where problems of merging from a lay-by occur, it may be possible to postpone the merge by providing a short additional lane which is the continuation of the lay-by.
- ❑ Where spillage of diesel fuel is likely to occur, e.g. at bus stops, concrete construction is more suitable than a bituminous surfacing. (Buses will not use the stops if the road surface has deteriorated.)
- ❑ Bus stops should be located beyond pedestrian crossings and after intersections to avoid stopped vehicles masking pedestrian and other crossing activities.

Other relevant sections: 3.8, 4.2.2, 5.11, 5.12, 5.13
Key external references: 1

............Located beyond pedestrian crossings and intersections so that buses do not obstruct crossing pedestrians. The replacement of numerous poorly defined access points to a major road by a service road with one well designed intersection will have substantial safety benefits. The benefits extend beyond the main road, and access roads provide safer refuge for pedestrians, cyclists and loading/ unloading of commercial vehicles.

4.1.17 Urban Footways

Background

Pedestrian accidents are of particular concern in most countries and form a substantial proportion of road accident deaths and injuries. Pedestrians are particularly at risk in the urban situation. In urban areas, highways are usually designed with raised footways as part of the cross-section. On interurban roads, footways are rarely provided, although in developing countries, pedestrian flows may be high.

The standard of maintenance and repair of facilities plays an important part in reducing both real and perceived danger and inconvenience for pedestrians.

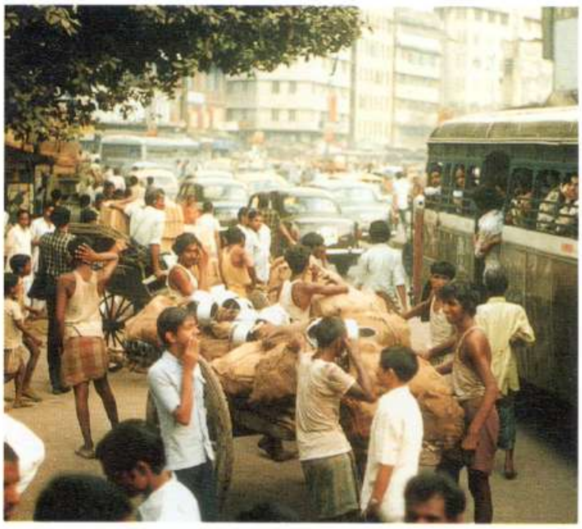


Fig 4.53
Congested footway causing pedestrians to overspill into roadway, India
(Ross Silcock Partnership)

Problems

Pedestrian activities are usually relatively unrestricted and consequently complex and confusing movements take place.

In some urban situations inadequate footway space can force pedestrians onto the roadway and create safety problems for all concerned. Pedestrians may also be forced onto the carriageway because of the poor condition of the footways, parked vehicles, or the use of the footway by street traders.

Poorly sited street furniture can prevent full use of the footway and impede visibility for road users. It is sometimes possible to site equipment such as traffic signal controllers, lighting columns and poles for signs, at the back edge of the footway rather than at the kerbside, but this is rarely done.

Parking on the footway is highly obstructive and can damage the surface as well as forcing pedestrians onto the road. Physical barriers to prevent parking on the footway can be useful.

Footways with uneven surfaces or otherwise in a poor state of repair are particularly hazardous and people may be forced to walk in the carriageway and hence be exposed to unnecessary risk.

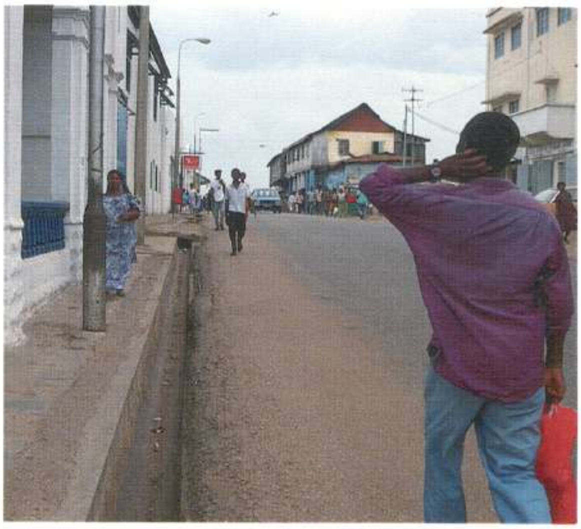


Fig 4.54
Inadequate footway width and street furniture obstructions force pedestrians to walk in road, Ghana
(TRL)

Summary

Footways have great implications for safety and every effort should be made to segregate pedestrians and vehicles where space allows. Separate routes make travel much more safe for vulnerable road users. In areas of high pedestrian activity it may be desirable to give greater road space to pedestrians and less to vehicles by the use of wide footways. In central areas it may ....

Possible Solutions/Benefits

Fig 4.55
Wide segregated urban footway, Kenya. Note bollards prevent vehicle encroachment
(Ross Silcock Partnership)

Fig 4.56
Segregated footway, China. Note pedestrian fences to confine movements on footway.
(Ross Silcock Partnership)

- Whilst it is clearly desirable to provide an extensive network of segregated footpaths and footways, this is rarely possible in countries with limited resources. Thus, attention should be directed to places more likely to benefit from the segregation of pedestrians from motorlsed traffic. Potential locations are places where pedestrians are found in large numbers, for example near schools, shopping areas and major sports facilities. In some areas it may be possible to widen the existing footway to avoid the necessity for pedestrians to step into the carriageway where the footway is too narrow for the demands placed upon it.

- Footways should be segregated by at least a raised kerb and in critical areas by guardrails as well. This is particularly important on narrow and/or high speed roads. However, dropped kerbs should be provided at preferred crossing places for wheelchairs, prams and barrows.

- Footways should be of good standard and of adequate width for the pedestrian flows involved and be kept clear of obstructions. UK guidelines recommend widths of 1 metre per 50 to 60 pedestrians per minute plus up to 1 metre for frictional effects (ie 'dead' width at the kerb edge and any sidewall).

- Measures which increase the capacity of the footway and reduce the time taken for pedestrians to cross the road can be especially useful where pedestrian movements cannot be concentrated at a formal crossing place. The loss of carriageway capacity for moving vehicles can sometimes be reduced if bays are provided for bus stops and arrangements are made to control loading and any on-street parking, thus preserving an adequate running width.

- In central areas, consideration should be given to pedestrianisation of certain streets for at least part of the day, possibly allowing access for service vehicles and public transport.

- Alternative, off-road routes should be sought, such as paths through parks and school playing fields.

Other relevant sections: 3.5.5, 4.1.9-11, 4.1.18, 6.9
Key external references: 1, 11

..............even be beneficial to pedestrianise some streets for at least part of the day but access must still be possible at other times for service vehicles. Care must be taken to ensure that footways do not become obstructed, especially by street traders and/or parked vehicles, and that the surfaces are easy to walk on.

4.1.18 Rural Footpaths and Footways

Background

Although pedestrians exist in lower concentrations in rural areas than in towns, they are still placed at considerable risk due to the higher speeds of traffic and lack of pedestrian facilities and street lights. In the developing world, where village people sometimes have to walk many miles into the cities, this can be particularly hazardous. The construction of a simple footway along the roadside, or even a wide shoulder, can remove many such conflicts.

As space is usually available in rural areas, it is often possible to provide segregated footways within the boundaries of the highway. These should be segregated from the carriageway by a grass verge and/or railings. Where space permits it is possible to allow shared use of paths by pedestrians and cyclists. Ideally, footways and cycleways should be provided on both sides of the highway.

Fig 4.57
Absence of footway forces pedestrians to use edge of rural road in Africa
(Ross Silcock Partnership)

Problems

Substantial conflict problems usually exist where roads pass through rural settlements as the road often passes very close to existing buildings leaving no footpaths for pedestrians. Also, in developing countries, rural roads are often used by the local population as footpaths, particularly in the rainy season as these usually provide the easiest and most convenient routes between communities.

In many developing countries, interurban roads have a cross sectional profile which makes it difficult to cater easily for pedestrians. The natural camber of the carriageway is carried over into the shoulder and this is followed by a steeper slope into the side drain. The side drains too are often deep U-type channels which (particularly in mountainous areas where the road is in a cutting) force pedestrians to walk on the roadway and expose them to increased risk.

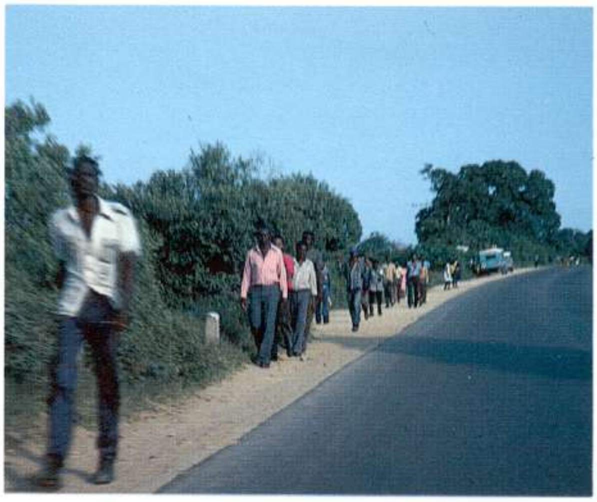


Fig 4.58
Narrow shoulder on *paved rural road in Africa provides some protection but inadequate for volume of usage*
(Ross Silcock Partnership)

Summary

Walking is a major mode of transport in the developing world and pedestrians form a high proportion of accident victims. The provision of simple segregated footpaths or footways adjacent to the carriageway can prevent accidents to vulnerable pedestrians in rural areas where vehicle speeds are high. It is crucial that they are given due consideration at the design stage, to see ....

Possible Solutions/Benefits

Fig 4.59
Pedestrians using benched embankment as footway on rural road in Papua New Guinea, provides safe segregated facility (TRL)

Fig 4.60
Wide shoulders with shallow crossfall gives space for pedestrians on rural road in Ethiopia (TRL)

The most important elements to consider are:

- Special consideration should be given to pedestrian movements along the route during the design stage of a highway. This will require separate surveys to estimate demand and appropriate provision as part of the design.
- On all but the lowest trafficked roads, the non-motorised movements should be segregated, either by providing a footpath/cycleway beyond the drainage facility, or on a segregated part of the shoulder. Where segregated facilities are designed for a light loading and there is likelihood of encroachment by heavy vehicles, provision, such as barriers or bollards, should be made to stop the passage of heavy vehicles which would damage the facility and make it unserviceable. Footpaths need not be expensive. Running a grader along one side of the road levels the ground and removes most of the vegetation to create a cheap segregated footpath.
- Where vehicle speeds are relatively high, crossing facilities should be protected by speed limiting devices, such as speed humps, and be readily visible. Parked vehicles should also be banned within 30 metres of each pedestrian crossing facility.
- A regular maintenance programme should be initiated to ensure that the surfaces of footways are kept reasonably clean and level, and that vegetation does not cause an obstruction either to passage or visibility.
- Visibility at crossing points is particularly important and advance warning signs should be used if good visibility is not available.
- On very low volume access roads, reduced geometric standards will reduce vehicle speeds and may allow pedestrians to use the road safely without segregation.

Other relevant sections: 4.1.10, 4.1.17, 4.1.19, 6.9
Key external references: 1, 7

............how pedestrian movements, both along and across the roads, may be catered for most safely and efficiently in all aspects of the design. Where such rural roads pass through isolated communities or trading centres this may require appropriately signposted raised crossings to slow down traffic. In rural sections where high volumes of pedestrians are expected, wide shoulders or a graded footpath alongside the road may be required.

4.1.19 Pedestrian/Cyclist Facilities on Bridges

Background

Bridges are expensive structures and have design hues which are substantially greater than the adjoining sections of highway. Thus, many bridges still in use were built when levels of traffic flow were very low and special consideration did not have to be given for pedestrians or cyclists. More recently, extra width for pedestrians or cyclists has not always been provided because of the additional cost.

In many places, bridges are probably the only means by which pedestrians and cyclists can cross the rivers, and proper provision has substantial social as well as safety implications.

Fig 4.61
Absence of pedestrian footway on bridge exposes pedestrians to danger from traffic, Ethiopia
(TRL)

Problems

Where bridges have been built with restricted carriageway width, there may not even be adequate clearance for a truck to pass a pedestrian in safety. On longer badges, it may not even be possible for a pedestrian to make a 'safe' decision on whether to commence crossing, and accident rates may be high. As flows increase, the problems become worse.

On narrow, two-lane bridges vehicle speeds may be high, and vehicles may not have sufficient extra clearance for pedestrians or cyclists to be passed safely. The problem may be particularly severe in locations where approach roads lead to a single lane bridge. Fast approaching traffic is then suddenly constrained to a much narrower area and may have problems in safely negotiating the bridge in any case. The presence of unprotected pedestrians on the bridge using up part of the limited space available increases the likelihood of accidents occurring

Fig 4.62
No footway on narrow bridge exposes pedestrians to danger from traffic, Africa
(Mott MacDonald)

Summary

When bridges produce a narrowing of the highway, special segregated provision should be made for cyclists and pedestrians, especially on long bridges. The level of provision will depend on pedestrian, cyclist and motorised vehicle flows and speeds. A minimum width of 1.5 metres is desirable. If this cannot be provided throughout the length of a bridge then periodic refuges ....

Possible Solutions/Benefits

Fig 4.63
Segregated footway, protected by barrier, Papua New Guinea. Note end treatment leaves barrier exposed to approaching traffic
(TRL)

Fig 4.64
Segregated footway as above but end treatment of barrier provides protection for both pedestrians and vehicles. Note grass should be kept cut to increase conspicuity. Papua New Guinea
(TRL)

- Where possible a segregated footway should continue across the bridge or a separate parallel foot/cycle bridge be constructed. It may be necessary for these modes to share a single facility. Where road-space is limited, an economic solution may be achieved by providing a separate pedestrian/cycle footbridge. Since motorised vehicles cannot use it, its structural strength can be lower. The pedestrian bridge may be cantilevered off the structure of the road bridge. A desired minimum width would be 1.5 metres, although this may need to be greater for high pedestrian and cycle flows. The additional cost of such a facility will be very small if incorporated at the design stage.

- If no facility can be provided throughout the length of the bridge, then refuges at regular intervals would be of assistance, particularly on the uphill side of along bridge as this is where speed differences are greatest.

- Where a pedestrian/cycle facility rejoins the road, it must be well signed and be at a point with good visibility.

Other relevant sections: 4.1.15-18, 6.9
Key external references: 1

...........with local widening should be provided. This will give pedestrians a safe place to wait whilst vehicles cross the bridge. Pedestrian bridges can be cantilevered off the road bridge and because the loads will be very low, will not need much structural strength. If incorporated at the design stage, the additional costs involved are likely to be very low.

4.1.20 Facilities for Cyclists & Slow-Moving Vehicles

Background

There is generally a lack of facilities for non-motorised vehicles in most countries. In China, cycles are registered and special facilities are provided for them since they constitute the largest group of vehicles using the roads. However, in most other developing countries, despite the large numbers of cyclists, and other human powered vehicles (e.g. becaks, rickshaws) very few special facilities are available. In such countries these vehicles have to compete for road space against cars, trucks and other motorised traffic using the roads.

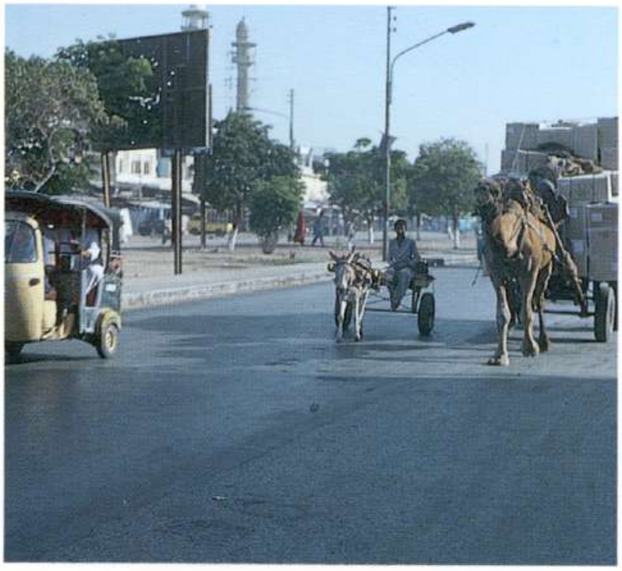


Fig 4.65
Slow-moving vehicles on a dual carriageway in Pakistan cause delays and potential conflicts with faster traffic (TRL)

Problems

In most developing countries flows of modern motor vehicles are mixed with animal-drawn marts and bicycles. As well as reducing capacity substantially, the presence of slow-moving vehicles on the same carriageway creates hazardous conditions. Other vehicles may be forced to slow down rapidly, or be tempted to overtake in dangerous circumstances. Alternatively, buses stopped adjacent to the kerb can obstruct cyclists and other slow-moving vehicles. Non-motorised vehicles are amongst the most vulnerable groups of road users and like pedestrians, are unprotected. Consequently, any impact, even a small one, can result in serious injury to riders and passengers.

Other kinds of slow moving vehicles can be even more problematic, especially if they are physically large - as are many animal drawn carts. Slow-moving animal drawn traffic can be particularly hazardous in rural areas and at night. Often unlit, they obstruct faster moving traffic in an unpredictable way. Unsuspecting drivers run serious risks of collision, either with the cart or with other vehicles if they attempt to overtake. It must be recognised, however, that in some countries animal drawn carts are still fundamental to the local, rural economy so cannot just be banned.

Fig 4.66
Freight trishaw in mixed traffic in China (Ross Silcock Partnership)

Summary

The mix of traffic in developing countries can lead to particularly hazardous situations because of the wide range of vehicle performance characteristics. Segregating the slower moving traffic from the motorised flows can offer safety benefits and an improvement in overall efficiency of the network. Although it is rarely practical to build completely separate networks in existing cities, ...

Possible Solutions/Benefits

Fig 4.67
Segregation by lane separates motorised and non-motorised trishaws from general traffic. India I
(TRL)

Fig 4.68
Segregated cycleway provides safe facility and reduces conflict in China
(Ross Silcock Partnership)

Different types of traffic need different facilities and slow-moving and vulnerable road users should be segregated wherever possible from faster motorised vehicles. Ideally, separate cycleways should be provided if cycling is a major mode of transport - as it is in some parts of the world. A wholly separate network of cycleways is generally impractical in existing cities on cost grounds but should be considered, particularly in new developments. Aspects which should be considered are:

- By simplifying the traffic situation with the segregation of slower moving traffic from the main streams, it is likely that a more efficient, and safer, situation will result for all road users.
- It is sometimes possible for cyclists to share facilities with pedestrians - for example, an underpass or overbridge - and at the same time to reduce delays caused to faster moving traffic by removal of the conflicts. Cycleways should usually be a minimum of two metres wide, with additional width to allow for high flows and, in some situations, use by other non-motorised vehicles. Segregation by a kerb or barrier will limit use by motorised vehicles.
- Opportunities for segregation may be less in rural areas. If animal-drawn traffic is still common, then the provision of a wider shoulder on major routes can act as a suitable track. The presence of the wide shoulder may also be of similar benefit to cyclists and pedestrians as well as offering a safe refuge for broken-down motor vehicles, off the main carriageway. If special shoulders are to be used in this way, care should be taken to ensure that they are sufficiently wide and segregated at least by road markings.
- There is a need for enforcement of laws applying to slow-moving vehicles, eg where they are banned (from motorway standard highways) and particularly in the provision of vehicle lighting when used after dusk.

Other relevant sections: 4.1.17,4.1.18,4.1.19,6.9
Key external references: 11

.........it may be possible to provide a safer network by providing additional facilities along certain routes and linking these by short, segregated sections. In new developments, segregated road and path systems can be included at the planning stage, often at little cost. Pedestrians and slow - moving vehicles can share facilities. The provision of shoulders along rural roads could provide one such facility.

4.2 Intersection Design
4.2.1 Selection of Intersection

Background

The basic principles of good intersection design are that they should allow transition from one route to another or through movement on the main route with minimum delay and maximum safety. To do this, the layout and operation of the intersection should be obvious and unambiguous with good visibility between conflicting movements. These objectives need to be achieved at reasonable cost so provision of unnecessarily high standards as well as inadequate ones needs to be avoided. Different intersection types will be appropriate under different circumstances depending on traffic flows, speeds and site limitations.

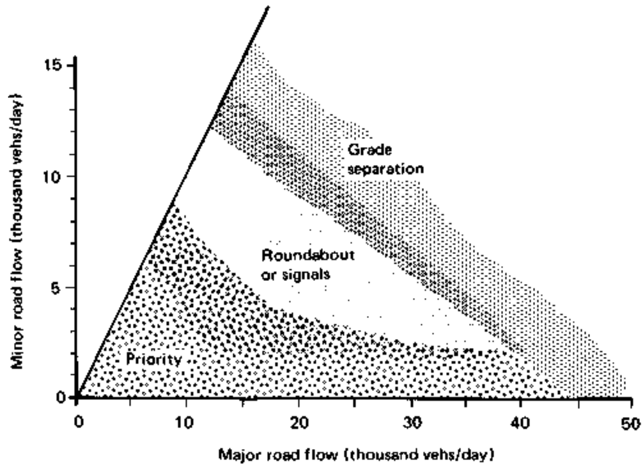


Fig 4.69
UK practice for intersection selection based on different combinations of traffic flows in urban conditions
(ref 1)

Problems

It is often difficult to determine the best intersection type for any particular situation, taking into account capacity, delay, safety and physical layout factors as several alternatives may be possible.

If intersections are not of an easily recognisable type, drivers may be unclear as to which flows have priority and accident risk may thus increase. Thus the isolated introduction of traffic signals in a developing country could have an adverse effect on road safety unless all drivers are fully aware of the meaning of the red signal and are familiar with that type of intersection.

Generally it can be expected that different driving standards and driving behaviour will exist in less developed countries and this may result in some intersection types being unsuitable for use in such countries.

The use of STOP signs at priority intersections which have clear sight lines in both directions will lead many drivers to infringe the law by not physically stopping their vehicle. This behaviour may then be carried over to more hazardous locations where the STOP sign is essential.

Sideswipe accidents are common at straight crossroads (particularly at night) where, owing to the unimpeded view across the function, drivers have not appreciated that there is a priority intersection ahead.

Summary

The choice of an intersection type requires a knowledge of demand, intersection performance and accident prediction. Local behavioural and vehicle performance characteristics are often not available to calibrate capacity and delay models, and much additional research is still required in this area in developing countries. Consequently it will generally be better to select proven ....

Possible Solutions/Benefits

GRADE SEPARATION	High flows Minimal delays. Expensive.
TRAFFIC SIGNALS	Low/Medium flows. Can accomodate heavy offside turning flows by using filter signal and channelisation Requires less space than roundabout Relatively high delays at off-peak times.
ROUNDABOUT	Low/Medium flows Good for turners having to both cross and merge with traffic streams Minimal delays at lower flows (i.e off-peak) Not good for safety of cyclists and other slow vehicles.
PRIORITY (Give-way/Stop)	Low flows. Can have high delay to minor road traffic No delay to major road. Major road needs stopping sight distance.

Table 4.11
Advantages and disadvantages of different types of intersection

The factors affecting safety at each type of intersection are considered separately in later sections. Intersection choice will be dictated by these considerations together with the local site details. In many situations, there will be little to choose between the alternative intersection types available. Proven designs which have been shown to work safely and which are familiar to drivers should generally be used. However, this should not preclude the introduction of new schemes and designs where appropriate. Such schemes should be publicised and closely monitored. The main factors to consider in intersection design are:

The delays and capacities can be estimated using standard formulae and programs, provided they are properly calibrated for local use. Capacity, however, should not be provided at the expense of safety.

Least problems will be caused by simple intersection design and 'easy' geometry. Intersections should be compatible with the type of road and with other intersections along the road to provide consistency.

In rural and lightly trafficked areas the cheapest solution is to adopt a "terminating road" rule, whereby traffic on the stem of the `T' (which has to slow down anyway) should give way to the straight through traffic.

GIVE WAY signs and markings should be used rather than STOP signs at intersections where there are good sight lines in both directions.

Staggered crossroads generally have better safety records than straight crossroads. The preferred orientation of stagger is such that drivers cross directly at right-angles to the nearest traffic stream first (ie right-left-stagger for driving on the left). Wherever possible, a protected turning area in the centre of the major road should be provided.

Care should be taken to have unambiguous signs and clearly marked lane segregation.

Sight distances should be related to the speed of the relevant approach with stopping sight distance being provided in all cases.

Other relevant sections: 3.3
Key external references: 1

..............intersection types which are known to be understood by local drivers and which already operate safely. This does not preclude new intersection types where necessary, but emphasises the need on such occasions for careful design, considerable advance publicity, driver education and monitoring after construction. As a general rule, intersections should be as simple as possible and designed to guide drivers safely through conflict points.

4.2.2 Priority Intersections

Background

Priority intersections are the most common form of intersection. Control is by a 'Give Way' or 'Stop' sign on the minor road with no restriction on the major road. Priority intersections fall into two basic categories: namely T-junctions and crossroads, with crossroads usually having the worst safety record for similar traffic patterns.

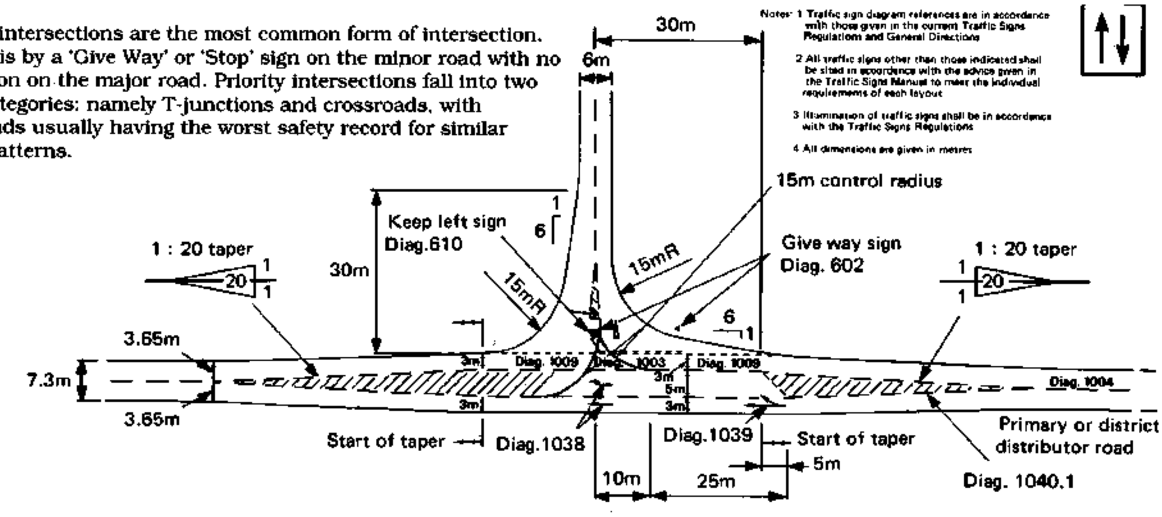


Fig 4.70
Dimensions for typical urban priority T junction as used in UK (ref 1)

Problems

Crossroads often have a poor safety record because of minor road traffic failing to stop for main road traffic either because of driver indiscipline or because the driver is not aware that there is a mayor road ahead. If the stop-line is in the dip at the edge of the major road camber it can be invisible from a distance on the minor road. The major accident types at priority intersections are accidents where side road vehicles fail to stop, implying inadequate visibility of the intersection from the minor road, and accidents with emerging vehicles, which suggests inadequate sight lines along the major road.

For all types of priority intersection, the problem of delay exists for minor road traffic which has to give way. If the delays are excessive, emerging drivers may take undue risks in order to enter or cross the main stream.

Multiple lane approaches place greater demands on the emerging driver and tend to be more hazardous locations.

Slow moving or stationary vehicles turning into a side road across a main road stream of traffic are often the cause of serious accidents, particularly at night Problems can also be caused in urban areas by inadequate kerbs which give an unclear layout and make little or no provision for pedestrians.

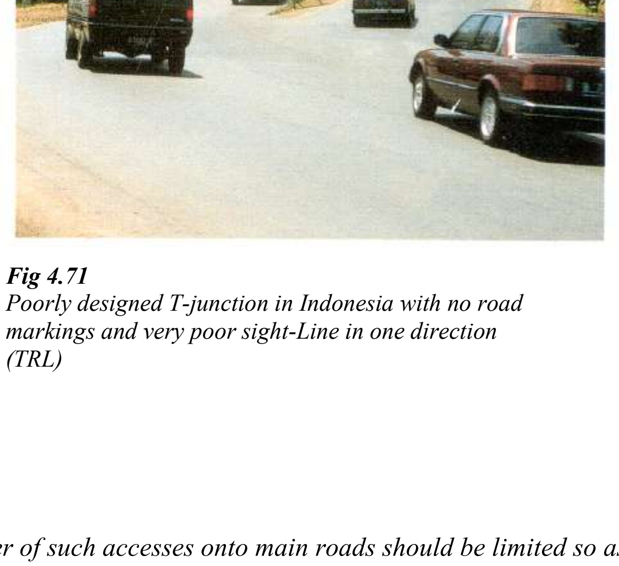


Fig 4.71
Poorly designed T-junction in Indonesia with no road markings and very poor sight-Line in one direction (TRL)

Summary

Although simple priority intersections are common, the number of such accesses onto main roads should be limited so as to concentrate the hazards involved at well located and designed intersections. Substantial studies have been undertaken in developed countries to identify particular accident problems and remedies. Good practice includes providing adequate visibility and ....

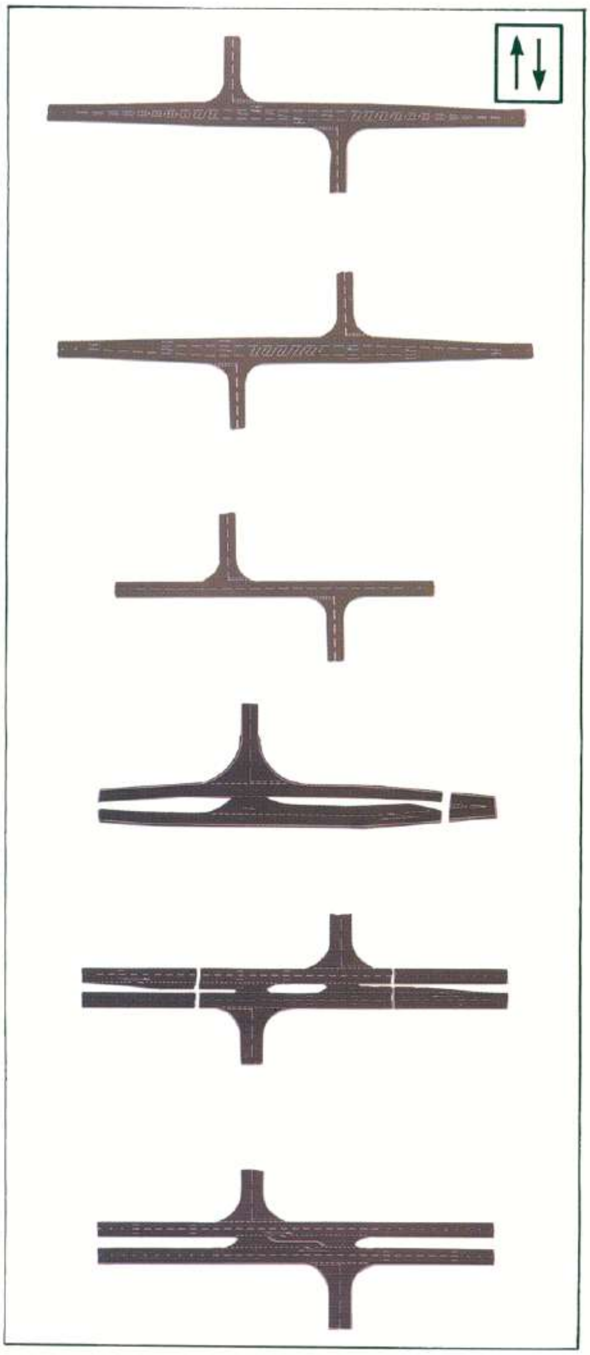


Fig 4.72
Typical Layouts of priority intersections showing UK practice and road markings
(ref 3)

Possible Solutions/Benefits

- Priority intersections should only be used where flows are relatively low (up to around 5,000 AADT on the major road and only 3,000 AADT on the minor road).
- Where space permits, staggered intersections are preferable to crossroads on safely grounds. The same effect may be achieved by the use of offset central islands at the entries. The stagger or offset should always allow minor road crossing vehicles to enter the intersection by crossing the nearest traffic stream and to leave the intersection using an unopposed turn.
- Multiple lane approaches should be avoided where possible. On fast dual carriageways the median should be built wide enough to accommodate the longest heavy vehicle found, otherwise part of the vehicle will overhang into an overtaking lane as the vehicle is waiting in the centre of the carriageway to complete the manoeuvre.
- Ghost island width should be a minimum of 3.5m in width. Where space allows and the major road has high flows and/or speeds, then an offside diverging lane can be of use. The length and taper of these depend on the design speed of the mayor road. Local widening may be required to create such facilities.
- The minor road approach must be designed to show clearly that a major road is ahead and that drivers must yield priority. Deflection islands, bollards and clear signing are necessary to achieve this. If visibility is in any way inadequate additional advance warning signs must be used. Sight distances must not be blocked by vegetation growth.
- The minor arm of a T-junction should be sited on the outside of a horizontal curve, if possible, and not on overtaking sections of single carriageways.
- Other possible safety measures include: restriction of turning movements, provision of skid-resistant surfaces; provision of pedestrian/ cycle facilities, good direction signing; and in urban areas, replacement by roundabout or signals.

Other relevant sections: 4.2.1, 4.2.8
Key external references: 1, 3

...........sight distances, clear road marking and signing, and the provision of islands and bollards to guide and protect drivers. Side road drivers must be aware that they are approaching a major road and, for crossroads, views from one minor road to the other should be broken by staggering the opposing arms or by offset islands at the entries. Local widening at the intersection can allow protected waiting areas to be provided for turning traffic.

4.2.3 Roundabouts

Background

A roundabout is a one-way circulatory system around a central island, entry to which is controlled by 'give-way' markings and signs. It is generally agreed that the better system is where priority is given to traffic already on the roundabout. Roundabouts provide a high capacity, cause little delay in the off-peak period and require no technical maintenance.

Roundabouts are particularly suitable where there are more than four arms to the intersection, although three or four arm roundabouts are generally used.

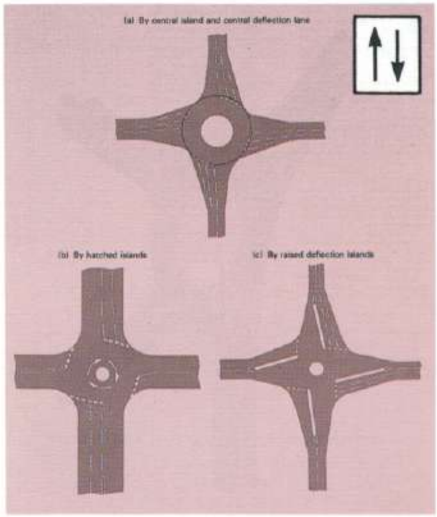


Fig 4.73
Typical layouts for small diameter roundabouts, showing use of road markings to increase vehicle deflection on entry and thereby reduce speeds (ref 3)

Problems

Poor visibility on the approaches or across the central island can result in drivers making unwise entry decisions. High entry speeds can lead to accidents between entering and circulating vehicles. Poor enforcement of priority rules can lead to high accident rates and inefficiencies in operation.

Long delays may result when there are substantial differences in entering flows. Flows on one arm may dominate at the expense of others and the resulting long delays may lead to unwise entry decisions Roundabouts can quickly become blocked if circulating traffic is not given right-of-way.

The central island may contain concrete and other structures. These substantially increase accident severity for those vehicles which fail to negotiate the roundabout through too high an approach speed.

Sources of danger in the geometry of roundabouts include: very acute merging angles, roundabouts which are not circular, poorly designed or positioned signing and steep gradients or poor skidding resistance on approaches. Accidents between motorised and non-motorised vehicles can be a particular problem because of the speed differences as they move through the roundabout, especially if it is large.

Although the safety record of roundabouts is generally good there can be problems with slow-moving vehicles such as cycles or animal drawn vehicles.

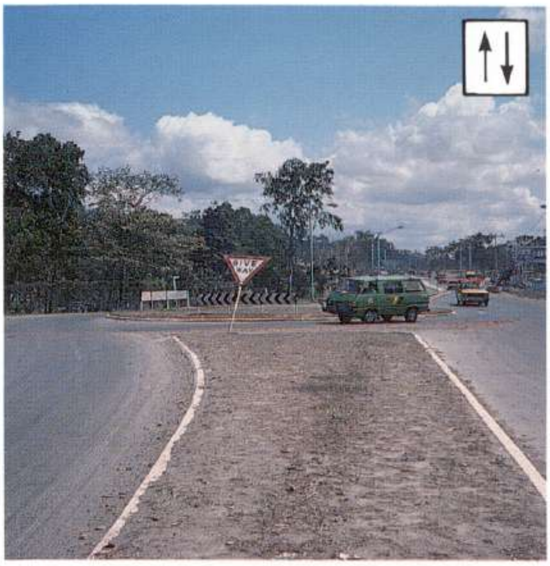


Fig 4.74
Roundabout in Papua New Guinea with insufficient deflection permitting vehicles to pass though without reducing speed, e.g. yellow vehicle (TRL)

Summary

Provided drivers observe the priority rules, roundabouts offer a safe, self-enforcing form of intersection for a wide variety of conditions. The design should reduce circulating and entering speeds. Good visibility is essential and chevrons or arrow signs should be placed on the central island. Although roundabouts are generally safe, they can be hazardous for cycles and other .....

Possible Solutions/Benefits

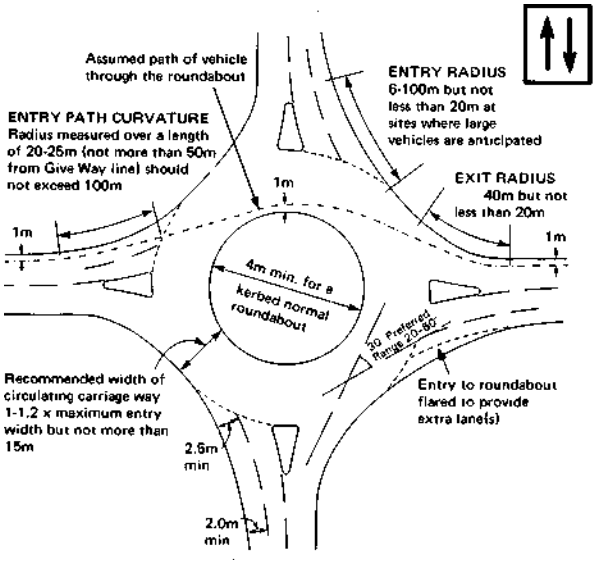


Fig 4.75
Urban roundabout, showing dimensions as used in UK (ref 1)

Fig 4.76
Experimental alteration to prevent overtaking on exit from roundabout and provide larger refuge for pedestrians (TRL)

- Low entry speeds may be achieved by deflecting entering traffic with road markings, islands and by channelisation. The radius of the entry path should not exceed 100 metres.
- Circulating traffic on the roundabout must have right-of-way and drivers should be educated in this rule with enforcement as necessary.
- Visibility for entering drivers must be sufficient to allow circulating drivers a stopping sight distance at the circulating speed. Visibility must be adequate and care must be taken to ensure that this silhouettes pedestrians on nearby refuges or crossings.
- Enforcement of priority is important and additional enforcement resources may be required in countries where driving behaviour is poor. If drivers fail to give way to traffic on the roundabout, then it may be both unsafe and inefficient.
- Special provision may need to be made for cycles and other slow-moving vehicles. Such movements can be combined with pedestrians at crossings on the approach inns, so that movement through the roundabout is avoided.
- Facilities for pedestrians to cross the arms of the intersection safely should be provided in most urban situations. They may be incorporated in entry island/refuge design for low pedestrian flows.
- Other measures which have been found to help safety include: improved provision and siting of signs, making the 'give-way' line more conspicuous, additional chevron signs, the provision of yellow bar markings on fast dual-carriageway approaches, improved skid resistance (micro-texture is important at low speeds) and the reduction of excessive entry widths by hatching or physical means.
- Roundabouts are particularly well suited for heavy turning movements which would cause safety problems with other types of intersections.

Other relevant sections: 4.1.5, 4.2.1, 6.8.2
Hey external references: 1, 3

..........slow moving vehicles. Roundabouts should be avoided where such vehicles are common unless special provision can be made for them. Solid structures likely to result in severe injury accidents if struck by a vehicle should not be placed on the central island. High painted kerbs around the island can increase conspicuity and reduce the risk of the island being overrun.

4.2.4 Signal Controlled Intersections

Background

Traffic signals are widely and increasingly used in urban areas. Assuming good driver discipline, they are also a relatively safe form of traffic control and have scope for provision of facilities for pedestrians and cyclists. However, in countries with poor records of driver behaviour and enforcement, capacity is reduced and accident rates can be high.

Signals can operate under fixed time plans, in response to traffic demands (vehicle actuated) or under manual control. They can also be linked together to provide control of a network as a whole.

Fig 4.77
Poorly defined, large signal-controlled intersection in Korea. Note long distance between stop lines and signal head, lack of road markings and absence of channelisation
(Ross Silcock Partnership)

Problems

Even where driver behaviour is of a high standard, traffic signals are often associated with accidents in which one vehicle in a traffic stream runs into the one in front which is waiting to turn.

Signal arrangements which permit turning movements on red are dangerous.

Drivers may continue into an intersection even after the signals have changed to red. This problem leads to particularly severe accidents in low flow conditions when speeds are high. Signals used at inappropriate intersections with low flows and fixed timings encourage violation. Enforcement of signal control is often poor in developing countries, and engineering decisions to increase the all-red time to allow safer clearance, may result in further incursions into the red phase.

Traffic signals are less appropriate to high speed roads and rural conditions, where attempting to stop the major road traffic is potentially hazardous.

Turning vehicles can be responsible for many pedestrian accidents, and pedestrians are often not given adequate consideration. Often no separate pedestrian phase is provided even on wide intersections with heavy pedestrian flows.

Accesses immediately adjacent to an intersection can make driver decisions much more complex and lead to hazardous conditions.

Traffic signals need regular maintenance and continuous power supply. Both signals and detection equipment are prone to malfunction so good maintenance capability is required.

It is common to find traffic police manually controlling signals in the belief that they can improve traffic flows. This is rarely true with cycle times under police control usually being much too long for optimum capacity. Long delays, driver frustration and potential hazards result.

Fig 4.78
A 'red-running' driver failing to stop at signal in UK; conflicts may arise due to insufficient 'all-red' on hush speed approach
(TRL)

Summary

Traffic signals generally work well in urban areas where high capacity is needed and where speeds are low. However, they are expensive to install and maintain, and also require very high levels of compliance to be safe. Failure to observe signals can lead to serious accidents and good enforcement is essential. They are also unsuited to locations with high proportions of conflicting ......

Possible Solutions/Benefits

- Signal heads must be conspicuous in all lighting conditions so that a driver can stop safely. Signals for competing phases must be located so they are visible only to the traffic for whom they are intended.
- A driver's path through the intersection must be clear from signs and road markings. Turning vehicles should he segregated by lane.
- The phasing of the signals should be as simple as possible, and enable all allowed movements to take place safely. The signals should clearly indicate which movements are allowed at any time. The use of green arrows aids clarity.
- Signal timings should be updated each year, based on sound design practice and current traffic flows. Engineers should inspect each intersection at least annually to ensure that the operations are safe and efficient. Approach speeds must not be too high. Police should not be involved in control, except in an emergency.
- Drivers must obey the signals, and police enforcement is essential. Enforcement must include the removal of nearby parked vehicles
- Signals must be adequately maintained with weekly inspections and fault response times of no more than a day. If adequate maintenance cannot be ensured, signals should not be used.
- Pedestrian phases should be provided where flows are high, or where crossing would otherwise be dangerous. Wherever possible, pedestrians should be given a signal that they can cross safely without conflict with vehicle movements.
- Some vehicles will be forced to stop at signals and the provision of adequate skid resistance is most important.

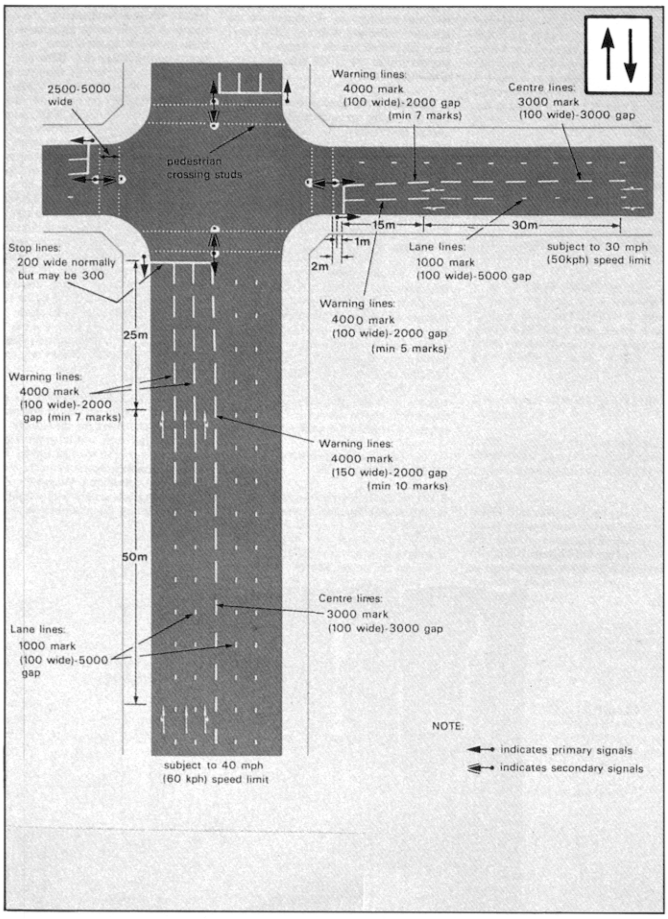


Fig 4.79
Layout of typical urban, signal-controlled intersection, based on UK practice and markings
(ref 3)

Other relevant sections: 4.2.1, 4.2.10
Key external references: 1, 3

...........turning movements, although this problem can often be reduced by the introduction of a one-way system. Assuming proper use they are a safe form of intersection and are more suitable than roundabouts where there are heavy cycle flows. Pedestrian crossing facilities must be properly included to avoid conflict. Care must be taken to ensure that signal heads are visible only to those for whom they are intended.

4.2.5 Visibility

Background

In general, the visibility offered to drivers should be sufficient to identify any necessary course of action and then safely to follow that action. A usual critical requirement is that a driver can stop safely, and this needs an understanding of speeds, reaction times and deceleration rates. Sight distance requirements are thus related to geometric design and speed controls, and are inherent in all design standards. Visibility may relate to another road user, or to an object such as a road sign. Conspicuity, i.e. the ease with which the object can be seen, is most important.

Main road drivers should also be able to see approaching side road vehicles as early as possible so as to be prepared and able to take evasive action if necessary. This is one of the reasons why recommended visibility splays usually involve the requirement for an approaching side road vehicle to be seen before it reaches the stop or give way line. Pedestrians also need to see and be seen and crossing movements are often concentrated at or near intersections.

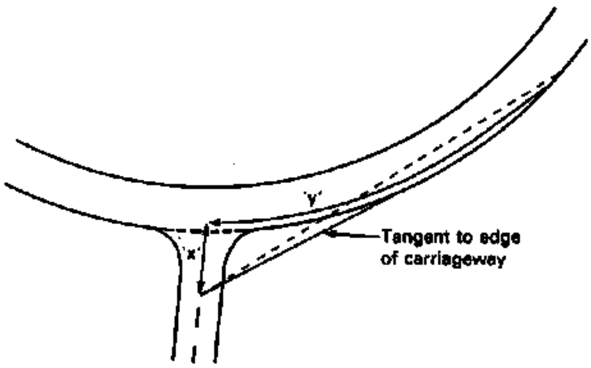


Fig 4.80
Visibility splay on curve, UK practice
(ref 1)

Design speed of major Road (km/h)	100	85	70	60	50
'Y' distance (m)	215	160	120	90	70

Table 4.12 '
'Y' dimensions for visibility splay at different design speeds adopted is UK
(ref 1)

Problems

The topography of the site may make sight distances difficult to achieve. A common accident problem associated with visibility is where a minor road meets a major road at a shallow angle. This encourages minor road vehicles to negotiate the intersection at speeds higher than is compatible with the visibility available to them.

Warning and information signs may be so sited that they have poor conspicuity, and the detailing of the road may not provide sufficient additional clues as to the hazard or decision ahead.

A further problem at angled approaches is caused by drivers having to turn their heads to see back along the major road. They may not then see what is happening directly ahead of them and nose-to-tail collisions can occur.

Even if visibility may be achieved at the required distance, there may be intermediate obstructions such as trees or road furniture.

Fig 4.81
Dangerous T-Junction in Zimbabwe due to very poor sight lines
(Zimbabwe Traffic Safety Board)

Summary

Adequate visibility at intersections is crucial to their safe operation. In common with other aspects of design, the principles behind visibility constraints are that drivers should not be taken by surprise. Intersections should be clearly visible to approaching drivers from an adequate stopping distance. Visibility along conflicting routes should be generous so that drivers waiting to emerge can see, ...

Possible Solutions/Benefits

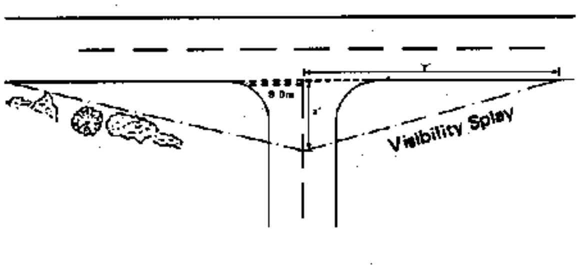


Fig 4.82
Visibility splay on straight sections UK practice (ref 1)

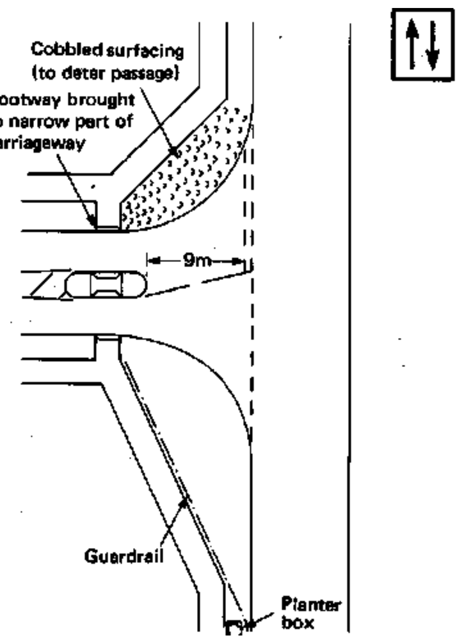


Fig 4.83
Layout of pedestrian footway at T junction to ensure visibility splay is maintained as adopted in UK
(ref 1)

- Permanent and temporary signs must be placed so that they can be read and acted upon safely.
- At an intersection between a minor road and a dual carriageway, where there is sufficient space in the central reserve for minor road vehicles to perform their manoeuvres in two stages, the sight distance need only be provided in one direction at a time.
- The visibility distance should be provided from a point setback from the stop line. For priority intersections on main roads, this should be nine metres, although for simple access roads on more minor roads it may be reduced to be as low as 2.5 metres, although this well require all vehicles to stop.
- The driver's eye height is about 1.05m (for cars) and visibility is usually more easily achieved in the dip of a sag curve. Sites at the crests of hills should be avoided. (Approach speeds at the bottom of a sag curve may, however, be high)
- Obstructions in the visibility envelope must be avoided. Consideration should be given to street furniture, telephone kiosks, road signs, vegetation (when fully grown) and parking. Maintenance is important and visibility should be achieved within the boundaries of the highway to allow this.
- Visibility requirements at roundabouts are to the next exit (or previous exit) or 50m whichever is the least, from a point 15m back from the stop line. From the circulating carriageway, the same distance should be provided from a point 2m from the central island.

Other relevant sections: 4.1.2, 4.1.3. 4.2.8, 4.2.10, 6.8.3
Key external references: 1

..........and be seen by, approaching traffic. Warning signs and street lighting are both elements which can contribute to the safe design and operation of intersections and relate to visibility considerations. This is particularly important at night and conspicuity can be increased markedly by the use of reflective road markings and signs.

4.2.6 Warning Signs and Markings

Background

Warning signs and warning markings are used to give advance notice of a potential hazard ahead or any unexpected feature of the road geometry. They are of particular use where a design element is sub-standard, such as at an unexpectedly sharp bend on an otherwise high speed road. In such a case the warning may be accompanied by a reduction in speed limit for that section. Other situations where advance warning would be appropriate, include intersections with inadequate visibility or where a new layout might cause confusion to regular users.

If all desirable geometric standards are met, then warning signs should be largely unnecessary except to warn of special features such as pedestrian crossings, the presence of a school and other potentially hazardous locations. In these cases advance warning of some kind should form part of the design. This can be a sign and/or a road marking.

Fig 4.84
Unmarked ford - absence of advance warning creates potential danger. Note scour on downstream side (Rendel Palmer & Tritton)

Problems

There is often a lack of signs and markings in developing countries, or those that are provided are non-standard.

A recurring problem with signs is their obscuration, either by permanent features such as street furniture and vegetation or by parked vehicles and, on dual carriageways, by moving vehicles in the nearside lane.

Signs can themselves obscure other features and may be visually intrusive from an environmental point of view. Too many signs can detract from their objective by overloading the driver with information leading to confusion, or to a situation where the driver ignores some signs.

Signs may not be visible at night because of poor illumination, lack of regular maintenance or continuous power supply. Reflective signs not regularly cleaned may not maintain their design properties.

A common accident problem occurs at roadworks and warning signs are often poorly placed by contractors.

Fig 4.85
Despite channelisation island in minor road, absence of warning signs has contributed to the T junction becoming a blackspot in Ghana
(Ross Silcock Partnership)

Summary

As with other elements of design, consistency of signing is important preferably using international conventions. Drivers should be able to understand warning signs quickly and in sufficient time to act upon them. For this reason symbols are preferred to words. This policy also offers advantages to illiterate and foreign drivers. The location of signs is critical so that they provide adequate ....

Possible Solutions/Benefits

Fig 4.86
Adequately signed seasonal ford gives early warning to approaching motorists
(Rendel Palmer & Tritton)

Fig 4.87
Map type direction sign also provides information about the type of intersection ahead in the UK
(Ross Silcock Partnership)

- The siting of signs is critical: they need to be far enough in advance of a feature to give sufficient time for the message to be understood and obeyed, but not so far in advance for the message to be forgotten by the time the feature is reached.
- To avoid problems of obscuration, attention should be paid to vegetation (bearing in mind the rapid growth that occurs seasonally) and parking restrictions. If obscuration is thought likely due to other moving vehicles then overhead signs or repeated side-mounted signs should be considered.
- Signs must be visible in darkness. In rural areas this can be achieved with reflective signs; in urban areas it may require externally or internally illuminated signs, depending upon prevailing lighting conditions. Regular maintenance is important.
- Where warning (and other) signs are associated with intersections, great care should be taken to ensure that they do not obstruct critical lines of sight.
- Apart from signs warning of approaching features, there are others for use at the site itself such as direction chevrons at bends or roundabouts. It is particularly important that they should not constitute a hazard in themselves to vehicles leaving the road. To this end, recent developments include a variety of knock-down signs which can be driven over but which spring back into position in the event of a collision.
- Emphasis should be on simple, clear and uniform signs, preferably from international conventions, using minimal wording. Symbols should be included as they generally aid rapid understanding of the message.
- Signs, markings and symbols used must be applied consistently. Uniform design standards should be devised for application throughout the country.

Other relevant sections: 4.2, 5.7, 5.8, 6.8.6
Key external references: 1, 3

……….warning or information but do not themselves obscure important road features. Obscuration by overgrown vegetation is the commonest problem and so siting to minimise the risk of this is of great importance. Signs must be visible at all times, thus reflective materials should be used and urban signs may require to be lit internally or externally.

4.2.1 Channelisation

Background

Channelisation by means of road markings, raised kerbs, traffic islands and bollards, can be used to guide vehicles along a specific path on the approach to and/or exit from an intersection. The benefits of this are that movements are simplified, less confusion arises and the number of conflict points is minimised. Effectively, the number of decisions required of a driver at any one time is reduced, allowing him to concentrate more on gaps in the opposing stream.

Traffic islands have the added benefit of providing a refuge for pedestrians crossing the road. They also provide a convenient location for street furniture such as signs, street lighting and drainage covers.

Urban channelisation schemes can be relatively complex, dealing with large traffic volumes. In rural areas concern is usually focused on protecting turning vehicles from faster moving traffic and to position vehicles correctly on the road.

Fig 4.88
Large rural 'Y'-junction without any markings or direction gives no indication of priorities, Papua New Guinea (Ross Silcock Partnership)

Problems

A lack of channelisation at intersections leads to poor driver behaviour such as corner cutting and lane blocking.

Physical channelisation has the disadvantage of reducing the available road width which may be critical at the approach to certain intersections. Local widening may be required at locations where channelisation is desired.

The presence of a raised kerb, island or bollard can form a hazard. Particular problems may occur when a central reserve is installed over a short section which includes a T-junction. Obstruction due to broken down vehicles can also be made worse as a result of channelisation.

Good, clear signs need to be provided with channelisation otherwise conflicts could be made worse by forcing uncertain drivers to make an early lane choice without adequate directional information. If the wrong lane is selected, some drivers will attempt to rejoin their route by making undesirable or illegal manoeuvres. These can be extremely hazardous.

Painted markings used to define channelisation will be ignored by some drivers. This can be particularly dangerous at high speed locations.

Fig 4.89
Urban intersection with inadequate channelisation creates conflict and congestion. China (Ross Silcock Partnership)

Summary

Channelisation is a useful and diverse tool in traffic management. By giving guidance and direction to traffic, indecision and confusion is minimised and smoother traffic flow results. It should be applied to all intersections on high speed roads. This may require local widening but the small additional cost of this at the design stage will be offset by future safety benefits in almost ....

Possible Solutions/Benefits

Fig 4.90
Painted road markings create effective channelisation on a large urban intersection in Korea
(Ross Silcock Partnership)

Fig 4.91
Channelised, priority intersection, Papua New Guinea, separates conflicting movements and provides safe turning areas
(TRL)

- Where space does not permit physical channelisation, the same effect may be achieved using 'ghost islands' indicated by white hatched markings on the road. These are not self-enforcing unless every second line is raised to create a rumble strip in the same way as physical islands but the intention remains clear. If local driver behaviour is such that many are likely to drive over painted islands then raised kerbs and a physical island become essential.

- A refuge for turning traffic at priority intersections should have a hatched area at least 3.5 metres wide. If a physical island is used, on high speed roads, 10 metres may be sufficient, and if local dualling is used, up to 30 metres should be provided. However, very short sections of two-lane dualling at intersections should be avoided to discourage overtaking at these locations.

- Consideration should be given to the potential restriction of movement caused by broken down vehicles within channelised sections.

- Although local widening is likely to be required for channelisation on high speed rural roads, the additional cost will usually be offset by safety benefits. Channelisation has proved to be most effective at T-junctions.

Other relevant sections: 4.2.2, 5.5, 6.8.1
Key external references: 1, 3

............every case. Consideration of the access needs of emergency and other priority vehicles is required, especially in the event of an accident or breakdown. If provision is not made for this, damage to kerbs will quickly develop. Channelisation guides the driver through the conflict points, provides safe areas for him to stop while making a manoeuvre and reduces conflicts between different flows.

4.2.8 Acceleration/Deceleration Lanes

Background

On major roads where speeds are high, it is beneficial to provide acceleration and deceleration lanes at intersections. These are used to aid the transition between the high speed of the major road and the low speed required in order to negotiate the intersection. They allow all turning vehicles to speed up or slow down without impeding through traffic.

Whilst acceleration lanes are restricted to the nearside only, offside deceleration lanes may also be suitable to assist turning traffic at channelised priority and traffic signal-controlled intersections.

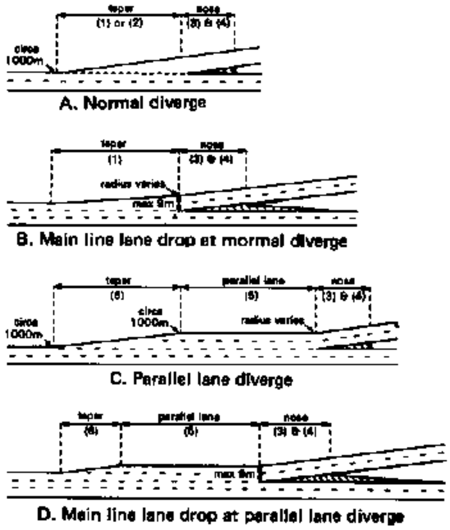


Fig 4.92
Diverging lane layouts (Numbers in brackets refer to Table 4.13)
(ref TD22/86)

Problems

Drivers using acceleration lanes have a narrow angle of vision with the main road flow. Drivers merging in a stream of vehicles may have difficulty in watching both the front vehicle and the stream into which they are merging. Accidents between vehicles in the acceleration lanes may occur as a result.

Acceleration or deceleration lanes may be blocked by parked or stopped vehicles and this may force drivers out into the main stream.
It should also be noted that even unobstructed and well designed deceleration lanes often remain unused.

Road Class	Single lane entry taper (1)	Two lane entry taper (2)	Min single nose taper (3)	Nose length (4)	Min parallel lane length (5)	Parallel lane taper (6)
Rural Motorway	1:45	1:25	1:15	80	200	1:20
Rural Dual Carriageway						
Design Speed 120 kph	1:40	1:20	1:15	70	170	1:15
Design Speed 100Akph	1:35	1:18	1:15	70	150	1:15
Urban Roads						
60 mph speed limit	1:25	1:15	1:15	50	125	1:10
50 mph speed limit or less	1:20	1:12	1:12	40	100	1:10

Table 4.13
Geometric parameters for diverging lanes (numbers in brackets refer to Fig 4.92)
(ref 7D22/86)

Summary

Acceleration and deceleration lanes are common in the developed countries and have important implications for safety. They allow traffic to merge and diverge safely at speed with minimum disruption to other traffic. As with other intersections, visibility and signing are very important ....

Road Class	Single lane entry taper (1)	Two lane entry taper (2)	Min angle nose taper (3)	Nose length (4)	Min parallel lane length (5)	Parallel lane taper (6)	Ghost island length (7)
Rural Motorway	1:55	1:40	1:40	115	230	1:20	180
Rural Dual Carriageway							
Design Speed 120 kph	1:40	1:30	1:30	85	190	1:15	150
Design Speed 100Akph	1:35	1:25	1:25	75	160	1:15	150
Urban Roads							
60 mph speed limit	1:25	1:20	1:15	50	125	1:10	n/a
50 mph speed limit or less	1:20	1:15	1:12	40	100	1:10	n/a

Table 4.14
Geometric parameters for merging lanes (numbers in brackets refer to Fig 4.93)
(ref TD22/86)

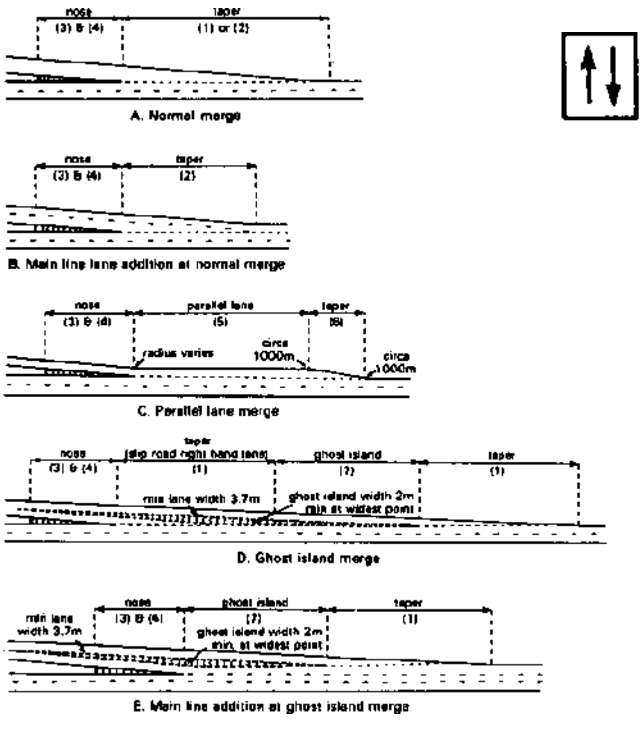


Fig 4.93
Layout of merging lanes (Numbers in brackets refer to Table 4.14)
(ref TD22/86)

Possible Solutions/Benefits

- Acceleration/ deceleration lanes provide an opportunity for traffic entering or leaving a faster stream to change speed without delaying other vehicles. This enhances safety and reduces delay.
- Good visibility is important and should be maintained through the lane In the case of merging lanes in particular, the lines of sight should be kept free from street furniture and road signs.
- To avoid obstruction of the lanes, parking restrictions should be implemented and strictly enforced. In case of breakdowns at critical places, additional parking or wider shoulders are desirable.
- To ensure more efficient use of the lanes, their existence and intended purpose should be well advertised by advanced signing. A self-enforcing measure would be to provide channelisation at the deceleration lane where space provides. Such a measure would also assist pedestrians crossing the road and slow-moving vehicles going ahead on the mayor road.
- Deceleration lanes can be used in conjunction with protected turning bays to provide a safe location for vehicles to slow down and wait before malting the crossing manoeuvre.
- The presence of these lanes can be made more noticeable to drivers particularly at night by using reflective road studs of different colours, eg green for exit deceleration lanes and red for entry acceleration lanes on fast dual carriageways.

Other relevant sections: 4.2.2, 4.2.5
Key external references: 1, 3

.........Enforcement of parking restrictions in these lanes is critical to avoid danger and delay should they become blocked. Conspicuity can be enhanced through the use of coloured reflective road studs.

4.2.9 Pedestrian Crossing Facilities

Background

All road users are pedestrians at some stage of each journey, and some are pedestrians the whole time. However, often little thought is given to their needs within the road system, and consequently, many accidents involve pedestrians, particularly children. Because pedestrians tend to follow traffic routes there are often concentrations of pedestrians wishing to cross roads at intersections or specific high generators of pedestrian traffic such as hospitals and schools.

Fig 4.94
Pedestrian crossing in Korea across 10 Lanes of traffic without central refuge and where right turn on red is allowed
(Ross Silcock Partnership)

Problems

Crossing at intersections can be particularly hazardous. At intersections visibility may be poor, especially at night, and the complex traffic movements may be difficult for a pedestrian to understand. Drivers may not always signal their intended manoeuvres.

In order to provide additional traffic capacity at intersections, local widening is sometimes earned out. This increases the crossing distance, again making matters worse for pedestrians.

Heavy crossing demands may occur away from intersections where vehicle speeds are high. Particular examples are where footpaths cross rural highways or immediately outside schools, shops and markets. Problems of visibility and the safe judgement of approach speeds may be hampered by poor or inadequate sight distances or the presence of obstructions such as parked vehicles. Buses stopping close to crossings often cause visibility problems just when pedestrians are more likely to be crossing. The provision of underpasses or overbridges may be too expensive and may not be well used.

In many countries, driver behaviour at crossings is very poor and drivers may not give way to pedestrians at unsignalised crossings.

Fig 4.95
No pedestrian facilities exposes school children to danger, Ghana
(Ross Silcock Partnership)

Summary

In urban areas in particular, walking is an important mode of transport. As motorisation increases, pedestrians are put at increasing risk and need to be protected whenever possible. Problems are particularly acute at intersections where pedestrian and vehicle, f lows converge. Crossing facilities have great implications for pedestrian safety at intersections if they are correctly used. Refuges.......

Possible Solutions/Benefits

Fig 4.96
Pedestrian crossing with central refuge provides safe waiting for pedestrians in centre of road in Zimbabwe (Zimbabwe Traffic Safety Board)

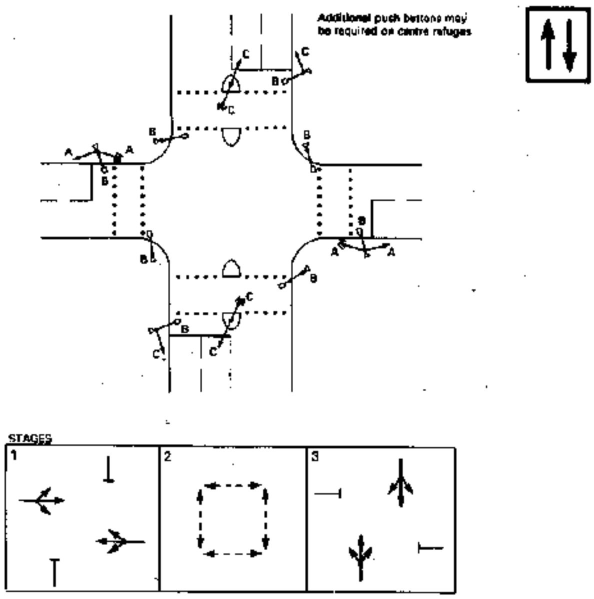


Fig 4.97
Pedestrian phase included at signal-controlled intersection (ref 1)

- The simplest and cheapest method is a central refuge which allows a pedestrian to negotiate one traffic stream at a time. Refuges consist of physical islands incorporating bollards, lit by the existing street lighting or supplementary flood lighting. Such refuges should be a minimum of 1.8 metres wide and can often be part of channelisation at an intersection.

- Small radii kerbing at corners can help pedestrians cross the mouths of side roads by reducing the speed of turning vehicles and reducing carriageway width. However, this may result in an increased risk of large vehicles mounting the kerb, so protective features such as bollards may have to be used.

- Continuing main road 'footway' across an intersection need not involve a closure of the side road but would require a change of level for vehicles. This measure assists pedestrians by giving them precedence and prominence by encouraging drivers to manoeuvre more slowly. The use of coloured and textured surfaces can be effective in reinforcing this change in priority.

- At traffic signals, it is possible to include a pedestrian only phase. However, if there is little demand, pedestrians can make good use of the inter-green periods to cross. This can be further aided by providing central refuges.

- Possible provision away from intersections includes crossing patrols, (by police or other official at peak times, e.g. school times), bridges, subways and measures to reduce traffic speed such as road humps.

- Grade separated facilities are the safest but also the most expensive. Pedestrian fences may need to be used to encourage then- use.

- Safe stopping sight distances are essential and visibility must be maintained in all lighting conditions Temporary and permanent obstructions must be avoided.

Other relevant sections: 4.1.17, 4.1.18, 6.9.2, 6.9.2, 6.9.5
Key external references: 1

.......and pedestrian phases at signals are particularly effective. Their use can be actively encouraged by the use of self-enforcing, restrictive measures such as pedestrian fences at other points. It is particularly important to discourage people from crossing near but not on a crossing as this is where drivers least expect to be confronted by a pedestrian.

4.2.10 Provision for Cyclists/Slow-Moving Vehicles

Background

Cycles and other slow-moving vehicles need separate consideration in a road system due to their different characteristics of movement, the fact that drivers do not tend to notice them as well as other vehicles, and they are vulnerable to injury in the event of an accident. Roundabouts in particular have a poor accident record for these vehicles, but difficulties can be experienced at all types of intersection.

Fig 4.98
Absence of faculties for cyclists at busy urban intersection, China, creates conflict and congestion. Note cyclists passing wrong side of island.
(Ken Huddart)

Problems

The problems of slow-moving vehicles stem from the differences in speed and their inability to get clear of trouble quickly

At priority intersections, these vehicles are mainly at risk when performing turning movements, but also when going straight ahead amidst other vehicles making turning movements across their path.

At traffic signals the problems tend to be caused by the general urgency of behaviour shown by other road users who are trying to minimise their own waiting time.

Roundabouts cause particular problems due to their free-flowing nature. Thus, slow-moving vehicles have to enter streams of traffic moving faster than their own capabilities. Poor conspicuity is a particular problem, ie drivers not noticing cyclists as easily as other vehicles, which results in many accidents on roundabouts due to vehicles colliding with cyclists already on the circulatory carriageway.

Shared pedestrian/cyclist facilities are sometimes illegally used by motor-cyclists unless they are physically prevented from doing so by the installation of carefully located special barriers.

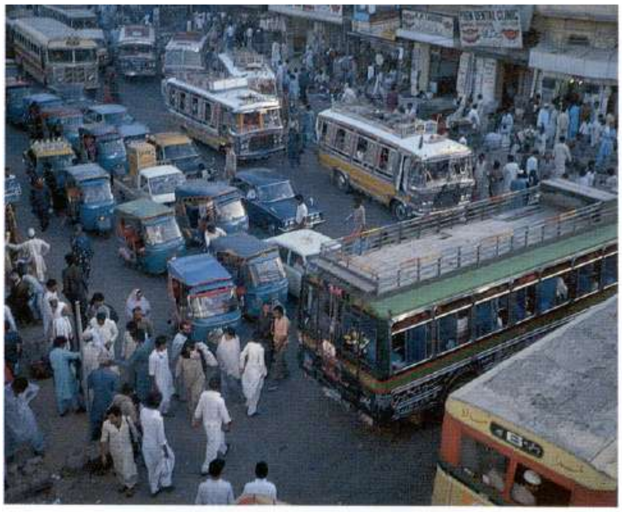


Fig 4.99
Slow-moving vehicles have considerable problems competing against other motorised vehicles, Pakistan
(Ross Silcock Partnership)

Summary

Many facilities have been designed and successfully implemented to segregate cyclists from potentially conflicting traffic. This is particularly important at intersections where their poor conspicuity and speed difference with motorised traffic puts them at particular risk. At priority intersections cyclists can be assisted by provision of channelisation. At signalised intersections...

Possible Solutions/Benefits

Fig 4.100
Cyclists using pedestrian crossing to cross busy traffic stream, China. impeded by traffic encroaching onto crossing (Ken Huddart)

Fig 4.101
segregated cycleway. India, provides protection and priority for slow-moving vehicles. Note only some cyclists within protected area (Ken Huddart)

- At priority intersections, slow-moving vehicles can be assisted by segregating their movements by channelisation or by providing central refuges allowing movements to be made in two stages.
- At traffic signals a useful method of assisting slow-moving vehicles is to allow them a separate phase (governed by separate signal heads incorporating, for example, a cycle symbol) or to give them a 'head start' from a separate stop line a few metres ahead of the stop line for other traffic.
- Problems at roundabouts are much more difficult and the best solution is to direct slow-moving vehicles to an alternative route. For cycles and other small vehicles it is possible to allow shared use of pedestrian facilities where they exist as a convenient alternative. In the UK, such shared use of facilities with pedestrians has proved a safe measure with pedestrian and cycle flows up to about 300 per hour.
- If no suitable route can be found to avoid a roundabout, and if slow vehicle numbers are significant, then a different type of intersection control may need to be considered.
- Cycle facilities must be attractive to cyclists or they will remain unused. They should not involve long detours, steep gradients, steps or dismounting, and should be well maintained.
- It is essential that parking is banned near roadside facilities, as slow-moving vehicles would otherwise be forced to make sudden unexpected movements into the traffic to avoid a parked vehicle.
- In new developments, many of the potential problems can be removed by the proper design of alternative segregated routes.

Other relevant sections: 4.1.19, 4.1.20
Key external references: 1, 11

………they can be given a special phase or a separate stop line ahead of other traffic to make them more conspicuous and to give them a head start. The provision of safe facilities is especially difficult at roundabouts. Here efforts should made to divert cyclists and slow-moving vehicles to alternative routes or to where they can share facilities with pedestrians.

PART III

HIGHWAY OPERATION AND ACCIDENT COUNTERMEASURES

5. OPERATING THE ROAD NETWORK FOR SAFETY

5.1 Introduction

Apart from the opportunities which engineers and planners have to influence road safety during the planning and design of new roads and networks, there is also scope on existing roads to rectify earlier insensitive designs by better operational control and the application of accident reduction countermeasures. Through selective use of traffic management and other techniques it is possible to create safer, less congested and more efficient road networks. The use and operation of the existing roads can be optimised without recourse to major reconstruction. Such an approach is particularly relevant to the needs and financial resources of developing countries. The general approach is applicable to both new and established urban areas and is based upon recognition of several underlying principles:

- Potential for conflict and accidents will exist wherever access is provided to roads carrying moving traffic and wherever roads intersect;
- Safety will be improved if road users clearly and unambiguously understand which road has priority at intersections;
- Pedestrians, cyclists and slow-moving vehicles (e.g. animal drawn) should be segregated from other moving vehicles;
- Effective land-use controls can avoid many of the road safety problems which would otherwise occur with unrestrained development; and
- A safe road network is one where there is maximum differentiation between roads intended primarily for access and roads intended primarily for through journeys (or movement).

Problems

Fig 5.01
Overloaded lorry in Thailand
(Rendel Palmer & Tritton)

Fig 5.02
Crash helmets required by law in Indonesia are often worn ineffectually
(TRL)

In the industrialised countries efforts are made to encourage and direct major traffic flows on to streets which have previously been designated as being primarily for through traffic, leaving residential and shopping streets to carry only local traffic. Specialist traffic engineers within municipal engineering departments work full-time in monitoring operational aspects of the road network for which they are responsible. Problem locations, whether in terms of congestion, parking, road safety or environmental nuisance are identified through surveys and site visits and studies are undertaken to find ways to improve any deficiencies. Consultations are held with the town planning authorities, local traffic safety organisations, traffic police and other emergency services to devise suitable traffic management countermeasures to overcome any deficiencies which have been identified. Implementation is normally undertaken in close cooperation with the traffic police. Often a very high traffic police enforcement presence is provided for the initial few weeks after implementation until drivers become familiar with the new system. Considerable advance publicity is normally organised through the newspapers, TV and radio stations. Consultations are also normally held with local residents, shopkeepers and others likely to be affected by the proposals. All are given an opportunity to comment upon the proposed schemes during the development stage so that, as far as practical, the final scheme which is implemented takes into account local fears and concerns.

Successful and safe operation of road networks, therefore, depends upon professionals within municipal engineering departments working with other interested professionals, such as traffic police and town planners, constantly to monitor the system in order to identify deficiencies and potential problems. In developing countries traffic police often have the dominant responsibilities for the traffic engineering and operational aspects of the road system. Where this is so they should take the lead in coordinating activities with engineers and planners.

This section discusses a number of the operational aspects of highways which can lead to safer use of existing roads. Many of the principles of safety-conscious planning and design outlined in sections 3 and 4 can also be applied in operational terms. These are identified in subsequent subsections.

Possible Solutions/Benefits

Fig 5.03
Police enforcing parking regulations in Bahrain
(Ross Silcock Partnership)

Fig 5.04
Axle detectors linked to roadside equipment in Egypt to monitor flow and enforce speed limit
(TRL)

5.2 Highway Authorities and Safety

Background

In order to focus the attention of central and local highway authorities on road safety, many industrialised countries have made the improvement of road safety a statutory duty. Under such legislation each level of local authority which acts as a highway authority is required to carry out road safety activities on its road network.

This often includes studies into road accidents on roads within the area of the authority and implementation of engineering measures for the reduction and prevention of such accidents. These include construction, improvement, maintenance or repair of roads and other measures for controlling, protecting or assisting the movement of traffic.

Fig 5.05
Poor drainage and inadequate maintenance leads to flooding of carriageways in Thailand
(JMP Consultants Ltd)

Problems

There tends to be many authorities with responsibility for roads and a general lack of coordination particulary in road safety activities. In some countries, national roads are excluded from the local authorities' statutory responsibilities. Promotion of road safety and such issues are handled directly by the central government highway authority, sometimes through its own regional offices.

There is often not even enough money to cover routine and periodic maintenance so road safety and related matters are often not clearly specified and are thus usually low in the list of their priorities.

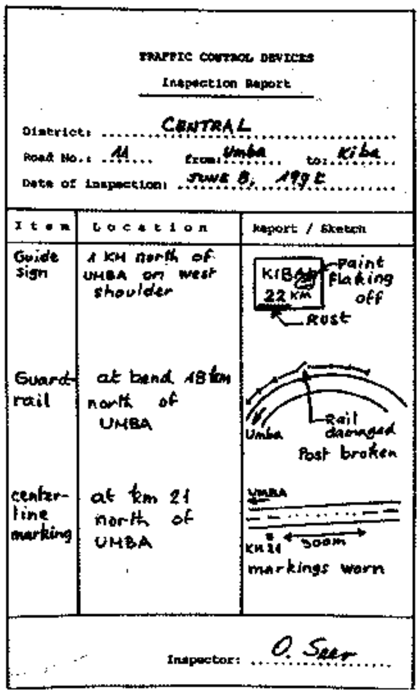
Another problem often faced is that accident statistics and reports are normally held by the Traffic Police HQ and are sometimes not available to the highway department seeking to improve road safety. Sometimes even the Police HQ itself receives only summary data and the actual accident reports are retained at the reporting station.

Fig 5.06
Although blackspot signs such as this in China give some warning to drivers, they are not adequate substitutes for physical improvements
(Ken Huddart)

Summary

Highway authorities should be given statutory responsibility to promote and improve road safety on roads in their area and should be required to show an item in their annual budget for this purpose. They should be required to show in annual reports, what road safety countermeasures have been implemented during the precious year. Arrangements should be made for the Traffic Police to ....

Possible Solutions/Benefits


TRAFFIC CONTROL DEVICES

Inspection Report

District: CENTRAL

Road No.: 11 from: Umba to: Kiba

Date of inspection: JUNE 8, 199[illegible]

Item	Location	Report / Sketch
Guide sign	1 KM north of UMBA on west shoulder	KIBA 22 KM — Paint flaking off; Rust
Guard-rail	at bend 18 km north of UMBA	Umba; Rail damaged; Post broken
center-line marking	at km 21 north of UMBA	UMBA; KM 21; 300m; markings worn

Inspector: O. Seer

Fig 5.07
Regular inspection and monitoring of traffic control devices and other safety features identifies maintenance needs (ref 12)

Fig 5.08
Distance posts installed every 100m along this highway in Malaysia are used by the police to record the location of accidents accurately (TRL)

It is clear from the experience of industrialised countries that:

- Highway authorities should have statutory responsibilities and obligations which require them to improve road safety on their road networks and to make safety audits of all new road schemes. Only by making it a statutory duty (which they will be required at the end of a year to show has been done) will it encourage them to set aside specific funds in their budgets for accident prevention and reduction work.
- Such obligations should extend to all roads in their area and funding for approved works on national roads could be recovered from central government.
- Road safety improvements can be very cost effective. Very high savings (in reduced accidents) can be achieved which are very many times the cost of countermeasures implemented. Hence road safety improvement schemes should form a part of every highway authority's annual programme
- It is necessary that good coordination be established between the different agencies to ensure that comprehensive programmes of countermeasures can be devised. This is particularly so in large urban areas where the major arterial routes carrying the most traffic (and having most accidents) are likely to also be part of the national road network, and hence excluded from the local highway authority's jurisdiction.
- The problem of access to Police data can be overcome, for example by arranging for non-confidential items of information, (e.g. site details, manoeuvres) to be supplied on a regular basis. Such information should be stored in a way which allows it to be stored, retrieved and analysed easily. Manual storage systems or microcomputer-based systems are now widely in use for such purposes (see Appendix C for details of the TRL system which is available free to developing countries).
- The establishment of a small full-time team to be responsible for road safety matters and to implement improvements can be very beneficial.
- Kilometre posts should be installed along rural highways both for the purposes of road maintenance and the identification of accident locations.

Other relevant sections: 5.3, 5.8, 6, Annexe C
Key external references: 1, 2, 12, 13, 14

………supply accident data on a regular basis. An accident data storage, retrieval and analysis system such as the TRL MAAP system should be established. Once accident data is available a comprehensive programme to identify and improve the worst accident blackspots should be initiated as a matter of urgency. This is best done by establishing a small full-time team to carry out such work.

5.3 Road Maintenance and Safety

Background

In industrialised countries with extensive road networks already established, increasingly larger amounts of effort need to be devoted to maintaining the existing network to keep it in a safe and operational condition. Typically up to half of highway authorities' budgets are set aside for routine and periodic maintenance activities.

The maintenance activities undertaken ensure that vegetation is regularly cut back to maintain visibility, that damaged signs and badly eroded road markings are replaced or repaired as soon as possible and that potholes are repaired before the damage becomes too severe.

Fig 5.09
Signal-controlled T-junction in Korea with signal head (arrowed) obscured by uncut foliage leads to potential danger at junction
(Ross Silcock Partnership)

Problems

Many developing countries continue to put inadequate resources into road maintenance activity and as a consequence many road networks in developing countries continue to deteriorate despite the fact that new roads are being built. Inadequate maintenance has an immediate and direct effect upon road users and the economy as the roads become more unsafe, vehicle condition deteriorates more rapidly, and operating costs increase substantially.

The problem is particularly acute in the case of road markings and road signs since `structural' elements of the road tend to be given priority when any funds do become available. As a consequence road markings and road signing in many countries tend to be in poor condition or even non-existent in many cases, and pedestrian facilities and crash barriers remain unrepaired after damage has occurred.

Fig 5.10
Poorly maintained road in Papua New Guinea, damages vehicles and presents danger to traffic
(Rendel Palmer &. Tritton)

Summary

Many developing countries have extended their road networks in recent years but few have undertaken sufficient maintenance to keep them in a satisfactory condition. The costs of rehabilitation have become very substantial. Badly maintained roads contribute to the growing road safety problems of developing countries. Significantly greater resources (manpower, equipment ....

Possible Solutions/Benefits

Fig 5.11
Illuminated temporary sign used to give clear warning of roadworks to drivers, Denmark
(TRL)

Fig 5.12
Cutting out damaged road surface with diamond saw, Fiji
(Ross Silcock Partnership)

The key areas of maintenance for road safety are:

- **Road structure.** Potholes which could damage vehicles, cause them to swerve suddenly, and even off-balance two-wheeled vehicles must not be allowed to develop. Surface texture and skid resistance must also be maintained (see section 5.4).
- **Drainage.** Drainage ditches must remain free of obstructions and retain their intended cross sections and grades. Surface and ground water should be able to drain away from the road or under the road.
- **Shoulder.** Ensure that the pavement has adequate side support, that traffic can use the shoulder at speed without danger, that parking of vehicles is possible and that surface drainage from the carriageway to the ditch is possible.
- **Slopes.** Ensure that side slopes are protected against the damaging effects of water, so that they retain their shape and stability.
- **Bridges.** Check that bridges are in sound structural condition and safe for traffic. At bridges over water, the water must flow unimpeded at all flood levels without damaging the bridge or the waterway.
- **Traffic control devices.** These include signs, reflectors, guideposts, kilometre posts, guardrails and pavement markings. Check that traffic control devices are in a good and usable condition. Ensure they remain correctly located, properly mounted, fixed, stable and visible at all times. Where necessary vegetation should be cut back.

Other relevant sections: 4.1.10, 5.2, 5.4
Key external references: 2, 12

........and funds) need to be applied in this area to ensure that the safety-related elements of the roads are kept properly maintained. The key areas of particular concern and which require maintenance for *road safety purposes are road structure, drainage, shoulders, slopes, bridges and traffic control devices*

5.4 Surface Treatment and Texture

Background

Skidding is a contributory factor in many accidents, particularly on wet roads on the approaches to intersections. It can be minimised by the preservation of a good skid resistant road surface, particularly on approaches to intersections and pedestrian crossings.

The surface texture of a road is described at two levels: the micro-texture refers to the detailed surface characteristics of the aggregate and mortar and the macro-texture is the large-scale surface profile visible to the naked eye. At low speeds, e.g. at or near intersections on the minor road, or on circulatory carriageways of roundabouts, a harsh micro-texture is required. At higher speeds, e.g. on slip-road exits from high speed dual carriageways, the macro-texture needs to be relatively rough.

The two criteria of most importance in surface materials are their resistance to polishing and their abrasion.

Skidding resistance of road surfaces can be measured with special equipment. This can range from a lorry mounted device (SCRIM) which can be operated at up to 80 km/h with minimal disruption to traffic to a portable hand-held pendulum device which can be used to check skidding resistance at accident blackspots.

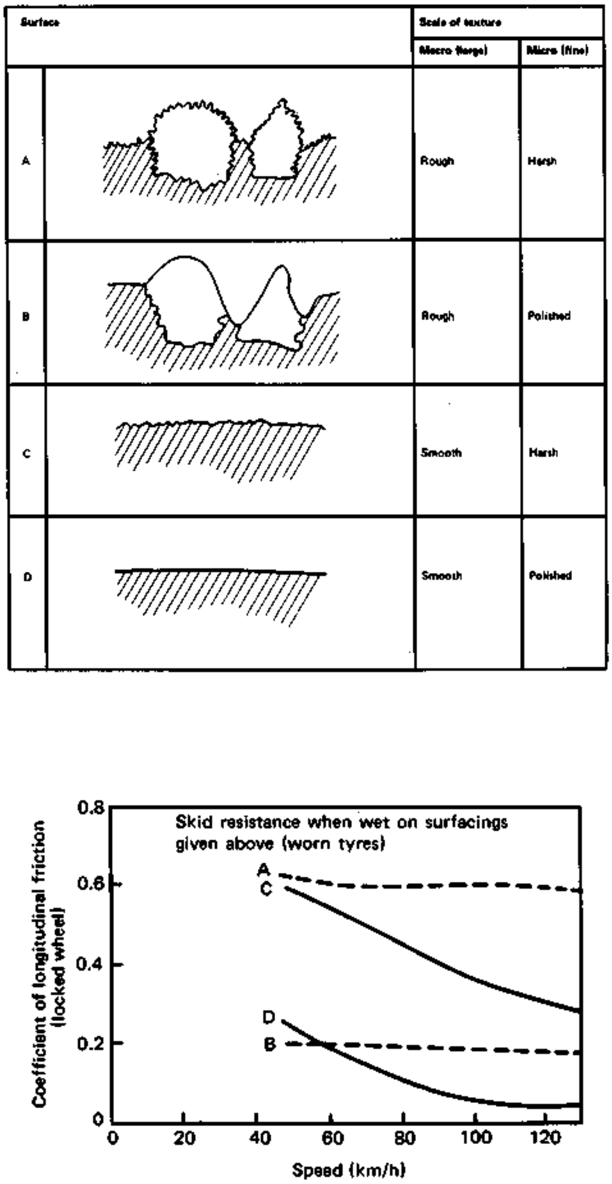


Fig 5.13
Illustration of terms used to describe surface texture (ref 15)

Problems

There is frequently a lack of standards laid down for road surface texture in developing countries. Often good quality aggregates and binders are not readily available and inadequate materials are used.

If the resistance to polishing is inadequate, the surface will become polished smooth by the action of tyres and if they abrade (wear) badly, the aggregate will quickly be lost by the road surface. In both instances the road surface will have a reduced skidding resistance and vehicles will skid especially if there is any water (e.g. rainfall) on the road and if the vehicles are travelling fast.

Even where abrasion and resistance to polishing criteria have been considered in the design procedures, they are often not given the importance they deserve in maintenance activities. Few countries have a regular testing programme to monitor surface texture or to carry out remedial treatment where the surface has fallen below standard.

Summary

The provision and maintenance of a good skid resistant surface is essential for the safe operation of vehicles. Monitoring should take place on a routine basis and the surface should be maintained right up to the edge of the carriageway to allow for cycles and other slow-mooing vehicles. Many techniques exist for improving the skid resistance of the road surface. Surface dressing ....

Possible Solutions/Benefits

Fig 5.14
Good skid resistant texture
(TRL)

Fig 5.15
Police in Egypt using TRL portable device to measure skid resistance
(TRL)

Minimum standards of skid resistance need to be specified.

Regular monitoring is very important particulary in tropical climates and frequent maintenance will be necessary to retain surface texture. Of particular interest in critical places such as accident remedial sites with a high prevalence of skidding accidents, is the Polished Stone Value, established by laboratory tests. If a location is found to be in need of attention, two categories of improvement are available:

1. Removal of material - the new surface is prepared by removing material from the surface by physical means, e.g. grooving, sanding or planing, or by chemical means using hydrochloric acid.

2. Addition of material - this method lays a new, non-structural, surface layer either by heating the old surface and rolling in chippings or by laying a layer of new binder and chippings.

- The normal method of surface dressing is to spread a thin layer of hot bitumen binder onto which is spread stone chippings which are rolled in with a rubber tyred roller. The binder viscosity and temperature and the size of chippings must be designed carefully to meet the particular needs of the site. Limestone aggregates should be avoided.

- Surface dressing gives good skidding resistance. Resinous binders give even better skidding resistance but these are more expensive; they may be justified, however, in critical circumstances.

- On smooth concrete roads the texture can be improved by cutting grooves with a diamond saw.

Other relevant sections: 5.3
Key external references: 12

………(Chipseal) is the cheapest. Specialist resinous binders and proprietary skid resistant surfacing are also available but tend to be expensive but can be worthwhile as accident remedial measures at difficult sites. On smooth concrete roads, the surface texture can be improved by cutting grooves with a diamond saw.

5.5 Traffic Management

Background

The term "traffic management" is used to describe the general process of adjusting or adapting the use of existing road systems to improve traffic operations without resorting to major new construction. Traffic management usually seeks to improve traffic flows, reduce accidents, improve environments or provide better access for people and goods.

These aims can sometimes be in conflict with each other and compromises may have to be made, depending upon the priorities in any particular road or area. However, most traffic management schemes would seek to improve road safety as a by-product even if this was not the main objective.

Fig 5.16
Absence of channelisation and marking leads to potential conflict and danger at a large intersection in Korea (Ross Silcock Partnership)

Problems

The absence or insufficient use of modern traffic management techniques can result in congested and unsafe road networks for road users. Often pedestrians are particularly at risk and little or no effort is made to improve conditions for such vulnerable road users. Traffic signing and road marking is frequently inadequate, guidance to road users via channelisation is maybe nonexistent and law enforcement is often ineffective.

Whereas these factors were not so critical when traffic volumes were very low, such deficiencies are now often a major contributory factor to the very poor road safety conditions and the high degree of congestion and traffic problems faced in many of the urban areas of developing countries. Pedestrians being slow and unprotected are particularly at risk in the chaotic traffic conditions which exist in such countries and this is clearly shown by the fact that they often constitute high proportions of road accident fatalities, e.g. 65 per cent in Kenya and 84 per cent in Ethiopia.

Fig 5.17
Incompatible mix of pedestrians and vehicles in Pakistan. Note absence of markings and channelisation (Ross Silcock Partnership)

Summary

Many of the traffic congestion and road safety problems in the cities of developing countries can be attributed to inefficient use of road space, poor enforcement, uncontrolled conflicts and the poor design of traffic and pedestrian facilities. Experience in the developed countries has demonstrated that some traffic management techniques can be a highly cost-effective way of alleviating ....

Possible Solutions/Benefits

Fig 5.18
Extensive channelisation of large, signal-controlled intersection in Korea, leads traffic safely through potential conflicts
(Ken Huddart)

Fig 5.19
Well regulated traffic streams and provision for pedestrians reduces conflict and improves safety in Thailand
(JMP Consultants Ltd)

The main traffic management options are described below. All of them can have benefits for road safety.

- **Parking and loading controls** on main traffic routes, at least at peak times and near pedestrian crossings, can relieve congestion problems and improve safety. Visibility for and of pedestrians is significantly increased so road crossing is safer. Alternative sites for parking should also be provided nearby.

- **Traffic control measures** seek to minimise conflicts. The range of measures is wide and they are usually applied on a comprehensive basis along a route corridor or in a specific area of the city.

- **Traffic circulation measures** include bans on certain conflicting movements, road closures and rerouteing schemes. They can be used to prevent non-essential, through or undesirable traffic from entering specified areas (e.g. congested central areas, residential areas etc). One-way systems can result in a reduction of conflicts and should improve safety but care must be taken to ensure that resultant increased speeds do not erode the safety benefits.

- **Segregation schemes** separating pedestrians from moving traffic by special crossing facilities or guard rails enhance road safety.

- **Intersection improvements** with traffic signals and/or channelisation can increase capacity and create safer crossing opportunities for pedestrians via a pedestrian phase of traffic signals and via safe pedestrian waiting areas on refuges or islands in cases where channelisation is introduced.

It must be emphasised that maintenance and enforcement are extremely important for the success of many of the above measures. These are often major problems in developing countries. Consequently, efforts should be made to design such schemes to be as maintenance free and as self-enforcing as possible.

Other relevant sections: 3.3, 3.5, 5.9.
Key external references: 1

……….congestion problems and can play a vital role in improving road safety. It is, however, important to recognise that effective enforcement and maintenance capability is a prerequisite for success and this often cannot be guaranteed. Traffic management schemes should therefore be designed to be as self-enforcing and as maintenance free as possible.

6.6 Access Control

Background

In industrialised countries, vehicular access onto roads, whether direct from a building or whether via a service road, is often strictly controlled by Highway and Planning authorities using development control powers. Through these powers it is necessary for any developer or individual wishing to create an access onto a road first to obtain approval and authorisation to do so from the relevant highway authority. Where such access could be a danger (e.g. on a corner, or near an intersection) permission would not be granted and the developer would be required to resubmit alternative access arrangements acceptable to the highway authority.

Fig 5.20
Unauthorised private access being constructed near brow of a hill, Indonesia
(Molt MacDonald)

Problems

Uncontrolled access to premises fronting a major road can substantially impede traffic flows and create severe road safety hazards as vehicles attempt to leave, merge with or cross traffic streams. For these reasons, attempts should be made to limit or control frontage access on primary and district distributors but, inevitably, there will be situations where this is not fully practical.

In many developing countries highway authorities rarely have an opportunity to comment on the road traffic and road safety implications of proposed development, far less actually preventing it from going ahead.

Information about development proposals is rarely coordinated and highway authorities often learn of such proposals too late to influence them. The problem is particularly acute with new roads, which attract adjacent development because of the potentially good transport links. Such developments should be controlled and then access proposals audited for safety.

Unauthorised accesses often become commonplace if the highway authority does not show sufficient vigilance and determination in preventing and removing them.

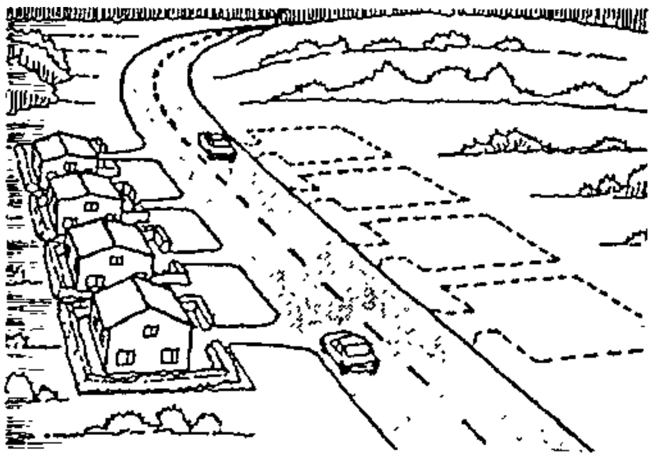


Fig 5.21
Individual houses have their own access onto a main road. New houses planned opposite will lead to further accident risk
(ref 7)

Summary

It is essential that highway authorities have complete control over accesses and developments impinging upon their roads and that they limit access as far as possible on roads which are primarily for movement. Effective development control procedures must be established to prevent people just adding accesses or roads directly to join the network wherever they please as there ....

Possible Solutions/Benefits

Fig 5.22
Temporary service road in Papua New Guinea segregates pedestrians and access traffic from through route
(Ross Silcock Partnership)

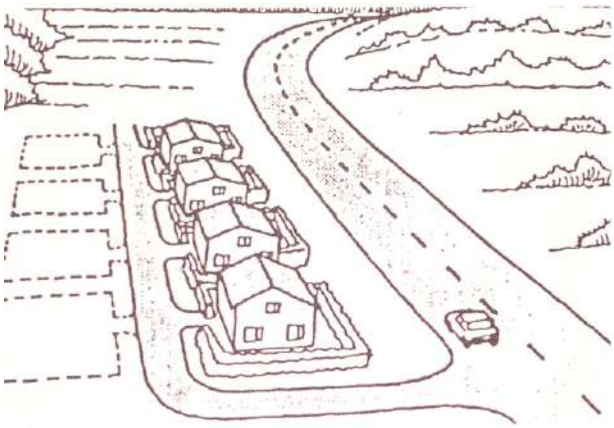


Fig 5.23
Individual houses have access via a side road with only a single T-junction onto main road
(ref 7)

The key points to consider are:

- Careful planning of new developments should ensure that the varying needs for access do not conflict unnecessarily and are catered for by suitable design, e.g. the provision of service roads to provide frontage access off the main highway.

- The number of intersections should be minimised wherever possible and wherever feasible, crossroads should be replaced with stagger or T - junctions. Streets should intersect only with streets in the same class or one class higher or lower in the road hierarchy. Traffic from access roads and local distributors should be channelled onto the district distributor road before joining the primary rather than joining the primary distributor directly from the local road.

- Priority must be given to vehicles travelling on the higher classified street wherever there is an unsignalised intersection between streets of different class. This concept is reinforced by give-way (yield) markings wherever a minor road joins the major road.

- Highway authorities, whether national or whether provincial or municipal should be given clearly defined powers to prevent and control any development along their roads. All developers and others wishing to place an access onto the road must be required to get written approval or a "no objection" certificate from the highway authority concerned.

- Highway authorities must establish a small team to ensure development control along their roads to prevent potential future hazards from being created. Furthermore, they should have powers to enforce the closure and removal of any illegal access which has not been approved by them.

- Access roads to parking areas of major facilities (hospitals, shopping centres, etc) should be at least 50 metres from street intersections.

Other relevant sections: 3.7, 6.8.11, 6.8.12
Key external references: 1, 7

...........is a great danger that future hazards will be created. Encroachment and unauthorised accesses onto the roads must also be strictly enforced and removed to ensure safe and orderly flow of traffic. This will need to be done in close cooperation with the Police and sites should be monitored periodically to ensure that it does not recur.

6.7 Road Signs

Background

Careful provision of road signs can make a considerable contribution to the safe and efficient operation of road networks. Traffic signs should be designed to convey clear and unambiguous messages to road users so that they can be understood quickly and easily. In industrialised countries, traffic signs normally conform to regulations and centrally specified standards so that there is consistency of signs throughout the whole country. There is an international agreement on the more important signs and many countries have adopted the UN convention on this topic.

Traffic signs may be divided into three broad categories. Warning signs, Regulatory signs and Information signs. To be effective signs need to be sited so that the correct information is given to road users when they need it - not too soon or too late - so that they are given sufficient time to carry out the required manoeuvre in safety. Road signs should be used in conjunction with road markings (see 5.8).

Fig 5.24
Profusion of signs, conflicting messages and no standardisation, India
(Mott MacDonald)

Problems

In some developing countries there is a multiplicity of languages and written signs require numerous words which can then become small and difficult to read. Literacy may also be limited. Whereas absence of good road signs was not so important when there were few vehicles on the roads, it becomes a serious problem when there are large numbers of vehicles and conflicts.

Roads and intersections are often inadequately signposted and drivers are provided with little guidance or information as they use the roads. Sometimes this is because of limitations on funds but it is often because there are no uniform national standards in use or the agency responsible for road signs and markings differs from that responsible for the road construction.

Maintenance, too, is often a major problem and it is commonplace to see worn, almost illegible, damaged or missing road signs on road networks. Unfortunately theft of signs (for the metal content) is also a problem in some countries.

Fig 5.25
Absence of signs or advance warning of bends in Papua New Guinea creates danger, particularly at night
(TRL)

Summary

Road signs (along with road markings) are used to communicate with the driver and to guide him safely through the road network. International standards exist which make extensive use of symbols rather than words. There are advantages in using these to develop local standards as this provides consistency and uniformity with international practice. Much greater use should be .....

Possible Solutions/Benefits

1. TYPE OF ROAD 85 percentile approach speeds of private cars	2. Examples of typical roads on which the speeds of private cars shown on column 1 may apply	3. Height of triangle of warning signs (mm)	4. Distance of sign from hazard (see notes in ref.3)	5. Recommended clear visibility distance of signs (m)
1.(a) up to 20mph	Very narrow urban roads carrying less than 1500 vpd and less than 350 commercial vpd	600	45	60
1.(b) up to 20 mph	Narrow rural roads carrying less than 1500 vpd and less than 350 commercial vpd	600	45	60
2. over 20mph up to and including 30mph	Urban and other rural roads of a local character	600	45	60
3. over 30mph up to and including 40mph	Urban and rural single carriageway 2 lane roads	750 (600)	45-100	60
4. over 40mph up to and including 50mph	Urban motorways and high standard 2 or 3 lane rural roads	900 (750)	110-180	75
5. over 50mph up to and including 60mph	Dual carriageway roads and single carriageway roads of 3 lanes or over	1200 (900)	180-245	75
6. over 60mph	Motorways and modern high standard all purpose dual carriageway roads	1200 (1500)	245-305	105

Note: Alternative sizes for signs are shown in brackets in column 3 to be used where amenity considerations or physical restrictions apply.

Table 5.01
UK standards for size of warning signs and siting details (ref 3)

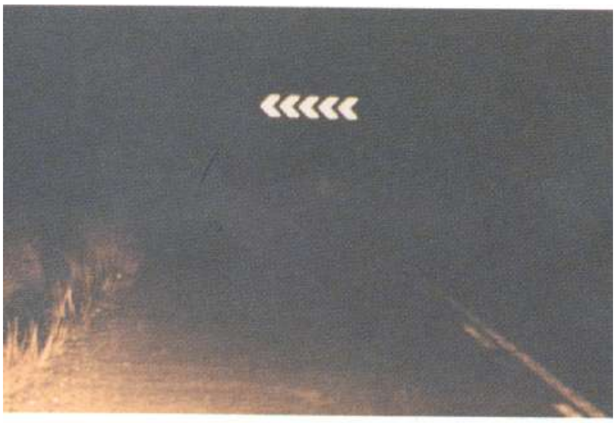


Fig 5.26
Reflectorised Chevron warning sign in Papua New Guinea is readily visible at night
(TRL)

The most important aspects with respect to road safety are:

- Road signs and road markings are extremely important tools of communication to guide and direct the driver through conflict points and hazards on the road network. They enable the driver to be given advance warning.
- Warning and regulatory signs preferably using international conventions, play a crucial role in terms of road safety, in giving information about rules and hazards further ahead. However, direction signs, especially of the map-type (where the layout of the intersection is shown diagrammatically) can also give advance warning of what is ahead.
- The general approach with direction signs should be first to guide traffic towards a general destination and then at the appropriate point, to direct it to more specific areas and finally, to local destinations.
- Map type direction signs are easier to understand than stack type (where destinations are displayed as a vertical list).
- The precise size, layout and siting of a sign will depend upon speed but care must be taken to ensure they are ether placed sufficiently back from the road, or designed not to be a danger to any vehicles which do hit them. (This could be done by having signposts which break on impact.)
- Reflective warning road signs have a particularly important role to play in reducing night-time accidents where there is no streetlighting, even on urban roads.
- Where theft of metal signs is a problem, drilling holes through the sign may make the metal less useful and less likely to be stolen. Alternatively wooden painted signs can provide an acceptable solution.
- Warning signs should be used to break the driver's line of sight where unexpected hazards could exist (e.g. chevrons at sharp bends).

Other relevant sections: 4.2.1, 4.2.6. 5.8, 6.8.6
Key external references: 3

...........made of road signs in developing countries than is done at present. Wherever feasible, reflective signs and markings should be used on major rural roads so that the carriageway is clearly delineated, (especially at night-time).

5.8 Road Markings

Background

Road paint or thermoplastic road markings are used on the road surface to convey warnings, to provide information and to indicate required manoeuvres and can make a significant contribution to the safe and efficient operation of the network. As with traffic signs, regulations and standards are normally specified nationally so that there is consistency in intersection layout and marking throughout the country.

To be effective, road markings need to be visible in all weather conditions and should convey the information required by drivers clearly and unambiguously. Road markings should be used in conjunction with road signs (see 5.7).

Fig 5.27
Inadequately marked T-Junction in Papua New Guinea offers little guidance to drivers
(TRL)

Problems

Although most developing countries often have national standards for road marking, few appear able to show a well marked, well maintained network. This is partly due to the fact that road marking paint available locally often tends to be very poor quality while imported road marking paint is very expensive.

The poor conditions of roads (potholes, deformations, etc) can also make road marking difficult to apply in any effective manner. Shortage of specialist machinery, skilled/trained technicians and the cost of imported thermoplastics all make its use problematic in many of the less wealthy countries.

Thermoplastic can be a problem in dry countries since the thermoplastic becomes black with rubber deposits left by vehicle tyres, and the rainfall is inadequate to provide any cleaning effect.

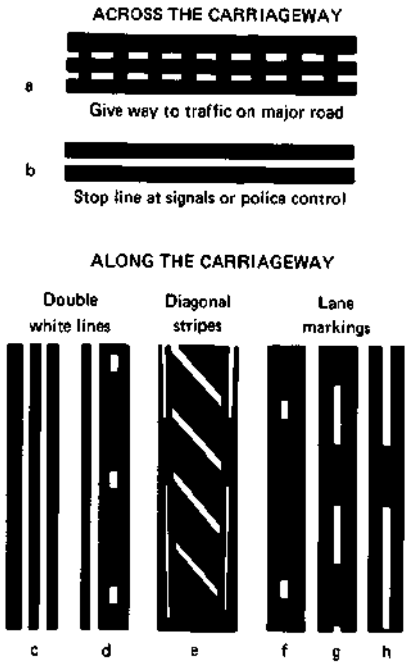
The limited budgets available make it difficult for engineers to keep the road markings to an acceptable standard. As a result pedestrian crossings, intersections, etc, often have no road markings to provide guidance to drivers. This significantly increases the risks and dangers to all road users.

Fig 5.28
Absence of road markings on wide roadway in Egypt causes confusion and increases accident potential
(Ross Silcock Partnership)

Summary

Road markings play a very important role in guiding the driver and providing him with the information necessary to negotiate conflict points on the road network and should be a high priority for those seeking to improve road safety. The driver can be given appropriate information through the use of different types and colours of road marking. Stop and glue-way lines at intersections ....

Possible Solutions/Benefits



Rules related to meanings of lines

LINES ACROSS THE ROAD

(a) All traffic must give way to traffic on major road but need not stop if there is no traffic on main road

(b) Stop-line at signals or police control. All traffic must stop at the stop-line and wait until it is safe to emerge into the road

LINES AND LANES ALONG THE ROAD

A single broken line, with long markings and short gaps, in the middle of the road is a hazard warning line. Do not cross it unless you can see that the road is clear.

(c) Where there are double white lines along the road and the line nearer to you is solid, you must not cross or straddle it except when you need to get in and out of premises or a side road, or when you are ordered to cross the lines by a policeman or traffic warden, or when you have to avoid a stationary obstruction.

(d) Where there are double white lines along the road and the line nearer to you is broken, you may cross the lines to overtake if you can do so safely and before reaching a solid white line on your side. It is up to you to be sure it is safe.

(e) Areas of white diagonal stripes or white chevrons painted on the road are to separate traffic streams liable to be a danger to each other or to protect traffic turning right. Do not drive over these areas if you can avoid doing so. Where the chevron has a solid white edge line you must not enter the area except in an emergency.

(f) Keep between the traffic lane markings - the short broken white lines which divide the road into lanes. Keep in the lane nearest the road - edge unless you are going to overtake, turn or pass parked vehicles.

Fig 5.29
Various road markings and their functions as used in the UK (UK Highway Code)

Road markings guide and assist the driver to negotiate conflict points and to be positioned at precisely the right location to make his manoeuvre in the safest and quickest way so that the time he is exposed to risk is minimised. National standards should be developed by the central highway authority of each country, ideally by adapting the UN conventions. These should then be widely distributed to all local highway authorities to encourage consistency of approach, layouts, signs and markings.

- Stop and give way lines on roads can position drivers so that they are brought to the safest point from which to make their manoeuvres through the intersection.
- Centreline and edgemarking of rural roads can help to delineate the road ahead so that any horizontal or vertical curvature can be clearly seen by approaching road users.
- Centreline markings can be used to convey information about whether or not it is safe to overtake, while painted marks in the centre of lanes can indicate particular hazards ahead (e.g. painted diamonds are used in S Korea to give advance warning of a pedestrian crossing ahead).
- Frequent repainting can give good results even if the paint quality is not high. If frequent repainting is not feasible, specialist contractors should be employed to apply thermoplastic markings. (These can last as much as 8 times longer than paint but are more expensive.)
- Where unlit roads occur, night-time visibility of road markings and hence any horizontal or vertical alignment can be markedly improved by mixing small glass beads into the paint or thermoplastic before applying it to the road surface. This solution is particularly appropriate for developing countries as many urban and rural roads are unlit in such countries.

Other relevant sections: 4.2.6, 5.7, 6.8.6
Key external references: 1, 5

………help to position the driver on the road to minimise his risk. Centrelines can be used to indicate locations where overtaking is dangerous while edgelines give advance warning of changes in alignment. Where possible, high quality paint containing small glass beads (for reflectivity at night) should be used.

5.9 Enforcement of Traffic Laws

Background

Traffic law enforcement is meant to achieve the safe and efficient movement of all road users, including pedestrians. It seeks to do so by enforcing traffic legislation.

Although driver discipline and respect for traffic laws is reasonably good in industrialised countries, this is not always the case in the developing world. TRL research in a number of developing countries has shown that driver behaviour at traffic signals, pedestrian crossings and priority intersections is generally very poor. Traffic law, if it is to stay relevant to the needs of rapidly motorising societies, needs to be updated periodically and the traffic police need to be capable of enforcing it.

Fig 5.30
Trucks 'red running' at traffic signals in Korea due to absence of enforcement
(Ross Silcock Partnership)

Problems

In many developing countries, the traffic police are grossly under-resourced and under-trained for the tasks they have to perform despite staffing levels being relatively high. In industrialised countries around 10 per cent of total police resources are normally devoted to traffic policing activities and in countries with particularly strong traffic policing (e.g. Japan) this can rise to 14-16 per cent of police budgets. In developing countries, traffic policing typically receives only 4-5 per cent of police budgets and overall police budgets themselves are often too low in the first place. As a consequence, traffic police in most developing countries, tend to be poorly paid, poorly equipped, untrained and increasingly incapable of dealing adequately with the serious traffic and road safety problems facing them.

The low salaries paid increases the risks of corruption and as a result, many offences remain unreported and unpunished. In many cases grossly and dangerously overloaded vehicles cause considerable road damage and create road safety hazards. The police often concentrate on traffic control and enforcement of parking or non-moving violations rather than the more serious moving violations.

Drivers thus blatantly disregard regulations and a general disrespect for the traffic police and traffic law often gradually becomes the norm.

Fig 5.31
Dangerous vehicle in Ghana. Unmarked protruding metal bar is a danger to following traffic
(TRL)

Summary

Enforcement is one of the key factors which can have a major influence on road safety. Traffic police seek to influence driver behaviour but this can only be done successfully if the traffic police personnel are, themselves, adequately trained and equipped. Traffic police forces should have clear career possibilities for those who wish to specialise and all personnel should be trained to drive ....

Possible Solutions/Benefits

Fig 5.32
Police enforcing parking regulations in Bahrain
(Ross Silcock Partnership)

Fig 5.33
Police checks in Ghana can deter use of unroadworthy vehicles at the roadside
(Ross Silcock Partnership)

Enforcement needs to be uniform and consistent across the country and applied equally to all road users if there is to be respect for the law. Key aspects to consider include:-

- Restructuring of the traffic police as a specialist division with clear career opportunities for officers to move up the ranks to senior positions.

- Traffic police personnel engaged in enforcing Traffic Regulations, should be able to drive so that they can better understand and appreciate the difficulties of the driver. Regular specialist training courses and refresher in-service courses need to be devised for traffic police personnel.

- Traffic police should be supplied with modern equipment and facilities to carry out their tasks. They should concentrate on enforcing moving rather than non-moving violations i.e. giving speeding and drunken driving offences a higher priority. In order to do this effectively they require vehicles equipped with radios, radar speed checking devices and alcohol testing devices and they need to be trained in their use.

- Enforcement techniques, while greatly assisted by modern enforcement equipment, do not need to be wholly dependent upon such resources. Much can be done with small teams of traffic police acting as mobile task forces to enforce particular safety-related topics, (e.g. brakes, tyres, parking) for short periods at a variety of sites each day.

- Technical assistance and funding for equipping and modernising traffic police forces is now often available from international aid and lending agencies, who have recognised that effective traffic law enforcement can improve traffic conditions, congestion and road safety. For example, control of vehicle overloading can be effective not only in maintaining safety but also in minimising road pavement deterioration and removing many excessively slow vehicles.

- Strengthening of Traffic Police forces allied to modernising of legislation and increased cooperation between Traffic Police and Municipal engineering departments can make a marked difference to the degree and effectiveness of enforcement. Enforcement should be highly visible in order to deter and act as a warning and reminder to other passing motorists. TRL experiments in Egypt have shown very marked reductions in accidents as a result of increased enforcement.

Other relevant sections: 2.2, 5.2, 5.5, 5.10
Key external references:

.............Opportunities should be taken where possible to modernise the traffic police force. Close cooperation with the relevant highway authorities will enable much more effective and high profile traffic policing to be undertaken. In particular, more use should be made of small task force units to carry out random checks on tyres, brakes and lights at different times and places. Priority should be given to the prevention of moving rather than non-moving violations.

5.10 Speed Limits

Background

There are no international standards. In urban areas 50 km/h is probably the most common but there are wide variations, with some primary routes, especially dual carriageways, having 65 km/h or 80 km/h limits. In rural areas some countries have no upper limit on motorways / expressways but most have a general upper limit on other categories of road.

Research has shown that lower speeds lead to fewer and less serious accidents. There is much debate, however, about the effectiveness of speed limits by themselves in achieving lower speeds as much will depend upon the amount and effectiveness of police enforcement.

Fig 5.34
Unrealistic speed limit sign in Papua New Guinea no change in character of road, no urbanisation
(TRL)

Problems

Throughout the world speed limits are widely abused, often flagrantly. In many developing countries, police authorities have neither the equipment nor the training to enforce them properly. Many drivers do not see any reason for speed limits which they regard as an unnecessary constraint on their driving freedoms. The police usually argue that failure to observe the limit, and their inability to enforce it, brings the traffic law into disrepute.

Speed limits are often not posted where main roads pass through villages. They require extensive signing, especially where a different limit applies on a major route joined by many minor roads. In such cases each minor road should ideally have a speed limit sign at its intersection with the major route.

Speed limits, if not consistent with the nature and type of road, will not be observed by drivers. Furthermore, too many speed limits make enforcement difficult and cause confusion to drivers. Unfortunately both of these deficiencies occur often in developing countries.

Fig 5.35
Major interurban road in Ghana with no speed limits as it passes through a rural community
(Ross Silcock Partnership)

Summary

Speed is a common contributory factor to accidents and reducing speeds at accident blackspots is often an important objective. There is doubt, however, as to whether the imposition of a speed limit alone will achieve the required speed reductions. Speed limits are commonly abused and can only be effective if subject to extensive, high profile enforcement. Such conditions rarely prevail in ....

Possible Solutions/Benefits

Fig 5.36
Police in Kenya using radar speed gun to detect speeding motorists and radioing ahead to have speeding drivers stopped and charged
(Ross Silcock Partnership)

Fig 5.37
30 km/h speed limit in a special residential area in Denmark. Note speed humps
(Ross Silcock Partnership)

Speed limits are usually set by national legislation and their use as a countermeasure at a particular location is not common. Nevertheless, excessive speed is a very common contributory factor to traffic accidents and if speed limits can be made to work where excessive speeding is a problem then their effects can be very beneficial. The key points to consider are:

- ❑ In the absence of physical measures to reduce speeds, extensive enforcement will be necessary to ensure compliance with the limit. In the long term this can be costly and may tie up scarce police resources at one location.
- ❑ Speed limits may be more effective if used as part of a more comprehensive scheme, especially in an areawide context. Thus, for example, if a residential area is subject to an areawide traffic management scheme including road closures to inhibit through traffic and to assist pedestrians, then it may also be appropriate to introduce a lower speed limit within the area than that which prevails on the surrounding roads.
- ❑ As traffic conditions and land-uses change over time, speed limits should be regularly reviewed to ensure that they relate to current circumstances, for example, on major routes where new settlements develop leading to greater pedestrian activity.
- ❑ Other locations in which special speed limits may be appropriate include school zones and other places where large numbers of pedestrians may be expected.
- ❑ There should be only a limited number of standard speed limits, e.g. 50, 80, 100 and 120 km/h to ease enforcement and to provide consistency for drivers.
- ❑ Exceptions to these are advisory maximum speed limit signs which can be effective before sharp bends with fairly long straight approaches.

Other relevant sections: 5.9, 6.8.9
Key external references: 1

..........developing countries. Speed limits may be made more effective if applied in conjunction with physical measures to reduce speed, or as part of a package of measures introduced on an areawide basis. Speeds on urban streets should be restricted to around 50 km/h and speed limits in specified residential areas could be even lower (e.g. 30 km/h) in order to create safe conditions for pedestrians.

5.11 Parking

Background

Experience in industrialised countries suggests that parked vehicles or those in the act of parking or leaving a parking space, are involved in around 10 per cent of all accidents. Parking is a contributory factor in 8-10 per cent of pedestrian fatalities. Ideally, kerbside parking should be permitted only if stationary vehicles do not unduly interfere with free and safe movement of vehicles. On roads which are primarily for moving traffic, efforts should be made to ban on-road parking and to provide off-road facilities wherever feasible. This, of course, cannot always be done so a number of measures have been devised to minimise the consequences, to create safer conditions and to reduce the conflicts between pedestrians and moving vehicles which can result from parked vehicles.

Fig 5.38
Uncontrolled parking causing obstruction and damage to footway, Qatar
(Ross Silcock Partnership)

Problems

In a number of developing countries the problem is often even more critical and difficult to control. Planning of CBS has often been done without adequate recognition of the need to provide for the car, with the result that parking demand is frequently far in excess of the available supply. Time is wasted and congestion and pollution is created by motorists driving around looking for parking spaces. Illegal parking is rife and pedestrian footpaths are often encroached upon, forcing pedestrians onto the roadway. Enforcement is often poor and this, allied to undisciplined, frustrated drivers, often leads to the creation of hazardous conditions for motorists and pedestrians. Insensitive planning and placement of buildings, car parks and roads can create unforeseen hazards by forcing people to walk across roads after parking.

Uncontrolled parking adjacent to main roads can result in unsafe conditions as vehicles slowing down to park or emerging from parking spaces conflict with the through traffic.

Fig 5.39
Poorly designed protected parking bays in Indonesia- collisions occur with kerbs particulary at night
(TRL)

Summary

Parked, parking and unparking vehicles, cause obstruction, interference and potential danger to pedestrians and other motorists. Provision of off-street parking with clearly defined entry/exit points where feasible, or displacement of parking to side roads, can create safer conditions by increasing conspicuity of pedestrians and removing parking/mooing car conflicts. Alternatively, ...

Possible Solutions/Benefits

Fig 5.40
Further along the same street as in Fig 5.38 small bollards are effective in preventing parking on the footway Ross Silcock Partnership)

Fig 5.41
Segregated parking area in Bahrain reduces hazard by concentrating entry/exit to a single location. Note higher kerbs or bollards may have prevented encroachment onto the footway
(Ross Silcock Partnership)

Many of these problems can be avoided by more careful planning, provision and control of parking facilities. There are 3 major factors to be taken into account when planning parking provision: the need to maximise access to traffic generating activities; the need to minimise interruptions to moving traffic; and the need to minimise traffic related road accidents. This can be done as follows:

- Parking on arterial roads carrying large volumes of traffic should be avoided. Parking should be displaced to side streets through partial or all day parking bans on the main road. Major traffic generators along such routes should, where feasible, be required to provide off street parking to meet their and visitors' needs.

- In busy shopping streets, carriageway narrowing can be used to create a clear distinction between the roadway for moving traffic and that for stationary vehicles. This can be done by extending footways to create pockets of sufficient 'off road' width for parking and manoeuvring so that moving traffic is not inhibited.

- In residential areas off-street parking should be provided wherever possible. If this is impossible (e.g. high density developments) on-street parking can be grouped nearby to create special residents' parking zones.

- In industrial areas, large articulated trucks need lanes to be about 3.5 m wide. Unless kerbside parking is prohibited and enforced, an additional 3 m will need to be provided as parking space.

- Parking schemes are often introduced in city centres to ration parking space by charging the motorist (via parking meters, parking tickets or attendant parking) for the use of the space. Charges are typically higher in city centres and the maximum amount of time allowed is often only 1 hour or less. The costs are usually lower and permitted maximum times longer further out from the centre.

Other relevant sections: 3.2, 3.3, 5.5
Key external references: 1, 10

.........narrowing of roads and use of redundant space for the creation of "off road" parking areas can also aid pedestrians crossing the road and enable manoeuvring activities to be done more safely, without interfering with the mooing traffic stream. Judicious use of parking bans, either all day or for parts of the day, can also keep important roads clear for mooing traffic and, by reducing conflicts, increase capacity and safety.

5.12 Heavy Goods Vehicles (HG Vs)

Background

In industrialised countries, usage of heavy goods vehicles (HGVs) is carefully controlled. Regulation and traffic management are used to minimise their danger and nuisance, especially in sensitive locations such as residential areas. Controls are also imposed to restrict axle weights so that roads are not damaged and to avoid inconvenience and danger to pedestrians and others through illegal parking.

Fig 5.42
Goods vehicle in congested conditions in Thailand with passenger riding illegally on load
(JMP Consultants Ltd)

Problems

HGV operations in many developing countries are not adequately regulated. Often anyone can become a goods vehicle operator, vehicles may be defective and there may be no criteria to define those who may drive the vehicle. Much of the long distance driving is undertaken with the aid of alcohol or drugs to keep awake. Vehicles themselves are frequently grossly overloaded, axle weights of up to 40 tonnes have been recorded in Iran and axle-loads of 25-30 tonnes are common in many developing countries. Police enforcement of axle-load restrictions is often minimal and ineffective due to corruption. Consequently, significant structural damage can occur to roads which were never designed for such loads.

Trucks are often not only overloaded in weight but may often be unstable due to very high loads. They may have protruding loads which are a danger to other road users. In urban areas such trucks are often parked on the roadways in unlit streets of residential areas at the homes of drivers or operators, despite the fact that they may be loaded with dangerous, inflammable or potentially explosive chemicals.

Resting points and refreshment stops for drivers develop along major routes. Unfortunately, apart from food, local alcohols and narcotic substances (e.g. betel nut) are often sold at such stalls. This can have very serious consequences in terms of accidents. In addition, the traffic congestion caused by such terminals can cause serious problems on the through-road unless parked vehicles can be relocated well away from the road edge.

Fig 5.43
Dangerous tyre conditions on a goods vehicle in Kenya
(Rendel Palmer & Tritton)

Summary

Heavy goods vehicles (HGVs) form an important part of the economic activity of all countries but their use on unsuitable streets or areas can be very detrimental to road safety. Industrialised countries have developed techniques to manage heavy goods vehicles, in terms of parking and access controls, and to control and influence the routes and overnight parking they use. Some of.

Possible Solutions/Benefits

Fig 5.44
Height gauge to protect bridge from damage by overloaded trucks in Jordan
(Ross Silcock Partnership)

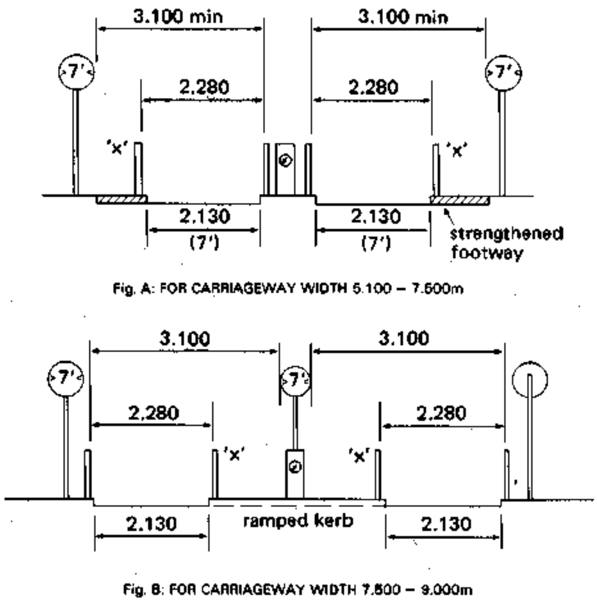


Fig 5.45
Examples of width restrictions to act as lorry barriers in UK (ref 1)

Much can only be done through increased government regulation and control of the freight industry with respect to safety-related features (e.g. roadworthiness of vehicles, qualifications of drivers, working hours). Periodic testing of heavy goods vehicles (and buses) is strongly recommended. However, even in the absence of such increased legislative control, improvements can be made to minimise the effects of such heavy trucks. These various measures are normally aimed at controlling the movement and parking of such vehicles and include:

- **Advisory routeing** uses advisory route signs to direct heavy goods vehicles to routes which are more suitable for such traffic and take them out of and around areas where their presence is undesirable.
- **Physical barriers** can either be of the "height" type, if designed to protect bridges from high loads, or more usually, the "width" type where the road carriageway is deliberately narrowed to about 2.2 metres at selected points using very substantial (150mm) steel posts.
- **Parking and loading restrictions** are often applied at certain times of day (e.g. peak hours) to ensure that moving traffic is not impeded on important routes. Deliveries or collections then have to be made early in the morning or late at night. In pedestrianised areas these may have to be done through rear servicing facilities.
- **Areawide lorry management schemes** are often used to deter and remove heavy vehicles from residential streets. This can be done by prohibiting lorries from passing into an area by having lorry bans on short sections. Lorry cordons can also be used to prevent through movement while still permitting access.
- **Hazardous loads.** Vehicles carrying hazardous goods are required to have clearly visible identifying plates indicating the type of hazard and what to do in the event of a spillage. They are normally required to use major roads only and to avoid residential areas.

Other relevant sections: 3.6.2
Key external references: 1, 7

.........these methods could be used by developing countries. However, the most important effort required is to regulate HGV operators with respect to road safety issues. These must ensure that the vehicles are roadworthy, that drivers are competent and capable, that dangerous freight is kept away from residential areas and that drivers do not drive excessively long hours, under the influence of drugs or alcohol, or with, overloaded/dangerous vehicles.

5.13 Providing for Public Transport

Background

In industrialised countries efforts are made to attract passengers to public transport by giving buses priorities over other traffic, by having convenient interchanges between bus and rail and by subsidising some socially desirable public transport operations. Road based public transport usually consists of buses and taxis and these are strictly regulated to ensure that passengers are able to travel in safety and at reasonable cost. Public transport in industrialised countries is a very safe form of transport.

Fig 5.46
Trucks carrying workers in Kenya. Such overloading results in many casualties in the event of collision
(Ross Silcock Partnership)

Problems

In most developing countries, a much larger variety of passenger carrying transport modes operate and compete for space against other traffic on roads which can be very congested. These range from motorised rickshaws and shared taxis in Asia to `mammy wagons' (passenger carrying trucks) in West Africa. Although this wide variety of public transport modes is not necessarily undesirable, it may mean that regulation of public transport operators is weak. Fare levels are so low that drivers often have to work extremely long hours to earn enough to pay the hire charges for the vehicle and still to leave enough profit on which to survive. Furthermore, drivers drive fast to beat competitors and stop suddenly to pick up extra passengers along the routes, frequently causing danger to their passengers and other traffic. Inadequate maintenance is undertaken, and the structural safety of the vehicles is very low.

Drivers are often poorly trained and educated and road accidents involving public transport vehicles are commonplace with, at trines, major catastrophes occurring (e.g. deaths of 80 or more persons in overloaded and unsafe buses in mountainous regions of S America, Africa and Asia). For convenience the Solutions/Benefits are discussed in terms of 'buses' but they also apply to other types of passenger carrying vehicles in developing countries.

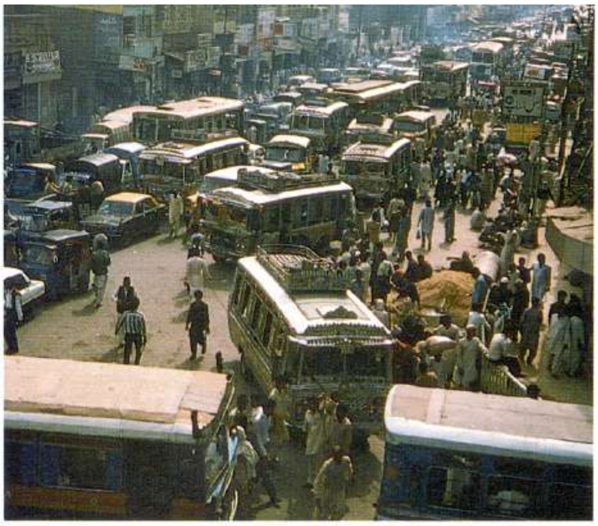


Fig 5.47
Inadequate bus terminus facilities, Pakistan
(TRL)

Summary

The range of public transport modes is often very large in developing countries. Economic factors can result in many of these being unsafe, but they are the only available modes of travel for the large majority. In such circumstances first priorities need to be aimed at limited regulation to ensure that the safety of passengers is adequately catered for through regular roadworthiness screening ....

Possible Solutions/Benefits

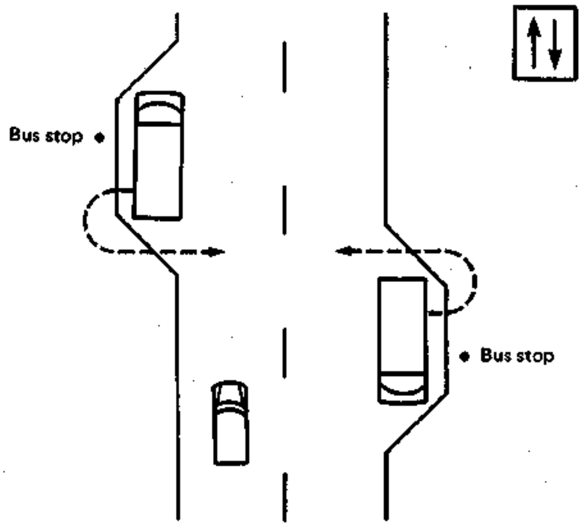


Fig 5.48
Bus stops on opposite sides of the road sited tail to tail to encourage passengers to cross behind the buses.

Fig 5.49
Bus only lane in Thailand
(JMP Consultants Ltd)

Governments have a responsibility to ensure that vehicles which are licensed by them for public transport operations meet basic safety criteria in terms of their structural safety. This can be done as follows:

- Vehicle owners should be required to have qualified drivers and their vehicles inspected regularly to ensure roadworthiness.
- Bus and paratransit stops should be placed at points where pedestrian routes to and from major generators converge. Avoid locations where road safety or congestion problems are likely.
- If buses stop on opposite sides of the same road, stops should be located tail to tail as these are safer (fig 5.48). Pedestrians will tend to cross behind the buses where approaching vehicles on the same side of the road can see them more clearly.
- Bus stops close to intersections or pedestrian crossings should be located beyond (i.e. past) the intersection or crossing. Parking restrictions must be enforced near bus stops, so that crossing pedestrians are not hidden by parked cars.
- Lay-bys can be beneficial in reducing delays to other traffic. The bus can also stand off the road while passengers board and alight.
- Special facilities are often used in industrialised countries in order to give greater priority to buses and hence to make public transport more attractive to potential passengers. These generally set aside a portion of the road for the exclusive use of buses where they can maintain reasonable speeds or reach the head of queues at intersections.
- Bus links, bus gates and bus only streets enable buses to penetrate right to the centres of shopping or business districts. They reduce walking distances for passengers but can increase the risk to pedestrians in the central areas.

Other relevant sections: 3.8, 4.1.16
Key external references: 1, 6

.......of vehicles and by having basic minimum standards for drivers and operators providing such services. In addition, consideration can be given to special measures, such as those used in industrialised countries, to give priority to passenger carrying transport, or to take passengers close to their destinations so that the number of roads to be crossed can be minimised.

6. ACCIDENT COUNTERMEASURES AT HAZARDOUS LOCATIONS

6.1 Introduction

The potential for accident reduction through low-cost, engineering measures at hazardous sites is particularly high. Simple measures can significantly reduce problems at such sites. For example, the use of road signs and markings to channelise traffic through complex intersections, or to provide safe waiting areas for turning vehicles, can often result in substantial reductions in accidents. Yet, because of lack of funds and poor maintenance capability known hazardous locations are often left untreated and remain causes of accidents. Drivers are often presented with misleading information or no advance warning, sightlines may be inadequate, pedestrians may not be catered for and accidents may occur because of a driver's inability to cope with the particular combination of circumstances and environment. By identifying and eliminating the features which make sites hazardous, engineers can improve road safety. This often means reducing the complexity of an intersection or enabling manoeuvres to be made in stages. Reducing the number of decisions drivers must make at any one time simplifies the driving task and helps drivers to progress in safety and comfort with a minimum of conflict with other traffic and pedestrians.

There are four basic strategies for accident reduction through the use of countermeasures. These are:

- Single site (blackspot programmes) - the treatment of specific types of accident at a single location;
- Mass action plans - the application of a known remedy to locations with a common accident problem;
- Route action plans - the application of known remedies along a route with a high accident rate;
- Area wide schemes - the application of various treatments over a wide area of town / city, e.g. including traffic management and traffic calming (speed reducing devices).

Blackspot treatment is likely to be the most effective and straightforward in countries with no prior experience of accident remedial work. Many highway authorities in industrialised countries began in this way and only later moved on to mass and route action plans as experience built up.

All of these strategies rely on the availability of data describing accidents and their locations to identify where accidents occur and what are the common features which contribute to them. Accident data and the use of collision diagrams, a key analysis tool for the traffic engineer, are discussed in the next sections.

Although the improvement of accident blackspots is a very important area requiring attention it has so far received little priority. However, research on this topic is now being conducted in Botswana, Ghana, Egypt, Pakistan, South Korea and Papua New Guinea. The results should demonstrate the effectiveness of low-cost engineering measures (particularly those which are 'self-enforcing').

This chapter first discusses data requirements, then how to identify and analyse accident problems, followed by illustrations of how low-cost countermeasures can be used to improve hazardous locations and to reduce accidents.

6.2 Accident Data

Most countries have a road accident recording system, invariably based on some form of legal obligation to report accidents to the police. The police then complete an accident report. The amount of detail, the accuracy of reporting, the percentage of accidents recorded and their availability to non-police users varies enormously from country to country.

Typically an annual statistical report is produced containing simple tables of types of accidents and, perhaps, regional variations. Whilst these contain useful background information they rarely contain sufficient detail for the identification of hazardous locations or accident analysis, as discussed in sections 6.3 and 6.4. For these tasks it is essential that data are available at a local level to those carrying out the investigation and the design of countermeasures.

To be of value it is essential that the accident report includes an accurate geographic location of the accident preferably using a location sketch, basic information describing the accident, its victims, the events leading up to the accident, a collision sketch showing paths of the road users involved, and summary information regarding the highway at the accident location.

Care must be taken in deciding the severity of accidents to include in a reporting system. If all accidents, including ‘property damage’ (in which no-one is injured) are supposedly reported, under-reporting is inevitable. On the other hand, if only injury accidents are included, their relative rarity may result in too few accidents being recorded for valid analysis. The choice will depend upon local circumstances.

The rapid rate of development of microcomputers in recent years, arid their declining costs, makes them attractive for accident data storage and analysis. TRL have developed a Microcomputer Accident Analysis Package (MAAP) especially for applications in developing countries. MAAP is available in English, French, Spanish, Arabic, Chinese and Bahasa Indonesian. It has been adapted to run on a wide range of microcomputers under a number of operating systems. Designed primarily for use at regional or local level, by staff with little or no previous computing experience, MAAP is now in use in many countries. It is particularly helpful in the processes of identifying accident blackspots and accident analysis, discussed in sections 6.3 and 6.4.

Data from the police accident report forms, or booklets, are typed into computer files containing accident records. This is an additional task which is not required if only paper records are kept, but the extra work involved here is more than offset by the simplification and speed of subsequent retrieval of data from magnetic (as opposed to paper) records. The process of identifying locations with high numbers of accidents can be done very quickly. The analysis of the accidents at a particular site, especially searching for patterns (see section 6.4) is made much simpler.

Fig 6.01
TRL MAAP in use
(TRL)

6.3 Identifying Accident Blackspots

Highway engineers and traffic police generally know of the tendency for road accidents to cluster together at certain locations, commonly termed 'accident blackspots'. The straightforward process of plotting accidents on maps (Fig. 6.02) reveals these and this method remains an important means of identifying accident blackspots in many countries. Reasonably accurate and complete records are essential for this. Without precise location data, accidents cannot be plotted with any certainty, although in the total absence of data - or during an interim period whilst data are being collected - it may be possible to make a start on remedial works at 'known' blackspots, based on local knowledge of sites where accidents occur most frequently. It is preferable, however, to identify blackspots in an objective way using accident records.

Road intersections are often accident blackspots. It is important to distinguish between accidents occurring at intersections or on links (the sections of road between intersections) as the factors contributing to the accidents and possible treatments are generally very different for each. Whilst in many cases the location will be clear, there will be accidents near to intersections which might fall into either category. In such cases, depending upon the quality and extent of data, it is desirable to examine the factors contributing to the accident in order to establish whether the features of the intersection were important, and if so to classify the accident accordingly as an intersection accident. Generally accidents which occur within 30 metres of an intersection can be regarded as 'intersection' accidents.

Research has shown that the numbers of accidents at a particular site will vary widely from year to year, even if there are no changes in traffic or in the road layout. In statistical terms, road accidents at individual sites are rare, random, multifactor events. This means that comparisons between the numbers of accidents at particular sites must be made with respect to a fixed time period, typically one year. Furthermore, a single year's data will be subject to considerable statistical variation (e.g. see Fig. 6.02). Ideally, several years' data are required, from which a mean, annual accident rate can be calculated. Three years is generally regarded as a practical minimum period for which a reasonably reliable annual average rate can be calculated.

Whilst the annual number of accidents at an intersection or other location is a straightforward concept, when considering links in the highway network it is helpful to think in terms of accident density. There will generally be specific locations at which accidents occur, for example an unexpected, sharp bend. Elsewhere, accidents may occur along a section of road without any obvious single feature. Here it is necessary

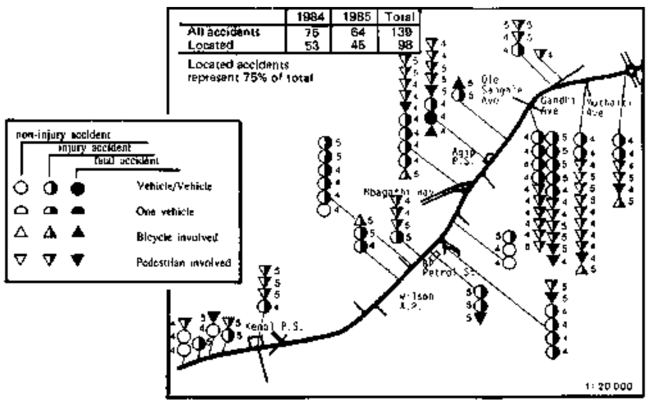


Fig 6.02
A pin map displaying accident locations in an urban area in Kenya (ref 8)

to think in terms of accidents per kilometre, that is, the accident density along a particular link.

Given these data, it is then possible to rank sites in terms of their accident history. For intersections, this would be in terms of average numbers of accidents per annum; for links it would be in terms of average accidents per km per annum.

The severity of accidents should also be taken into account, as accidents with fatal and serious injuries are more costly in both social and economic terms. If sufficient research has been carried out to identify the costs of accidents of different types and with different severity, then they can be weighted relative to their cost. Thus, if a fatal sideswipe accident costs a society 20 times more than a similar slight injury accident, then it can be counted as 20 accident units. Using weightings, however, has the disadvantage that a few, random fatal accidents can sometimes dominate the selection. Alternatively, if such cost information is not available, qualitative weighting can be applied. For example, in South Korea and in Trinidad and Tobago, the Equivalent Accident Numbers (EAN) used for initial ranking purposes are 12 for a fatal; 3 for an injury accident and 1 for a damage-only accident. An EAN score can thus be awarded to each site, based on the sum of EAN values. This allows comparison of sites. Care should be taken to choose sites where remedial action will be most effective. For example, treatment of a site having 3 injury and 3 damage-only accidents with similar causes is more likely to be successful than treating a site with the same EAN comprising a single fatal accident.

Where possible, the effects of traffic volume should also be considered. In simple terms, more traffic would be expected to lead to more accidents. If traffic flow data are available it can be helpful to compare sites in terms of accidents per unit of traffic. Such accident rates are often expressed as accidents per million vehicles entering an intersection or accidents per million vehicle km on a link. If such data are available sites can be compared in terms of these rates which gives an indication of their relative safety, given their traffic volumes.

Traffic flow data are rarely available in sufficient quantity or accuracy to justify this approach. It is recommended that effort be concentrated on collecting comprehensive and accurate accident data, and that blackspots be identified initially on the basis of annual accident totals, where possible averaged over a three-year period. If sufficient data are available, these can be weighted to reflect severity. Fig. 6.03 summarises the accident blackspot approach. The feedback arrow at the top of this chart emphasises the continuous process of accident monitoring for evaluation of the countermeasures implemented.

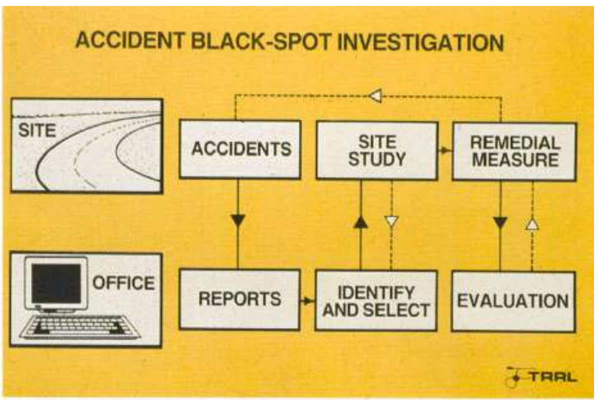


Fig 6.03
'Accident blackspot' flowchart
(TRL)

6.4 Accident Analysis

Having identified a blackspot or problem locations along a route, the next step is to establish the nature of the problem(s) leading to the poor safety record. It is rare for there to be a single `cause' of an accident. Indeed, the term should generally be avoided and traffic police and engineers should be trained to think in terms of `contributory factors'. Accidents are complex events and many factors must usually combine for an accident to occur. If this were not the case there would be many, many more accidents. Accidents are rare events: a very high proportion of the vehicles passing through an intersection in a year do so safely (often numbering millions). Occasionally, when a particular set of contributory factors combine, an accident occurs. Accident analysis is primarily concerned with identifying common features and contributory factors, especially objectively reported features such as vehicle manoeuvres, day/night or road surface condition.

As with identifying blackspots, identifying contributory factors and common features is largely dependent upon the availability of adequate data. The primary source of this is the police accident report, either directly or in some summary form. In some cases, this may exist on a computerised database but in many countries reports are likely to be stored in paper filing systems only. Important information can also be gained from plans and site visits.

It is convenient to think of the analysis in two stages. First, a preliminary analysis is carried out to identify common features amongst accidents and the predominant type(s) of accident. This is followed by a detailed analysis, where the factors contributing to the predominant type(s) are identified, allowing remedial measures to be designed to eliminate or counteract them.

The preliminary analysis should be quantitative. It would include the preparation of summary tables which would disaggregate the total number of accidents by such items as: collision type; severity; vehicle type; time of day; day of week; weather conditions and pedestrian involvement. Collision diagrams, which summarise the types of manoeuvre involved, would also be prepared (e.g. Fig. 6.04). From these it is usually possible to identify a few predominant types of accident which occur most frequently at many sites or at a particular site.

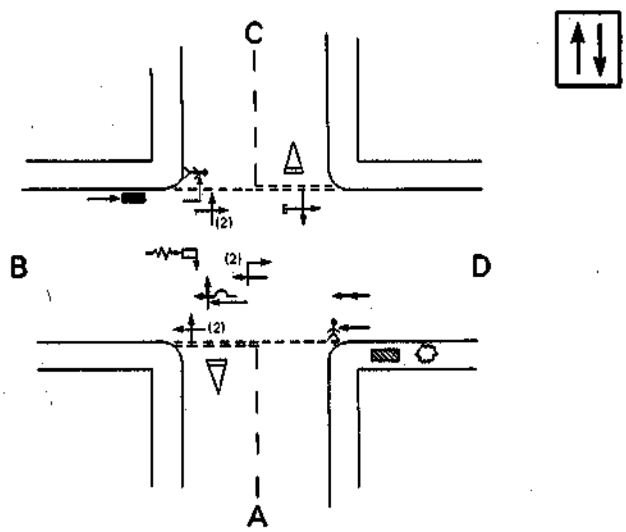


Fig 6.04
Typical collision diagram
(ref 5)

Accident analysis requires a systematic process to be carried out in order to identify the dominant accident type(s) which can be treated. An accident grid (Fig. 6.05) is a straightforward way of doing this. The grid summarises, for each accident, the features of the accident which appear to be relevant. By scanning each line of the grid features common to many accidents are revealed. Because pattern recognition of this kind is a skill which takes time to acquire, a useful technique is to cut the grid along the vertical lines - in order to produce a strip or `stick' for each accident (Fig. 6.06). These can then be rearranged in many different orders until a dominant pattern, which suggests a potential remedial action, is revealed. As described in section 6.2 computerised techniques can greatly reduce the time needed for this (Fig. 6.07). A more detailed explanation of the techniques involved in accident analysis is given in reference 5.

Detailed analysis will be dependent on the amount of information available. If the original police report forms are available, these should be studied. Sketches and statements may contain vital clues. A site visit is essential at the times when accidents most frequently occur. The site must be examined from the viewpoint of drivers, pedestrians and those road users most frequently involved in accidents. At a busy site, an hour or two's observation or, preferably, a more formalised traffic conflict study can often reveal much about the way in which drivers approach or pass through a site. Broken glass, skid-marks or wheel-tracks on the road surface can also help to identify problems - especially at intersections and on bends. This is detective work, collecting information from many sources and using it to build up a picture of events and the factors contributing to accidents in order to identify possible remedial measures. By concentrating on the dominant accident types the most cost-effective countermeasures are likely to be found.

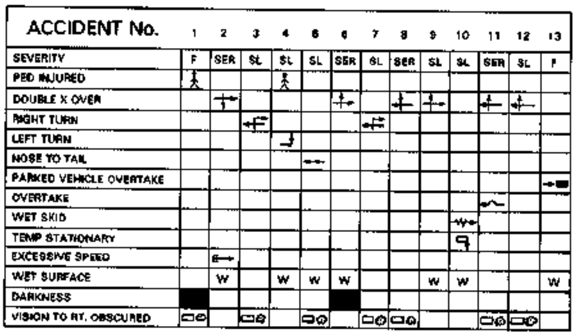


Fig 6.05
Accident grid
(ref 5)

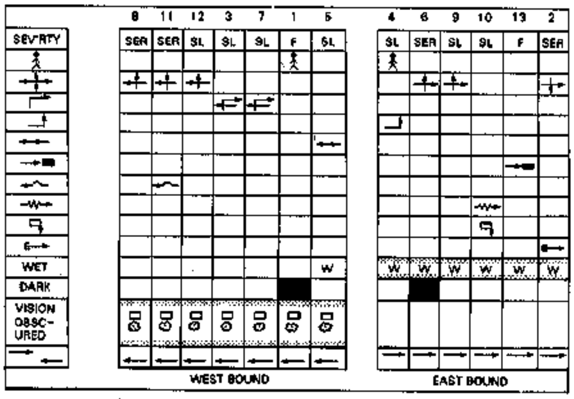


Fig 6.06
Accident grid from Fig 6.05 rearranged to show dominant factors
(ref 5)

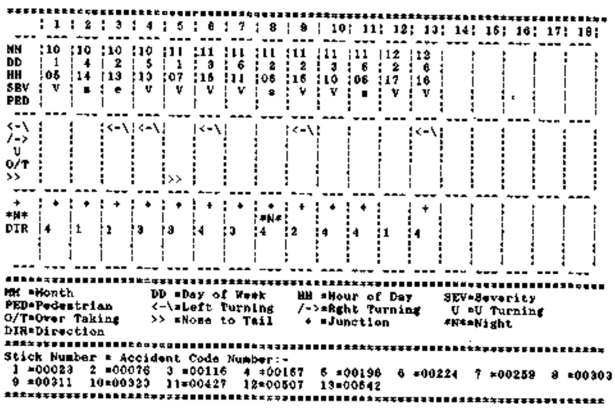


Fig 6.07
Stick diagram analysis from TRL MAP output (see Appendix C)

6.5 Monitoring and Evaluation

Present experience and knowledge regarding the effectiveness of countermeasures in developing countries is very limited. Monitoring is vital, therefore, when schemes are implemented; but this should not be restricted to accident records alone as there are a number of other aspects which should be taken into account when evaluating a particular countermeasure.

Whilst the fundamental aim of a countermeasure is to reduce accidents (of a particular type) this often results directly from changes brought about in road users' behaviour. It is desirable, therefore, to evaluate countermeasures in terms of changes in behaviour. This must be done in as objective a manner as possible. For example, if the countermeasure is intended to reduce speeds, then measure speeds. If it is intended to prohibit a particular turning movement at an intersection or to control pedestrian movements, then observe the extent of compliance. Many such aspects are directly quantifiable and a straightforward `before and after' survey, if carried out with due care and attention to sampling and statistical validity, will yield valuable results regarding the effectiveness of countermeasures.

In addition to the desired effects, countermeasures may also have unexpected, and sometimes undesirable, effects. It is possible that these could lead to accidents of a different kind occurring so that a reduction in one group of accidents may be offset by an increase in another. This is a further reason for monitoring behaviour so that problems are detected, if possible, before accidents occur.

One problem area in the evaluation of any road safety scheme is identification of the underlying trend in accidents, especially in situations of high traffic growth, in order to determine the expected accident rate at a particular site. Thus, if nothing were done at a site which was subject to an underlying growth, accidents would increase each year, on average (e.g. Fig 6.08). After implementation of the remedial treatment (shaded), it may be that the small initial accident saving becomes more pronounced as time progresses. It is always necessary to select similar untreated sites to act as a `control' group when assessing the true accident reductions due to remedial work.

Another problem in evaluation studies is the regression to the mean effect where, due to the random component of accidents, blackspot sites are likely to have some fewer accidents in subsequent years even without treatment. This effect should ideally be taken into account when calculating the accident savings. Also alternative routes to the treated sites should be monitored in order to detect any accident migration effects. The diagram assumes that 8 years' valid data are available for statistical analysis but this is unlikely in most developing countries. In such cases assessment may just have to be made without firm statistical confirmation.

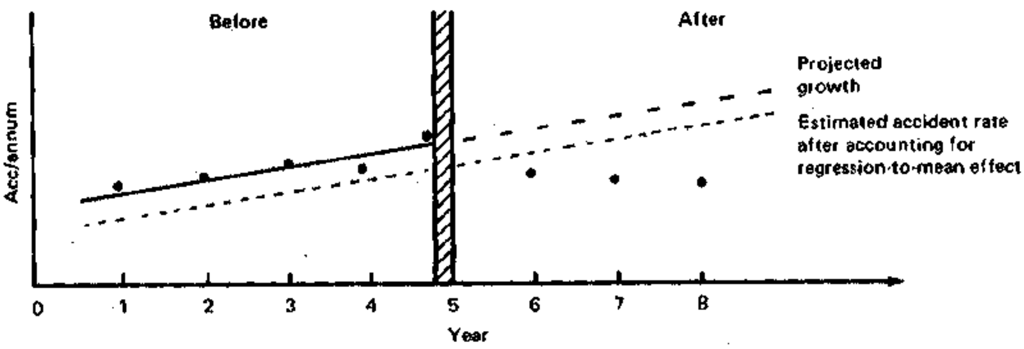


Fig 6.08
Accident trends before and after comparison

6.6 Development of Countermeasures

Assuming reasonable success in identifying common features and contributory factors, thoughts must turn to the development and application of countermeasures, or remedial works. The emphasis in this Guide is on low-cost engineering, which has proven very successful in many industrialised countries. Examples of typical countermeasures are described and discussed in later sections. It is important to recognise, however, that the circumstances under which each will - or will not - be appropriate can vary quite widely. Often there will be a choice of countermeasure and that choice must be based on an analysis of the common features and the identification of contributory factors, as discussed in the preceding section. Countermeasures are problem-oriented and the choice of measure(s) for a particular set of contributory factors must be aimed at resolving problems. Ideally, some knowledge of their likely effectiveness in similar conditions is required.

As with many problems, there are often several points of view. It is sometimes difficult to get people to think from alternative perspectives in order to identify a range of possible solutions. Consider a simple situation by way of example. A major route curves around a hill which obstructs visibility of a pedestrian crossing. Accident records show pedestrian/vehicle accidents and suggest excessive speed to be a contributory factor.

The problem is pedestrian/vehicle conflicts to which poor visibility and excessive speed make major contributions. Potential solutions - and hence the basis for countermeasures - are of three types:

(i) remove the conflict;
(ii) improve visibility; or
(iii) reduce speeds.

From the drivers' viewpoint removing the conflict, implying stopping pedestrians from crossing, is preferable - but this would not meet the apparent need for crossing the road. The pedestrians would like speeds reduced, but drivers' generally would resist this. Improving visibility may give drivers and pedestrians more chance of avoiding conflicts but could result in vehicles travelling faster.

A balance of interest must be struck, depending upon traffic volumes, the extent of pedestrian demand and the cost-effectiveness of countermeasures. Possibilities under each of the three headings are:

Remove the conflict
- ❑ prevent pedestrians crossing
- ❑ protect pedestrians whilst crossing

Improve visibility
- ❑ move the hill
- ❑ move the crossing

Reduce speeds
- ❑ speed limits
- ❑ speed hump or other physical device

The contrast can perhaps be seen most readily with the two means of improving visibility. Many would say if the problem is that the crossing cannot be seen, then move whatever is in the way - a `move the mountain' approach. Yet it may well be just as effective, and a good deal cheaper, to relocate the crossing to a place where it can be seen more easily. There is nothing sophisticated or technical in this - just a requirement to think around alternative solutions to a problem and occasionally to think laterally.

Practical experience is needed to confirm the way in which countermeasures can be applied and work in a particular context. Experience in this respect is largely restricted to industrialised countries and it cannot just be assumed that what is effective, say in the UK, will be effective elsewhere. Over time, however, a body of expertise will build up and it should become increasingly possible to rely on this if monitoring is carried out (see section 6.5).

Because of this there are significant benefits to be gained from an experimental approach. A temporary installation, using cheap materials, will enable ideas to be tried out and minor modifications to layout to be made at negligible cost (Figs 6.09, 6.10). This should not be interpreted as lacking conviction in the merit of a scheme, but a recognition of the need to learn from experience in a local context (e.g. will drivers adopt the correct behaviour for ghost islands, or is a more expensive solution necessary?), and to respond to changes which will occur when a scheme is implemented. There is also advantage in fine-tuning until the scheme is working as required. Schemes should always be closely monitored, however, to ensure that the `improvement' implemented has not inadvertently worsened the situation.

Possible Solutions/Benefits

Fig 6.09
Road closure and pedestrian crossing created from oil drums and paint, Papua New Guinea (Ross Silcock Partnership)

Fig 6.10
Temporary channelisation and access control created from painted kerbs and oil drums. Papua New Guinea (Ross Silcock Partnership)

Key external references: 1, 2, 14 (for sections 6.2 to 6.6)

6.7 Problems and Remedies

Each accident site will have its own set of contributory factors which define the problem(s) to be overcome. General prescriptions for treating blackspots must, therefore, be taken with caution. Nevertheless, there are a number of commonly occurring situations which have been dealt with successfully in the past - mostly in industrialised countries. In many of these, accident numbers have been reduced substantially, often by 40 to 50 per cent and in some cases by as much as 80 per cent. Tables 6.01-6.03 below and overleaf identify some of these common accident situations under broad classifications and list remedies which have proven successful in the UK. The references given refer to sections of the document where the remedies are discussed. Some have already been dealt with earlier in the document under chapters on design and operation. Others receive more detailed consideration in Sections 6.8 and 6.9 which follow.

General Accident Situation	**Potential Remedy**	**Relevant section(s) in this Guide**
Skidding	- restoring surface texture	5.4
Collisions with roadside obstacles	- better delineation - guardrails - safety fences - frangible posts	4.1.11, 4.1.12, 4.1.13, 4.2.7, 5.7, 5.8, 6.8.7, 6.8.8, 6.9.4
Pedestrian/vehicle conflicts	- pedestrian/vehicle segregation - facilities for pedestrians - pedestrian protection	3.5.5, 3.8, 4.1.11, 4.1.17-4.1.19, 4.2.12, 6.9
Loss of control	- road markings - delineation - speed controls - guardrails	4.1.11, 4.1.12, 4.1.14, 4.2.7, 5.7, 6.8.6, 6.8.7, 6.8.8, 6.8.9
Darkness	- reflective signs - delineation - road markings - street lighting	4.1.12, 4.1.15, 4.2.7, 5.7, 5.8, 6.8.6, 6.8.8
Poor visibility	- conspicuity - realignment - improved sightlines	4.1.3, 4.2.5, 4.2.6, 6.8.3
Poor driving behaviour/lane discipline	- road markings - enforcement - median barriers	4.1.14, 4.2.7, 5.7, 5.8, 5.9, 6.8.6, 6.8.7

Table 6.01
General Accident Situations

Rural Accident Situations	Potential Remedy	Relevant Section(s) in this Guide
INTERSECTIONS		
Turning movements	- turn prohibition - channelisation - acceleration/deceleration lanes	4.2.7,4.2.8,6.8.1,6.8.11
Overtaking	- protected turns - markings - advance warning	4.2.6, 4.2.7, 4.2.8, 5.7, 5.8, 6.8.1
Overshoot from minor	- intersection conspicuity - channelisation/ road markings - speed reducing devices - intersection control	4.2.6, 4.2.7, 5.7, 5.8, 6.8.1, 6.8.3, 6.8.6, 6.8.9
LINKS		
Overtaking	- prohibition/lane markings - overtaking zones - median barriers	4.1.14,6.8.5,6.8.6,6.8.7
Roadside stalls	- enforcement/control - provision of off-road facilities - relocation	3.7, 4.1.16, 5.6
Ribbon development	- bypass - speed reducing devices - service roads	3.4, 4.1.16, 6.8.9
Pedestrians	- shoulders - bridge footways	4.1.18 4.1.19

Table 6.02
Rural accident situations

Urban Accident Situations	Potential Remedy	Relevant Section(s) in this Guide
INTERSECTIONS		
Turning movements	- channelisation - signals - turn prohibitions - roundabouts	4.2.3,4.2.4,4.2.8,6.8.1,6.8.10, 6.8.11
Overtaking	- channelisation - markings	4.2.8,4.2.7,5.7,6.8.1,6.8.6
Pedestrian/vehicle conflicts	- refuges - crossing facilities - underpass/overbridge - guardrails/fences	4.2.10, 4.2.12, 6.9.1-6.9.5
Poor visibility due to parking	- parking controls	4.2.6, 5.8, 5.11
Darkness	- lighting - reflective signing/ marking	4.1.15, 4.2.7, 5.7, 6.8.6
LINKS		
Parked vehicles	- parking controls - parking provision	5.10
Speeding	- speed limits - enforcement - speed control devices	5.9, 6.8.9
Pedestrians	- access controls/ road closures - crossing facilities - guardrails/fences - wider footways - underpass/overbridge	3.5.5, 3.8, 5.6, 4.1.17, 4.2.10 4.2.12, 6.9

Table 6.03
Urban accident situations

6.8 Examples of Typical Countermeasures
6.8.1 Intersection Layout: Channelisation

Background

Intersections are potentially hazardous because they are the places where traffic movements conflict. Traffic streams which must cross, or merge, are more prone to accidents than those travelling in parallel or diverging. The first step in deciding on appropriate countermeasures is to prepare a collision diagram (e.g see Fig 6.12). Reduction of conflicts to minimise these collisions by separating traffic streams either simply by road markings or by small islands to channelise traffic, is a very effective measure to improve safety. Channelisation can be applied under a wide range of circumstances ranging from uncontrolled rural intersections to busy urban signal controlled intersections.

Fig 6.11
Uncontrolled Y-junction in Papua New Guinea with no markings, priority or traffic islands, causes conflict and uncertainty between merging and opposing traffic
(Ross Silcock Partnership)

Problems

If the channelisation is at a priority intersection then compliance with 'give-way' or 'stop' signs is vital. If drivers do not obey such signs then the effectiveness of the channelisation will be reduced.

Channelisation guides the driver along a desired path and must be carefully designed to ensure the motorist is not exposed to danger at any point of his manoeuvre. Often channelising islands are not wide enough to protect turning vehicles, leaving them protruding into through traffic.

Where the channelisation is created by road markings alone it requires regular maintenance and high quality reflective paint/ thermoplastic to remain visible at all times. This can be a problem in many developing countries.

Channelisation will often require local widening. This may result in some drivers trying to overtake at the intersection where the road has been widened, especially if only paint is used to define the channelisation.

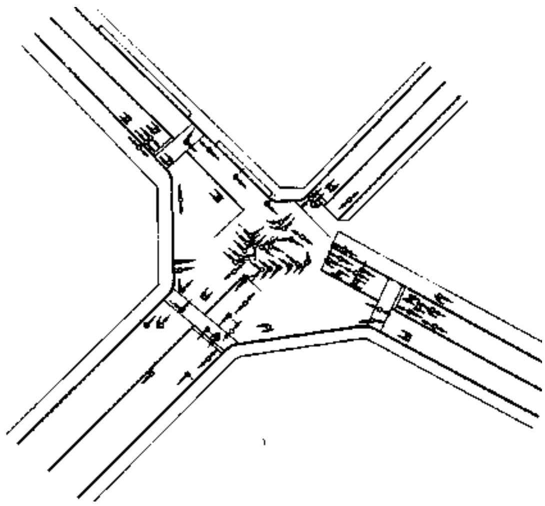


Fig 6.12
Collision diagram at urban accident blackspot which highlights problems of turning/crossing manoeuvres and rear-end shunts, Korea
(Road Traffic Safety Association. Korea)

Summary

Most accident blackspots occur at road intersections. Accidents are more likely if conflicting manoeuvres at an intersection all occur in an undefined open space in the centre. By separating traffic streams and vehicles travelling at different speeds drivers will be given a clearer understanding of how the intersection is intended to operate. The complexity of the driving task ....

Possible Solutions/Benefits

Fig 6.13
Y-junction in Papua New Guinea converted to T-junction with temporary kerbing and markings which clearly define priority (Ross Silcock Partnership)

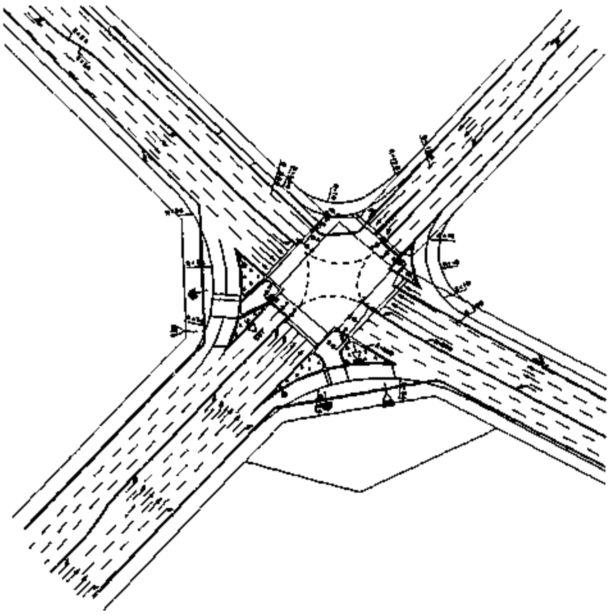


Fig 6.14
Proposed channelisation and signal control to eliminate side-impact collisions and reduce others at the intersection illustrated in fig 6.12
(Road Traffic Safety Association, Korea)

Channelisation is often used as a countermeasure in order to separate traffic streams to make clear to drivers which vehicles are about to make which manoeuvre. If space permits traffic streams can be separated so that potential conflicts occur further apart, giving drivers more time and the opportunity to concentrate on one problem at a time.

Channelisation may be an appropriate remedial measure in situations where the following contributory factors appear consistently in accident records at an intersection.

- Collisions between through traffic and slow moving or stationary vehicles waiting to turn into the minor road(s):
- Conflicts between traffic turning into and out of the minor road(s);
- Vehicles overtaking at an intersection: and
- Confusion amongst drivers about the manoeuvres being made by other vehicles.

Islands and raised median strips can be installed initially with cheap local materials and adjusted as necessary until an optimum layout is determined at which point it can be made permanent. The geometry of the channelisation must ensure safety for large vehicles. Care must also be taken to allow adequate turning radii at corners and clearance of street furniture.

It may be necessary to modify street lighting at some sites to ensure proper illumination. Permanent islands will also need 'keep left' or 'keep right' signs. Islands are preferable if local driving behaviour is likely to lead to problems of drivers overtaking at the function.

Advance signing is necessary to ensure that drivers select the correct lane for the manoeuvre which they attend to carry out. Without adequate signing, inappropriate and probably dangerous vehicle movements will occur when drivers attempt to correct their previous mistakes.

Other relevant sections: 4.2.1,4.2.7,4.2.8,4.1.13
Key external references: 1

.........will be reduced. Channelisation can often be achieved simply and at low cost with road markings alone. If more substantial schemes are required, they can often be laid out on an experimental basis initially using cheap materials - e.g. old tyres painted white. Once the optimum layout is determined more permanent materials can be used. Advance signing and clear direction signs are an essential part of channelisation.

8.8.2 Intersection Layout: Roundabouts

Background

The use of roundabouts as an accident countermeasure is not commonplace although they can be effective under certain circumstances.

Roundabouts (sometimes termed rotaries or gyratories) are intended to remove many of the conflicts present in ordinary intersections. As the diagram illustrates, a normal crossroads has 32 possible conflict points where traffic streams merge, cross or diverge. The principal of a roundabout is, by introducing a central island around which all traffic must travel in the same direction, to reduce the number of conflict points. Just 8 conflict points remain with a conventional roundabout.

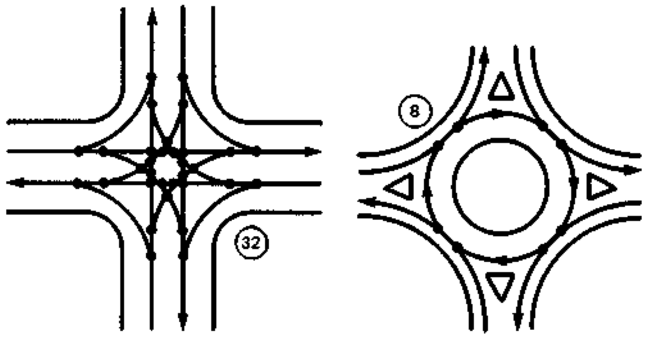


Fig 6.15
Common points where vehicles making manoeuvres can come into conflict with other vehicles at an uncontrolled cross roads and a 4-arm roundabout

Problems

The most obvious problem regarding the more widespread use of roundabouts is the lack of familiarity with this type of traffic control. This is especially the case in those countries without a 'give-way' or 'yield' rule in their traffic code or where this rule is ignored. Roundabouts depend upon drivers entering yielding priority to vehicles already circulating. Failure to do this can lock the roundabout.

Large roundabouts have large land requirements and can be costly to implement, but are more likely to offer safety benefits. Small or mini roundabouts require careful design and good driver behaviour if they are not to introduce as many problems as they are intended to overcome. All roundabouts but especially mini roundabouts, introduce hazards onto the road particularly where there are multiple lane approaches.

A common error in roundabout installation is that sufficient deflection for all vehicle movements has not been imposed, thereby allowing drivers to pass straight through the intersection without slowing.

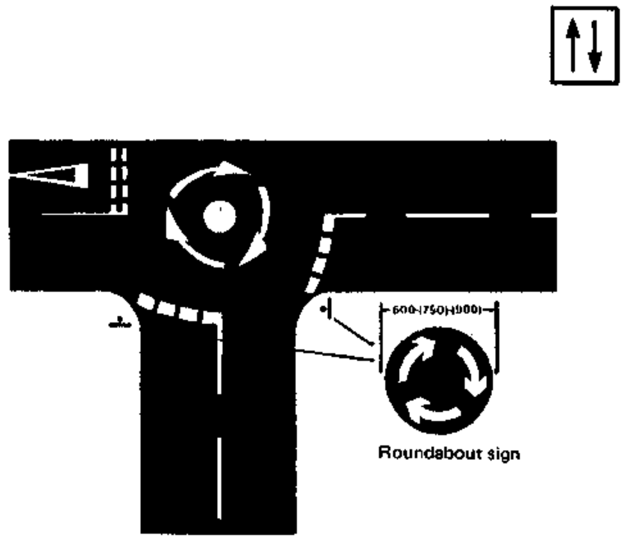


Fig 6.16
Poor roundabout layout: no deflection on entry thus traffic can pass through without slowing down
(ref 3)

Summary

Roundabouts are likely to be most appropriate as countermeasures in situations where traffic flows on all arms are similar, turning movements are high and accidents at the site frequently involve turning traffic. The application of small diameter roundabouts is likely to be limited unless give-way' rules apply widely in a country and a high level of compliance is expected. On faster principal ....

Possible Solutions/Benefits

Fig 6.17
Typical roundabout of type recently introduced in Papua New Guinea which provides good deflection to reduce approach speeds
(TRL)

Fig 6.18
Double mini roundabout used in the UK for staggered cross roads
(TRL)

Roundabouts are especially suitable at intersections where traffic flow volumes on all entries are similar and turning traffic is heavy (say 20% or more), particularly if this applies in both directions and 'hooking turns would otherwise result.

As accident countermeasures, they may be appropriate where the following contributory factors appear consistently in accident records:
- ❑ A high proportion of turning manoeuvres; and
- ❑ Excessive speed through the intersection.

Roundabouts require clear advance warning so that approaching drivers can see that there is a roundabout ahead.

The presence of the central island and the requirement for traffic to circle it introduces deflection and reduces the speed of through traffic. Hence the consequences of accidents which do occur are minimised.

Lane markings should be used to ensure that vehicle paths are deflected on entry. This will minimise the probability of traffic passing through the intersection at high speed in straight lines. High kerbs around central islands prevent over-running but such kerbs should be brightly painted (white or striped) so approaching drivers can see the island ahead more clearly. Multiple lane approaches should be avoided.

Roundabouts can be of various sizes, defined most simply in terms of the diameter of the central island. In rural areas they are often quite large, with long weaving sections permitting moderate speeds to be maintained. In urban areas central islands can be reduced substantially in size, often being little more than a slightly raised circle of paint, three metres in diameter.

Other relevant sections: 4.2.1, 4.2.3
Key external references: 1

……and rural roads, roundabouts usually need to be relatively large in order to maintain the integrity of a route but in urban areas small or mini roundabouts can be used. Careful design is essential to ensure safe and appropriate vehicle routes through the intersection. Roundabouts must always be well marked on the central island to give advance warning to approaching motorists.

6.8.3 Intersection Conspicuity

Background

Because of the concentration of traffic conflicts at intersections, and the potential danger which results from them, intersections must be clearly defined. A driver approaching an intersection must first be made aware that there is an intersection, and secondly, what type of manoeuvres he may make and what type of manoeuvres he can expect others to make. This is especially important on roads where traffic is travelling at high speeds and where the consequences of misinterpretation are potentially disastrous.

Making an intersection more conspicuous (i e. noticeable to drivers) may be an effective accident countermeasure if accident records suggest that drivers are not seeing the intersection early enough or are misinterpreting an intersection.

Fig 6.19
Poorly defused urban intersection, UK (TRL)

Problems

An intersection may not be visible sufficiently far in advance because of topography or road alignment. In such circumstances making the intersection more visible is likely to be very costly and warning signs may be the only remedy. The frequent absence of road markings and warning traffic signs, absence of lighting on most rural and many urban roads and the limited use of channelisation in many developing countries often result in poor conspicuity of intersections and hence danger to approaching drivers.
This can be particularly dangerous if a driver on a minor road approaching a major route does not appreciate the fact until he is too close to stop.
Problems may be particularly acute at night.
Roads often intersect at acute angles (e.g. Y-junctions) leading to accidents at high speed when minor road traffic fails to give way to mayor road traffic.

Fig 6.20
Inconspicuous side road in the UK (TRL)

Summary

Many accidents occur at intersections because the intersection is inconspicuous and as a result drivers may not see the intersection soon enough or may misjudge the manoeuvres required. By making the intersection more conspicuous to road users the potential for accidents can be reduced. This can be done by ensuring adequate visibility, advance signing and by providing clear and ....

Possible Solutions/Benefits

Fig 6.21
Improvement to intersection shown in Fig 6.19, to give better conspicuity and warning to drivers of approach to intersection. Mini roundabout also installed
(TRL)

Fig 6.22
Improvement to intersection shown in Fig 6.20 to increase conspicuity and give emerging drivers a better view
(TRL)

Improving conspicuity is likely to be beneficial where accidents with the following characteristics are found:

- ❑ Excessive speed on intersection approaches;
- ❑ Failure to observe traffic signs or controls;
- ❑ Minor road traffic failing to stop or yield and overrunning into major road; and
- ❑ Night-time accidents.

A variety of techniques can be adopted to make intersections more conspicuous. In some cases, simply ensuring that vegetation growth is kept low so as not to encroach on sightlines may be sufficient. In others lane markings, painted kerbs, give-way lines and prominent signs may serve to initiate action and maintain alertness amongst drivers. Depending upon the road surface and standards of maintenance, reflective paints and/or road studs can be used to highlight the presence of an intersection. In more difficult situations minor realignment of the intersection may be necessary to reinforce priorities and to create a deliberate break in the apparent continuity of the road for drivers on the minor route. Where roads intersect at right angles, offsetting channelising islands on the minor road can make it impossible for minor road traffic to cross without slowing down or stopping. Where roads cross at an acute angle, it may be possible to realign the minor roads to make a stagger intersection (i.e. 2 T-junctions). Right/left staggers are safer when driving on the left and left/right staggers are safer when driving on the right.

Intersection conspicuity at night-time can be greatly improved by the provision of lighting. If urban streets are not lit, street lighting should first be provided at intersections. Where streets are lit, intersections with many night-time accidents could benefit from better illumination, especially if a high proportion of pedestrians are involved. Lighting is unlikely to be an option in rural conditions. In unlit conditions use of painted kerbs and road markings plus reflective road signs placed to break the sight-lines of drivers can give early warning of an intersection ahead.

Other relevant sections: 4.1.15, 4.2.2, 4.2.6
Key external references: 1

............early warning of the type of traffic control and the manoeuvres allowed. Wherever possible, urban intersections should be lit to reduce problems in hours of darkness. Reflective signs and markings should be used and, if possible, kerbs of channelising islands should be painted white or striped to make them more visible from a distance. Roundabout islands should have a small sign or chevron facing the approaching driver.

6.8.4 Driver Expectancy

Background

The road and its environment are constantly providing drivers with visual cues about the road ahead and the driving tasks which they may need to perform. Drivers develop expectations from these and a coherent road design should be consistent with them. Drivers should not suddenly be faced with unusual or unique circumstances which do not conform with their expectations. If they do meet such situations, then many will take longer to react, and some may react inappropriately or not at all and hence become involved in an accident.

Fig 6.23
Absence of advance signing and marking results in approaching driver being unaware of intersection ahead in Ghana
(TRL)

Problems

In a situation where a tine of utility poles or trees runs parallel and adjacent to a long section of straight roadway, this creates the expectancy that the straight alignment with no intersections will continue. An expectancy violation occurs when something unexpected suddenly intrudes, such as no advance warning of a priority intersection ahead in Fig 6.23. Treatments at such locations must change the expectancy earlier by giving advance warning of the intersection ahead. Another more common problem is of along straight road with a sudden sharp change in direction. By showing alignment ahead with signs, pavement markings and delineators, the driver expectancy of a straight road ahead can be eliminated.

This example illustrates the principles involved. Road geometry, surrounding buildings or trees, markings and the general driving environment combine to inform the driver of what conditions to expect ahead. These influence his driving, his preparedness to take particular actions and the manoeuvres he intends to make. If some or all of the surrounding features and messages mislead or confuse the driver, false expectations will result and this can lead to hazardous situations and accidents. If no or inadequate information is provided regarding potential hazards ahead then drivers will be unprepared for the potential danger.

Fig 6.24
Incorrect superelevation and inadequate signing has resulted in a high accident rate on approach to bend in Ghana
(TRL)

Summary

Drivers and other road users are constantly receiving information from the road, its environment and other traffic. These create drivers' expectations of the conditions which they will meet ahead and the driving tasks required. If misleading information is provided, or none is available, hazardous situations can result. Driver expectancy is an important determinant of driving ....

Possible Solutions/Benefits

Fig 6.25
Well defined curve in Singapore, guiding drivers and giving ample information of road geometry ahead
(TRL)

Fig 6.26
Rumble strips on shoulder to alert drivers who have strayed from carriageway before bend ahead, USA
(Ministry of Construction. Korea)

The selection of countermeasures in these circumstances should aim to improve the 'readability' of the road and to encourage drivers to react in a way that is consistent with the potential hazards ahead. In some cases this requires the removal of misleading conditions, as in the example quoted. In others it may require the introduction of signs, markings, channelisation or measures intended to modify driving behaviour, often in terms of speed control. An interesting example of this is the use in the UK of yellow bar markings on the approaches to intersections on high speed dual carriageways. These are discussed further in section 6.8.9.

Drivers and pedestrians must be given consistent and coherent information if they are to be expected to behave in a consistent and safe manner. This information will come from the road geometry, signs, markings and other aspects of the traffic environment. Factors contributing to accidents which are indicative of driver expectancy problems are:

- Unexpected or apparently wrong manoeuvres or actions by road users;
- Illegal behaviour; and
- Speeds and other aspects of driving inappropriate to the conditions.

On interurban roads and main traffic routes, it is important to ensure consistency of road characteristics and delineation. In urban areas a clear definition of the road hierarchy, and who has priority at every intersection, is very important. Drivers, especially those on the minor roads, must be given clear guidance regarding which traffic flow has priority. In this way the risk of conflicts is minimised as drivers are prepared for circumstances ahead and take appropriate action.

Other relevant sections: 6.8.3, 6.8.9
Key external references: 3, 9

...........behaviour. Accident countermeasures should be designed and applied to give road users unambiguous information in sufficient time for them to take any necessary action. The aim should be to guide drivers so that they drive in a manner consistent with the road and conditions they will meet ahead.

6.8.5 Overtaking Zones

Background

Overtaking is an inherently dangerous manoeuvre, especially on single carriageway roads where it creates the potential for head-on collisions. Even if the oncoming vehicle can be seen, judging its approach speed and the amount of time available to pass the slower moving vehicle in safety are among the most difficult driving tasks. Accident blackspots often prove to be locations where drivers repeatedly misjudge these, or where they attempt to overtake at locations with inadequate visibility, for example on bends.

Whilst the provision of dual-carriageways with central medians overcomes the problem of poor judgement of gaps in traffic, it is expensive, especially if land purchase is required. Overtaking zones offer a cheaper alternative approach and they can sometimes be achieved within the existing road structure at relatively low cost.

The basic principle is that of local widening of the carriageway in one direction, usually to provide two lanes rather than one. If the overall road width is adequate for three lanes of traffic, then this will not require new construction, it can be achieved with lane markings alone, or with the introduction of a narrow median.

Fig 6.27
Dangerous overtaking on a steep winding road in Indonesia with many HGVs and buses but no crawler lanes
(TRL)

Problems

There is an obvious potential risk if traffic travelling in the opposite direction (i e. without the overtaking lane) is likely to cross into the overtaking zone, perhaps itself to overtake a slower vehicle. If local driving behaviour and absence of enforcement is such that these manoeuvres are likely to be prevalent, then consideration must be given to the construction of a physical barrier between the two directions of travel (see Section 6.8.7, lane dividers).

Problems arise even in developed countries where adequate space and warning have not been provided at the termination of an overtaking zone where two vehicle streams need to merge.

Signs and markings at the start and end points of such zones are often not well maintained.

Summary

Overtaking on single carriageway roads is potentially dangerous, especially in rural conditions where speeds are high. If the carriageway is sufficiently wide, or with judicious use of local widening, it is often possible to provide an overtaking zone for one direction of travel, at low cost. Alternating the provision of such facilities by direction can improve journey times on a rural ....

Possible Solutions/Benefits

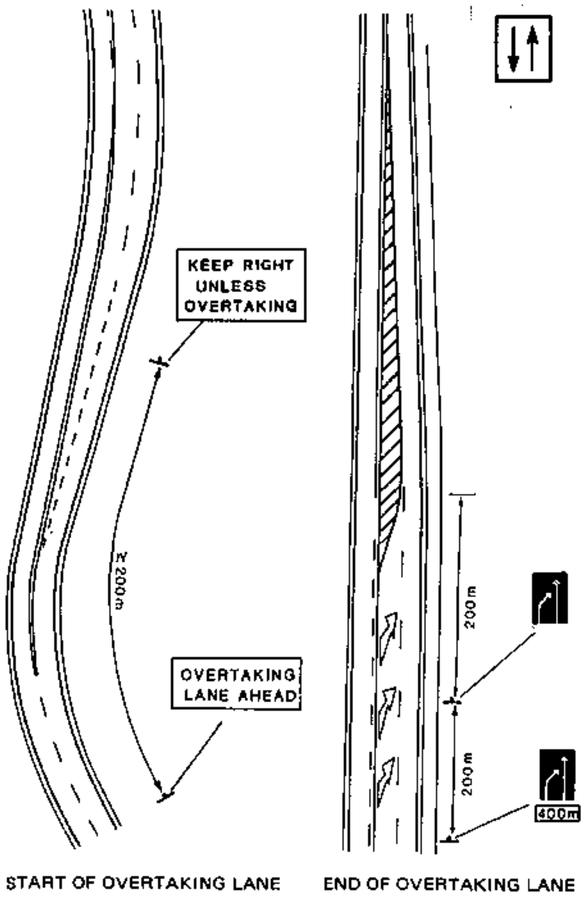


Fig 6.28
Typical layout of start and end of overtaking lane (ref 16)

Overtaking zones, as a countermeasure, are likely to be appropriate as part of the comprehensive improvement of a route, as well as at specific blackspots. Whilst they are targeted at accidents in which overtaking was a major contributory factor, they can also offer substantial economic benefits in reducing delays caused by slow moving traffic. If carefully located along a major route, typically providing overtaking opportunities for each direction of travel in turn, they can reduce journey times along a route as well as improve its safety.

Overtaking zones are most suited to rural roads where traffic flows do not warrant full dualing, but where delays caused by slower traffic lead to impatience and dangerous overtaking manoeuvres. In addition to the overtaking section(s) itself, periodic advance signing advising drivers that overtaking opportunities exist not too far ahead can persuade some drivers to be patient and to wait for safer opportunities to pass.

Clear definition of where overtaking is permitted, and where it is not, is essential. This should be done with traffic signs and with distinctive lane and centreline markings. It is essential that signs and markings are well maintained especially at the start and end points of overtaking zones.

This treatment can be particularly useful where there is a mix of slow and faster traffic using a road. By offering regular opportunities for overtaking, drivers may be less inclined to overtake at hazardous locations, being content to wait until they reach the next purpose-built overtaking zone. There are also particular locations where isolated overtaking zones may be appropriate, for example on the uphill side of a steep gradient where traffic could otherwise be delayed by, and risk overtaking, a slow moving heavy goods vehicle. Such locations are often called 'crawler' lanes since HGV traffic tends to slow down significantly as it climbs the hill.

Other relevant sections: 4.1.8, 4.1.14, 6.8.7
Key external references: 4, 8, 9

........route and improve its safety. In situations where driving standards and observance of traffic rules are relatively good this can be achieved simply with appropriate signs and longitudinal road markings. In other cases a median barrier may be needed to ensure compliance. Regular maintenance of signs and markings is essential, especially at the start and finish points of the zones.

6.8.6 Road Markings

Background

Traffic capacity and safety almost invariably increase if traffic streams are separated into clearly marked lanes by the use of road markings painted on the road surface. Road markings of this kind are part of most accident countermeasures on metalled roads, but cannot be applied on gravel or other loose surfaces. Markings should be durable, visible by day and night, skid resistant and unambiguous. They give drivers clear information to guide them safely along the road and through any potential conflict points such as intersections.

Fig 6.29
Unmarked intersection in Papua New Guinea provides inadequate guidance for drivers: island is temporary countermeasure prior to re-design of intersection
(TRL)

Problems

Markings are nearly always less distinctive in wet road conditions. It is difficult to specify a fixed interval for renewal or cleaning. Wear is affected by many factors: the product used; the amount of traffic; oil deposits; climate; sand and dust.

In countries where a single, solid centre line is used to prevent overtaking, e.g. approaching the brow of a hill, the prohibition applies to both directions of traffic, yet it may often be safe to overtake in one direction. This tends to lead to abuse of the restriction.

Some countries do not use yield or give way lines at all. Only stop lines are used and this eventually becomes self-defeating. Drivers generally will not come to a full-stop if there is no apparent need - for example when approaching an intersection with good visibility when no other vehicles are in sight.

In both the above cases, drivers lose confidence in the markings, begin to ignore them and on some occasions, possibly expose themselves to unnecessary danger as a result. Using a single type of marking in all circumstances leaves little flexibility to the road engineer to convey appropriate information.

Fig 6.30
Inappropriate use of solid centre line in Ghana (indicating no overtaking) at a location where visibility is adequate in one direction leads to abuse
(TRL)

Summary

Road markings are an essential component of almost every countermeasure. They are cheap ways of imparting information to drivers and other road users. When properly used they give clear indications of the correct position on the carriageway and permitted manoeuvres. For best effect they need to be applied to good quality road surfaces, with reflective thermoplastic paints ....

Possible Solutions/Benefits

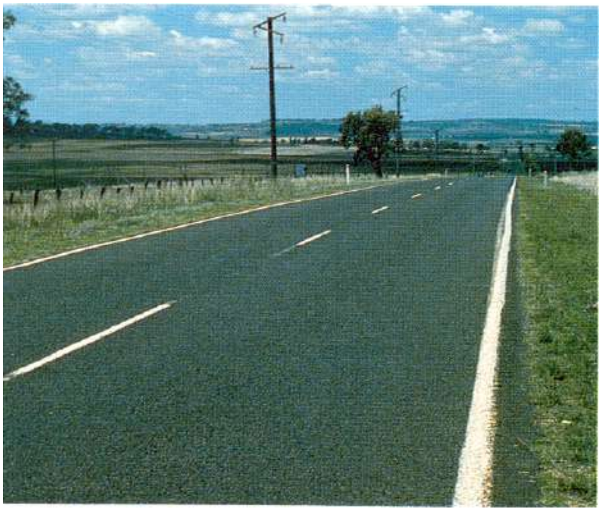


Fig 6.31
Clearly defined centre line and edge line, Australia (Rendel Palmer & Tritton)

Fig 6.32
Double centre line to designate no overtaking and conspicuous edge marking to defuse tight curve. USA (Ministry of Construction, Korea)

There are many circumstances in which markings can be used as countermeasures, or as components of countermeasures. Road markings are often basic components of channelisation.

Longitudinal markings (along the road) can be applied in many circumstances where lack of lane discipline prevails. Both edge and centre line markings can be used to give clear information to drivers as to the correct position on the road. They can also be used to modify behaviour. For example, the likelihood of vehicles crossing to the wrong side of the road on a bend is reduced if a clear, perhaps extra-wide, centre line is marked. A double centre line is preferred to a single line. One side can then be broken or dashed to show where overtaking is permitted.

Lateral markings across the direction of travel by their very presence indicate a potential need to stop or take care and can be used to position vehicles at the safest point from which to make a manoeuvre. Because the driver's view is foreshortened lateral markings must be wide. A minimum width of 300 mm is desirable. At intersections 'Give-way' and 'Stop' lines can be very cheap and effective accident countermeasures. They clearly define to drivers the presence of an intersection with a major road and that other traffic has priority. In urban areas with frequent intersections, the use of 'Give-way' markings is essential to define the road hierarchy.

Pictorial markings, especially turn arrows or symbols on the carriageway to warn of hazards ahead, are appropriate as parts of many countermeasures.

Other relevant sections: 4.2.6, 4.2.7, 5.8, 6.8.1
Key external references: 3

............However, lower quality materials can be effective if regular repainting can be guaranteed. Whilst such regular maintenance requires good management and strong institutions the materials and skills involved are straightforward if road paint is used. With thermoplastic material special equipment and skilled operators are required, but it lasts about 8 times longer.

6.8.7 Lane Dividers/Median Barriers

Background

Whilst the longitudinal centre line markings discussed in Section 6.8.6 allocate space on the carriageway between directions of travel, there are situations in which a more substantial barrier is necessary to separate traffic streams.

On high speed and/or high volume highways, the result of a vehicle crossing the centre-line is often a head-on accident and the resultant injuries are usually very severe. The installation of a median barrier will virtually eliminate crossover, head-on accidents of this type.

Several types of barriers are used in industrialised countries to prevent median crossover by passenger vehicles. These median barriers have been designed to minimise the possibility of injury to the occupants and the likelihood that the vehicle will be thrown back into the traffic. The 3 main types of barrier are described in reference 9.

Such barrier systems are classified as flexible, semi-rigid or rigid. The flexible systems require much space in which to deflect when struck, the semi-rigid systems require less space, the rigid systems require no space.

Fig 6.33
Use of hard, raised cobbles as lane divider in Pakistan. These provide low cost advance warning of a bend but they could cause tyre damage. They should be painted to increase conspicuity
(TRL)

Problems

In many countries insufficient use is made of lane dividers and median barriers to separate opposing streams of traffic. Sometimes this is because of the cost and the absence of specialist skills to install such facilities accurately. Vehicle collisions with the ends of barriers which are not specially protected can result in very serious injuries (see Section 4.1.11).

Fig 6.34
Truck U-turning on a fast, dual carriageway in Egypt. These dangerous manoeuvres are eliminated by median barriers
(TRL)

Summary

In situations where lane discipline is poor and accidents occur because drivers habitually cross onto the wrong side of the road, a median barrier of some kind can virtually eliminate the problem. Various types of barrier are in use around the world. The more expensive, purpose designed types are intended to minimise the risk of injury when struck and to avoid vehicles being thrown back ......

Possible Solutions/Benefits

Fig 6.35
Small triangular kerb on centreline of dangerous curve in Indonesia provided a low cost solution to reduce accidents (TRL)

Fig 6.36
Median barrier on rural road in Kenya prevents U-turns and crossover accidents (Rendel Palmer & Tritton)

Median barriers as countermeasures will only be effective in cases where head-on accidents predominate. In such cases they are highly effective. They can be used as a general countermeasure, along the length of a major route, especially as traffic volumes increase or as the route is being upgraded. This approach is relatively costly. In certain circumstances it may be more appropriate to install short lengths of barrier, for example on a bend where head-on accidents are frequent.

In some countries other means have been adopted which, whilst not meeting the same design criteria as the sorts of formal barriers used in industrialised countries, can nevertheless be effective in preventing most crossover accidents. These usually consist of a raised kerb of some kind, sufficient to define the centre line clearly and to discourage crossing, but not so substantial as to cause serious damage if struck. If funds or equipment availability constrain the use of purpose designed barriers then such an alternative may be an acceptable interim solution.

Concrete barriers have the advantage of being difficult to remove and of less value if stolen than steel barriers. Precast concrete units can be joined together simply to make temporary barriers which can be useful in urban conditions. Here, impact speeds are likely to be lower, thus permanence is less important for safety. Temporary barriers, which can be moved, are useful to protect roadworks and to define temporary layouts at intersections.
Particular care must be given to end details, to reduce the risk of serious injury if the end of a barrier is struck by a vehicle.

Reflective road studs along the centre-line, although not a barrier, can be used to warn motorists they are straying over the centre-line.

Other relevant sections: 4.1.14, 6.8.6.
Key external references: 8, 9

……..into the traffic stream. These require accurate and secure installation and particular care with the end details. A simple raised kerb may be almost as effective if the more expensive barriers are not available, provided it is conspicuous in darkness and designed not to damage tyres if struck.

6.8.8 Delineators

Background

Delineation is intended to give drivers a clear indication of the road alignment for some distance ahead of them. Delineators usually consist either of reflective road studs placed at the edge of the carriageway or, more frequently, of lightweight posts about one metre high, set a metre or so from the edge of the carriageway, with a reflective unit set near the top. They are particularly useful at night when equipped with reflectors, or if painted with reflective paint.

An OECD report in 1975 suggested that delineator posts should meet the following requirements:

low cost, easy transport, easy maintenance, resistance to severe atmospheric conditions, no safety hazard to road users, and no psychological obstacle to road users with regard to keeping the vehicle in a correct position near the road edge.

Furthermore, they should be designed to ensure a width adequately visible at long distance, and a high enough position so as not to be soled by mud. The tables in section 4.1.12 give some general dimensions and indications of spacings in a number of industrialised countries when installed in general use along major highways.

Fig 6.37
Inadequate edge delineation with steep ditch and roadside trees in Australia
(Rendel Palmer & Tritton)

Problems

Although individual units are cheap, when installed in thousands along an entire route the total cost becomes substantial.

In some countries there is a tendency to make new street furniture, including delineators, very substantial. This is done to reduce the likelihood of theft, and sometimes, to protect it from damage caused by being struck by vehicles. With frequent, regularly spaced roadside obstacles such as delineators, it is clearly counter-productive if these were to become accident hazards themselves when struck. Care must be taken to ensure that they break off easily if struck by a vehicle.

Road studs, require a good quality road surface to ensure a good bond between the stud and the surface and regular and vigilant maintenance to replace any studs which have become loose. This is often difficult to achieve in developing countries.

In the commonly found situation where the edge of the carriageway is crumbling, or poorly maintained, road stud type delineators cannot be used and post type may be the only alternative.

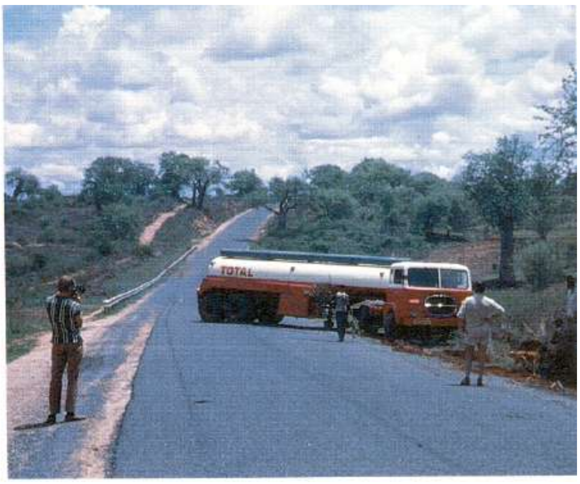


Fig 6.38
Absence of edge delineation may have contributed to this truck accident In Kenya
(Rendel Palmer & Tritton)

Summary

Clear definition of the road ahead is an important contribution to road safety. In situations where accidents occur because of unexpected road geometry or intersections, then edge of carriageway delineators should be used to improve drivers' expectancy of the circumstances ahead. Delineators are especially useful at night when equipped with reflectors or painted in reflective paint ....

Possible Solutions/Benefits

Fig 6.39
Edge lines and painted bamboo posts provide low cost delineation in Indonesia
(TRL)

It is not suggested that delineators be used along an entire route as a countermeasure, but that discrete sections of road which are known to be accident blackspots should be delineated. This is most likely to be effective on bends and on the approaches to intersections, where it is particularly important to give clear indications of the alignment ahead.

If loss of control is a prominent contributory factor in the accident records, then advance warning of changes in alignment, as provided by delineators, can be effective.

Delineation can be achieved by a variety of means in addition to delineator posts. Lane markings, painted kerbs and reflectorised studs are in common use. Painted markings and reflectors are particularly useful on bends.

Low cost solutions are often appropriate and the use of painted wooden or bamboo (as in Fig 6.39) posts can be effective.

Fig 6.40
Curve delineated by painted kerbs and chevrons. Note also crash barrier and speed reduction markings, Singapore
(TRL)

Other relevant sections: 4.1.12, 6.8.4, 6.8.6
Key external references: 8, 9

..........Delineators should not be so substantial as to cause damage or injury if struck by a vehicle. Care must be taken to ensure that they break off easily. Carriageway delineation can also be achieved by road markings and reflectorised road studs placed at the edge of a carriageway. The spacing of delineators should be carefully designed to give smooth continuous guidance at the speed of approaching traffic.

6.8.9 Speed Reduction Devices

Background

Excessive speed is one of the most commonly occurring contributory factors to road accidents. Reducing speeds, therefore, is likely to offer substantial safety benefits. As discussed in 5.10, speed limits are widely abused and in many countries the police have insufficient training, manpower and equipment to enforce them.

This suggests that self-enforcing physical measures are necessary to encourage, or force, drivers to slow down. A number of methods have been developed to achieve this and Table 6.04 and Fig 6.44 below are based upon the descriptions given in reference 1.

Measure	Description	Use	Applications
Road humps	Single humps or a series extending across the carriageway at right angles to the direction of flow.	Best used as part of an areawide scheme and especially appropriate on access roads where layout encourages speed. Should not be used on major routes.	Urban
Bar markings	Standard marking is 90 yellow transverse lines applied over about 400 metres, the spacing between which progressively reduces towards the hazard.	On approaches to roundabouts on major routes.	Mainly rural on high speed roads
Rumble areas	Continuous length of carriageway with coarsely textured surface designed to produce a rumble within vehicles driving over it which increases with speed.	In urban areas but consider noise nuisance if adjacent to residential development.	Urban and rural
Rumble strips and jiggle bars	A series of lateral bands of surface treatment designed to cause intermittent noise within vehicles driving over them. Variable spacing and dimensions.	For use on roads with high flow levels. More applicable to local distributors than access roads. More effective than a rumble area but consider noise nuisance if adjacent to residential development.	Urban and rural

Table 6.04
Summary of speed reducing devices (ref 1)

Problems

While the other methods are not commonly in use, the concept of road humps is accepted in many developing countries. However, their design and construction is often very poor resulting in them becoming ineffective or dangerous. In many cases road humps are too short and sharp and drivers, at the risk of serious damage to their suspension systems, can drive over them fast without experiencing discomfort. It is only the long humps (Fig 6.44) which result in progressively greater discomfort to drivers as vehicle speeds increase. Such humps are more costly and more difficult to construct, but are the most effective in preventing high speeds while also being the safest.

All devices which rely on audible warnings to drivers are likely to cause complaints from residents if sited close to properties.

Rumble areas are unlikely to produce noticeable reductions in speed.

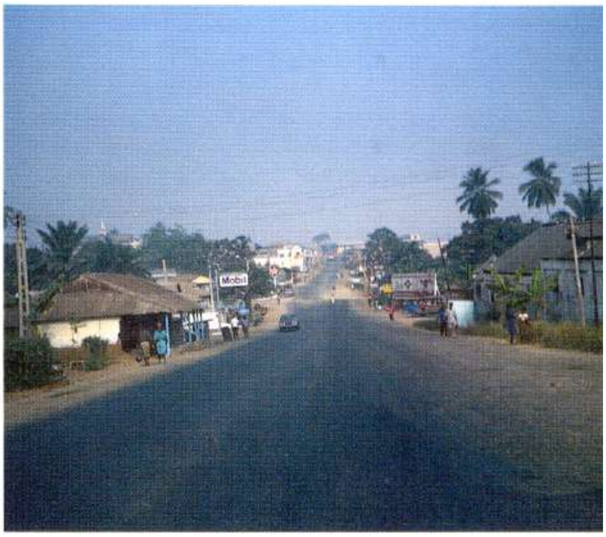


Fig 6.41
A typical community on an interurban road in Ghana where high speed, through traffic conflicts with pedestrians leading to many accidents
(Ross Silcock Partnership)

Summary

Excessive speeds and driver inattention are a common occurrence at accident blackspots. Countermeasures designed to alert drivers to the conditions and to encourage or force them to reduce speed can be effective in such circumstances. Self-enforcing devices, such as road humps, are especially desirable in countries where enforcement is limited and there is widespread abuse……..

Possible Solutions/Benefits

Fig 6.42
Speed humps in *Kenya. Note posts to prevent bypassing and perforations* in *sign to reduce its potential value to thieves (Ross Silcock Partnership)*

Fig 6.43
Lane narrowing and chicane used as a traffic calming (ie. speed reducing) device in Denmark
(TRL)

Road humps are likely to be most useful in residential areas where pedestrian/vehicle conflicts occur or to slow down vehicles on long rural roads at points where they pass through isolated communities or trading centres. It is important to indicate the transition from high speed roads to a low speed area by road narrowing, perhaps with a hump, and then to continue the low speed treatment throughout the area. The presence of humps will slow traffic and provide safer locations for pedestrians to cross. They may also be used on approaches to schools, to slow traffic in the presence of children.

Bar markings rely for their effect on the visual impression of speed given to drivers as they pass over them. The closer spacing gives a greater impression of speed and produces a natural tendency for drivers to slow. This is effective on the approaches to intersections on high speed dual carriageways where they can be an effective countermeasure.

Rumble strips, jiggle bars and rumble areas adopt a similar principle to bar markings but provide a sound stimulus to drivers. As the vehicle passes over the rougher texture, noise levels increase. The intermittent nature of rumble strips alerts drivers and creates an impression of speed. If the texture 7s sufficiently rough, as with jiggle bars, then vibration also occurs, which should cause drivers to reduce speeds. These methods are most appropriate on the approaches to accident blackspots where high speed and drivers' inattention has been found. Typical examples may be on the approach to a trading area on a major rural route, or to a dangerous intersection.

Speeds can also be reduced and pedestrian safety improved by making changes to the road alignment, for example, by narrowing or modifying intersection layouts to slow traffic down and to reduce the width of road to be crossed.

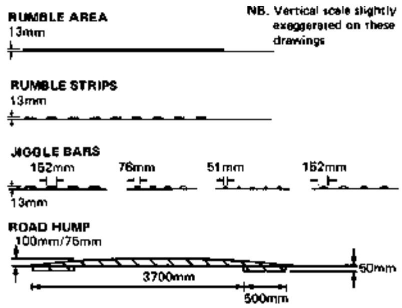


Fig 6.44
Dimensioned sketches of speed reducing devices (ref 1 and 4)

Other relevant sections: 4.1.2, 5.10, 6.8.10
Key external references: 1

.......of regulations. Physical measures such as road humps always require advance warning so that motorists are given ample opportunity to slow down. On fast, rural roads warning devices such as rumble strips or jiggle bars alert drivers as they approach a settlement. Road humps could be used to reduce speeds as vehicles pass through the settlement.

8.8.14 Limiting access/Street Closures

Background

Limiting access by street closure is usually done for two reasons. Firstly to limit the number of side roads joining a major route, in order to reinforce a road hierarchy and to concentrate potentially dangerous turning movements at a single intersection which can then be properly designed for such movements. The second reason is to reduce through traffic in a residential area, by making the route into and through an area tortuous and long. Only those requiring access will continue to enter.

These situations are predominantly urban, although there can be examples of trading posts on major rural routes where a number of direct access points occur at closely spaced intervals. Such locations are often accident blackspots, due to uncontrolled turning movements and pedestrian activity. By closing most (or all but one) of the accesses, turning movements can be concentrated at one point where other measures can be applied to deal with them more safely. The benefits and disbenefits of street closures are discussed at length in reference 6 and are summarised below.

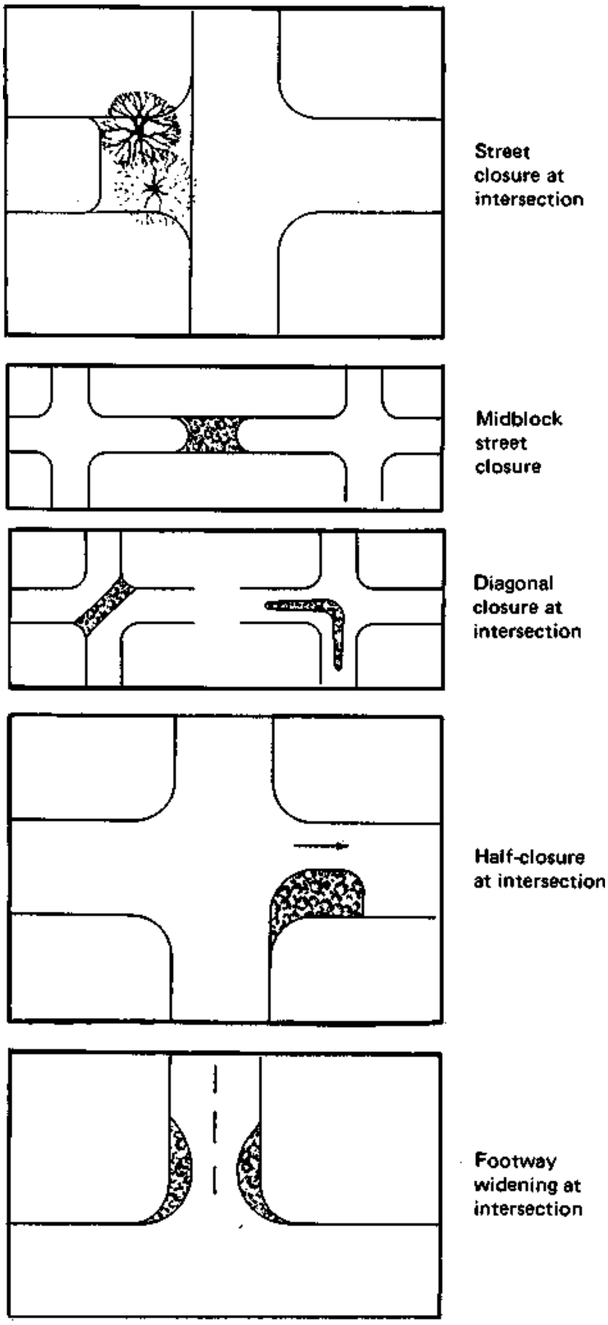


Fig 6.45
Illustrations of types of street closure (ref 6)

Problems

The difficulties which might be caused by street closures are listed below.

Street closure at intersections If a street is used by significant volumes of non-local traffic its displacement onto other streets and arterials may lead to congestion and controversy elsewhere and increased local travel distance.

Midblock street closure This increases some local travel distances, interferes with service vehicles, displaces traffic onto other streets and makes it difficult to provide turning space.

Diagonal closure of intersection This causes extra local travel and problems with space if full width pavements are taken around corners.

Half closure at intersection This is not self-enforcing and is open to abuse.

Footway widening at intersection This can cause some problems with space required for turns, if road-width reduction is close to the intersection.

Summary

Street closures of carious types can be effective in reducing accidents by removing through and inappropriate traffic from a particular street or area. As a consequence, the road hierarchy can be reinforced and pedestrian/ vehicle conflicts in residential areas can be reduced creating a safer environment for pedestrians, especially children. Different types of closure are evaluated in the ....

Possible Solutions/Benefits

Fig 6.46
Access limited by carrying raised footway across a T-junction in the UK to give greater priority to pedestrians (Ross Silcock Partnership)

Fig 6.47
Half closure at intersection, UK (TRL)

Street closure is a predominantly urban countermeasure to remove through traffic from residential areas, thereby reducing pedestrian vehicle conflicts. It can also have similar effects to turn restrictions (see section 6.8.11) by eliminating turning movements. Because access needs must still be met street closures can rarely be applied in isolation and are usually part of a package of measures designed to serve a larger area. Care must be taken to ensure that displaced traffic does not generate greater problems elsewhere than its removal has solved.

The benefits of each type of closure are summarised below.

- Street closure at intersection reduces the thirty-two conflicts and merges of an intersection down to only nine, is self-enforcing, can be an opportunity for improving visual character of a street, provides a positive means of clarifying network and directing vehicle paths, helps resolve priority at intersections and reduces total non-local traffic in the vicinity.

- Midblock street closure provides a means of deterring all non-local traffic and an opportunity for landscaping.

- Diagonal closure of intersection allows control of traffic without complete restraint on movements, reduces or eliminates conflicts, can be adapted for emergency vehicles, deters non-local traffic and can provide safer pedestrian crossing opportunities.

- Half-closure at intersection can greatly reduce conflicts, enables control without full restrictions, reduces through traffic and offers opportunities for landscaping.

- Footway widening at intersection provides protection for parked vehicles, emphasises minor street role and character and reduces width to be crossed by pedestrians.

Other relevant sections: 3.5.5, 5.5, 5.6, 6.8.11
Key external references: 1, 6

.........panels above. It must be noted, however, that displaced through traffic will reappear elsewhere on the network and care must be taken to ensure that the result of street closure is not simply to moue the problems to other locations. The carious options available have different benefits and disbenefits and final selection will depend upon the particular characteristics of the area and the specific site concerned.

6.8. 11 Banning Turns and Crossing Movements

Background

One possible way of reducing accidents where one particular turning movement is prevalent in the accident records is simply to ban that turn at the intersection and/or to relocate it to a safer location. The most common restriction is 'no right turn' (when driving on the left), as turns across oncoming traffic on the priority route, or turns out of a minor road which cross busy traffic, are amongst the most dangerous manoeuvres.

Concentrating turns at one location where adequate turning facilities can be provided is generally safer than dispersed turning movements all along a street.
At traffic signals it may be necessary to ban turns so that pedestrians may cross safely, especially if there is not sufficient time in the signal cycle for them to have a protected phase. Turn bans can be introduced by signs, or with physical barriers of some kind. If compliance is low, and enforcement is not stringent, a physical barrier of some kind is likely to be necessary.

Fig 6.48
Illegal U-turns just over the brow of a hill have caused accident problems at this site in Ghana
(TRL)

Problems

Turn bans can lead to a number of problems, as follows.

Turns banned by signing also affect legitimate local traffic. They are not self-enforcing and, if not obeyed, could encourage abuse of turn bans elsewhere. The need for policing can make control of turns by signs alone an unreliable means of local traffic control in some developing countries.

Turns banned by physical barriers may not always be possible as roadspace may be inadequate, and smaller installations may present visibility problems. It also may not be possible to control 'left in' or 'left out' movements (driving on the left).

Fig 6.49
Permitting all movements at locations which are unsuitable can sometimes cause congestion and safety problems, as in this example in Egypt
(TRL)

Summary

Turn bans are a common traffic engineering tool which can be used to reduce conflicts at accident blackspots or at a series of minor intersections along a major route. To be effective they must either be self-enforcing, by the use of physical barriers, or be subject to active, high profile enforcement by the police. The banned manoeuvres will, of course, be displaced to elsewhere in the network ....

Possible Solutions/Benefits

Fig 6.50
Physical barrier constructed with painted oil drums to ban turns and create pedestrian crossing facility, provides a low cost solution in Papua New Guinea
(Ross Silcock Partnership)

Fig 6.51
Banned right turn in UK. Note small channelising island to prevent turning manoeuvre at T-junction
(TRL)

The use of turn bans as an accident countermeasure is clearly directed at situations where turning traffic is involved in a disproportionate number of accidents relative to the respective traffic volumes, or where a turn is inherently dangerous, for example, due to restricted visibility. In addition to particular problem intersections, turn bans can be applied more comprehensively to concentrate turning movements at a few locations where facilities such as signals or roundabouts can be installed to make them safer. Care must be taken to ensure that compliance is high - either by adequate enforcement or by the use of self-enforcing restrictions.

A particularly useful form of turn ban can be achieved by a median barrier in the main road at minor intersections. Traffic to/from the side roads cannot then cross or turn through the main road traffic. Thus reduces the number of conflicts involving crossing vehicles and pedestrians. It may, however, require U-turn facilities to be provided further along the route if other access routes are not available.

- Turn bans by signing if observed, could limit entry of non-local traffic and reduce interference to the major traffic stream. They require lower capital cost than closure or half-closure of a road but could have adverse effects on local residents.

- Turn restrictions by physical barriers are relatively low cost (various treatments possible) These can significantly reduce non-local traffic with only moderate interference to local movement and can also be used to eliminate straight-across movements at minor/major intersections. They can be made mountable by emergency vehicles and are generally acceptable to residents.

Other relevant sections: 6.8.7, 6.8.10
Hey external references: 1

…...A package of measures must be introduced to cater for these safely to ensure that the problem is not simply transferred elsewhere. Generally banning turns at locations where they are undesirable and/or unsafe should be always accompanied by provision for such displaced movements at an alternative location nearby where such movements can be made in safety and without impeding other traffic.

6.9 Countermeasures for Pedestrian Accidents

6.9.1 Introduction

All road users are pedestrians for one or more stages of every journey even if it is just a short walk from office to car park. Shorter journeys are more likely to be made on foot. Even in the UK, with relatively high car ownership, over 60 per cent of journeys under 1.5 km long are made solely on foot. In urban areas in the UK about one-third of all journeys are made entirely on foot. In developing countries walking is even more important as a mode of transport, both in terms of the number and length of journeys made on foot, yet facilities for pedestrians are often sadly lacking.

Pedestrians, particularly the young and elderly, are the most vulnerable group of road users. They do not have the protection of a vehicle's bodywork to keep them from injury in a minor collision. Indeed it is that very same metal bodywork which protects a car driver that may kill a pedestrian. Because they are unprotected it is essential to consider pedestrians' needs within the transport system and to give them greater consideration than other road users. In an accident pedestrians are much more likely to be injured or killed.

European experience in new towns has shown that segregation of pedestrian and vehicular traffic by creating separate networks for each can bring about very significant improvements in pedestrian safety. Unfortunately, apart from in new developments, extensive segregation is seldom likely to be economically feasible. Alternative methods need to be found to improve pedestrian safety on existing networks. Industrialised countries have developed a number of ways of achieving improved pedestrian safety, some of which are discussed in following sections.

The great majority of pedestrian movement is local in nature. It takes place on footways adjacent to carriageways or on the edge of the carriageway. It therefore follows that the problem of pedestrian/vehicle conflict must be an important consideration in highway design and traffic management. Attention needs to be paid to minimising conflicts and providing facilities for pedestrians which are safe, convenient and pleasant to use.

Pedestrian activities range from trips concerned only with direct travel between two points to those which have a more diverse or recreational character. In some areas footways are also used for play, market areas or places where people congregate and talk. All of these aspects should be considered in the design of pedestrian facilities.

Problems

Fig 6.52
Pedestrian/vehicle conflict in Egypt (Mott Macdonald)

Footways in developing countries are often obstructed by hawkers' stalls, commercial activities and parked cars. Action can be taken to clear the footways through enforcement or by better engineering (i.e. high kerbs or poles at the pavement edge to prevent encroachment by parked cars). Where pedestrian flows are heavy and the footway is too narrow, widening should be considered. The introduction of small kerb radii at intersections to slow turning traffic, can also help pedestrians cross the mouths of side roads more easily by slowing traffic. There may even be benefits in continuing the footway of the main road across the side roads to create "raised crossovers". This enables pedestrians to proceed on the level while drivers have to manoeuvre slowly over the raised crosswalk (Fig 6.53).

To encourage usage, footways need to be reasonably even and well drained. Vegetation should not be allowed to obstruct the footway. When construction work is in progress alternative temporary arrangements must be made for pedestrians displaced from the footway by building works.

When pedestrians are involved in a substantial proportion of accidents at a particular site their needs must be considered carefully in the design and selection of countermeasures. Where possible, measures which segregate vehicles and pedestrians should be used. A selection of these are discussed in subsequent sections. Earlier parts of this Guide have described pedestrian facilities in terms of design of footways (sections 4.1.17, 4.1.18 and 4.2.9). The countermeasures described in this section relate more to protecting pedestrians with fences or barriers and to facilities which make crossing the road safer.

Possible Solutions/Benefits

Fig 6.53
Raised footway continued across minor road in the UK reduces speeds and enhances pedestrian safety whilst permitting access
(TRL)

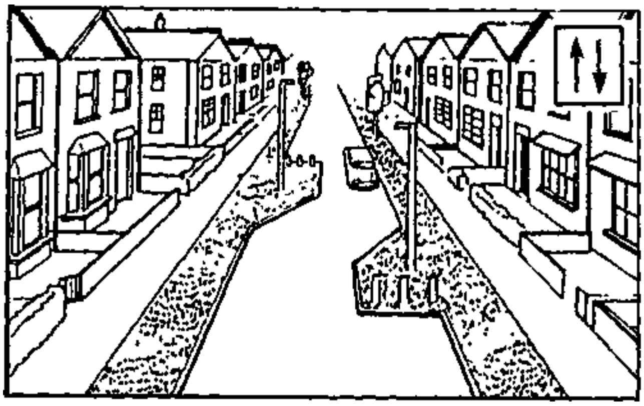


Fig 6.54
Chicanes with local road narrowing offer a means of reducing speeds and improving conditions for pedestians
(UK Department of Transport)

6.9.2 Pedestrian Crossings

Background

Pedestrian crossings are a common feature in many cities. When located and used correctly they can be effective in reducing pedestrian/vehicle conflicts. Pedestrians always tend to take the shortest routes between any two points. If using a crossing imposes much additional walking distance, then there will be a marked reluctance to use it. Great care is needed, therefore, in siting pedestrian crossings so that use is maximised and so that they are clearly visible to drivers. As discussed in 6.9.4 it may be desirable to use guard railings to channel pedestrians onto the crossing.

The principle of a pedestrian crossing is that pedestrians are given priority over vehicular traffic for part of the trine, either by using traffic signals to stop traffic or by a general rule which requires vehicles to stop if a pedestrian is at a designated crossing point.

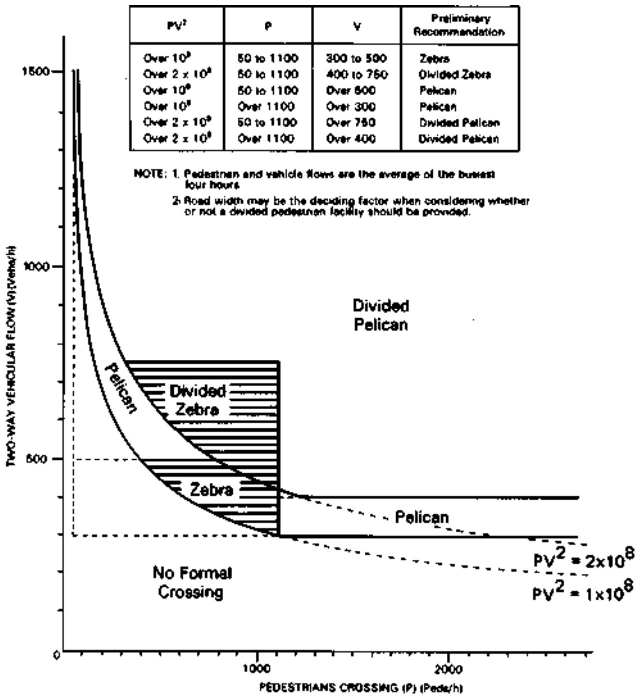


Fig 6.55
UK warrants for pedestrian crossing facilities (ref 1)

Problems

Crossings based on priority rules rather than signals demand a degree of driver compliance that is rarely found in busy cities. Many such crossings are not well marked in any case so drivers often have little warning that they are at a crossing.

In many countries it is an offence for pedestrians to cross the road away from a crossing, but such rules are often widely disregarded and rarely enforced.

Pedestrian crossings on high-speed roads can lead to rear end collisions if drivers are not given sufficient advance warning.

Warrants for the installation of crossings vary from country to country. The criteria in the UK are based on PV^2= (see Fig 6.55) where:

P =the pedestrian flow (pedestrians/hour) across a 100 m length of road centred on the proposed crossing site; and

V =the number of vehicles in both directions (vehicles/ hour).

Pedestrian crossings can be considered as countermeasures in locations where the level of pedestrian/vehicle conflict is high, and there is a clearly identified crossing movement.

Summary

Pedestrian safety can be improved substantially if formal crossings are provided to assist them to cross busy roads. Because they require traffic to stop they are often signal-controlled in order to achieve compliance. This does, however, disrupt traffic, f low and can introduce hazards of a different kind if vehicle speeds are relatively high on the approaches to the crossing. The Location....

Possible Solutions/Benefits

Fig 6.56
Pedestrian crossing ahead in Korea: note painted diamond on carriageway to give advance warning
(Ross Silcock Partnership)

Fig 6.57
Signal controlled crossing in the UK. Note central refuge and fencing to force users to face oncoming traffic before crossing each carriageway
(Ross Silcock Partnership)

Fig 6.55 illustrates the values of PV^2 deemed appropriated for 'Pelican' crossings (with traffic signals) and 'Zebra' crossings (no signals, priority rule). Reference 1 describes their use as follows.

Zebra crossings (black and white stapes painted on the road) can be provided at relatively low cost but are unsuitable where traffic is heavy and fast moving. Pedestrians wishing to cross find it difficult to judge the speeds and stopping distances of approaching vehicles. Where driver compliance is low and vehicle speeds are high pedestrian crossings can be amalgamated with road humps to give a raised pedestrian crossing (80-100 mm high). These are very effective but must be clearly marked and require considerable advance warning.

Pelican crossings are more appropriate than zebra crossings in the following situations:

- Where there are significant numbers of elderly and infirm pedestrians;
- At sites with high approach speeds;
- Where pedestrian flow is heavy and a pelican will prevent pedestrians establishing a continuous flow on the crossing;
- At special sites such as contra-flow bus lanes; and
- In areas operating under urban traffic control, as pelican crossings can be linked with traffic signals.

On dual carriageways and on single carriageways more than 15.0 m wide, pelican crossings should be of the staggered type of layout which operates as two separate crossings so that pedestrians stepping onto the road from the refuge turn to face the approaching traffic before they cross the road. The central storage area should be large enough to accommodate the expected numbers of pedestrians gathered during each signal cycle.

Other relevant sections: 4.2.9, 6.9.3, 6.9.4
Key external references: 1

.......of crossings also requires careful consideration in order to ensure that they are well-used by pedestrians as pedestrians will normally prefer to take the shortest route. Approaching traffic must have adequate visibility and time to stop when required. Raised crossings (80-100 mm) should be considered where motorists consistently do not give pedestrians priority and where speeds are

6.9.3 Pedestrian Refuges

Background

Pedestrian refuges (or traffic islands) are the most common and generally one of the least costly type of crossing aid for pedestrians. They permit pedestrians to concentrate on crossing one stream of traffic at a trine, by creating a relatively safe waiting area, usually in the centre of the carriageway.

The reduced width of carriageway resulting from installing a refuge can reduce vehicle speeds, but sufficient width is still needed to permit safe passage of the largest vehicles likely to use the road. A series of refuges along a residential street can be effective in reducing the apparent image of a through route. They also offer frequent crossing opportunities.

Intersection channelisation schemes often create pedestrian refuges from the islands constructed to direct traffic. Thus at intersections, pedestrians are given facilities to help them cross, at the same time as assistance is being given to traffic. Even a simple 'sputter island' at the mouth of an intersection can be inexpensive yet effective in this way.

Fig 6.58
A wide pedestrian crossing without central refuge in Korea. Note vehicle not giving way to pedestrians
(Ross Silcock Partnership)

Problems

Crossing busy roads with relatively fast flowing traffic even on a zebra crossing can be a particulary difficult task if no central refuge has been provided. This is because the pedestrian has to decide on suitable gaps in streams of traffic in both directions simultaneously.

In industrialised countries refuges carry an internally illuminated bollard, and they are normally only installed on streets which are lit at night. This is not always a practical possibility in developing countries. An unmarked, unlit raised island in the centre of the road could become an additional hazard, especially at night, for the unwary driver.

If refuges are sited too far away from intersections they will not be effective because pedestrians will continue to cross at the intersection rather than walk the extra distance involved.

Refuges should not be sited directly opposite bus stops because they can prevent other vehicles in the traffic stream from overtaking a stationary bus or may create a condition where vehicles attempting to overtake a bus collide with the refuge itself. Parking near pedestrian refuges can also cause problems by masking pedestrians from approaching vehicles.

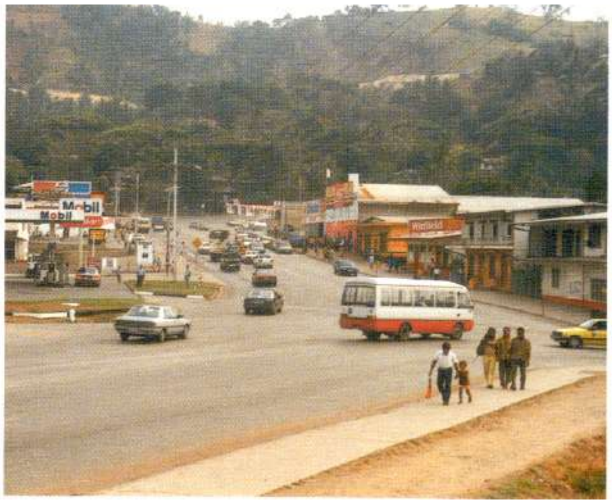


Fig 6.59
Absence of refuge on wide fast road in Papua New Guinea increases danger for crossing pedestrians
(TRL)

Summary

The provision of a small traffic island, or refuge, can often be an effective means of protection for pedestrians when crossing the road. It clearly divides the two traffic streams and enables pedestrians to cross each separately, with a safe place to wait in the centre of the road. At intersections, splitter islands used as part of a channelisation scheme can offer similar benefits ......

Possible Solutions/Benefits

Fig 6.60
Pedestrian refuge in the UK where a zebra crossing could not be justified
Ross Silcock Partnership)

Fig 6.61
Zebra crossing in Denmark where central refuge provides a safe wafting area for pedestrians
(TRL)

Refuges are often appropriate at sites where pedestrian crossing movements are concentrated but are insufficient in number to justify a more formal crossing. Where movements are less concentrated, pedestrians sometimes cross near to a refuge using the space between traffic streams as a 'shadow refuge.

Wide, multi-lane roads are especially difficult to cross safely. The provision of a central refuge, to allow each direction of flow to be crossed separately, can be beneficial in these circumstances.

At major/minor intersections, the provision of traffic islands which serve as refuges will help pedestrians to cross the minor road or the major road if there is an established need for a crossing point.

Refuges are often beneficial on local distributors acting as bus routes, especially where crossing movements are drawn to a particular location near local shops or a bus stop. Refuges are particularly valuable where a crossing cannot be justified by the numerical criteria normally used for controlled crossings (see 6.9.2).

Refuges should generally be at least 1.8 metres wide and never less than 1.2 metres to ensure that protruding wing mirrors from trucks and buses do not injure pedestrians standing on the refuge island.

Where bollards on refuges are not internally illuminated it is essential that they are prominently painted with reflective paint and that such markings are kept in good condition.

Other relevant sections: 4.2.9,6.8.1,6.9.2,6.9.4
Key external references: 1

………to pedestrians who can cross traffic streams one at a time. Away from intersections, refuges can also reduce traffic speeds, by an apparent narrowing of the carriageway, which again can be beneficial to pedestrians. They are most appropriate in lit, urban streets; if used in unlit streets then every effort must be used to ensure they are well painted with reflective paint and are well maintained.

6.9.4 Pedestrian Barriers/Fences

Background

Fences can be used to channel foot traffic onto the crossing and away from dangerous sites. They may also be appropriate in the area immediately adjacent to a crossing in order to prevent pedestrians from crossing the road near to, but not on, the crossing.

Fences should be set back (normally 500 mm) from the kerb to give adequate clearance for passing vehicles but must leave sufficient room (at least 1.5 m) on the footway for pedestrians perhaps carrying heavy loads. Specially designed fences which do not obstruct vision are available and should be used wherever visibility is important (e.g. adjacent to intersections or pedestrian crossings).

Where barriers are used at bus stops, access to the carriageway will be necessary, but the fence should be continued along the queueing area. It is sometimes necessary to leave gaps in the railings to accommodate trees or street furniture but it may be preferable to resite the obstruction.

Fig 6.62
Pedestrians forced to walk in carriageway past construction site in India because no facilities for pedestrians provided by contractor
(TRL)

Problems

Where no pedestrian barriers have been erected pedestrians will choose to cross at any point along a length of road rather than be channelled to specially provided crossings where the risk of accident should be lower.

A fence at the kerbside inhibits access and causes problems with loading and unloading. If openings are created they are often left open for long periods, thus removing the continuous protection that the barrier should provide. Parking should not be allowed adjacent to fences. as this prevents safe access from the vehicle to the footway. This conflict is not serious in practice, as situations which demand fences are also likely to be those where parking should, in any case, be controlled.

Widening of the pavement may sometimes be necessary before fences can be erected. The main disadvantage of fences, apart from their obtrusive appearance and their cost, is that they prevent pedestrians from crossing a road wherever they wish and may require them to walk considerably further to cross the road. Their excessive use can encourage pedestrians to climb over or through the fencing and make diagonal crossings.

Fig 6.63
Pedestrians do not readily accept barriers if they attempt to block mayor pedestrian routes. Egypt
(TRL)

Summary

In some situations where pedestrian accidents are prevalent it may be necessary to restrict the opportunities for pedestrians to cross the road by the use of physical barriers. Whilst some fit. young people will always elect to climb over these, they are usually effective in channelising the great majority of pedestrians along the footway to a location where crossing facilities are ....

Possible Solutions/Benefits

Fig 6.64
Visibility of pedestrians, especially children, has been markedly improved for nearside drivers in the UK where special 'see through' fencing such as VISIRAIL. (above) has been used
(Hugh Logan Engineering)

Fig 6.65
Pedestrian barrier on median to prevent crossing and to direct pedestrians to footbridge in Thailand
(JMP Consultants Ltd)

Fences can be used to alter patterns of pedestrian movement as part of any road safety measure. They can be used in short lengths in front of school entrances, recreation grounds and footpaths to prevent children running straight onto the carriageway. Asymmetric or off-centre positioning can deflect emerging pedestrians and encourage them to face on-coming traffic before crossing the road. At busy locations, such as congested intersections and railway or bus stations, fences can be used to keep pedestrians off the carriageway.

Their use should normally be confined to district and primary distributor roads. Only at intersections and other particularly hazardous locations are they appropriate on local distributor and access roads. The deterrent value of fences to discourage illegal or obstructive parking could be an additional consideration at critical locations.

Fences should be difficult to climb, with a top rail about 1 m above footway level. They are more difficult to climb if there are no flat rails more than 100 mm above the footway. Fences should be sufficiently robust to deter theft and to withstand slow speed impacts. It is preferable to use galvanised material to reduce corrosion and maintenance costs.

Other relevant sections: 4.1.11, 6.9.2, 6.9.3

Key external references: 1

........available. They can be used to restrict pedestrians from crossing near bus stops, schools or on bends and intersections. Care must be taken with their siting to ensure adequate visibility and to meet access needs. Fences should be difficult to climb with atop rail about 1 metre high and no flat rails more than 100 mm above the footway level.

6.9.5 Pedestrian Footbridges/Underpasses

Background

In urban situations where pedestrian flows are high and traffic conditions are such that stopping traffic by means of signals would lead to added congestion and/or risk of accidents due to high speeds, it may be appropriate to provide grade separation of pedestrians and vehicles. There are also some circumstances away from congested urban areas where grade separation may be appropriate, such as on fast, primary routes where signal control may be inappropriate or potentially hazardous.

Subways require less vertical separation and thus fewer steps. The initial movement for a subway is downwards and easy.

Fig 6.66
Pedestrian crossing at-grade, despite presence of footbridge, Thailand. Note absence of pedestrian fences
(JMP Consultants Ltd)

Problems

Footbridges and underpasses are costly and their installation should always be subject to rigorous economic evaluation (i.e. balancing the cost of installation and maintenance against costings for likely savings in delays to pedestrians and motorists as well as accidents). It is also the case that pedestrians will often avoid using them, especially if substantial differences in elevation are involved, implying many steps to climb. Also, in some countries concern is often expressed regarding public safety in underpasses. If they are not well-lit and patrolled, they may provide a focus for criminal activities.

Maintenance, or lack of it, can also create difficulties. Footbridges require painting and structural maintenance if they are not to become unsafe. Subways can soon become dirty, unpleasant locations if not regularly cleaned. Particularly in monsoon climates, they are liable to flooding if not well-designed with adequately maintained drainage.

A further problem is that any concentration of pedestrians is an attractive location for street traders seeking to sell their goods. Footbridges and subways often become crowded and congested with traders, making their use difficult, thereby reducing their effectiveness. If pedestrians cannot use them easily, then they become more likely to try to cross the road at surface level.

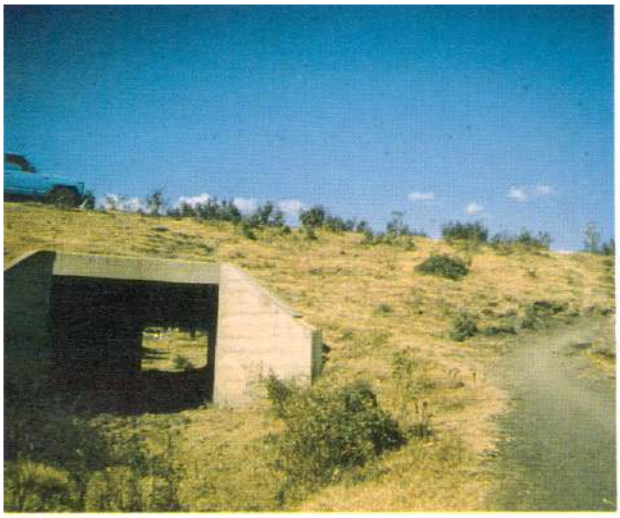


Fig 6.67
Drainage culvert under major rural road in Ethiopia which for little additional cost could have been designed to serve also as a pedestrian underpass
(TRL)

Summary

In locations with high concentrations of pedestrians and traffic they may be cost-effective and if traffic speeds are high there may be no adequate alternative to ensure pedestrian safety. They often require the use offences along the adjacent highway in order to minimise the numbers of pedestrians crossing the road at surface level. Maintenance problems can become extensive, ...

Possible Solutions/Benefits

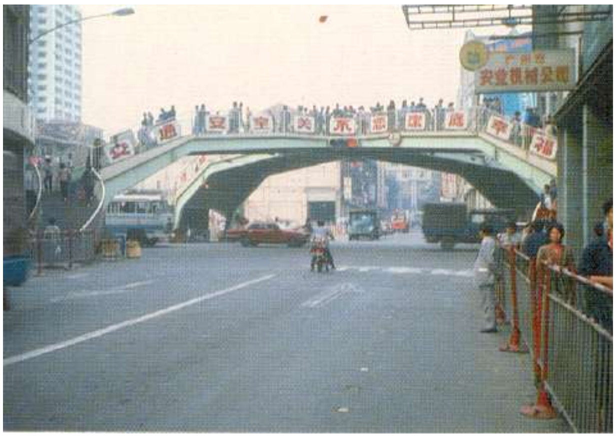


Fig 6.68
Pedestrian footbridge in China. Note pedestrian fences channelise pedestrians over the bridge
(Ken Huddart)

Fig 6.69
Pedestrian footbridge in Hong Kong crossing main road (to the right) with an at-grade crossing of service road
(Ken Huddart)

Because of the high cost of construction, footbridges or underpasses are only likely to be appropriate in very special circumstances where high pedestrian volumes require to cross busy roads. Such circumstances can occur in congested town centres, or occasionally in suburban or even rural trading centres where ribbon development along each side of a major route has resulted in excessive vehicle/ pedestrian conflict.

There may also be circumstances (for example, China where very large cycle flows can be expected) in which a pedestrian subway or bridge can be used by cyclists as well as pedestrians. This could improve the economic case for construction, although the shallow approach ramps needed for cyclists are likely to increase the cost and require additional land. A wheeling strip at the edge of the steps is sometimes an acceptable alternative. In urban situations, especially in CBDs, this land is unlikely to be available.

Footbridges and subways should be located as closely as possible to the maximum pedestrian movements. They should make best use of any topographic features to minimise the effort involved in their use.

It is common for fences to be installed on the approaches to footbridges and subways, to channel pedestrian flows onto them and to inhibit crossing the carriageway at surface level.

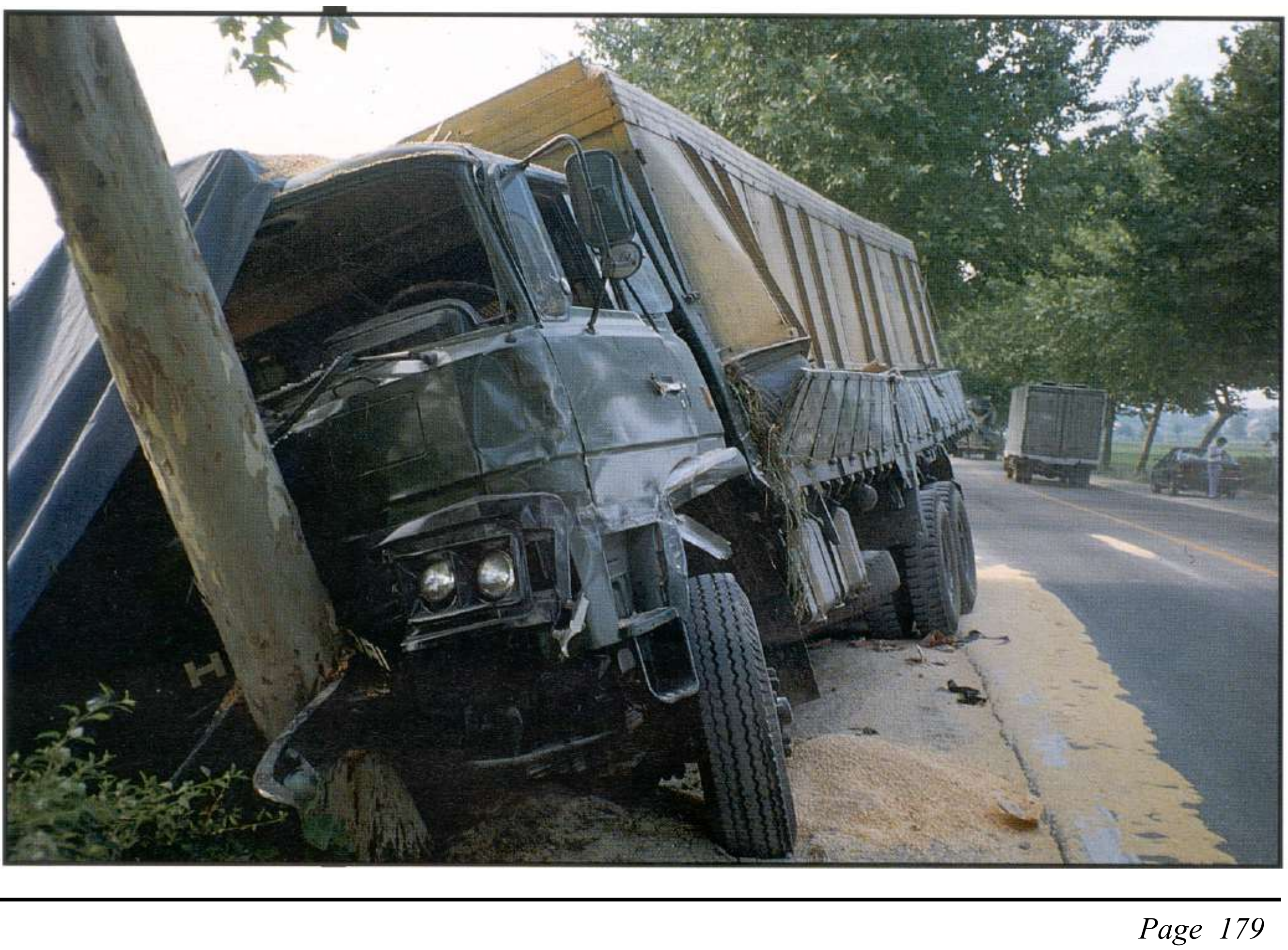
Footbridges in hot or wet countries can be provided with roofs to protect pedestrians from sun and rain.

Other relevant sections: 6.9.4
Key external references: 1

.........especially with the drainage of subways in wet tropical climates. The concentration of pedestrians at these facilities is also attractive to hawkers and for street trading. This may need to be restricted if the bridge or underpass is to be fully utilised. It may be possible to incorporate a wheeling strip at the edge of steps to permit cyclists to also use the facility.

PART IV

ROAD SAFETY CHECKLISTS



7. ROAD SAFETY CHECKLISTS

7.1 Formal Road Safety Checking of Proposed Schemes

THE NEED FOR SAFETY CHECKING

Many governments still do not realise the magnitude of the road safety problem facing their countries. Very few resources are spent to improve road safety and the limited resources available are not always spent to best effect. Not only is current expenditure sometimes misdirected, but present planning and design practices may, unintentionally, be creating situations that will produce road safety problems in the future. Roads are being built, often with aid funding, which will have many more accidents than would result if road safety was considered at the planning and design stages. At the root of many of these avoidable accidents are:

- inadequate planning and access controls;
- designs inappropriate to local conditions;
- weak or non-existent operational controls; and
- inability to develop and implement countermeasures.

These problems are institutional as well as technical but many can be overcome if a systematic and rigorous process of safety checking is carried out. The authors' experience in the UK and overseas suggests that a significant proportion of accidents at major improvement sites could often have been avoided had a safety audit been carried out. In countries with less specialist staff, less developed planning systems and less systematic design processes, the opportunities for reducing accidents by safety audits must be significantly higher.

WHO DOES THE CHECKING?

Road safety checks (called safety audits in some countries) are intended to ensure that adverse features are not introduced unintentionally into a highway scheme. If they cannot be avoided, or it would be uneconomic to remove them, the safety check should ensure that appropriate remedial action is taken to minimise the likelihood of accidents. The checks are best done by highway planners and engineers with experience of road safety work - such as blackspot improvements. Planners and designers of the schemes should, of course, be encouraged to carry out their own informal checks using the checklists just to ensure they have covered most key issues before submitting the scheme for approval. Those doing the final formal checking should not have been involved in the planning and/or design of the scheme, unless this is completely unavoidable.

HOW TO CHECK

A document recently published in the UK (reference 13) gives guidelines for safety audits. Although intended for UK conditions this provides detailed guidance and checklists for safety audits. The principles of those guidelines have been incorporated here in a modified form suitable for developing countries, although much of the detail is omitted. The following pages contain checklists, expressed as a series of questions, which the safety checker must answer. If the answer to any question is `no', then the reader is directed to the section in the text where relevant information is to be found. This will give guidance on the principles to be adopted for a `safe' design in respect of that topic, or the kinds of remedial measure needed to overcome potential problems. It is inevitable that these general checklists will not cover every issue for every country, so as experience builds up, local planners and engineers should add their own additional questions and modify others where necessary to tailor the checklists to their needs.

CHECKLISTS

For convenience the safety checklists have been compiled under a number of headings, relating to the planning, design and operation of highways and to the improvement of accident blackspots. These are:

Checklist A:	Land use/Physical planning
Checklist B:	Network planning
Checklist C:	Highway design
Checklist D:	Countermeasures related activity

Checklists A-C should be used on all proposed schemes to ensure that road safety issues have been given sufficient attention and priority. Senior managers and decision makers could make the 'safety checking' of all proposed schemes obligatory upon all their engineers and planners by insisting that all schemes submitted for final approval will be assumed to have successfully passed the safety checks. This would put responsibility firmly on the planners and designers involved, either to create the required safe conditions through the planning and design principles advocated in this guide, or to justify why this was not done. Checklist D is intended to ensure that adequate attention and activity is being devoted to identifying and improving accident blackspots on the existing network. Appendix B contains some example checklists for the investigation of commonly occurring accident situations which are intended to assist the accident investigators in identifying problems and potential solutions.

7.2 Checklist A: Land-use/Physical Planning

(a) General

1. Is there a zoning plan and does development conform to this? (3.2)

2. Are major facilities like hospitals, district shopping centres and petrol stations which create large volumes of motor vehicle traffic, located on distributors? (3.2-3.5.3)

3. Are activities creating high pedestrian flows, like the schools, shopping centres and health centres, connected with each other and with dwellings by continuous footpaths or footways? (3.5.5)

4. Are bus stops connected with the dwellings and nearby services, like shops, by footpaths or footways? (3.8)

5. Are bus stops located close to the pedestrian crossings, footways and footpaths in such a way that it is convenient for the passengers to use these facilities? (3.8)

6. Are bus stops located beyond the pedestrian crossings and after street intersections? (4.1.16)

7. Are activities creating bicycle traffic, like industrial and other working areas, schools and shopping centres, connected with each other and with dwellings by a continuous cycleway network? (3.2,3.6.1-3.6.4,4.1.20)

8. Does the cycleway network consist of local streets, wide shoulders of streets and mainly of separate, sealed bicycle and pedestrian ways? (3.6.1-3.6.4,4.1.20)

9. Are unauthorised developments, accesses, structures and advertising hoardings removed if they obstruct visibility or increase danger to road users? (3.7)

10. Are alternative off-road sites available for traders and paratransit pickup points which are removed from the roadside so that siting of stalls and pickup points can be relocated off the main road or on side roads at least 50 metres from the main road? (3.7)

11. Are all accesses to roadside properties and car parks at least 50 metres from street intersections on road categories higher than access roads? (5.6)

(b) Residential Areas

12 Have residential areas been planned so that they are self-sufficient in basic services, like local shopping and primary schools? (3.6.1)

13 Is there a network of segregated footpaths/ cycleways in the area? (3.6.1)

14 Is parking located away from childrens' play areas? (3.6.1)

15 Are roads designed to exclude through traffic, to induce slow speeds and to give equal priority to pedestrians? (3.6.1, 6.8.10)

(c) Industrial Areas

16 Does the industrial area have direct access onto a primary or district distributor? (3.6.2)

17 Is the industrial area physically separated from nearby residential areas? (3.6.2)

18 If not physically separated, have specific measures been implemented to minimise the undesirable effects of HGV traffic? (3.6.2)

19 Are intersections on nearby routes carrying industrial site traffic wide enough and designed to allow easy manoeuvring by HGV traffic? (3.6.2)

20 Is there sufficient off-road space for parking and loading activities? (3.6.2, 5.11)

21 Have networks of footpaths or footways and of cycleways been provided between industrial areas and main areas where people live? (3.6.2)

(d) Commercial/Retail Areas

22 Are commercial/trading areas separated from through traffic by provision of service roads? (3.6.3)

23 If not, are they well clear of the edge of the road so that they do not result in obstructions/ danger to road users? (3.6.3)

24 Are there safe facilities for pedestrians to cross the traffic stream? (3.6.3, 4.2.10)

25 Are speeds of through traffic low enough to enable pedestrians to cross in safety? (3.6.3, 6.8.9)

26 Do delivery and servicing arrangements minimise potential dangers for pedestrians and other traffic? (3.6.3)

27 Has visitor parking been provided off the road? (3.6.3)

28 Are exit/entry arrangements to the site as safe as can be? (3.6.3)

(e) Recreational/Tourism Areas

29 Have special traffic management and parking plans been developed for major events? (3.6.4)

30 Is the main access and parking area segregated from through traffic? (3.6.4)

31 Are entry/exit points from parking areas safe and suitable for the volumes of traffic expected? (3.6.4)

32 Are the entry/exit points located in a way which disperses traffic over the road network? (3.6.4)

33 Has an adequate direction signing plan been prepared for major events to direct traffic to and from such locations? (3.6.4)

7.3 Checklist 8: Network Planning

(a) Road Networks

1. Have roads been categorised into a hierarchy of the street network: primary distributor, district and local distributors and access streets? (3.3)

2. Do the arterials form the primary network for the whole town or region and carry most of the through traffic? (3.3,3.5)

3. Whenever an arterial has two or more lanes in each direction, are the driving directions separated by means of a median barrier or a central reserve? (3.3,3.5)

4. Do local distributor roads serve only the traffic within a residential estate, village, or similar area, and connect these areas with district distributors? (3.3,3.5.3)

5. Does each street intersect only with streets in the same category or streets one category above or below its category? (3.3)

6. Have access streets been so designed that they are not suitable for through traffic? (3.5.4,6.8.10)

7. Are all access roads loop roads or culs-de-sac not longer than 200m? (3.5.4)

8. Are all intersections between two arterial streets channelised, signal-controlled intersections or roundabouts (or where very high volumes are involved, grade separated)? (3.5.1,4.2.1)

9. Are all intersections between an arterial street and collector streets, priority T - junctions, (with priority to the arterial road) roundabouts or signal controlled? (3.5.1,4.2.1)

10. Are all intersections between a collector street and an access street, priority T - junctions (with priority to the collector road)? (4.2.1)

11. At intersections between arterial and collector streets has consideration been given to channelisation to provide a protected turn bay for turning traffic cutting across the main traffic stream? (4.2.8)

12. Is intersection spacing on arterial streets at least 250m? (The desirable maximum number of intersections is 3 per km.) (3.3,5.6)

13. Is access to local parking areas from access roads only? (Access to larger parking areas at hospitals, district shopping centres, petrol stations and similar developments which create large volumes of traffic can, in exceptional cases, be from a collector street.) (5.6,3.5.4)

14. Have proposed vehicular accesses from nearby properties been checked to ensure that there is no direct access less than 50 metres from an intersection? (5.6)

15. Is visibility and signing at intersections such that road users can readily see which road has priority and where they should stop or give way? (4.1.3, 4.2.6, 4.2.7)

16. Is vehicle parking controlled or prohibited on arterial roads carrying large volumes of traffic? (3.5.1, 5.10)

17. Have suitable bus and paratransit stopping places been provided at safe locations? (4.1.16)

(b) Pedestrian Footpath Networks and Facilities

18 On busy roads are pedestrians channelled to safe locations where special facilities have been provided for safe crossing? (4.2.10)

19 Are main footpaths separated from the streets wherever possible? (3.5.5)

20 Do main footpaths always cross streets at well designed, properly signed and where possible, lit pedestrian crossing facilities? (4.2.10)

21 Do arterial and collector streets have footways (sidewalks), if there are no separate footpaths nearby? (3.5.1,3.5.3,4.1.6)

22 On all arterial and collector streets is there reservation for a separation strip between the carriageway and the footway (sidewalk)? (3.5.5)

23 Are all pedestrian crossings on arterial streets grade separated or controlled by traffic signals or designed to have pedestrian refuges such that the pedestrian never needs to cross more than two lanes of traffic at a time before reaching a safe refuge? (3.5.5, 6.9.3)

24 If there are two or more traffic lanes for each direction, is there a refuge, at least 1.2 metres (and preferably 2.0 metres) wide, at locations where pedestrians are likely to cross? (6.9.3)

25 Are pedestrian crossings on collector streets controlled by traffic signals, if the AADT is above 7500 veh/day? (4.2.10,4.9.2)

26 Does every access street serving more than 100 dwellings or 200 working places have a footway (sidewalk)? (3.5.4, 3.5.5, 4.2.10)

27 Have all under or overpasses been so designed that the pedestrian will prefer to use the under or overpass rather than cross on the carriageway? (If necessary by installation of pedestrian fences to make the surface alternative longer.)(4.2.9,4.2.10,6.9.5)

28 Are there safe, attractive (e.g. shaded and well drained) segregated routes for pedestrians between major residential shopping, schools and work areas? (3.5.5)

(c) Cyclist Networks and Facilities

29 Do main bicycle ways avoid crossing arterial streets or can they do so using pedestrian under or overpasses? (4.2.10)

30 Have the crossing needs of cyclists been taken into account in detailed intersection design at locations where there are large numbers of cyclists? (4.1.20,4.2.10)

31 Do main bicycle ways cross streets only at locations where pedal cyclists can stop easily? (e.g. not on long downhills or at the bottom of a hill.) (4.1.20,4.2.10)

32 Are exclusive bicycle ways at least 2 metres in width? (4.1.20,4.2.10)

33 Are combined bicycle and pedestrian ways at least 2.5 metres in width? (3.5.5,4.1.20,4.2.10)

34 Are there segregated networks of footpaths/cycleways (preferably shaded from direct sunlight) providing alternative safe routes for cyclists? (3.5.5,4.1.20,4.2.10)

7.4 Checklist C: Highway Design

(a) Highway Link Design

1. Have estimates been made of vehicle speeds likely to occur on the highway section? (4.1.2)

2. Have estimates of current and future pedestrian usage been made and appropriate facilities provided for pedestrian safety? (4.1)

3. Has a geometric design procedure been used which takes into account the vehicle speeds which are likely to be found in practice? (4.1.1,4.1.2)

4. Are the stopping sight distances available along the road above the minimum values required for the estimated speeds? (4.1.3)

5. Are the radii of horizontal curves, with superelevation where required, above the minimum identified for the estimated speeds? (4.1.4,4.1.5)

6. Are the vertical curves adequate for the estimated speeds? (4.1.6)

7. Is the cross section adequate for the levels of traffic flow predicted? (4.1.5,4.1.9)

8. Do the combined geometric design elements produce a consistent and safe alignment? (4.1.1, 4.1.7)

9. Are the combined gradients on the cross sections and longitudinal sections sufficient to avoid standing water? (4.1.54.1.7)

10. Does the alignment allow regular overtaking opportunities? (4.1.3,4.1.8)

11. Have climbing lanes been introduced where necessary to provide adequate and safe overtaking opportunities? (4.1.3,4.1.8)

12. Will the road enable safe driving in darkness? (4.1.3,4.1.12,4.1.15,4.2.5,4.2.6,4.2.7)

13. Have centreline and edgeline markings been designed which give adequate guidance/control for drivers to position their vehicles and overtake safely? (4.1.3,4.1.9,4.1.12)

14. Will the design lead to reduced severity in the event of an accident? (4.1.10,4.1.11,4.1.13,4.1.14,4.1.17,4.1.18,4.1.19,4.1.20)

15. Has adequate provision been made for parked and stopped vehicles, including buses, so that they do not pose a danger to other road users? (4.1.9,4.1.16)

16. Have specific safety provisions been made for pedestrians walking both along and across the road? (4.1.3,4.1.9,4.1.10,4.1.11,4.1.15,4.1.17,4.1.18,4.1.19)

17. Have specific safety provisions been made for non-motorised traffic? (4.1.3,4.1.9,4.1.20)

18. Does the proposed cross section include hard or soft shoulders for broken down vehicles, buses etc? (4.1.9)

19 Are road edge obstructions, such as embankments, advertising hoardings, vegetation, buildings set back to provide sufficient forward visibility? (3.7, 4.1.3, 4.2.6)

20 Are crash barriers on the outside of bends provided where large drops (over 3 metres) in levels occur? (4.1.11)

21 Are crossing facilities with adequate advance signing provided at well sited locations on highways close to villages or agricultural fields where villagers (including animals) frequently cross? (4.2.10, 6.9)

22 Are pedestrians and non-motorised traffic discouraged from using rural roads, or are special provisions made for this traffic (this is more important on bypass sections to urban areas rather than on main inter-city roads which have traditionally been used by all types of road user)? (4.1.18,4.1.20)

23 Is there a means of controlling and authorising the provision of private access points onto the road network? (5.2, 5.6)

(b) Intersection Design

24 Will the intersection carry the design traffic load with an acceptable level of reserve capacity? (4.2.1)

25 Have the traffic and safety performance of alternative intersection designs been considered? (4.2.1,4.2.2,4.2.3,4.2.4)

26 Is the route through the intersection as simple and as clear to all users as possible? (4.2.2,4.2.3,4.2.4)

27 Is the presence of the intersection clearly evident at a distance to approaching vehicles from all directions? (4.2.2,4.2.3,4.2.4,4.2.5)

28 Are warning and information signs placed sufficiently in advance of the intersection for a driver to take appropriate and safe action? (4.2.5,4.2.6)

29 On the approach to the intersection, is the driver clearly made aware of the actions necessary to negotiate the intersection safely? (4.2.5,4.2.6,4.2.7)

30 Are the different turning movements sufficiently segregated for capacity and simplicity of action by the driver? (4.2.7,4.2.8)

31 Are lane widths and swept paths adequate for all vehicle movements and all vehicle types? (4.2.1, 4.2.2, 4.2.5, 4.2.7)

32 Do the decisions which need to be made by a driver follow a simple, logical and clear sequence? (4.2.6,4.2.7,4.2.8)

33 Are the drainage features sufficient to avoid the presence of standing water? (4.2.2,4.2.3,4.2.4)

34 Is the level of lighting adequate to identify the intersection at night? (4.2.2,4.2.3,4.2.4,4.2.5)

35 Is the level of lighting adequate to silhouette pedestrian and other movements? (4.2.9)

36 Are sight lines sufficient and clear of obstructions, including parked and stopped vehicles? (4.2.5)

37 Are accesses prohibited within 50 metres of the intersection? (4.2.2,4.2.3,4.2.4)

38 Have adequate special facilities been provided for pedestrians (footways, refuges, crossings, etc)? (4.2.9)

39 Have adequate special facilities been provided for cyclists and other non-motorised users? (4.2.10)

40 Where roads cross, does the design clearly identify rights of way and priorities? (4.2.2,4.2.3,4.2.4)

41 Is the design of the intersection consistent with the road types and adjacent intersections? (4.2.1)

42 Are there gaps in central islands of sufficient size to store waiting/turning traffic? (4.2.2)

7.5 Checklist D: Countermeasures Related Activity

1. Do you have access to accident data? (6.2)

2. Does your accident data system record

   (a) details of all injury accidents? (6.2)
   (b) detailed accident locations? (6.2)
   (c) site details of accident locations? (6.2)

3. Is your accident data system computerised? (Appendix C)

4. Do you have staff whose primary task is to deal with road safety matters and to carry out road safety improvements at accident blackspots? (6.3)

5. Do you identify blackspots on the basis of accident data? (6.3)

6. Can you identify precisely the worst accident blackspot locations? (6.3)

7. Do you carry out site visits to blackspots and collect detailed site information? (6.4)

8. Do your site visits include walking/cycling/driving through the site from all directions at times when accidents most frequently occur? (6.4)

9. Do site visits take place at times and in weather/lighting conditions when accidents occur? (6.4)

10 Do you have access to detailed police reports for accidents at blackspots? (6.4)

11 Do you prepare collision diagrams for accident blackspots? (6.4)

12 Do you analyse accident data to produce accident grids and stick diagrams from which dominant accident types are identified? (6.4)

13 Do you check with historical records whether identified accident types may be related to any changes which have occurred at the site? (6.4)

14 Do you select countermeasures in response to problems? (6.6)

15 Do you identify and evaluate a range of possible countermeasures in the light of local experience? (6.6)

16 Do you implement schemes on an experimental basis initially using temporary materials? (6.6)

17 Do you monitor the effects of your countermeasures in terms of

   (a) accidents? (6.5)

   (b) road user behaviour? (6.5)

18 Do you produce an annual report recording the road safety activities undertaken, the sites treated and the expenditure incurred? (6.5)

PART V

APPENDICES

APPENDIX A
KEY REFERENCES

1. Roads and Traffic in Urban Areas (1987). Institution of Highways and Transportation and Department of Transport, UK.

2. Highway Safety Guidelines - Accident Reduction and Prevention (Second edition 1986). (International edition 1990). Institution of Highways and Transportation, UK.

3. Traffic Signs Manual (published Chapter by Chapter) Department of Transport, UK.

4. Overseas Road Note 6 - A guide to geometric design (1988). Overseas Unit.

5. Accident Investigation Manual (Volumes 1 and 2) (1986). Department of Transport, UK.

6. Planning for Road Safety (1984). Department of Transport Office of Road Safety, Australia.

7. Manual on Urban Transportation Planning Land-Use and Road Safety (1988). National Road Safety Council, Kenya.

8. Manual of Accident Prevention using Low-Cost Engineering Countermeasures (1988). National Road Safety Council, Kenya.

9. Handbook of Highway Safety Design and Operating Practices (1978). Federal Highway Administration, Department of Transportation, USA.

10. Design Bulletin 32. Residential Roads and Footpaths (1977). Department of Transport, UK.

11. Providing for the Cyclist (1983). Institution of Highways and Transportation, UK.

12. Road Maintenance Handbook (1982). United Nations Economic Commission for Africa (English language version available from TRL).

13. Guidelines for: The Safety Audit of Highways (1990). Institution of Highways and Transportation, UK.

14. Guidelines for: Urban Safety Management (1990). Institution of Highways and Transportation, UK.

15. Hazardous Road Locations: Identification and Countermeasures (1976). OECD, Paris.

16. Road Safety Manual on Low Cost Engineering Countermeasures (1990). United Nations Economic Commission for Africa, Ethiopia.

17. Manual of Road Lighting in Developing Countries (1990). Institution of Lighting Engineers/ TRL , UK.

Sources of Key References

Refs 1, 3 & 15:	HMSO Publications Centre, P O Box 276, London SW8 5DT, UK (mail order).
Refs 2,11 & 13:	Institution of Highways & Transportation, 3 Lygon Place, Ebury Street, London SW1W 0JS, UK.
Refs 3 & 10:	Department of Transport, 2 Marsham Street, London SW 1, UK.
Refs 4,12 & 17:	Overseas Unit, TRL , Crowthorne, Berkshire RG11 6AU, UK.

Ref 5:	Royal Society for the Prevention of Accidents, Cannon House, The Priory, Queensway, Birmingham B4 6BS, UK.
Ref 6:	Australian Government Publishing Services, Canberra, Australia.
Refs 7 & 8:	National Road Safety Council, Nairobi, Kenya.
Ref 9:	Superintendent of Documents, US Government,Printing Office, Washington DC 20402, USA.
Ref 16:	United Nations Economic Commission for Africa, PO Box 60075 Addis Ababa, Ethiopia.

USEFUL BACKGROUND DOCUMENTS FROM UK

The following are the main UK Department of Transport Departmental Standards, Advice Notes and British Standards related to road safety. These provide detailed guidance and advice for UK engineers responsible for road planning, design and construction. They can be acquired by post from the sources given at the end of this section.

Departmental Standards

HD 3/80	Specification for road and bridge works: texture depth of bituminous surfacings for high speed roads.
HD 15/87	Skidding resistance of in-service Trunk roads.
TD 6/79	Transverse yellow bar markings at roundabouts.
TD 9/81	Road layout and geometry - highway link design.
TD 14/83	Signing for traffic management at certain major road works sites.
TD 16/84	The geometric design of roundabouts.
TD 19/85	Safety fences and barriers.
TD 22/86	Layout of grade separated junctions.
TD 23/87	Pedestrian crossings: pelican and zebra crossings.
TD 29/87	Mobile or short duration static lane closures.
TD 30/87	Design of road lighting for all purpose roads.

Advice Notes

HA 8/80	Specification for road and bridge works: texture depth of bituminous surfacings for high speed roads.
HA 36/87	Skidding resistance of in-service Trunk roads.
TA 4/80	Access to highways - safety implications.
TA 6/80	Traffic signs and safety measures for minor works on minor roads.
TA 8/80	Carriageway markings: markings for right-turning movements at cross-road junctions.
TA 12/80	Traffic signals on high speed roads.
TA 15/81	Pedestrian facilities at traffic signal installations.
TA 16/81	General principles for control by traffic signals.

TA 18/81	Junction layout for control by traffic signals.
TA 19/81	Reflectorisation of traffic signs.
TA 20/81	Junctions and accesses: the layout of major/ minor junctions.
TA 23/81	Junctions and accesses: determination of size of roundabouts and major/minor junctions.
TA 24/81	Road safety during installation and maintenance of permanent traffic signals and related equipment on all-purpose roads.
TA 28/82	Layout of roads in rural areas: a guide to revisions 1982.
TA 32/82	Roads in urban areas: revisions subsequent to 'A guide to revisions 1979'.
TA 42/84	The geometric design of roundabouts.
TA 43/84	Highway link design.
TA 48/85	layout of grade separated junctions.
TA 49/86	Appraisal of new and replacement lighting on Trunk roads and Trunk road Motorways.
TA 52/87	Design considerations for pelican and zebra crossings.
TA 54/87	Signing and illumination of road humps: 2-way, 2-lane single carriageway roads.
TA 55/87	Mobile or short duration static lane closures.

British Standards

BS 5489	Code of practice for road lighting: Parts 1 and 2.

Sources of Background UK Documents are:

Departmental Standards and Advice Notes:

Department of Transport,

Publications Sales Unit,

Building One,

Victoria Road,

South Ruislip, Middlesex.

HA4 ONZ, UK.

British Standards:

HMSO Publications Centre,

P O Box 276,

London SW8 5DT, UK.

APPENDIX

CHECKLISTS FOR ACCIDENT INVESTIGATION AT BLACKSPOTS

The following pages contain lists of questions which should be asked by the accident investigator carrying out accident analyses at blackspots. A few, commonly occurring accident types have been chosen to illustrate the concept. For each, a series of questions are posed which will help the investigator to identify potential problems at sites of this type so that appropriate countermeasures can be devised. These are targets based on the types of questions used in references 5 and 13.

It is strongly recommended that these lists of questions be expanded and developed in a local context, to suit local conditions. What is presented here is a starting point on which to build. For illustrative purposes questions have been devised for the following types of accident blackspot which are commonly found in many developing countries.

A Pedestrian accidents at ribbon developments and trading centres.

B Accidents at bends.

C Accidents on crests.

D Nose-to-tail collisions.

E Accidents at intersections

(a) overshooting at stop/give way controlled intersections

(b) restarting from stop/give way lines (single carriageway)

(c) restarting from stop/give way lines (dual carriageway)

(d) accidents at roundabouts

(e) accidents at traffic signals.

Similar lists should be developed for all commonly occurring accident situations in each particular country.

A. PEDESTRIAN ACCIDENTS AT RIBBON DEVELOPMENTS

(where a major through road passes through a small rural community or trading centre)

1. Are the footways adequate for the levels of pedestrian traffic?

2. Do market stalls and street traders encroach onto footways forcing pedestrians onto the road?

3. Are footways well maintained and separated from the carriageway by a drainage ditch or kerbing, so that pedestrians are not forced or encouraged to walk on the carriageway?

4. Are sufficient pedestrian crossing facilities provided and are they at locations where the greatest numbers of pedestrians wish to cross?

5. If many accidents occur at night, is adequate street lighting provided such that pedestrians and other vehicles are clearly visible?

6. Is the road alignment consistent with a low speed, conducive to pedestrian safety?

7. Is there a speed limit and is it suitable for the area through which the road passes?

8. Is the observed 85 percentile speed above the speed limit?

9. Do signs and markings warn drivers of the roadside development ahead?

10 Is adequate off-street parking provided so that stopped or stopping vehicles do not interfere with the through traffic movements?

11 Is there a need for physical speed reducing devices to be installed to reduce speeds of through traffic?

12 Can physical speed reducing devices be installed?

13 Can pedestrian crossings be incorporated into road humps to create raised crossings?

14 Do pedestrian fences need to be installed to channel pedestrians to safe crossing points?

B. ACCIDENTS AT BENDS OR CURVES

1. Are there single vehicle accidents?

2. Are the speed limits realistic?

3. Is there adequate advance warning of the bend ahead? Are there bend warning signs, are they reflectorised and large enough to be seen, is SLOW painted on the road?

4. Are there chevron boards at the bend? Are they large enough and reflectorised, are they in the correct position?

5. Are there delineators or painted edge-markings to guide the driver?

6. Are there lighting columns? Do they give a false impression of layout either by day or by night?

7. Is the crossfall correct for the location? Is there a need for superelevation? Are any transitions satisfactory?

8. Is surface texture depth and skid resistance appropriate for the speeds of traffic?

9. Are there head-on collisions? Are there adequate centre lines indicating no overtaking? Can central hatching be provided? Is a median necessary?

10 Are overtaking vehicles involved? Can centre lines prohibiting overtaking be extended to discourage overtaking near the bend? Is the main traffic stream impeded by slow vehicles? Can the carriageway be widened or a "crawler" lane be provided?

11 Is there encouragement to overtake immediately before the bend due to earlier narrow road, heavy traffic, slow moving vehicles?

12 Can overtaking opportunities be provided well before the bend?

13 Does the road widen on the approach to the bend? Can this be narrowed by hatching?

14 Is the speed restriction raised on the approach to the bend? Should this sign be resited after the bend?

15 Does the carriageway marking change from two to three or four lanes on the approach to the bend? Are the lanes wide enough?

16 Should the change in carriageway marking be delayed until after the bend?

17 Is the bend shrouded in darkness by day or night? Do earth banks, high hedges or trees need to be removed to increase visibility?

18 Does the carriageway drop away at or near the bend and conceal the direction and layout of the road ahead? Can hedges or marker posts be raised to delineate the road?

C. ACCIDENTS ON CRESTS

1. Answer all the questions in Section B with slight amendment as necessary.

Note:

The basic problem lies in the fact that the oncoming vehicles can be hidden until the last moment. The risk increases where the gradient on the far side is steeper than that on the approach side and where the carriageway is visible in the distance but obscured in the foreground.

D. NOSE-TO-TAIL COLLISIONS

1. At intersections (not controlled by automatic traffic signals) do the accidents occur on the main road?
2. Do they involve collisions with vehicles turning or waiting to turn across a traffic stream into a side road or to make a U-turn?
3. Can a lane be marked exclusively for such turners?
4. Can a turning lane be protected by providing a ghost island?
5. Can a median and filter turning lane with adequate space be provided?
6. Do such turns across the traffic stream need to be banned?
7. Do they involve collisions with diverging traffic?
8. Can the inside lane be reserved for diverging turners?
9. Can a deceleration lane be provided?
10. Can some of the gaps in the central reservation be closed and safe protected turning lanes be provided at a reduced number of locations along that road?

E. ACCIDENTS AT INTERSECTIONS

(a) Overshooting at stop/give way controlled intersections (i.e. failure to stop at line when required)

1. Is there a stop/give way line? Is it visible and located correctly?

2. Are there lane markings and direction arrows in the lanes and are they visible?

3. Is there a stop/give way sign of the correct size? Is it reflective and located so that it is clearly visible?

4. Is the sign obscured or difficult to see amidst excessive advertising billboards and other signs?

5. Does the sign need to be moved to make it more conspicuous?

6. Is there an advance warning sign sited further back on the approach to the intersection?

7. Is there a central refuge in the side road with an arrow to increase conspicuity of the intersection?

8. At a crossroads can the straight ahead view from the minor road be broken by slightly offsetting the refuge island so that drivers realise there is an intersection ahead?

9. Are there map type advance direction signs on the approaches to the intersection to give advance warning and information?

10 Is the driver on the minor road misled into believing there is no intersection ahead because of rows of trees, telegraph poles, walls, hedges, etc?

11 Can the continuous lines of perspective along the minor road be broken by resiting of poles, staggering of central refuges, landscaping or other means to prevent a clear view straight over the main road?

12 Can intersection conspicuity be improved by use of larger signs, painting refuges and guide islands, etc?

13 Is the intersection obscured by vertical or horizontal curvature? If so, can advance warning signs, or "slow" markings on road etc. be used to warn approaching motorists?

14 Do observations and studies reveal heavy braking? If so are speed limits realistic? Is skid resistance and road texture appropriate for expected speeds?

(b) Restarting from stop/give way line (when entering single carriageway)

Note:

It is most important to differentiate between RESTART accidents and OVERSHOOT accidents because they require quite different treatment, despite the fact that both types are often classified as "failure to stop/give way" in police records. It is necessary to study the actual statements made to the police and/or to carry out an on-site conflict check and observations over several days in order to determine which of the two types are occurring. Where both types occur there are two quite separate problems to be dealt with.

1. Is there a clearly defined stop/give way line? Is it positioned right up to the edge of the main carriageway to maximise the view of the emerging driver but without exposing emerging traffic to danger?

2. Is the line excessively thick (e.g. several layers of thermoplastic) or slippery such that it can cause difficulty for cycles and slow moving vehicles or wheel slip resulting in start delays?

3. Is there a stop/give way sign and is it positioned correctly?

4. Is there a central refuge in the wide road? Does it obstruct the drivers' view or encourage the driver to stop too far back from the main carriageway, thus causing danger when he emerges? Can the refuge be moved to a point 3 m from the edge of the main carriageway?

5. Is the drivers' view to the right and/or left obscured by foliage, walls, hedges, grass, etc and can his visibility be improved?

6. Does the side road meet the main road at a sharp angle? Can the side road be realigned to avoid this or the driver positioned via road markings or refuges to minimise difficulties?

7. Are intersection warning signs provided on the main road and can intersection conspicuity be improved when viewed from the main road?

8. Are overtaking vehicles on the main road involved? If so can overtaking be reduced by providing ghost islands or hatching to reduce traffic to a single lane?

9. Do accidents occur when main road traffic flows are heavy? Are emerging drivers accepting small gaps due to excessive delays? If so, should a mini roundabout or traffic signal control be provided, or should high risk movements be banned altogether?

(c) Restarting from stop/give way line (entering a dual carriageway)

1. Answer questions 1-9 of section (b) above.

2. Is the median gap wide enough to provide safe storage? Are there collisions with protruding vehicles? Can large vehicles be rerouted or the median widened?

3. Are there collisions between traffic emerging from the median gap and approaching main road traffic? If so, is the view from the median obscured by foliage or other queueing vehicles?

(d) Accidents at roundabouts

1. Is there adequate advance warning of a roundabout ahead? Are there map type direction signs and advance warning signs on all approaches with SLOW painted on the road?

2. Are there collisions with the central refuge? If so, check if the deflection is too sharp, that the roundabout is not concealed by a bend, a crest or a bridge pier and that the kerbs round the centre island are painted black and white to increase conspicuity.

3. Is there over-running of the central island? Are advance warning signs located well enough back and can conspicuity of the island be improved by provision of chevron boards, planting bushes to obstruct view of road beyond island or painting kerbs?

4. Are approach speeds too high? Can they be reduced by using transverse yellow lines or rumble strips?

5. Do vehicles fail to negotiate the roundabout? Is the line of entry smooth? Is the skid resistance and texture depth appropriate for expected speeds? Is the crossfall satisfactory, especially on transitions as approach road becomes the roundabout?

6. Are there accidents on the exit from the roundabout? Is the exit smooth? Are there too many weaving difficulties? Is the exit obstructed by bus stops, pedestrian crossings, queueing vehicles, pedestrians or paratransit? If so, can they be removed?

7. Are there accidents resulting from weaving movements? If so check that entry radii, weaving lengths, exit radii central island diameter and lane widths, are correct for the volumes of traffic expected. Does the roundabout need to be replaced by a different type of intersection?

8. Are there accidents resulting from failure of drivers entering the roundabout to give way to traffic on the roundabout? If so, is the view of entering traffic obstructed? Is the deflection inadequate?

(e) Accidents at automatic traffic signals

1. Did the accidents occur when signals were awaiting maintenance/repair? Can maintenance response times be improved?

2. Are the timings appropriate to the present distribution of traffic flows? Can settings be modified to ease difficulties of drivers making high risk movements (i.e. those manoeuvres most frequently involved in accidents)?
3. Do drivers overshoot the red signal other than at the beginning or end of the phase? If so, is the signal head clearly visible to approaching motorists and is there adequate advance warning approaches?

4. Is the approach speed of the vehicle on the commencing red phase in excess of 30 mph (50 km/h)? If so, check that there is. sufficient inter-green time to allow the intersection to be cleared before the opposing flow is given a green signal and that waiting vehicles on the opposite phase are clearly visible.

5. Are there accidents involving turning vehicles?

   Note:

   It is necessary to consider the accidents which occur at the beginning, middle and end of the GREEN phase separately (see 7 and 8 below).

6. Do the turning accidents occur at the beginning of the GREEN phase? Does the intersection cover a wide area and does this encourage turning traffic to try to beat oncoming traffic? Is the intersection small and does that cause problems for turning traffic? Can oncoming traffic be held by the use of the "delayed start"?

7. Do turning accidents occur in the middle of the GREEN phase? Is the oncoming traffic travelling at a fast speed which turning traffic misjudges? Is the view of the turning drivers obscured? so, can any obstructions be resited? Can a separate phase be provided for turning traffic or can traffic management measures be devised to avoid turns across the traffic stream?

8. Do traffic accidents occur at the end of the GREEN phase? Do accidents involve opposing vehicles trying to beat the signal or turning traffic attempting their manoeuvre without pausing? C) an "early cut off' facility be used to hold one of the conflicting flows?

9. Do many nose-to-tail collisions occur? Is there adequate advance warning of the intersection? Is it possible to provide protected turning bays? Is the skid resistance on approach roads adequate for expected speeds?

APPENDIX C

MICROCOMPUTER ACCIDENT ANALYSIS PACKAGE

TRL OVERSEAS UNIT

As part of its research programme, the Overseas Unit of TRL has developed a Microcomputer-based road Accident Analysis Package designed for use in less developed countries.

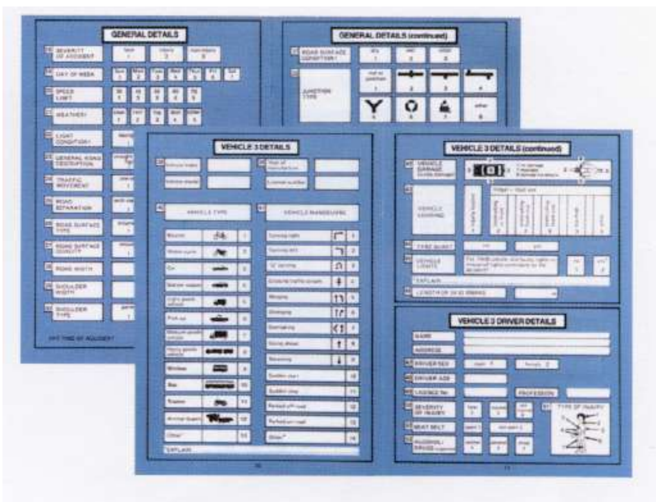
It was originally designed for use at ‘local highway authority' level (county, state, governorate, large city, etc) where up-to-date information on local accident patterns are required on a day-to-day basis.

Ease of use

In developing the package, particular emphasis has been placed on making it easy to use, with the operator merely having to select one of a number of options ('menu-driven') and thus requiring minimal knowledge of computers.

Data recording

A `model' accident report form has been developed for use by the police or accident reporters attending the scene of an accident. This form has been designed to be attractive and easy to fill in and contains all the information considered necessary for accident investigation and the evaluation of remedial measures implemented. The package can, however, be configured to other report form layouts with different features recorded; the aim being to enter accident details directly onto the microcomputer, without the need to transcribe data onto



separate coding sheets. The operator is simply asked for each item of information in sequence, and various logical and range checks are made by the computer to help ensure it is a valid entry.

Hardware

The package will operate on all IBM-compatible machines running DOS but there are different versions available for other systems. The accident data are stored on hard-disk or on 5 1 /4 inch or 3 1 / 2 inch floppy disks with a regular backup facility for files available, normally to floppy disks. This enables datasets to be supplied easily to a central agency or to bodies with road safety responsibilities. A high density diskette can now store about 5000 accident records.

Cross tabulations

N/S CASUALTY TABLE 1 TYPE A:ALL CASUALTIES

ACCIDENT RECORD FILES: PORTS
CONDITIONS SET: NONE

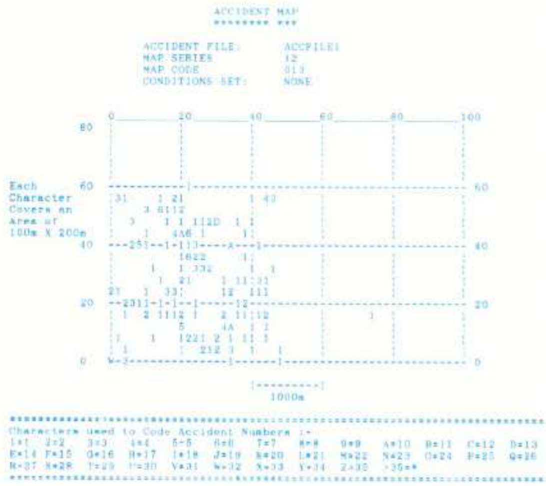
AGE	Ped'n	Cycle	Moped	Scoot	M/Cyc	Combo	InvTr	3WCar	Taxi	Car	Other	Total
					CLASS OF ROAD USER							
0-5	48	4	0	0	0	1	0	1	0	29	6*	89
6-10	90	29	1	0	0	0	0	0	0	30	0*	150
11-15	96	160	2	0	0	0	0	1	1	18	4*	282
16-20	73	184	211	48	299	2	0	4	2	193	11*	1027
21-25	51	115	36	5	171	1	0	1	1	199	18*	598
26-30	30	62	11	0	55	2	0	4	2	86	14*	266
31-35	27	36	15	2	32	0	0	2	2	64	12*	194
36-40	15	44	16	2	28	0	0	1	7	62	12*	187
41-45	15	29	7	1	13	0	0	1	3	57	8*	134
46-50	16	25	13	2	13	0	0	0	4	44	17*	134
51-55	13	28	6	1	7	0	0	0	2	44	9*	110
56-60	16	17	6	2	13	0	0	1	0	21	7*	86
61-65	23	14	3	2	4	0	0	1	0	35	11*	93
66-70	33	13	3	0	1	0	0	1	0	24	14*	89
71-75	29	8	2	0	3	0	1	0	0	14	6*	63
>75	66	9	0	0	0	0	0	0	0	28	16*	119
Total	641	779	332	65	639	6	1	18	24	951	165*	3621

(Total Number of Casualties on File = 3621)

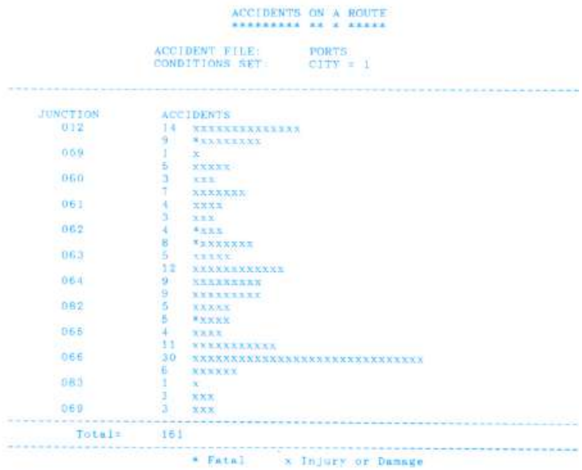
These are an important tool for those investigating the nature and cause of road accidents. Tables of frequencies or percentages can be produced for (1) ACCIDENTS, (2) CASUALTIES, or (3) VEHICLES. For each of these three types, the operator may either select pre-defined standard cross-tabulations, or he may ask for his own special tabulations

Accident Maps

A facility is provided to produce accident frequencies plotted on a simple grid coordinate system. Printouts of these can be overlaid onto the existing map of the local 40 road system to visually determine where blackspots exist. Enlargements of areas on the displayed map, typically by four times the scale, can be immediately produced.

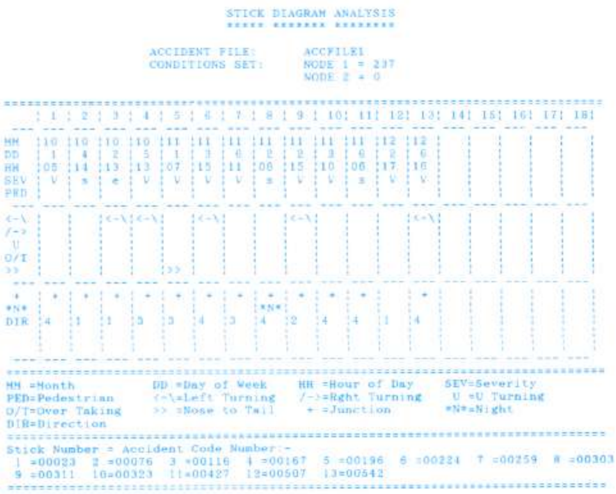


It is also possible to produce graphical representations accidents that have occurred along a particular road or route across a city, or by numbered kilometre posts where these are available along a rural road.



Stick diagrams

For accidents at one particular location, stick diagrams are frequently used by traffic engineers to display the key features in the form of a column (or stick) of data. The operator can choose from a number of different sticks and can sort the variables into any specified order.



STICK DIAGRAM ANALYSIS

ACCIDENT FILE: ACCFILE1
CONDITIONS SET: NODE 1 = 237
NODE 2 = 0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MM	10	10	10	10	11	11	11	11	11	11	11	12	12					
DD	1	4	2	5	1	3	6	2	2	3	6	2	6					
HH	05	14	13	13	07	15	11	00	15	10	06	17	16					
SEV	V	s	e	V	V	V	V	s	V	V	s	V	V					
PED																		
<-\			<-\	<-\		<-\			<-\				<-\					
/->																		
U																		
O/T																		
>>					>>													
+	+	+	+	+	+	+	+	+	+	+	+		+					
N								*N*										
DIR	4	1	1	3	3	4	3	4	2	4	4	1	4					

MM =Month DD =Day of Week HH =Hour of Day SEV=Severity
PED=Pedestrian <-\=Left Turning /->=Rght Turning U =U Turning
O/T=Over Taking >> =Nose to Tail + =Junction *N*=Night
DIR=Direction

Stick Number = Accident Code Number:-
1 =00023 2 =00076 3 =00116 4 =00167 5 =00196 6 =00224 7 =00259 8 =00303
9 =00311 10=00323 11=00427 12=00507 13=00542

Retrieval of accident records

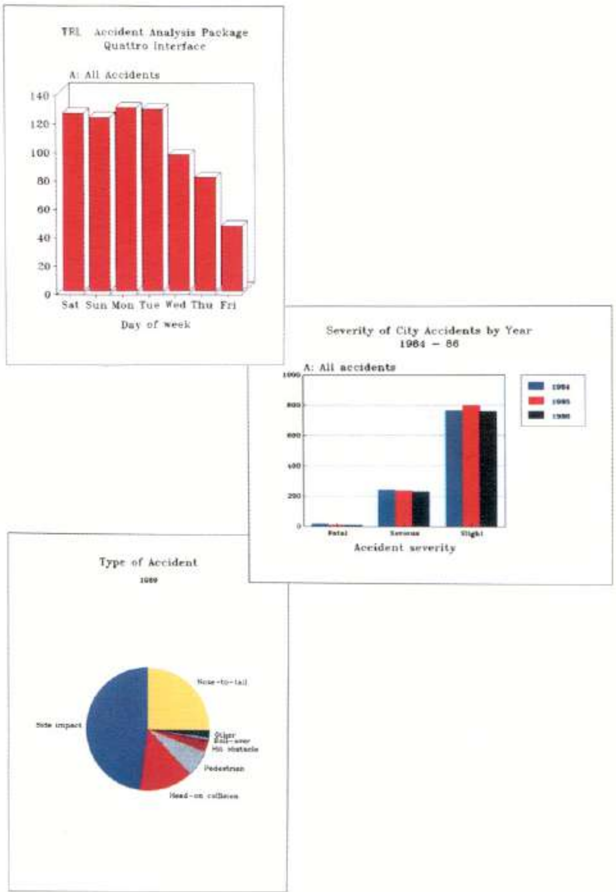
The package can provide a priority listing of the worst accident sites in a city or area. Accident reference numbers can be quickly obtained and individual records displayed or printed.

Dual language versions

By simply pressing a control key, the current computer screen of menus or results can be immediately displayed in another language. French or Spanish versions are available from TRL but text files can be easily translated into any other language by the user.

Export of summary tables to other packages

The cross-tabulation data can be exported as an image or comma-delimited Ascii file making it available for import by various other software packages. An interface to Borland's QUATTRO, an inexpensive spreadsheet package, has been produced so that good graphical outputs of the tables (in the form of bar graphs or pie charts) can be achieved easily and without the need for any prior knowledge of this package.



If you would like any further information about the package, please write to:

The Overseas Unit
Crowthorne
Berkshire RG11 6AU
Great Britain

INDEX

Most of the words listed below appear in many parts of the text, because of the inter-related nature of many road safety concepts. The index lists only those pages where the topic is discussed as one of the primary issues and where a reader can turn for first reference on a subject. Further reading is suggested within each section in the boxes listing internal cross references and external documents.

D

E

F

Towards Safer Roads in Developing Countries

QUESTIONNAIRE

Request to be included on TRL Mailing List

Name ………………………………………………. ***Position*** ……………………………………………..

Organisation ……………………………………………………………………………………………....

Type of activity (e.g. Government Highway Authority) ……………………………………………….

………

Address …………………………………………………………………………………………………....

………

………

It would be very beneficial if you could complete the following questionnaire and send us your comments on the first edition. This will help us to make later editions even more relevant to the problems and needs of developing countries.

A . General background information

1. Does your organisation have easy access to reliable accident data to enable you to identify and improve accident blackspots?

………

2. Do you know (from accident data) where the worst accident blackspot sites are on your road network?

………

………

3. Do you do or have you done accident blackspot improvement work on a regular basis?

………

………

4 Does your organisation have a team working full-time on road safety improvements?

………

5. What low cost countermeasures have been particularly sucessful in your country? (If possible send details and before and after data showing the reductions in accidents as a result of the countermeasures.)

………

………

………

B. *Comments on the 1st Edition.*

(If space is insufficient, please continue onto other sheets if you wish and just attach them to this page.)
If possible refer to specific sections or page numbers of the 1st Edition when making comments.

C. *Request for photographs/slides and illustrations for future editions*

We would like to illustrate the next edition with further examples of "good" and "bad" practice from the developing world. If you have any information, photographs or slides (35 mm) which you think may be worth including in a future edition we would be most grateful if you would send them to us. Regretfully, we will not be able to return these to you so you should send only copies of such materials that we may keep in our files for potential future use. Each item should be clearly marked on the back with location, what is being shown, a suggested caption and name of person or organisation supplying the picture.

D. *Once completed, this questionnaire should be sent to:*

Overseas Unit,
Crowthorne, Berkshire,
RG11 6AU, United
Kingdom.

Notes

Notes