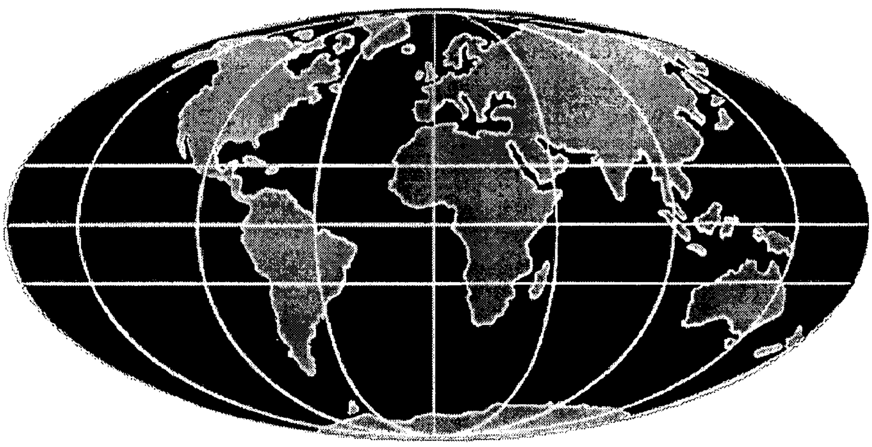
TRANSPORT RESEARCH LABORATORY

TITLE: Engineering Approach to Accident Prevention and Reduction

by: A Downing and H Iskandar



Overseas Centre
Transport Research Laboratory
Crowthorne
Berkshire RG45 6AU
United Kingdom

PA3304/97

PA33304/97 DOWNING, A and H ISKANDAR (1997).**Engineering approach to accident prevention and reduction.** *KRTJ-5, Yogyakarta, 22-24 September,1997*

Republic of Indonesia
Ministry of Public Works
Agency for Research and Development
Institute of Road Engineering

Road Research Development Project

Published Paper PA 6

ENGINEERING APPROACH TO ACCIDENT PREVENTION & REDUCTION

by

Andrew Downing
Hikmat Iskandar

Paper (Indonesian version) presented at the 5th Konferensi Regional Teknik Jalan (KRTJ-5), 21-24 September 1997, Yogyakarta, Indonesia.

TRANSPORT RESEARCH LABORATORY

Transport Research Laboratory, United Kingdom. *in association with* PT Yodya Karya, Indonesia.

ENGINEERING APPROACH
TO ACCIDENT PREVENTION & REDUCTION

List of Contents

		Page No.
	ABSTRACT	1
1.	INTRODUCTION AND OBJECTIVES	1
2.	THE MAGNITUDE OF THE ROAD ACCIDENT PROBLEM	2
3.	TOWARDS SAFER ROADS	3
	3.1 An Integrated and Scientific Approach	3
	3.2 Accident Prevention and Reduction	5
4.	ROAD ACCIDENT PREVENTION BY IMPROVED PLANNING AND DESIGN	5
	4.1 Background	5
	4.2 Safe planning of roads	6
	4.3 Safe design of roads	12
5.	ACCIDENT REDUCTION	18
6.	EVALUATION OF ROAD SAFETY IMPROVEMENTS	22
7.	CONCLUSIONS	24
8.	ACKNOWLEDGEMENTS	24
9.	REFERENCES	24

ENGINEERING APPROACH
TO ACCIDENT PREVENTION & REDUCTION

by

A J Downing, Transport Research Laboratory
H Iskandar, Institute of Road Engineering

ABSTRACT

Although road accidents are usually blamed on road users, it is evident that poor planning and road design will often have contributed to or compounded these errors. Indonesia, in common with other rapidly developing countries, has problems with inappropriate development along highways and outdated design standard. The introduction of modern accident prevention and reduction approaches should therefore have considerable potential for saving lives, injuries and property damage in Indonesia.

The Institute of Road Engineering (IRE) has in collaboration with the Transport Research Laboratory (TRL), UK, initiated the development of a Microcomputer Accident Analysis Package and a black spot investigation and treatment methodology which has been applied in four trial areas. Also TRL has produced a Guide, Towards Safer Roads, and slide pack for planners and engineers to encourage both the safe planning and design of new road (Accident Prevention) and the effective treatment of existing roads (Accident Reduction). Indonesia has made a sound start but, given the rapid road development, these safety conscious approaches need to be adopted nationwide before it is too late.

This paper outlines some of the key principles of the TRL Guide. For example, land use planning and zoning to reduce travel and exposure of vulnerable groups to traffic, restricted access to arterial roads and avoidance of ribbon development, the establishment of road hierarchies with real functional and design differences, the provision of safe facilities for vulnerable road users, improved delineation and control of overtaking and speed. The principles are supported with examples and some evidence from case studies from Indonesia and South East Asia.

1. INTRODUCTION AND OBJECTIVES

Studies of police road accident records show that, in all countries, the police typically identify the main cause of road accidents as human error. Indonesia is no exception with most of the accidents in 1995 being attributed to human error, and very few to road problems. Does this means engineers have no role to play in road safety ? No, far from it; in many motorised countries engineers have led the attack on road accidents with outstanding success. Why then should engineers play a leading role in road safety ? There are four key reasons as follows.

1). Inconsistencies and complexities in the road design and road network will significantly increase the difficulty of the road users' tasks and result in more road accidents.

2). Inappropriate planning of the road network in relation to land use and road function will unnecessarily expose road users, particularly the vulnerable, to the risk of road accidents.
3). Research in many countries (Downing, 1997) has shown that road planning, design and engineering countermeasures can lead to significant accident reductions and provide a more forgiving environment thus reducing the severity of injuries.
4). Road engineering improvements are relatively straightforward to implement and they usually have an immediate effect.

Generally, road planners and engineers in the highly motorised countries have learnt from the mistakes made in the past and realised the potential of road safety conscious planning and design. However, most of their counterparts in developing countries are often still preoccupied with the problems of road construction and maintenance and increasing the network capacity. Thus, all too frequently, roads and road systems are being built or upgraded with little consideration given to road safety. As a result 'black spots' and 'black links' are created and many road users are being killed or injured unnecessarily. Therefore, the purpose of this paper is to bring road safety to the forefront of the minds of planners and engineers and to give examples of the key safety principles of accident prevention and reduction.

The paper highlights the magnitude of the road accident problem in Indonesia and summarises some of the key principles from two key manuals ie the Transport Research Laboratory's (TRL, 1991) "Towards Safer Roads in Developing Countries" and from the "Interim Manual on Accident Investigation Procedures and the Development of Low-Cost Engineering Improvement Schemes" produced jointly by Pusat Litbang Jalan (IRE) and TRL (TRL/IRE, 1993).

It is important that these principles and approaches are verified in Indonesia conditions and the paper concludes with a review of the results of some road safety studies in the South East Asian region.

2. THE MAGNITUDE OF THE ROAD ACCIDENT PROBLEM

The reported road accident statistics from the Indonesian Traffic Police Headquarters are shown in Table 1 together with vehicle data and an estimate for the 1995 casualties allowing for under-reporting of accidents by the public.

From the table it is clear that vehicle registrations have increased by over 70 per cent from 1986 to 1995 whereas reported accidents have declined by 60 per cent, thus the accident rate has dropped from 57 in 1986 to only 13 in 1995. The fatality rate has also declined but much more slowly than the accident rate and numbers of deaths have remained fairly stable with 1994 and 1995 having the highest figures in the last ten years.

These figures overall look promising but there are two worrying features ie 1) the number of casualties per reported accident increased steadily from 1986 to 1993 and 2) the fatality index or the percentage of casualties who die in road accidents has increased steadily over the last 10 years to a level which is nearly double that of ten years ago. These trends indicate that the accidents reported to the police are becoming more serious. This finding may reflect a real change in Indonesia, for example there may be an increase in the involvement of public service vehicles in accidents or vehicle occupancy levels may be increasing with a corresponding increase in passengers killed or injured. Alternatively, and this seems more likely, there may be a change in the public's accident reporting behaviour with an increasing tendency to report only the most serious accidents. Under reporting is clearly a characteristic of the road accident statistics in Indonesia and even deaths from road accidents are under estimated as the statistics are not updated for victims who die after they have been removed from the scene of the accident.

The Highway Capacity Manual Project (SweRoad/Bina Marga, 1995) attempted to estimate the real magnitude of the problem in Indonesia using typical ratio's of Fatalities to other severities of casualties based on Swedish experience. It was assumed that the minimum increase in fatalities was 50 per cent (similar to the Indonesia insurance claim statistics) and then other casualties were calculated using multipliers of the number of deaths. In Table 1 the same approach was used but the multipliers were based on those which applied to the UK in 1927 as these give a more conservative estimate of the number of casualties in relation to deaths. With these figures there were an estimated 478,065 casualties in Indonesia in 1995 compared with only 32,804 reported to the police ie 93 per cent of the casualties are missing from the national statistics. This figure must be treated with caution and research is needed to compare hospital and medical cases with police cases to obtain a more reliable estimate of the real problem. Nevertheless the national statistics, even without correction, show a very serious problem as regards the fatality rate which is more than six times higher than that of the UK (see Table 1).

3. TOWARD SAFER ROADS

3.1 An Integrated and Scientific Approach

It widely recognised that road safety is the responsibility of many sectors and that an integrated approach to national and local action is required. Remedial action is usually grouped under the 3 E's ie engineering, education and enforcement with additional concepts also recommended such as evaluation and encouragement.

In order to successfully implement a multi-disciplinary action programme, a number of key requirements need to be met. The most important are:

1). A reliable and valid national road accident database
2). A national road safety plan based on a scientific and rational diagnosis of the road accident problem.
3). National and local coordinating agencies with the necessary authority and resources to implement the plan.
4). Professional staff trained in the latest road safety approaches and technology.
5). Evaluation of the measures with feedback to the national plan.

Table 1 Accident Statistics 1986-1995

Years	Number of Vehicles (1)	Number of Accidents (2)	Fatal (3)	Injured (incl. Fatals) (4)	Accident Rate per 10000 vehs (2)/(1)	Fatality Rate per 10000 vehs (3)/(1)	Casualty Rate per accident (4)/(2)	Fatality Index, deaths/ all casualties x 100 (1)/(4)
1986 *UK 1986*	7,308,436 *22,750,000*	41,683 *248,000*	9,714 *5,382*	55,990 *316,000*	57 *109*	13 *24*	1.34 *1.30*	17.3 *1.7*
1987	7,426,274	36,756	10,637	58,206	49	14	1.58	18.3
1988	7,770,949	30,388	10,456	50,724	39	13	1.67	20.6
1989	8,243,982	25,243	10,075	43,873	31	12	1.74	23.0
1990	8,850,739	25,741	10,887	46,143	29	12	1.79	23.6
1991	9,230,741	22,492	10,610	41,902	24	11	1.86	25.3
1992	9,922,737	19,920	9,819	38,028	20	10	1.91	25.8
1993	10,237,069	17,323	10,038	34,528	17	10	1.99	29.1
1994	11,373,217	17,469	11,040	34,407	15	10	1.97	32.1
1995 *UK 1995*	12,635,459 *26,000,000*	16,510 *230,000*	10,990 *3,621*	32,804 *307,000*	13 *88*	9 *1.4*	1.99 *1.35*	33.5 *1.2*
Estimate from Highway Capacity Manual	12,635,459	487,870	16,485	873,705	386	13	1.79	1.8
Indonesia 1995 estimate based on UK 1927 ratios	*12,635,459*	*412,125*	*16,485*	*478,065*	*326*	*13*	*1.16*	*3.4*

Indonesia has taken a number of positive steps to reduce the road accident problem, for example there is a National Road Safety Plan and an improved accident information system known as Triple-L. Also the traffic law has been revised and trial black spot treatments introduced with evaluation carried out by Pusat Litbang Jalan (IRE).

However there are still many potentially, highly effective measures and improvements for Indonesia to implement. Of course, care needs to be taken with the transfer of technology from one region of the world to another, but in the case of strategies and approaches to managing road safety, it is likely that these are applicable worldwide. Individual countermeasures or treatments on the other hand need to be appropriate for local conditions and integrated with other actions particularly publicity and possibly enforcement if they are to be successful.

3.2 Accident Prevention and Reduction

An important road safety concept is the distinction between Accident Prevention and Accident Reduction.

Accident Prevention involves improved planning and design of new roads and related developments to minimise road accidents and casualties. Not only are schemes designed with safety in mind but also they are checked by impartial safety specialists (road safety audit) to ensure that safety considerations have been met.

Accident Reduction involves the application of cost effective measures to the existing road network particularly those sites, sections or areas with known accident problems.

To encourage developing countries take up these approaches the Transport Research Laboratory (TRL) in collaboration with the Ross Silcock Partnership, developed a guide for planners and engineers (TRL/Ross Silcock, 1991) and a slide pack (TRL/Ross Silcock, 1994). Also the TRL, in collaboration with IRE, produced an interim manual on the development of low-cost engineering improvement schemes (TRL/IRE, 1993) in order that a systematic approach for reducing road accidents at hazardous locations could be introduced in Indonesia. The next two sections of this paper summarise the key principles of these two manuals with examples. There are many other useful publications for road safety professionals and a selection of these is listed in the reference section of this paper.

4. ROAD ACCIDENT PREVENTION BY IMPROVED PLANNING & DESIGN

4.1 Background

The Government of Indonesia is committed to major investment in expanding the road network and providing safe and efficient roads for the general public. It is therefore essential that safe planning and design practices are adopted. Table 2 shows some of the key characteristics of accidents found in 4 areas of Java (IRE, 1997).

Table 2 Key characteristics of accidents in Java, 1993-95

Casualty/Accident Characteristic		Percentage of casualties of accidents	
		Urban	Rural
1. Casualties were:	1). Motorcyclists 2). Pedestrians 3). From buses/minibus	40 25 12	25 14 33
2. Accidents occurred:	1). Away from junctions 2). In residential areas or villages	77 65	93 89
3. Collisions were:	1). Head on 2). Side swipe 3). Note to tail	19 26 21	42 10 17

The planning and design improvements should focus on reducing the main accident problems. From the Table, priority needs to be given to improving the safety of motorcyclists, pedestrians and buses particularly in areas of residential development both on urban and rural roads. The percentage of accidents occurring on rural roads with residential land use is exceptionally high but not surprising given the ribbon development prevalent in Java. Indonesia's expansion of its road network provides an ideal opportunities to introduce safer planning and design practices. Some important strategies which need to be adopted are:

1). Match the function, design and use of roads and classify roads into a hierarchy.
2). Provide road designs and environments which guide and match road user expectations.
3). Manage speed and keep speed below 30 kph where pedestrians share the road space with vehicles.
4). Control access and development to minimise high risk manoeuvres and exposure of vulnerable road users.
5). Provide a road environment which is forgiving and tolerant of human error.
6). Check schemes for safety at the various design and completion stages (safety audit) and modify as necessary.

The "Towards Safer Roads" manual contains many principles, recommendations and examples and, given the space and time restrictions of this paper, only those most relevant to the Indonesian situation have been selected and described below.

4.2 Safe planning of roads

The five priority components of safe planning are as follows.

1). **Road Hierarchy.** The roads in a network should be clearly defined and classified into those which are primarily for movement (through traffic) and those which are primarily for local access. Some key principles are:

- o Network hierarchy aids Development Control
- o Hierarchical levels assigned on intended or desired and not historical functions
- o Networks should create self contained zones to exclude extraneous traffic
- o Natural barrier effects of main routes can be used to segregate/contain incompatible uses
- o Appearance and design standards should clearly convey role of road and include appropriate speeds of traffic
- o Existing grid network layouts can be modified to hierarchical networks
- o Numbers, type and spacing of intersections should be consistent with expected traffic
- o Roads should intersect only with roads in same level or one level higher or lower in the hierarchy

An example of an ideal hierarchy is shown in Figure 1.

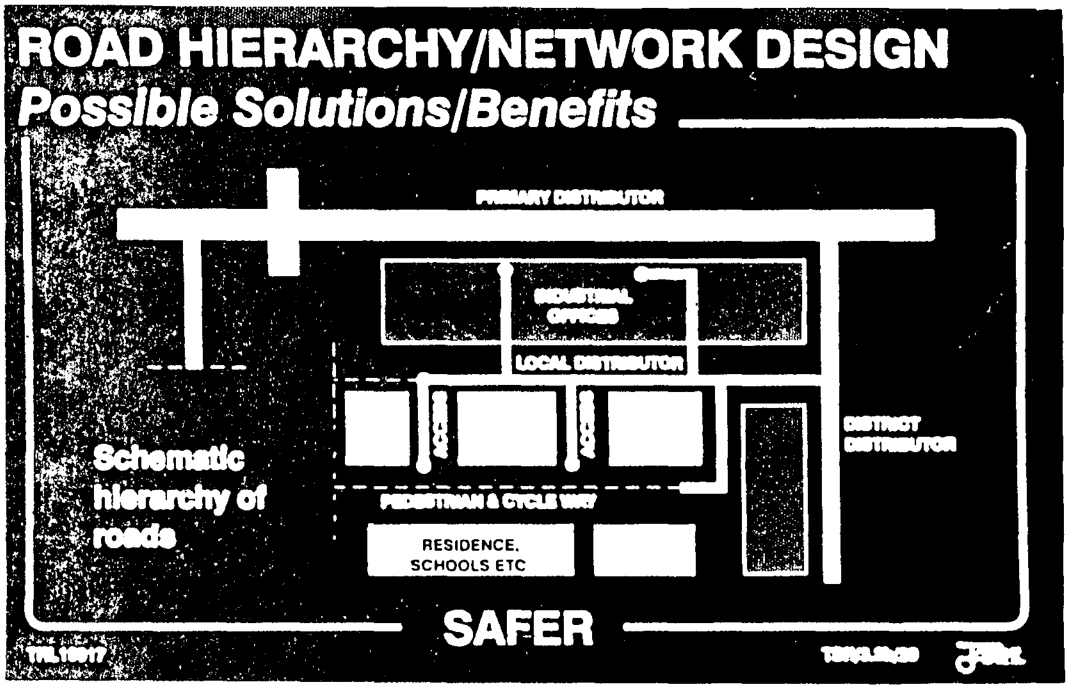


Figure 1 Ideal road hierarchy

2). **Land use.** Land-uses should be organised and controlled to minimise traffic and pedestrian conflicts and reduce the need for travel. Ideally people's work needs and shopping requirements should be located within safe walking distance of their homes. The key principles are:

- o Control of land-use and traffic is vital
- o Segregate incompatible uses
- o Design networks to minimise conflicts
- o Plan land-use to minimise travel and maximise accessibility to public transport

An example of unsafe and safer land use is shown in Figure 2 and the importance of development control in Figure 3.

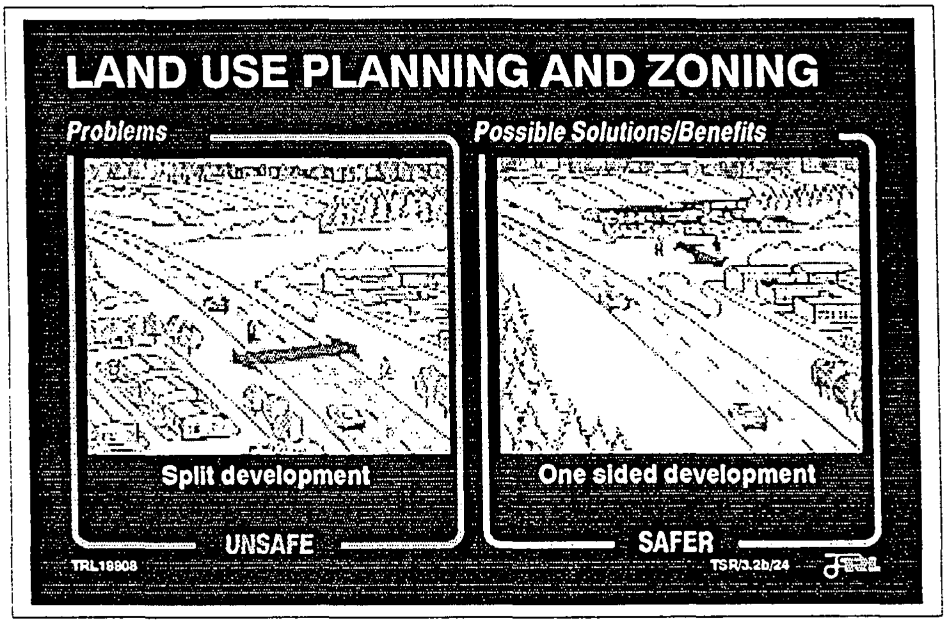


Figure 2 Land use to minimise pedestrian conflicts

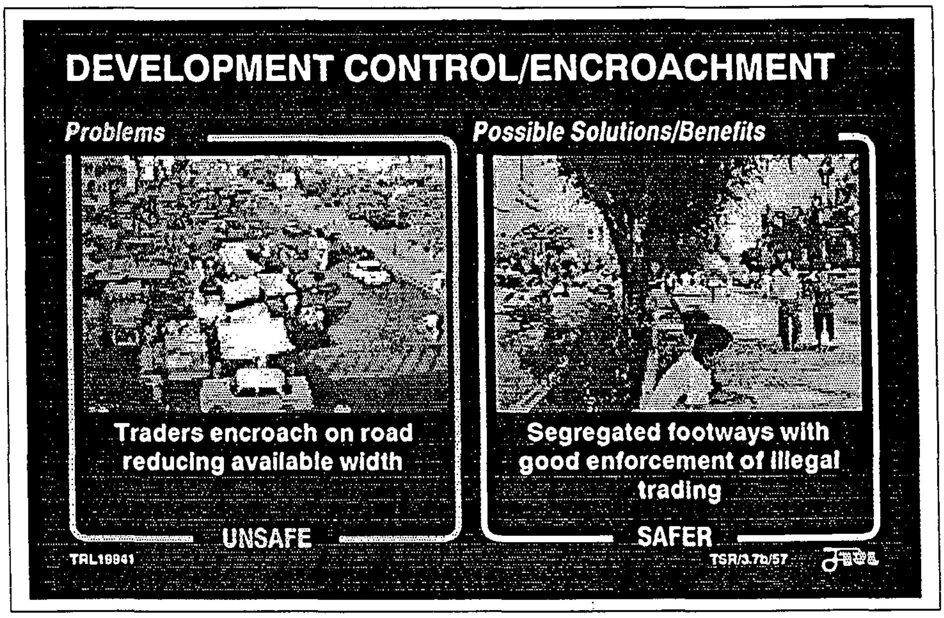


Figure 3 Development control

3). **Access Control.** Direct frontage or access onto major roads or near intersections should be minimised and not permitted at all at dangerous locations such as bends or hill crests.

- o Number of intersections should be minimised, junctions simplified and service roads provided
- o Traffic should work up through hierarchy of roads to reach primary road
- o Priority should always be given to road higher in hierarchy. All minor roads to have stop or give way marking/signs where they meet major road
- o Highway authorities must introduce control system which requires developers to get permission when they wish to access onto public roads
- o Small full-time development control team needed to assess/review access proposals - must have powers to enforce closures and remove illegal accesses
- o Access roads to parking areas of major facilities (hospitals, shopping centres etc) to be at least 50m from junctions

An example of good and poor access control is shown in Figure 4.

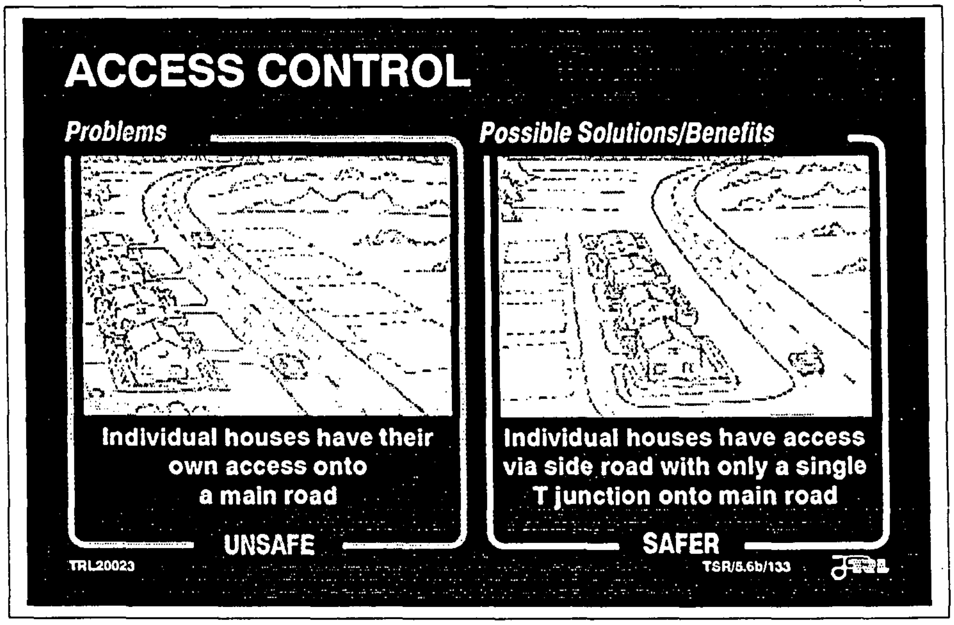


Figure 4 Access Control

4). **Arterial Roads.** Capacity expansion and rehabilitation projects must consider the existing usage of the road and ensure that the local user's needs and safety are maintained. The key principles are:

1. Where bypasses can be justified
    - o Downgrade old road to discourage through traffic, reduce speeds and reinforce hierarchy
    - o Provide only a few links from old road to new road, preferably via spur roads
    - o Prohibit direct access from adjacent frontage land onto new road
    - o Leave provision for future expansion of community but serve via spur roads

2. Where bypasses cannot be justified
    - o Slow down through traffic speeds as it passes through community
    - o Examples of techniques:
        - advance warning signs and rumble strips to warn of speed reducing devices ahead
        - chicanes, road narrowing or road humps to slow traffic where pedestrians predominate; and refuges where necessary
        - "gates" such as chicanes or road narrowing to alert drivers that they are entering low speed area
    - o Provide urban high speed road along existing alignment only if separate service roads, restricted access, and grade separated pedestrian crossing facilities can be provided.

The importance of speed control on arterial roads especially interurban roads passing through towns or villages cannot be underemphasised. An example of this type of problem is shown in Figure 5.

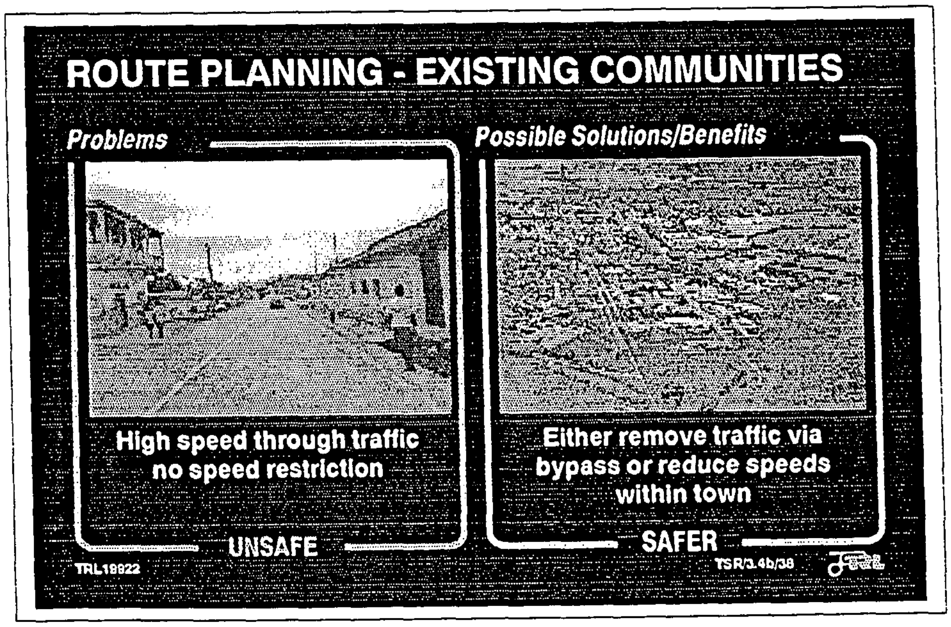


Figure 5 Arterial roads

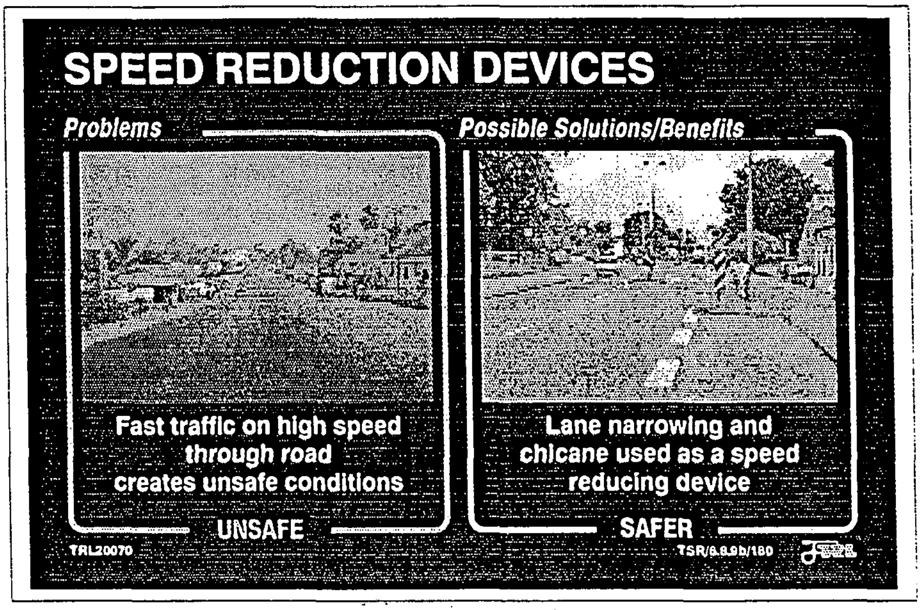


Figure 6 Speed reductions

5). **Access and residential roads.** Access roads should aim to provide a safe and comfortable environment for the local community particularly for the vulnerable road users. The key principles are:

- o Access roads should have safety, security, social and environmental issues as primary concerns
- o This can be brought about as follows:
  - vehicle flows minimised and unnecessary traffic eliminated
  - vehicle speeds kept low through appropriate design eg roads short (<100m) and winding and use of shared space
  - cul-de-sac and loop roads used to deter through traffic
  - "T" junctions and compact junctions to reduce conflicts and to aid pedestrians
  - threshold treatments at entry points to area creating "gate" effect
  - parking off road and away from play areas wherever possible
  - use mountable kerbs to reduce widths yet permit occasional larger vehicle especially for emergency access

Figure 7 illustrates how network design can prevent through traffic.

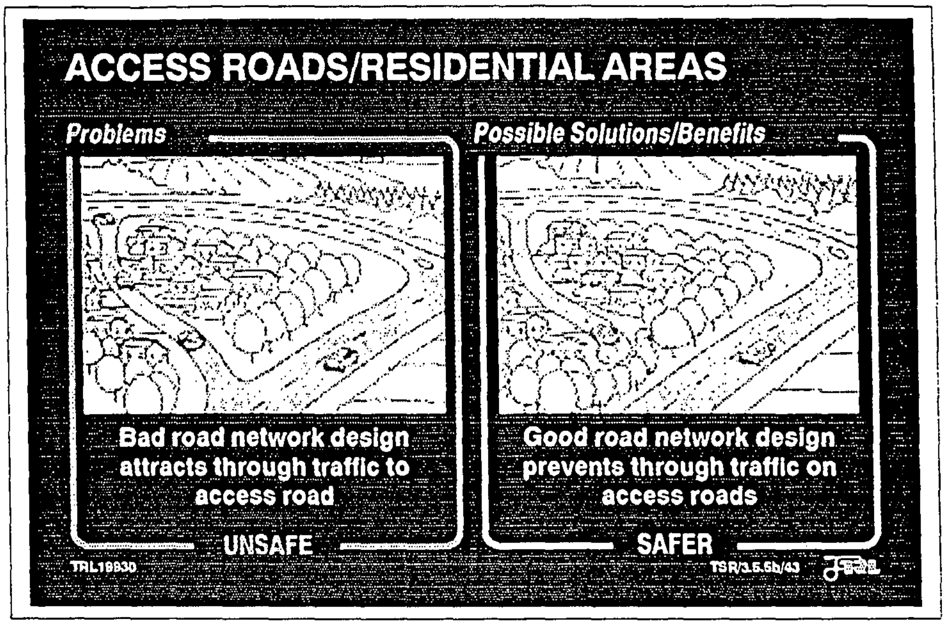


Figure 7 Preventing through traffic

4.3 Safe Design of Roads

Research mostly from developed countries (TRL, 1997) has clearly demonstrated the relationships between road design and accidents and some of the benefits of improved design are shown in Table 5 in Section 6.

In Indonesia many standards are adopted from those issued by developed countries. Although this is an efficient practice care must be taken to ensure that they are safe for Indonesian conditions and that the standards are then applied universally throughout Indonesia. The road environment and road classification lead road users into certain expectancies and sudden unexpected road characteristics could result in accidents.

Some of the aspects of road design most relevant to problems found in Indonesia have been summarised below.

1). **Driver expectancy.** Safe design should aim to provide road users with clear, simple and consistent tasks and avoid surprises or giving misleading or confusing information. The key principles are:

- o Aim should be to improve "readability" of road. This may require removal of misleading cues or placement of additional cues.
- o Introduction of advance warning signs and markings guides driver through hazard and clarifies priorities at junctions.
- o Drivers and pedestrians must be given consistent guidance, by design, signs, markings, channelisation etc.

- o In urban areas clear definition of road hierarchy via design features is important to encourage traffic onto suitable roads.
- o Contributory factors indicative of driver expectancy problems are:
  - Unexpected or wrong manoeuvres or actions
  - Illegal behaviour
  - Inappropriate speeds for conditions/location
- o On interurban and main routes, important to ensure consistency of alignment characteristics and delineation.

An example of misleading design is shown in Figure 8.

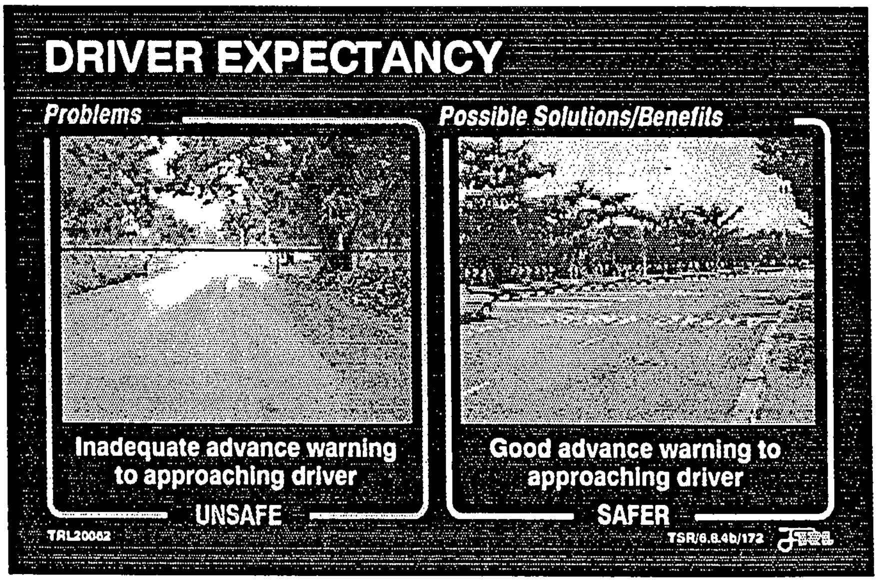


Figure 8 Driver expectancy

2). **Intersections.** Good intersection design should allow for through movement on the main road and transition from one route to another with minimum delay and maximum safety. Some key safety principles are:

- o Safe design of intersections must consider:
  - visibility
  - sight distances
  - clear road markings and signing
  - islands and bollards to protect drivers/pedestrians
  - restriction of turning movements
  - segregated and safe routing for pedestrians
- o Priority intersections should only be used where Annual Average Daily Traffic flows are low.
- o Preference should be given to T junctions and if possible straight through cross roads and Y junctions should be avoided.

- If space permits, staggered intersections are preferable to cross roads on safety grounds.
- Local widening should be used to protect turning vehicles on the major road.
- Avoid minor arm of T junction on inside of horizontal curve.

An example of safe and unsafe junction design is shown in Figure 9.

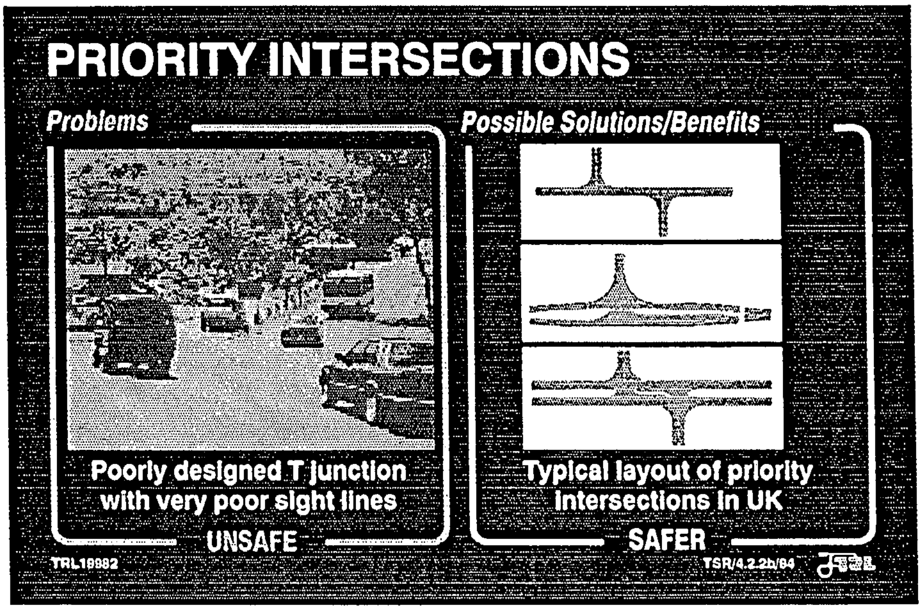


Figure 9 Intersection design

3). **Medians and barriers.** Medians and barriers are useful for segregating traffic and preventing head on accidents. Care must be taken to ensure that the medians or the barriers do not themselves become a hazard. Some key principles are:

Median barriers
- Physical barriers stop U-turns and prevent or reduce head on collisions.
- Median barriers can be used to channel pedestrians to safe crossing points.
- Provision is needed for access by emergency vehicles.
- Careful end detailing can reduce the potential hazard of the barrier itself.
- Where barriers are not considered essential desirable median width is 5m.
- 1.2m is minimum width needed for safe pedestrian refuges.

Pedestrian barriers
- Fences can be used to divert pedestrian movement to safer locations and keep pedestrians off roadway at busy locations.
- Useful in short lengths at exits from schools, recreation areas, and footpaths to prevent children running straight onto road.
- Suitable positioning can force pedestrians to face oncoming traffic before they cross it.

- Should normally be confined to district and primary distributors but at intersections and hazardous locations they can be applied on local distributor and access roads
- Can be used to deter illegal or obstructive parking by denying direct access to properties.

Examples of safe and unsafe practices are shown in Figure 10 to 12.

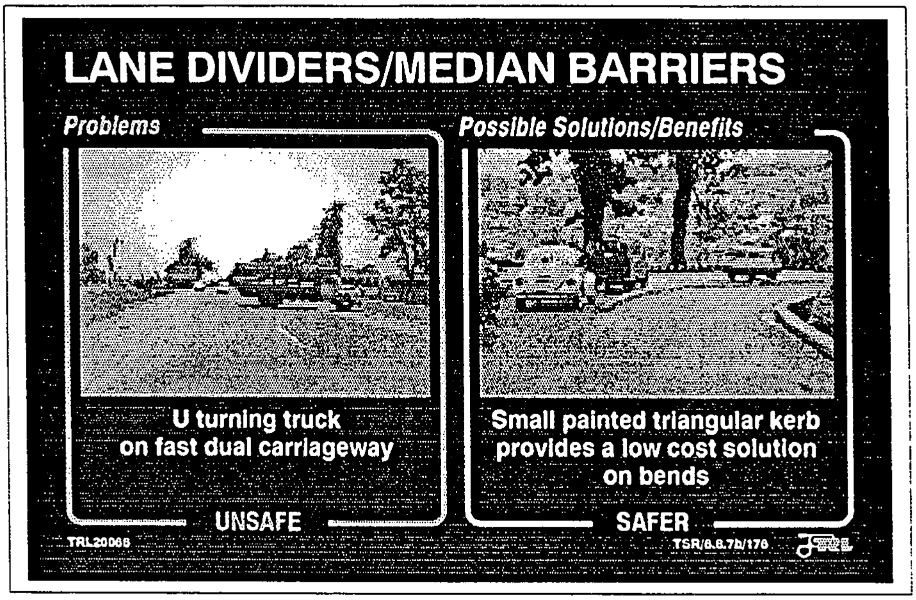


Figure 10 Median barriers

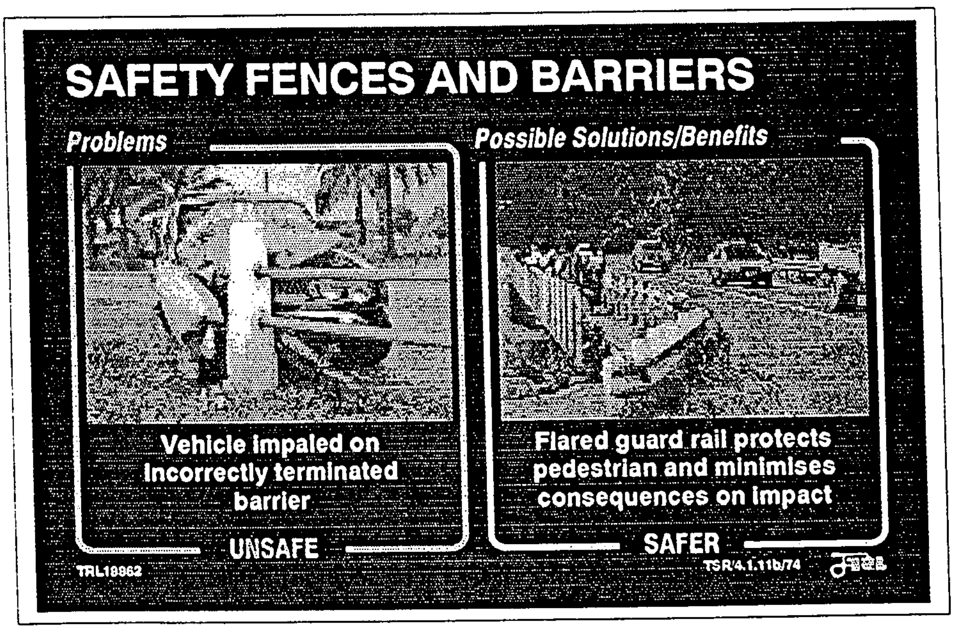


Figure 11 Forgiving barriers

Figure 12 Pedestrian barriers

4). **Pedestrian Facilities.** Pedestrian are the most vulnerable group of road users and improvement schemes should consider their needs. Some of the key principles are:

- o Provide adequate footway areas kept clear of obstructions. UK guidelines are 1 m width per 50-60 pedestrians per minute + 1 m for kerb and side wall avoidance effects.
- o Provide safe crossing facilities including footbridges or subways for high speed roads.
- o Use barriers to channelise pedestrians onto safe facilities.
- o Consider low speed limits (30 kph) or speed reduction devices in areas where many pedestrians use the road.
- o Consider pedestrianisation of selected commercial areas.
- o Provide central refuges on wide roads to allow crossings to be made in two stages.
- o Provide special crossing patrols for school pupils.
- o Ban parking near (within 30 m) of crossing facilities.
- o Site bus stops to maximise safe movement of embarking and disembarking passengers.

Pedestrian facilities should also be considered for rural roads. An example is given in Figure 13.

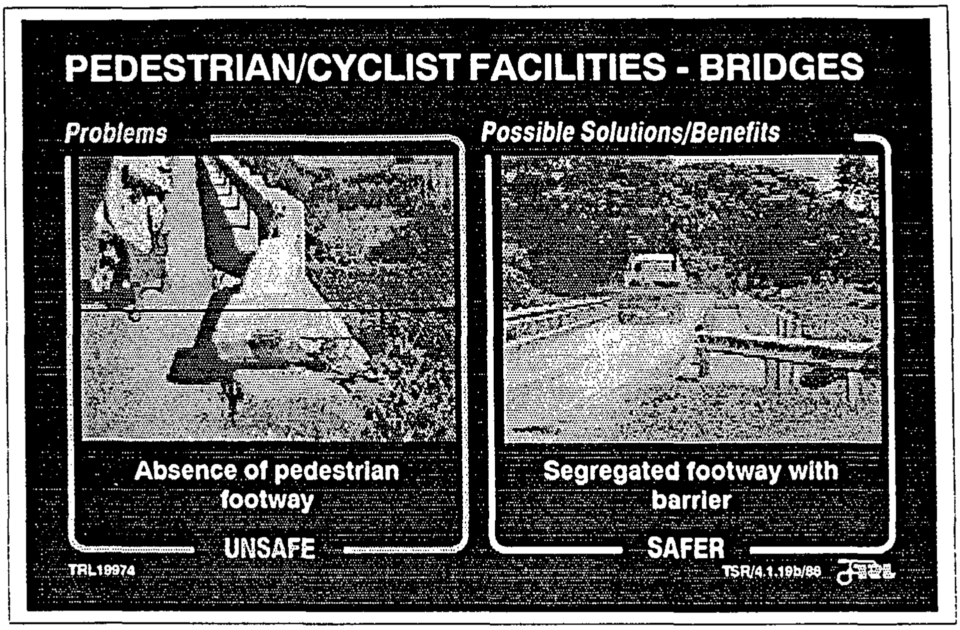


Figure 13 Footpaths on bridges

5). **Two wheeler and non-motorised facilities.** Motorcycles, bicycles rickshaw and other non-motorised vehicles are an important part of the traffic in many parts of Indonesia. Some cities such as Yogyakarta have provided separate lanes for these vehicles. Road designs should consider the needs of these users and provide facilities as appropriate. Some key principles are:

- o Slow lanes approximately 2 m wide
- o Separate lanes with barriers or kerbing
- o Separate phases at traffic signals
- o Special ramps when sharing footbridges

An example of segregated lanes is shown in Figure 14.

Figure 14. Cycle Lanes

5. ACCIDENT REDUCTION

There are four recognised approaches to accident reduction by the application of cost effective treatments of existing roads. These are:

1. **Single sites:** treatments of specific sites or short lengths of roads at which accidents cluster.
2. **Mass action:** application of a known remedy to locations which have common accident factors.
3. **Route action:** application of remedies to a road having above average accident rate for that type or class of road.
4. **Area action:** aggregation of remedial measures over an area with an accident rate above a predetermined level; particularly aimed at dealing with scattered accidents and usually in urban areas.

Also the technique of **traffic calming** has been widely adopted by developed countries and this is applied to residential areas or rural routes to bring vehicle speeds down to below 30 kph and provide a safer and more comfortable environment for pedestrians.

All these above approaches have considerable potential for Indonesia but priority has been given to establishing a methodology for accident investigation and treatment of hazardous locations. Thus in 1993 the IRE and TRL jointly developed a manual for engineers (TRL, 1993) which gave detailed guidelines on 12 key steps. These are shown in Figure 15.

A selection of typical accident problems and solutions is shown in Table 4.

Prerequisites for implementing accident reduction schemes are:

1). An accurate and reliable accident database
2). Professional know how and resources
3). Funds for improvements

Indonesia has introduced a improved accident database (3 - L) although the problem of accident reporting needs to be addressed. Also road engineers and other professionals have been trained in accident reduction techniques and the availability of a manual together with combined training programme should ensure a stronger road safety capability in the future. Road safety improvements have been implemented on a trial basis and it is hoped that future safety treatments will be funded from either the annual maintenance budgets or from safety project funds. The extent of this support should be based on the cost effectiveness of the countermeasures and monitoring and evaluation are absolutely vital. The IRE is conducting a programme of researching road safety improvements and the results of these and other studies are summarised in the next section.

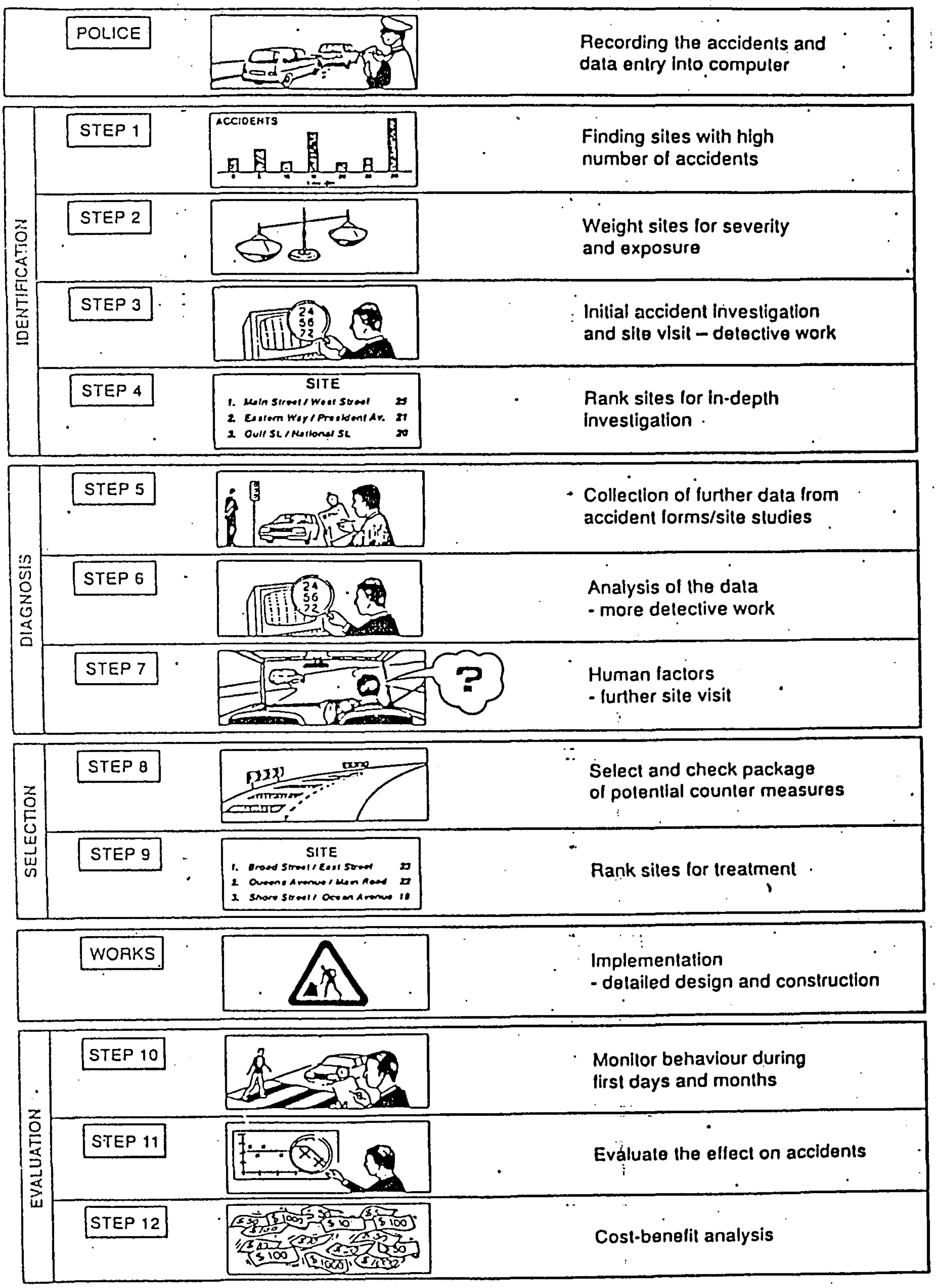


Figure 15 The twelve steps of accident investigation

Table 4. General Accident Situation and Remedial Measures

General Accident Situation	Remedial Measures
Skidding	Restoring surface texture Resurfacing - high skid resistance material Improve drainage
Collisions with roadside objects	Better delineation Guardrails or fencing Frangible posts Remove objects
Pedestrian/vehicle conflicts	Pedestrian/vehicle segregation Pedestrian crossing facilities Pedestrian fences or other protection Parking controls Speed control
Loss of control	Bigger or better road signs Road markings Speed controls Safety fencing Superelevation
Night-time accidents	Reflective signs Delineation Road markings Street lighting
Poor visibility	Trim or remove vegetation Improved sightlines Realignment
Poor driving behaviour or lane discipline	Parking controls Road markings Enforcement Median barriers Overtaking lanes
Junction accidents	Channelisation, signs and markings Change control system and/or layout Speed reduction, alerting devices Bus stopping areas
Accidents along ribbon development	Speed reduction Pedestrian facilities Service roads Planning constraints Bypass
Overtaking accidents	Ban overtaking Channelisation, signs and marking Widen road Medians

6. EVALUATION OF ROAD SAFETY IMPROVEMENTS

There have been many studies evaluating road safety improvements and a recent review by TRL/IRE (1997) has examined the findings of a number of studies of road engineering improvements. A summary of the results is shown in Table 5. The mean accident reductions are averaged across studies and in general they range from 14 per cent to 62 per cent. These figures have to be treated with caution as the results varied considerably within studies and across studies. This variation is indicated by the Standard Deviation figure. Also there have been very few studies from developing countries and a great deal more research is needed to determine the transferability of some of the benefits particularly those measures which rely on road user discipline such as road signs and markings.

Table 5 Summary of accident reductions from review of engineering improvements

No.	Feature	Accident type assessed	Statistical Information		
			No. of studies	Mean reduction	Standard Deviation
1.	Control of access	IA	4	34%	15.00
2.	Improved road geometry	TA	2	20%	-
3.	Dualling	IA	3	31%	1.15
4.	Widening to three lanes	IA	1	22%	-
5.	Passing lane	IA/TA	10	21%	10.60
6.	Climbing lane	TA	5	24%	6.29
7.	Carriageway width	TA/IA	21	16%	28.50
8.	Shoulder width	TA/IA	10	15%	13.20
9.	Road verge width	TA	2	28%	10.90
10.	Sealed/unsealed shoulder	TA/IA	5	49%	22.40
11.	Skid resistance	TA	4	52%	20.70
12.	Staggered junction	TA	6	54%	28.57
13.	T-junction*	TA	4	30%	12.09
14.	Y-junction*	TA/IA	2	-21%	43.91
15.	Roundabout*	TA/IA	26	46%	22.20
16.	Turning lanes	TA/IA	10	28%	18.60
17.	Traffic islands		1	39%	-
18.	Junction control by signs	TA/IA	32	51%	27.80
19.	Traffic signal control	TA/IA	12	29%	16.85
20.	Traffic signal modifications	TA	8	40%	30.00
21.	Channelisation	TA	16	37%	19.50
22.	One way roads	TA	7	38%	15.58
23.	Speed decrease	TA/Inj per km	4	25%	9.19
24.	Speed increase	TA/Inj per km	4	-17%	9.63
25.	Signs and markings	TA	7	46%	25.68
26.	Warning signs	TA/IA	19	41%	21.60
27.	Road markings	TA	8	34%	35.36
28.	Lines	TA	14	37%	23.70
29.	Raised reflective markings	TA	4	14%	5.15
30.	Post mounted delineators	TA	6	31%	11.30
31.	Flashing beacons	TA	8	41%	25.80
32.	Road lighting	TA	14	35%	19.44
33.	Sight distance	TA	4	28%	-
34.	Medians along links	TA	12	35%	11.29
35.	Crash barriers along links	TA	3	-24%	8.50
36.	Guard fencing		7	49%	24.24
37.	Frangible supports	IA	2	30%	-

No.	Feature	Accident type assessed	Statistical Information		
			No. of studies	Mean reduction	Standard Deviation
38.	At-grade pedestrian crossing	TA	10	36%	17.88
39.	Grade-separated pedestrian crossings	TA	2	62%	32.50
40.	Cycle lanes	Cycle	1	36%	-
41.	Cycle crossing facilities	Cycle	2	24%	15.90
42.	Area-wide schemes	TA	9	36%	20.48
43.	Rumble strips	TA	5	34%	9.60
44.	Parking	TA	2	42%	6.36

TA = All reported accidents, IA = Ing way accidents

Also some measures led to accident increases. These were Y junctions, speed increases and crash barriers. The first two are well recognised as unsafe and the introduction of crash barriers leads to an increase in minor accidents but a significant reduction in Fatal and Serious injury accidents. The overall reduction figures can therefore be misleading.

The Institute of Road Engineering (IRE) has evaluated engineering improvements at 3 sites in Bandung (Rudjito et al, 1996) and these together with some other results from Asian countries have been summarised in Table 6.

Table 6 Accident Reductions in 4 Asian Countries

Country and measure	Reported Road Accidents per year		Percentage reduction corrected for control group
	Before	After	
Indonesia (1)			
1). Median	10.5	0.33	89
2). Channelisation	8.5	0.67	71
3). Channelisation	4.5	0.00	87
Malaysia (2)			
1). Motorcycle lane (inj. accidents)	155	112	34
Papua New Guinea (3), (4)			
1). 6 new roundabout sites	1.17	0.55	53
2). Median	48.33	22.33	54*
3). Footbridge	24	17.67	26*
4). Footpath (ped. accidents)	4.7	1	85
Pakistan (4)			
1). 3 raised pedestrian crossings	7.5	3.5	37

* = not corrected for control accident trends; (1) = Rudjito et al, 1996; (2) Radin U and Hussain A, 1996; (3) = Hills B et al, 1991; (4) Downing A, 1997.

All the reduction figures are based on relatively small amounts of data from before and after studies and no allowances have been made for any possible biases due to regression to the mean or changes in reporting levels etc. It is therefore too early to be confident about reduction levels for individual measures but clearly the overall results indicate there is considerable accident reduction potential for engineering improvements in Indonesia and other countries in the region.

7. CONCLUSIONS

This paper has

1. Demonstrated the severity of the Indonesian road accident problem and highlighted the need to allow for under reporting levels which could be in the region of 90 per cent.

2. Identified the need for: 1) more road safety conscious planning and design and provided examples of accident prevention approaches from TRL's 'Towards Safer Roads' Manual; 2) accident reduction approaches aimed at problems in the exist road network and outlined the method developed jointly by IRE and TRL.

3. Demonstrated the accident reduction potential of road engineering improvements with research findings from an international review, Indonesia and other Asian countries.

Actions to improve road safety are needed now in Indonesia to ensure new roads are built to the highest safety standards and that existing problems are resolved. It is hoped that this paper will encourage and facilitate the adoption of road safety conscious road engineering practices in Indonesia.

8. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the Police in Indonesia with their help in collecting and providing accident data and researchers and road safety professionals from IRE, TRL and other countries who have provided the information and experience to make this paper possible.

9. REFERENCES

1) **Downing A J, 1997.** Pedestrian Safety in the Developing World. Jurnal Puslitbang Jalan, No. 1 tahun XIV, Mei, 1997.

2) **Hills B L, N M Thompson and K Kila, 1991.** Accident Research in Papua New Guinea, in PTRC. Nineteenth Transport, Highways and Planning Summer Annual Meeting, Proceedings 9-13 September 1991. PTRC Education and Research Services Ltd, London.

3) **Institute of Road Engineering, 1997.** Development of Road Safety Technology. Department of Public Works, Agency for Research and Development, Institute of Road Engineering, Bandung.

4) **Radin U, A Hussein and Berhard, 1996.** How effective is the exclusive motorcycle Lane ? In Proceedings of The Second Conference on Asian Road Safety, 28-31 October 1996. The Society of Traffic Engineering, Beijing.

5) **Rudjito D, S Umar and R Sargeant, 1996.** Black Spot Investigation in Indonesia. In Proceedings of The Second Conference on Asian Road Safety, 28-31 October 1996. The Society of Traffic Engineering, Beijing.

6) **Swe Road/Bina Marga, 1995.** Highway Capacity Manual : Traffic Safety and Environmental Impacts. Work Package Report A : 2.1, Directorat General Bina Marga, Jakarta, Indonesia.

7) **Transport Research Laboratory (TRL)/Ross Silcock Partnership, 1991.** Towards Safer Roads in Developing Countries. A Guide for Planners and Engineers, TRL, Crowthorne.

8) **TRL/Institute of Road Engineering (IRE), 1993.** Interim Accident Investigation Manual. Technical Assistance and Research Training Project, Second Phase (TARP II), Project Report. Pusat Litbang Jalan, Bandung.

9) **TRL/IRE, 1997.** Literature Review of Engineering Countermeasures and Road Accident Reductions. Road Research Development Project (RRDP), Project Report. Pusat Litbang Jalan, Bandung.

10) **TRL/Ross Silcock Partnership, 1994.** Towards safer roads in developing countries: Slide Pack. TRL, Crowthorne.

Additional Useful References for Road Engineers.

11) **The Institute of Highways and Transportation (IHT), 1990.** Guidelines for : The Safety Audit of Highways. The Institute of Highways and Transportation, London.

12) **IHT, 1990.** Highway Safety Guidelines : Accident Reduction and Prevention - International Edition. The Institute of Highways and Transportation, London.

13) **IHT, 1991.** Urban Safety Management. The Institute of Highways & Transportation, London.

14) **The Institution of Lighting Engineers (ILE), 1990.** A manual of road lighting in developing countries. ILE, Rugby.

15) **Organisation for Economic Co-operation and Development (OECD), 1990.** Integrated safety management in urban areas. OECD, Paris.

16) **TRL, 1988**. Overseas Road Note 6 : A Guide to geometric design. TRL, Crowthorne.

17) **County Surveyor's Society, 1994.** Traffic Calming in Practice. County Surveyor's Society/Landor Publishing, London.

18) **TRL/Ross Silcock Partnership, 1997.** Road Safety Guidelines for Asia & Pacific Region. (To be published) TRL, Crowthorne.