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FEDERAL OFFICE OF ROAD SAFETY

IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS : PROCEDURAL GUIDELINES

Prepared by

RACV Consulting Services
MELBOURNE

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Performing Organisation
RACV CONSULTING SERVICES
123 QUEEN STREET,
MELBOURNE, VICTORIA, 3000

Sponser
Federal Office of Road Safety
P.O. Box 594
Civic Square. ACT.2608

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Abstract This project was commissioned to determine a practical and effective procedure for identifying and ranking of hazardous road locations. The Procedural Guidelines specify IDENTIFICATION INVESTIGATION and PROGRAMME IMPLEMENTATION phases but concentrate on the identification and programme implementation phases as the majority of authorities have established investigation procedures.

The identification procedure for intersections is based on the "casualty accident rate being significantly greater than the system average" and that for road sections is based on the "casualty accident number related to distance being significantly greater than the system average". The programme implementation is based on a ranking by benefit-cost ratio related to implementation cost so that for a fixed implementation budget the number of locations and the overall benefit-cost ratio are readily determined.
The research justifying these procedures is included in the Identification of Hazardous Road Locations:Final Report.

Keywords Identification, Procedures, Hazards, Roads, Urban, Rural, Intersection, Section, Accident, Countermeasures, Cost-Effectiveness

IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS

PROCEDURAL GUIDELINES

RACV Consulting Services

123 QUEEN ST., MELBOURNE, VICTORIA, 3000, AUSTRALIA.
TELEPHONE: (03) 607 2385 TELEX: AA 30223

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However, RACV Consulting Services would particularly like to acknowledge the cooperation of the Highways Department in South Australia, and the Road Construction Authority and the Road Traffic Authority in Victoria for making data available for the Study.

*RACV Consulting Services is most grateful for the constructive comments received from the reviewers of this Report. **These comments have undoubtedly benefited** the presentation and usefulness of the Report.*

1. INTRODUCTION

1.1 THE IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS STUDY

The objectives defined by the Federal Office of Road Safety for this project on the identification of hazardous road locations were four fold, namely:-

Review the available information on methods of identifying and improving hazardous road locations, taking into account:

- relevant research in Australia and overseas
- current practices and approaches
- possible new alternatives.

Identify those factors which contribute to the existence of hazardous road locations.

Comment on the adequacy of the existing methods identified, for application in Australia, considering:

- the adequacy of current data sources
- the practicality of the methods.

Based on existing data sources, formulate a practical and effective procedure for identifying and ranking of hazardous road locations and demonstrate its feasibility.

The research and investigations associated with the first three parts of the study are summarised in the complementary report entitled Identification of Hazardous Road Locations: Final Report. The conclusions resulting from the research and investigations are outlined in the introduction to each of the relevant chapters. However, if the derivations of these conclusions are required, the Final Report should be consulted.

These Procedural Guidelines concentrate on the fourth objective aimed at formulating a practical and effective procedure for identifying and ranking hazardous road locations.

The Guidelines present the preferred procedures resulting from the detailed research. This is one of the few projects world-wide which has attempted to compare the many options available for identifying hazardous locations. Therefore, it is hoped that these procedures will be integrated into the many programmes presently being undertaken in Australia. Even though this may create immediate problems in the implementation period, it is considered that this will result in long term benefits to everyone involved in identifying hazardous locations.

1.2 A HAZARDOUS ROAD LOCATIONS PROGRAMME

A hazardous road location programme includes the following phases:

identification of high risk locations,

diagnosis of accident problem(s) at identified locations,

identification of countermeasure(s) to alleviate accident problem(s),

selection from countermeasure options, and development of countermeasure implementation priorities, to maximise the economic benefits from the programme.

The first phase will be called the IDENTIFICATION Phase, to match the limited objectives of historical hazardous road location identification programmes. The second and third phases will be collectively referred to as the INVESTIGATION Phase. The fourth and final phase, in which particular attention is given to the selection of countermeasure options, will be referred to as the PROGRAMME IMPLEMENTATION Phase.

These Guidelines describe each of these phases but generally concentrate on the IDENTIFICATION and PROGRAMME IMPLEMENTATION Phases. This is because in the majority of instances authorities have established road improvement programmes, although not necessarily black spot programmes, and have well developed procedures for the INVESTIGATION Phase.

The intention of these Guidelines is to detail the IDENTIFICATION and PROGRAMME IMPLEMENTATION Phases so that these can be incorporated into existing programmes, either manual or computer orientated, so that hazardous road location programmes are based on researched procedures.

This phasing and its relation to the contents of the Guidelines is illustrated in Figure 1.1.

It is not the intention of these Guidelines to superimpose on any authority a new methodology for the INVESTIGATION Phase, because any methodology must be a balance between programme formalisation and engineering judgement.

There are a number of studies referenced in this report which have considered the selection of countermeasures in the investigation phase. These are briefly mentioned in this report for completeness but not considered in detail.

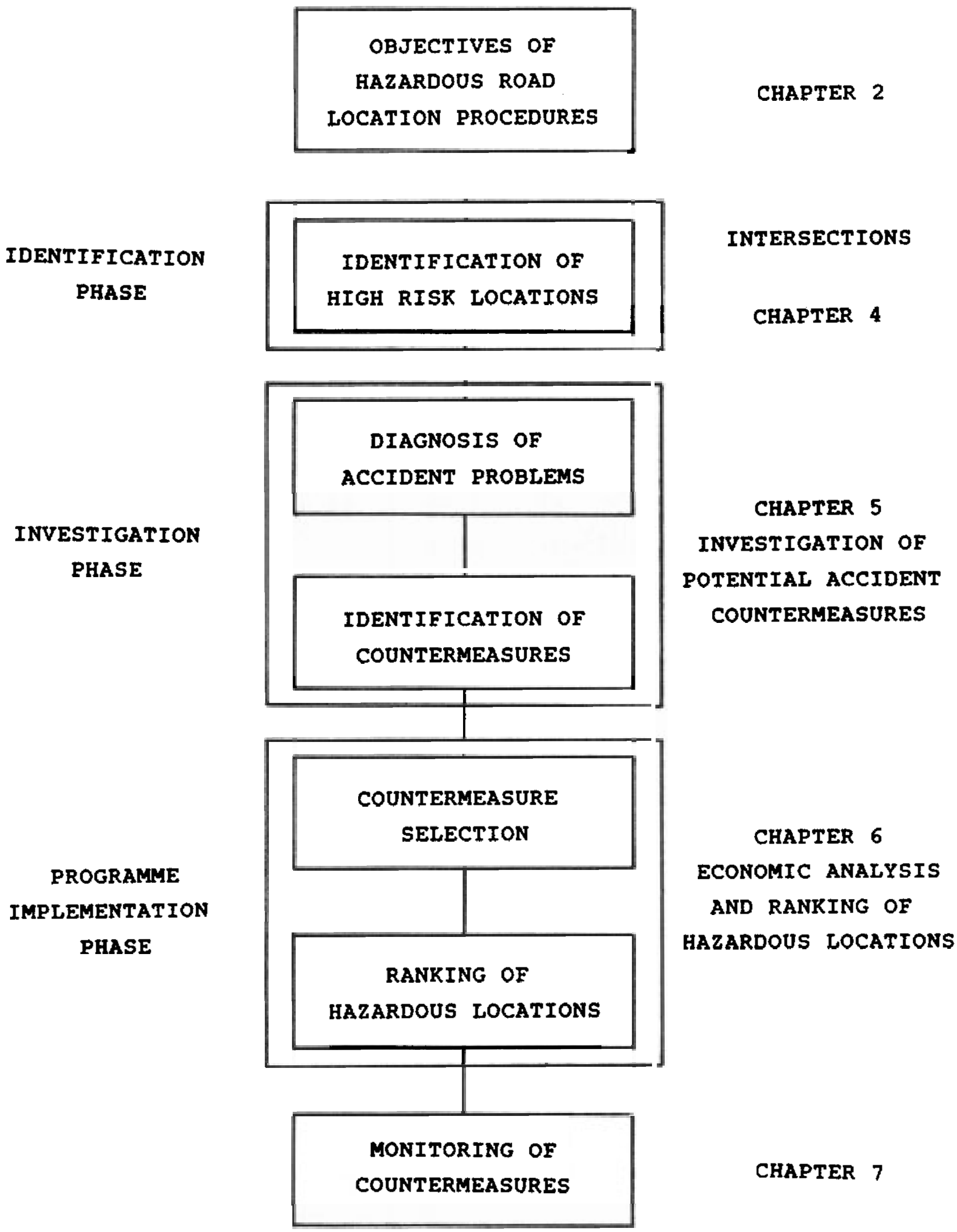
1.3 PROCEDURAL GUIDELINES

Prior to undertaking a hazardous location identification programme it is necessary to consider the objectives of the programme. Therefore:

Chapter 2 discusses the objectives of the recommended programme.

FIGURE 1.1

PHASING OF HAZARDOUS ROAD LOCATIONS PROGRAMME



The nature of the problem, the data availability and requirements, the data analysis procedure, the types of countermeasures available, the different economic criteria and the incompatibility of accident numbers at intersections and on road sections in urban and rural areas all suggested the necessity to consider these categories separately during the research.

However, the research undertaken as part of this project has suggested that similar identification procedures, in fact, are applicable to all intersections and to all road sections, no matter whether in urban or rural areas. Each of these locations is considered separately in this IDENTIFICATION Phase. Therefore;

Chapter 3 details the alternative identification procedures for intersections

Chapter 4 describes the identification procedure for road sections, defined as a length of road between major intersections.

These procedures define the data requirements. Should the data outlined not be available it will not necessarily invalidate the procedures; however, it will influence their accuracy.

Similarly, if authorities have different definitions, it would be appropriate to amend the procedures. However, the level of departure from the overall procedures and definitions should be minimised.

In the INVESTIGATION Phase, the procedures for diagnosis of problems and the identification of countermeasures are basically the same for intersections and road sections. Therefore;

Chapter 5 reviews the investigation of potential accident countermeasures.

Again, in the PROGRAMME IMPLEMENTATION Phase the procedures are basically the same for intersections and road sections. Therefore;

Chapter 6 discusses the economic evaluation for the selection of countermeasures at each location and for the ranking of locations.

One of the principal deficiencies of safety programmes has been the inadequate evaluation of the resultant savings. Therefore;

Chapter 7 outlines the need for monitoring individual countermeasures and the overall programme.

1.4 USERS OF THE GUIDELINES

These Guidelines have been prepared for the use of engineers in municipalities and State Road Authorities. While the level of detail may not be appropriate for the latter the principles still should be of use to them.

It should be noted that the recommended procedures call for overall system-wide statistics if they are to be comprehensive. It should be the responsibility of State Road Authorities to research and provide this information.

The basis for these recommended procedures are detailed in the complementary report entitled Identification of Hazardous Road Locations: Final Report.

2. OBJECTIVES OF HAZARDOUS ROAD LOCATION PROGRAMMES

2.1 INTRODUCTION

It appears that no existing programme for identifying hazardous road locations is concerned solely with the identification of such locations. More commonly, hazardous location programmes have dual objectives of identifying and investigating hazardous locations. However, some programmes tend to consider the identification independently from the investigations.

Quite often, these objectives can be inter-dependent, in which case, an accident blackspot programme can be aimed at identifying locations with sufficient accidents of the same type to identify a pattern for which cost effective remedial measures are readily available.

The general objectives of hazardous road location programmes should include:

identification of locations at which

- there is an inherently high risk of accident losses, and
- there is an economically justifiable opportunity for reducing this risk, and

identification of countermeasure options and priorities which maximise the economic benefits from the programme.

Relating these objectives to existing black spot programmes of the different States illustrates that there may be different criteria for each parameter, for example:

the definition of actual locations can differ between authorities, particularly when considering sections of road between main intersections (in that minor intersections may be included or excluded).

the concept of high risk can differ depending upon an authority's road safety philosophy, either the reduction in the number of accidents or the reduction in the accident rate (defined in various ways).

the economic justification used by authorities may be different, it may be based upon individual site analysis or it may be based on the economic return for the overall programme. Usually it is the former rather than the latter.

Therefore, there is a need not only to recommend an identification procedure but also to define each of the specific criteria to achieve these overall objectives.

2.2 NEED FOR COMPATIBILITY

At the present stage in the development of hazardous road location procedures, the identification phase is predominantly undertaken by a central authority or its agency. However, with the increased use of technology it may be possible to link municipalities to the central data base. Therefore, individual municipalities could consider the identification of problem locations in their own areas.

It is essential, therefore, that each Authority undertakes its analysis using the same procedures, particularly if municipalities are competing for limited funds and have to make submission for those funds.

3. INTERSECTIONS

3.1 OUTLINE OF IDENTIFICATION PROCEDURES

The research into procedures for urban intersections on the main road network has shown that:

1. The identification method "casualty accident rate significantly greater than system average" identified a list of sites with the maximum benefit-cost ratio following investigation and treatment, for the installation budgets considered.

2. The identification method "casualty accident rate after number" was not inferior to "casualty accident rate significantly greater than system average" in terms of identifying sites representing the best investment of a given installation budget. However, the former method had the distinct advantage of requiring exposure data only for the sub-set of sites initially selected by casualty accident number significantly greater than system average.

3. The best number-based identification method* (casualty

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*There has been and still is, considerable debate as to the value of accident numbers or accident rates to identify hazardous locations. The choice often lies in the objectives of the programme. If the objective is to minimise cash loss, accident numbers are used as the principal identifier but, if the objective is to minimise loss but take into account movement, mobility and exposure, accident rates are used as the principal identifier.

Both methods are used throughout Australia, indicating the objectives of each State. This research, which was related only to the cost-effectiveness criteria for the programme clearly identified casualty accident rates as a better identification method providing greater cost-effectiveness of the programme.

accident number) identified sites with significantly lower benefit-cost ratios than the rate identification methods described above.

4. This evaluation tentatively suggested that the economic benefits of an objective identification and treatment programme (where only those sites treated are those expected to be cost-beneficial) were only marginally greater than those where all identified sites within practical limits are treated. This conclusion appeared to hold particularly for the relatively small installation budgets.

5. For lower installation budgets, there was no advantage in using a three-year identification period compared to the two year period for either of the rate identification methods described above. However, identification periods as short as one year should be avoided, and for higher installation budgets three years was still preferred.

6. The measure of intersection exposure based on the "square root of the product of conflicting flows" was marginally superior, in terms of economic performance, to the "sum of entering volumes" measure. The "product of conflicting flows" measure resulted in relatively poor economic performance and should be avoided.

As these investigations indicated an identification method based on a **"casualty accident* rate significantly greater than the system average"** identified a list of sites providing the maximum benefit-cost ratio for a given implementation budget, this is the RECOMMENDED PROCEDURE.

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*Throughout these Guidelines a casualty accident refers to an accident in which at least one person requires medical treatment. Even if reliable information is available on total accidents the research has shown that for the purpose of identification it is detrimental to the procedure to include such accidents.

However, the investigations have shown also that an identification method based on a "**casualty accident rate after casualty accident number significantly greater than the system average**" is not significantly inferior in terms of identifying sites representing the best investment for a given implementation budget. This methodology requires fewer resources because exposure data need only be collected for a limited number of sites. Therefore, the procedure is presented as an ALTERNATIVE PROCEDURE. If resources are limited this alternative may be the more appropriate to use.

It was not possible to compare the identification procedures for rural intersections due to the low number of intersections with accident records sufficiently high to be identified as hazardous locations. Therefore, it is suggested that the intersections should be considered by a similar identification process to that recommended for the urban intersections.

3.2 DATA REQUIREMENTS

The data requirements for identification and investigation phases are similar, particularly that related to accidents, so it is generally appropriate to prepare a total data base at the initial stages. The data requirements, which are similar for both the recommended and alternative procedures are summarised below.

3.2.1 Identification Data

The only data absolutely necessary are the intersecting road names or a recognised method of identifying intersecting roads.

However, if using a computerised system it may be appropriate to detail other identification data which could be used in subsequent monitoring of countermeasure performance. The useful data would include:

Intersection reference number

Hierarchy of intersecting roads (primary arterial, secondary arterial, collector, local) where a hierarchy has been defined

Configuration (multi-leg, cross, tee)

Control (signals, roundabout, stop, give way, uncontrolled).

3.2.2 Accident Data

The accident data required are;

Accident numbers by severity (fatalities and personal injury, both of which are used in the Identification Phase, and property damage only, which may be used in the Investigation Phase)

Accident numbers by type of accident for use in the Investigation Phase

Accident details for use in the Investigation Phase, particularly those related to weather, road conditions and lighting availability.

3.2.3 Traffic Volume Data

For each location, or for those identified in the initial analysis of the alternative procedure, the two way annual average daily traffic (AADT) is required for each leg of the intersection.

If AADT volumes are unavailable, estimates can be made. Similarly, if count data is not available for every year being considered, interpolation between years is acceptable since the calculation is not sensitive to minor estimation errors.

For multiple leg intersections the traffic volumes on the least important leg(s) can be added to the traffic volumes on the nearest important cross route(s) to create a cross intersection for ease of computation of the exposure measure.

3.2.4 Period for Data

The research has demonstrated that data should be collected for an identification period of three years but, if resources are limited, a period of two years is acceptable. Identification periods of one year must be avoided.

3.3 RECOMMENDED PROCEDURE

3.3.1 System-wide Accident Data

The identification procedure requires an average casualty accident rate for all intersections in the system as a basis for comparison of individual locations to the system being considered.

There are two possible levels of system-wide accident data depending upon the level and objectives of the study being undertaken:

For a State-wide programme, it would be necessary to have detailed State-wide system averages so that each location could be compared on a like basis. In this instance, the averages should only include intersections on the main road network since these would generally be the responsibility of the State Authority.

For a municipal programme, it would be necessary to have detailed municipal system averages, again for comparison on a like basis. In this instance, the averages should only include intersections for which the municipality would have the responsibility.

In a municipality, this procedure would only include high accident locations. This should not deter municipalities from treating locations with low accident rates which, with very simple and cheap treatments such as stop or give way signs, could still have significant savings. However, these would normally be considered as traffic facilitation rather than road safety intiatives.

Initially, the preparation of this data will be resource consuming but it is essential for the overall success of a hazardous road locations programme.

It was found that categorisation by intersection geometry and type of control did not significantly improve the identification procedures. Therefore, there is no reason to consider signalised intersections differently from other intersections, even though many authorities presently do this.

Average Accident Number and Rate

If information is not available on the accident experience of the total population of intersections, a method of estimating the required information can be used (Appendix 1).

This method is based on intersections with one or more accidents, and the assumption of a Poisson distribution for accident occurrence.

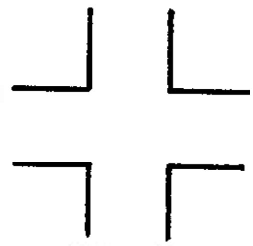
The Appendix also describes a procedure for estimating the system-wide average accident rate per exposure if exposure data is not available for all intersections.

Exposure

The research compared the most commonly used methods of calculating intersection exposure, namely the number of the vehicles entering the intersection, the product of the conflicting flows, and the square root of the product of conflicting flows. The latter measure was shown in the research to produce the best results for a given identification method and implementation budget and, therefore, is recommended as the appropriate measure of intersection exposure.

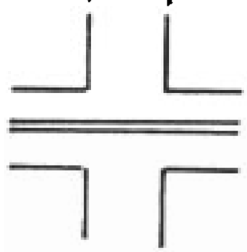
The recommended square root of the product of conflicting flow measure of exposure is defined as:

- for a four way intersection

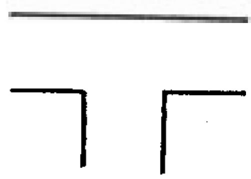


$$2\sqrt{\frac{(V1 + V3)}{2} \times \frac{(V2 + V4)}{2}}$$

- for a four way intersection divided by a continuous median the factor 2 in the first term of the equation is replaced by $\sqrt{2}$

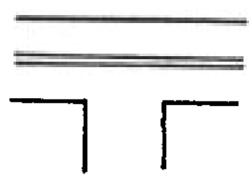


- for a three way junction



$$2\sqrt{\frac{(V1 + V3 - V2)}{2} \times V2}$$

- for a three way junction divided by a continuous median the factor 2 in the first term of the equation is omitted.



Where V1 and V3 are the two way traffic volumes (AADT) on opposite legs, as are V2 and V4. V4 is omitted for a three way junction.

3.3.2 Critical Accident Rates

The casualty accident rate for each intersection is directly compared to the system-wide average to determine whether the accident record of each location is significantly greater than the system average.

The statistical signficance above the system average is determined by standard critical values (upper 5% value, one tailed) given by Deacon et al (1975) and found by Jorgensen (1966) to be accurate approximations to the true critical values based on a Poisson distribution for accident numbers.

The critical casualty accident rate is calculated for each intersection using the formula:

$$CR = A + 1.645 \sqrt{\frac{A}{M} + \frac{1}{2M}}$$

where

CR is the critical rate

A is the average casualty accident rate per exposure

M is the measure of exposure

1.645 is based on a 95% confidence limit implying there is a 5% chance that the intersection may be indicated as having a significantly high accident rate, even though the intersection is not specifically hazardous.

Those intersections for which the casualty accident rate is above the critical rate are considered worthy of detailed investigation. The critical intersections, however, are not ranked at this stage since final ranking for implementation will be based on economic criteria (see Chapter 6).

3.3.3 Numerical Example

Introduction

In the metropolitan municipality of Downtown there has been an increase in the number of accidents at major intersections to such an extent that the City Engineer and Council are concerned. Therefore, Council has requested that the City Engineer determine which intersections should be considered for treatment in the next financial year.

From the information provided by the State Road Authority, the City Engineer has been able to calculate the metropolitan system-wide data to determine a critical accident rate. Subsequently the accident rate at the major intersections in the municipality have been compared to the critical accident rate to determine the intersections to be considered for treatment.

Examples of the calculations undertaken are outlined below.

Metropolitan System-Wide Accident Data

The overall accident statistics (system-wide averages) for the metropolitan area are:

Average number of casualty accidents per intersection per year on the main road network	8.650
Estimated annual average daily traffic exposure ($x10^3$ vehicles)	21.42
Average casualty accident rate per exposure per intersection on the main road network (calculated by dividing the average number of casualty accidents per intersection per year by the estimated annual average daily traffic)($x10^{-3}$)	0.404

Local Intersection - North and West Roads

The intersection of North Road, a primary arterial, and West Road, a secondary arterial, has been the subject of concern because there have not only been a number of injury crashes over the past five years, but also a substantial number of property damage accidents.

The accident record for this location was:

The average number of casualty accidents at this intersection in the previous three years was	10.00
The average exposure ($x10^3$ vehicles) was	10.57
The average casualty accident rate (per 10^{-3} exposure) at this intersection in the previous three years was	0.946

The critical accident rate was calculated:

$$CR = A + 1.645 \sqrt{\frac{A}{M}} + \frac{1}{2M}$$

$$= 0.404 + 1.645 \sqrt{\frac{0.404}{10.57}} + \frac{1}{2 \times 10.57}$$

$$= 0.404 + 1.645 \times 0.038 + 0.047$$

$$= 0.404 + 0.322 + 0.047$$

$$= 0.773$$

Clearly this intersection had a casualty accident rate above the critical rate (0.946 compared with 0.773). Therefore, this intersection should have been included with other similarly identified intersections and subject to detailed investigation.

Local Intersection - South and East Roads

The intersection between South Road and East Road has a similar accident history to the North and West Roads Intersection but has been accommodating marginally higher traffic volumes.

The accident record for this location was:

The average number of casualty accidents at this intersection in the previous three years was	10.00
The average exposure ($x10^3$ vehicles) was	13.75
The average casualty accident rate (per 10^{-3} exposure) at the intersection in the previous three years was	0.727
The critical rate, using the same calculation as above was	0.722

This intersection had a casualty accident rate at approximately the critical rate (0.727 compared with 0.722) . Therefore, it probably has been worthy of consideration but obviously at a lower priority than the previous intersection.

Local Intersection - High Street and Low Road

The intersection between High Street and Low Road had a similar accident history to the previous two intersections, but still marginally higher traffic volumes which provided accidents such as:

The average number of casualty accidents at this intersection in the previous three years was	10.00
The average exposure ($x10^3$vehicles) was	16.75
The average casualty accident rate (per 10^{-3} exposure)	

at the intersection in the previous three years was 0.597

The critical rate, using the same calculation as above was 0.689

This intersection had a casualty accident rate below the critical rate (0.597 compared with 0.689) and would not have been included in further work.

Investigations

The City Engineer had identified two intersections which were worthy of investigation and evaluation to determine whether a financial commitment was necessary to improve the accident record of the intersections.

3.4 ALTERNATIVE PROCEDURE

3.4.1 System-wide Accident Data

The initial stage of the identification procedures requires an average casualty accident number for all intersections on the network as a basis for comparison of individual locations to the overall main road network.

Again, if information on the total population of intersections is not available, an estimation can be made using the procedures outlined in Appendix 1 of these Guidelines.

The second stage requires an average casualty accident rate calculated as for the recommended procedure.

3.4.2 Critical Accident Numbers

The initial stage compares the individual intersection casualty accident number to the system-wide average to determine whether the accident record of each location is significantly greater than the system average. This usually reduces the group of intersections to be considered substantially.

Statistical significance above the system average is determined by reference to the critical casualty accident number. In this instance the accident rate of the previous equation is replaced by the accident number, and the exposure term (M) is omitted. Therefore, the critical number equation becomes:

$$CN = A + 1.645\sqrt{A} + \frac{1}{2}$$

where

CN	is the critical number
A	is the average number of casualties
1.645	is based on a 95% confidence limit implying there is a 5% chance that the intersection may be indicated as having a significantly high accident number, even though the intersection is not specifically hazardous

3.4.3 Critical Accident Rates

The second stage for the reduced set of intersections is identical to the recommended procedure. Casualty accident rates are calculated only for the reduced set, hence exposure data need be obtained only for these intersections.

4. ROAD SECTIONS

4.1 OUTLINE OF IDENTIFICATION PROCEDURE

The research related to rural road sections, defined as a length of road between any two intersections, independent of the scale or importance of the intersections, has shown that:

The identification method based on "casualty accident number related to distance" (ie, casualties/km) identified a list of sites with a higher benefit-cost ratio.

The identification method based on "casualty accident rate" (ie, casualties/million vehicle kms) identified lists of locations with significantly lower benefit-cost ratios compared with the "casualty accident number related to distance"

The identification methods based on a combination of "casualty accident number related to distance" and "casualty accident rate" did not provide any greater benefits (when compared to the work to be undertaken) than the individual methods.

The investigation methods, based on benefit-cost ratio to select from alternative treatments at each identified site, resulted in greater economic return than those based on net present value.

The research related to urban road sections has shown that:

The identification of hazardous sections, including or excluding minor intersections, produced similar rankings by both the "casualty and total reported accident number related to distance" and "casualty and total reported accident rate" methods. It was concluded, therefore, that evaluation should be based on sections including accidents at minor intersections.

The identification of hazardous road sections using casualty and total reported accidents produced similar rankings by both the "accident number related to distance" and "accident rate" methods. It was concluded that evaluation should be based on casualty accidents only, since Victorian records do not consistently include property damage only accidents.

The identification of hazardous road sections using total accident rates or type accident rates was similar. Therefore, the total rate was considered the appropriate reference value for identification purposes.*

The identification of hazardous road sections by "casualty accident number related to distance" and "casualty accident rate" methods produced similar rankings and either could be used for identification purposes.

As a result of these conclusions, the recommended identification method outlined in this report is based on a **"casualty accident number related to distance greater than a system average"** for all roads. Accident numbers in this instance include all mid-block and minor intersection accidents.

The only difficulty with this approach is in defining major and minor intersections in rural areas. This will have to be at the discretion of the engineer involved but probably each intersection could continue to be considered as such, if only to restrict the lengths of sections being considered.

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*It is accepted that the accident rate can differ for different road types. However, the research showed that in identifying hazardous locations it was not necessary to consider the rates for specific road types individually. The different road categories, such as arterial and local roads, are taken into account when determining the system-wide averages which are by de facto category when grouped by responsibility.

4.2 DATA REQUIREMENTS

The data requirements for identification and investigation phases are similar, particularly that related to accidents, so it is generally appropriate to prepare a total data base at the initial stage.

4.2.1 Identification Data

The only data absolutely necessary are the road name, intersecting roads defining the end of the section (or a recognised method of identifying intersecting roads) and the length of the section.

However, if using a computerised system, it may be appropriate to detail other identification data which could be used in subsequent monitoring of countermeasure performance. The useful data would include:

Section reference number

Road category (freeway, primary arterial, secondary arterial, collector, local, either urban or rural)

Whether divided or undivided

Number of lanes

4.2.2 Accident Data

The accident data required, including accidents at minor intersections along the length of the road section are:

Accident numbers by severity (fatalities, personal injury which are used in the Identification Phase and property damage only which can be used in the Investigation Phase)

Accident numbers by type of accident for use in the Investigation Phase, particularly those related to weather, road conditions and lighting availability.

Accident details for use in the Investigation Phase, particularly those related to weather, road condition and lighting availability.

There is often a difficulty in identifying the exact location of accidents on road sections, particularly in rural areas, because of the lack of definable landmarks for the Police informant to use in accident reports. Care must be taken in checking the location of accidents on road sections because it can create inaccurate identification if allocated to an adjacent section.

4.2.3 Traffic Volume Data

Unlike the intersection identification procedures, the two way annual average daily traffic (AADT) for each section is not required for the road section identification procedure. However, traffic volumes could be considered because they can be a useful indicator of road section boundaries, as ideally the traffic volumes should be consistent throughout the length of the section.

4.2.4 Period of Data

The research on road section procedures did not specifically consider the length of the identification period. However, the period of three years found for intersections also would appear to be appropriate although, if resources are limited, a period of two years is acceptable. Identification periods of one year must be avoided.

For rural road sections an historical period as long as possible may be required to provide sufficient data for the identification of countermeasures.

In determining the period for the accident data, it is necessary to take cognisance of changes, either controlled or uncontrolled, which may affect the accident pattern over the period. Major changes could invalidate the procedures.

4.3 RECOMMENDED PROCEDURE

4.3.1 System-wide Accident Data

The annual average accident rate per kilometre is required as a basis for comparison of individual locations to the system being considered.

There are generally three possible levels of system-wide accident data depending upon the level and objectives of the study being undertaken:

For a State-wide programme concentrating on major interstate and intrastate highways it would be necessary to have detailed State-wide averages so that each location could be compared on a like basis. In this instance, the averages should only include these highways.

For a State-wide programme concentrating on rural arterial roads, it would be necessary to have detailed State-wide averages for such highways/roads.

For a municipal programme, it would be necessary to have detailed municipal averages again for comparison on a like basis. In this instance the averages should only include roads for which the municipality would have the responsibility.

A fourth level may be considered for National Highways since these are the responsibility of the Federal Department of Transport. However, such a programme would have to be initiated at that level because of the need to compile data from each State.

In the urban research, the intersection results were checked by calculating the average for all roads and by road type to simulate the different road characteristics. This showed there was no increased benefit from using categorised rates.

In the rural section evaluation, the average used was for all routes not categorised by road type, as the urban intersection and section research did not suggest a superior identification when considering categorised rates.

In the light of this research, it was concluded that a separate rate for urban and rural roads is appropriate for identification.

The research suggested that the accident data should be based on casualty accidents only because of the lack of consistent data on property damage accidents.*

4.3.2 Critical Accident Rates

The annual casualty accident rate per kilometre for each section is compared.

The critical casualty accident rate is calculated using the formula:

---

*If reliable information is available on total accidents, States may wish to use total accidents. This, however, was not shown to improve the accuracy of the procedures in the research.

$$CR = A + 1.645\sqrt{\frac{A}{M}} + \frac{1}{2M}$$

where

- CR is the critical rate
- A is the average casualty accident rate
- M is the length of the section in kilometres
- 1.645 is based on a 95% confidence limit implying there is a 5% chance that the section of the road may be indicated as having a significantly high accident rate, even though the section is not specifically hazardous.

Those sections for which the actual casualty accident rate is above the critical rate are considered worthy of detailed investigation. The critical road sections, however, are not ranked at this stage since final ranking for implementation will be based on economic criteria (see Chapter 6).

4.3.3 Numerical Example

Introduction

In the rural shire of Upshire a number of recent accidents on the Alphabet Highway has given rise to concern. The Shire Engineer has decided to investigate the accident record along the Highway to determine whether any one section is particularly more dangerous than any other section.

From the information provided by the State Road Authority the Shire Engineer has been able to determine the average casualty rate for the total length of rural highways in the Shire. Subsequently, the accident rate for each section of the highway in Upshire has been compared to the critical accident rate to determine whether any of the sections should be considered for treatment.

Examples of the calculations undertaken are outlined below.

Highway Accident Data

The average annual casualty accidents per kilometre for the total length of highway in the Shire has been calculated at 0.4 accidents per kilometre, based on:

. Average number of casualty accidents per annum on the rural road network	75
Total length of rural road network (km)	187
Average casualty accident rate per kilometre on the rural road network (calculated by dividing the average number by the length)	0.401

Section Data

The individual sectional data is illustrated in the following Table with all necessary calculations. The critical accident rates are calculated using the equation detailed in Chapter 4. One calculation is illustrated:

For the Aback-Babble Roads Section

$$CR = A + 1.645 \sqrt{\frac{A}{M}} + \frac{1}{2M}$$

$$= 0.4 + 1.645 \sqrt{\frac{0.4}{1.37}} + \frac{1}{2 \times 1.37}$$

$$= 1.65$$

ALPHABET HIGHWAY

Intersecting Road	Intersecting Road	Distance km.	Accidents in 4 year period PDO	PI	F	Casualty accidents per annum per km.	Critical Rate	Critical Section
Aback Rd.	Babble Rd.	1.37	5	8	1	1.64	1.65	?
Babble Rd.	Cab St.	1.64	3	7	0	1.07	1.51	
Cab St.	Dale St.	0.48	0	4	0	2.08	2.94	
Dale St.	Eager Rd.	0.41	3	9	0	5.48	3.24	*
Eager Rd.	Fable Rd	1.63	5	9	0	1.38	1.52	
Fable Rd.	Gala St.	0.87	1	4	2	1.72	2.08	
Gala St.	Hack Rd.	0.69	2	9	2	3.98	2.37	*
Hack Rd.	Ideal St	1.03	2	1	0	0.24	-	
Ideal St.	Jay Rd.	8.56	0	4	0	0.23	-	

PDO is property damage only; PI is personal injury;
F is fatal accident

Note the critical rate has not been calculated for the Hack Road to Ideal Street and Ideal Street to Jay Road sections as the casualty accident rate is below the average rate.

Investigations

Clearly only Dale St - Eager Rd and Gala St - Hack Rd have a casualty rate above the critical rate. Therefore, the Shire Engineer should include these sections with other similarly identified sections and subject them to detailed investigation. In this instance, the casualty accident rate for the section between Aback Road and Babble Road was relatively close to the critical rate and, therefore, this section may have been considered for further investigation.

5. INVESTIGATION OF POTENTIAL ACCIDENT COUNTERMEASURES

5.1 INTRODUCTION

It is generally acknowledged that it is not always easy to highlight the exact problem at locations identified as being hazardous and, therefore, it can be difficult to select the appropriate countermeasure. Countermeasure selection must be a balance between formalised procedures and engineering judgement since, in the majority of instances, mprovements are site dependent and will rely upon experience gained from previous applications of countermeasures.

However, as a basic input to the formalised procedures, it is paramount that a detailed systematic analysis of accident data, road characteristics, traffic data and driver behaviour be undertaken. Such an analysis will ensure a level of accuracy and completeness commensurate with all the information available, and should avoid premature conclusions.

The following sections indicate a basis for this analysis but, again, it is stressed that it is not the intention of these Guidelines to superimpose the methodology on any authority.

5.2 DIAGNOSIS OF ACCIDENT PROBLEMS

5.2.1 Accident Data

The type of information required is summarised by the Organisation for Economic Cooperation and Development (OECD) (1976) as the accident history in a specific time period in terms of:

accident types (according to movements before accident)

collision types

number of accidents

accident severity (fatal, serious and minor injury, or property damage only. The last if possible as a monetary value).

The simplest means of presenting this information is the collision diagram (Figure 5.1) or a summary of accident statistics (Figure 5.2) or a combination of the two (Figure 5.3). The collision diagram is particularly useful for intersection investigations whilst the tabular statistics or combination is more related to road section investigations.

5.2.2 Road Characteristics

A complete inventory of road characteristics should be undertaken at any identified location. Landles (1980) suggested a comprehensive check list of factors which may be appropriate for detailing these characteristics (Figure 5.4). This list may have to be modified for the more complex accident sites, particularly rural sections.

5.2.3 Traffic Data

The traffic volume data previously outlined also should be collected if not already available.

In some investigations, such as provision of right turn lane or phase at traffic signals, turning count data may also be required.

5.2.4 Driver Behaviour

In many instances the predominant accident causation factors may not be obvious from the basic data and it will be necessary to undertake more detailed studies involving driver behaviour analysis. For example, speed studies may be required to determine a particular problem, or a detailed conflict analysis may highlight problems not previously evident from basic data.

FIGURE 5.1

ILLUSTRATIVE EXAMPLE OF A COLLISION DIAGRAM

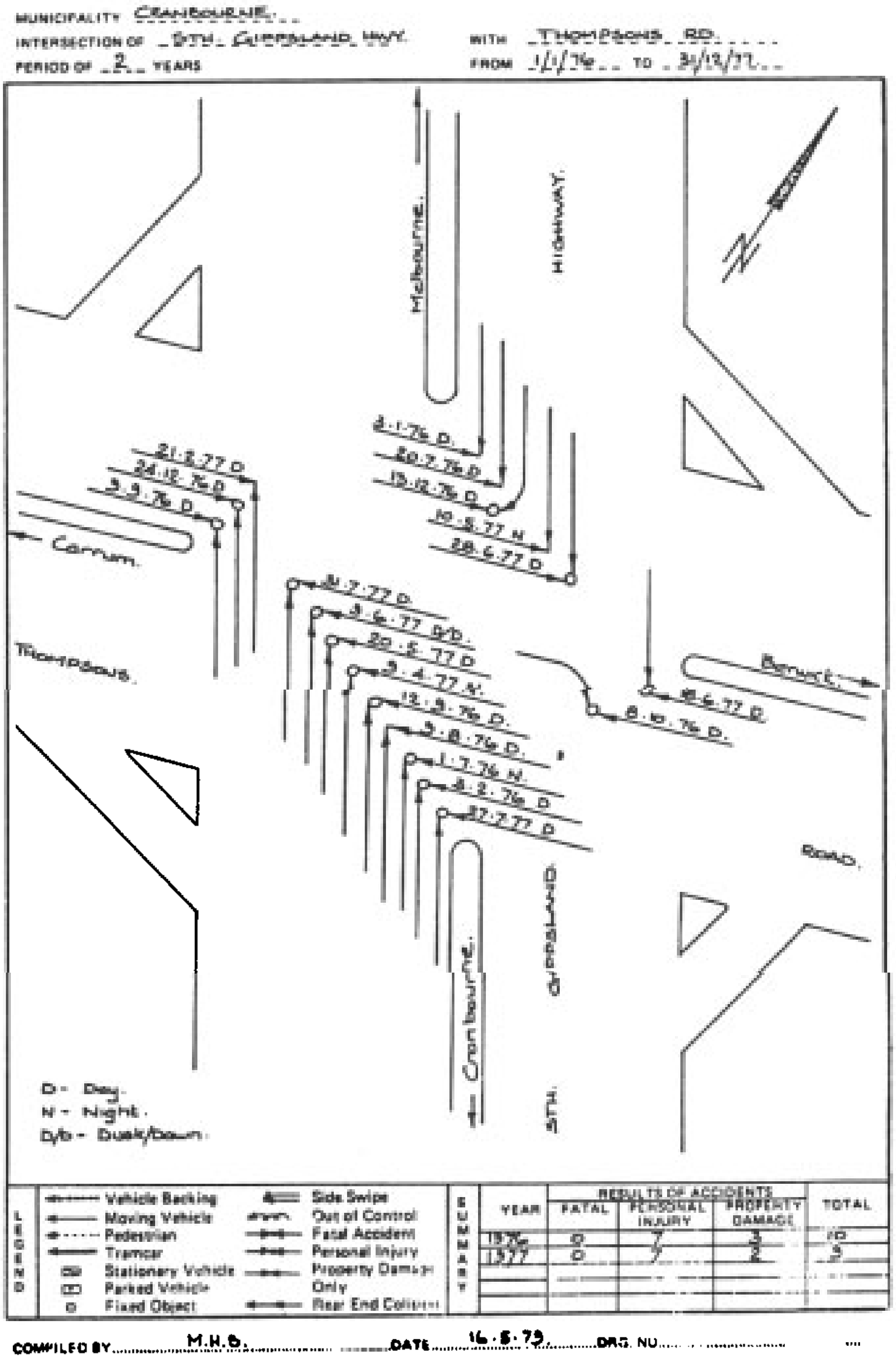


FIGURE 5.2

ILLUSTRATIVE EXAMPLE OF A TRAFFIC ACCIDENT ANALYSIS SHEET

TRAFFIC ACCIDENT ANALYSIS

1. Location

2. Accident History

Period of Data: from to

	F	PI	PD	CASUALTY ACCIDENT (F + PI) Wet	Dry	Night*	Day	ROAD USER MOVEMENT (RUM)
1973								
1974								
1975								
1976								
1977								
1978								
1980								
TOTAL								

3. Wet to Dry Ratio

   Wet/Dry =

*Dawn/Dusk = Night

4. Night to Day Ratio

   Night/Day =

5. Estimated Cost of Accidents (1980 values)

   Average weighted cost of all accidents per casualty accident,

   C = $20,000 Urban

   = $30,000 Rural

   No. Casualty Accidents (F + PI) =

   Est. Cost of All Accidents = $

6. Casualty Accident Rate

   (a) Intersection

   $$R = \frac{A \times 10^6}{n \times 365 \times 2 \sqrt{V_a \; V_b}}$$

   =

   (b) Mid-block

   $$R = \frac{A \times 10^8}{n \times 365 \times V \times L}$$

   =

Where

A = F + PI

n = no. of years

$V_a = \sum$ AADTs of the two approaches with the highest & 2nd highest approach volumes

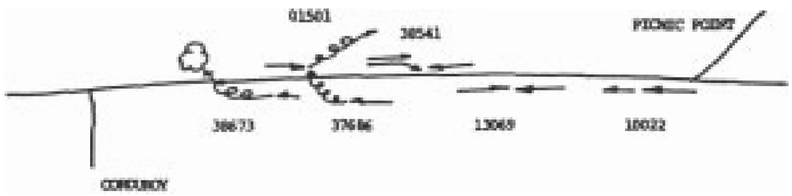
$V_b = \sum$ AADTs of the two approaches with the 3rd & 4th highest approach volumes

L = length of mid-block

SOURCE: Road Construction Authority, Victoria

<u>FIGURE 5.3</u>

ILLUSTRATIVE EXAMPLE OF AN ALTERNATIVE PRESENTATION OF ACCIDENT DATA

LOCATION	
CORDUROY PICNIC POINT	

Accident No	38673	01501	37686	38541	10022	13069
Date : Day	12:12:80 Fri	13:01:80 Sun	06:12:81 Sun	10:12:81 Thur	11:04:79 Wed	08:05:80 Thur
Time:Light	18:30 Day	05:45 Night	19:30 Day	13:50 Day	15:30 Day	17:10 Day
Weather	DRY	DRY	DRY	DRY	DRY	DRY
SEVERITY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY
	200m East of Corduroy Westbound vehicle lost control on gravel shoulder swerved across the carriageway and struck tree 45m away.	300m East of Corduroy Eastbound vehicle veered onto gravel shoulder and lost control, struck post.	300m East of Corduroy Westbound vehicle swerving to avoid vehicle unparking on north shoulder, lost control on gravel shoulder and swerved across the road.	400m East of Corduroy Eastbound vehicle overtaking another vehicle saw approaching vehicle, braked lost control and side-swiped vehicle.	500m West of Picnic Point Westbound vehicle ran into rear of stationary vehicle awaiting direction from flagman at roadwork.	Undefined Location Eastbound vehicle collided with westbound vehicle which had lost control. Vehicle ran off road into paddock.

FIGURE 5.4

ILLUSTRATIVE COMPREHENSIVE CHECK LIST FOR DETAILING ROAD CHARACTERISTICS

SITE CHECK LIST The undermentioned items are suggested as a guide when making a site inspection. It will obviously only be necessary to use those parts of the list applicable to the particular site and problem involved	LOCATION:- DATE:-
ROAD:- Width Single-dual - one-way No of lanes Bus Lanes Markings (hatch-box junction etc) Refuges - bollards - toffee apples Camber Gradient Kerb ramps Centre strip gaps Guard railing - extent and type	SIGNING (Note on plan) Type If illuminated Foliage obstruction VISIBILITY Site lines Obstruction to view (Post boxed - litter bins etc) Concealed entrance SPEED Limit 85 percentile speed
LIGHTING Type Height of columns:- Position of Columns (show on plan) Obstruction by foliage STATUTORY UNDERTAKINGS Show manhole covers etc on plan	PUBLIC TRANSPORT Route Nos Type of vehicles Frequency Location of Stops Shelters Stands etc Taxi Rank
ROAD SURFACE Type Condition Anti-skid treatment (show on plan) RESTRICTIONS (Show on plan) Waiting - Meter Zone Loading - Banned turns Clearway - Bus Stop Clearway	AUTOMATIC TRAFFIC SIGNALS Company High Intensity Type of detector Pedestrian phase Early cut off Position of Secondary light Phasing and Cycle times Linking Area Traffic Computer Control
PEDESTRIAN FACILITIES Zebra/Pelican Crossings (show on plan - plain centre islands - stagger) Spot lights Illuminated poles Toffee Apple Children School Crossing Patrol or Police (hours of attendance) Footbridge or underpass VEHICLES Parked Car Parks Rear access	ENVIRONMENT School Church Library Place of Entertainment Station Bus Terminus Cafe/Take Away Toilets Public House Garage - Petrol Station Fire-ambulance-police station PHOTOGRAPHS TRAFFIC COUNTS

SOURCE: Landles (1980)

5.3 SELECTION OF COUNTERMEASURES

The use of an appropriate countermeasure for a particular accident problem is generally not well documented, the selection being based on professional judgment as well as objective data.

OECD (1976) summarised the selection procedure by stating that "No simple formula can be drawn up to define the crucial step from diagnosis of problem areas to selection of treatment. This decision must be made by the engineer, based on his experience and judgment...". Laughland et al (1975) reiterated the point by stating that "Someday we may be able to feed a computer with data on all circumstances and conditions and receive back a 100% foolproof solution. But, until that time comes, there is no substitute for careful, comprehensive and logical analysis by an experienced person...".

This is clearly an area requiring much more research to assist the engineer to select the appropriate countermeasure for hazardous locations. This has been recommended in the Final Report of this Study.

However, the literature does provide lists of possible countermeasures for consideration. A comprehensive list was reported by OECD (1976) which included the types of countermeasures in five categories, namely:

Geometric design
Road surfaces
Road markings and delineation systems
Road signals and furniture
Traffic management

Each countermeasure was then discussed together with its possible use and the accident types which can be alleviated by its implementation. Figure 5.5 illustrates one of the summary

FIGURE 5.5

EXAMPLE OF A SUMMARY RELATING ACCIDENT TYPE AND POSSIBLE COUNTERMEASURE

Accident Type	Possible Treatment	Potential Benefit
High accident rate over a specific road section.	- Local speed limit - Enforcement of speed limit	Overall reduction in accidents. Reduction of single vehicle accidents.
Single vehicle accidents at bends.	- Local speed limit - Advisory maximum speed limit - Selective enforcement of speed behaviour by automatic warning system which is activated by too fast driving vehicles	Reduction of run-out-of-road accidents.
High accident rate at intersections.	- Installation of traffic signals .... - Change type of priority control and installation of Stop or Yield sign (at uncontrolled intersections) - Prohibit parking and stopping near intersections .... - Improve and modernise existing signals	- Reduction of right-angle-accidents .... - Reduction in right-angle and turning accidents .... - Reduction in right-angle-turning and nose-to-tail accidents
High proportion of accidents involving left-turning vehicles at intersections.	- Exclusive left-turning phase at traffic signals - Prohibition of left-turn - Addition of left-turn lane	Reduction of accidents involving left-turning vehicles, both head-on and nose-to-tail accidents.
High proportion of nose-to-tail accidents at intersections.	- Improve visibility of signal head - Co-ordination of individual signals to a progressively timed signal system	Reduction in nose-to-tail accidents.
High proportion of pedestrian accidents at intersections.	- Installation of traffic signals .... - Installing of exclusive pedestrian phase at existing traffic signals - Introducing of one-way system	- Reduction of pedestrian accidents .... - Reduction of pedestrian accidents involving turning vehicles
High proportion of accidents due to pedestrian/vehicle conflict.	- Installation of zebra crossing or light controlled pedestrian crossing - Construction of underpasses or bridges for pedestrians - Installation of fences along sidewalks to prevent pedestrians crossing at unsafe places - Prohibit parking and stopping - Introduction of one-way street - Introduction of speed reducing measures like road humps	Reduction of accidents involving pedestrians but also other types of accidents.
High proportion of accidents involving parked vehicles.	- Prohibition of kerb parking and stopping - Providing of parking facilities outside roadway area	- Reduction of accidents involving parked vehicles, reduction of pedestrian accidents - Reduction of pedestrian accidents in association with parked vehicles particularly effectual to reduce accidents involving children

Note : Left-turning refers to right hand driving. In Australia this would be right-turning.

SOURCE: OECD (1976)

tables which relates the type of accident to possible treatment and potential benefit.

Other comprehensive lists of countermeasures are available in hazardous road locations literature, for example Barton (1977) and Nelson English (1981). Sometimes these, for example ADI(1981), include the accident reduction effect expected from these countermeasures.

The accident reduction capability of the various countermeasures is discussed in more detail in Chapter 6.4.4.

6. ECONOMIC EVALUATION AND RANKING OF HAZARDOUS ROAD LOCATIONS

6.1 INTRODUCTION

Having determined which countermeasures may reduce the number or severity of accidents at critical locations, it is necessary to select the best countermeasure for each location and rank these in priority order for implementation.

If funds and resources were unlimited, all appropriate countermeasures could be implemented at each location. However, because funds are usually constrained, every effort must be made to achieve the greatest overall benefit from available funds.*

The economic objective assumed for this programme is that the identification of countermeasures and their priority implementation maximises the economic benefits from the overall hazardous road locations programme.

6.2 RECOMMENDED EVALUATION PROCEDURE

Several traditional evaluation criteria have been used in economic analysis, particularly:

benefit-cost ratio

net present value, if annualised this is referred to as net annual benefit

----

*It has been suggested that the investigation of all locations identified as hazardous may be unnecessarily resource consuming, especially if the identification procedures produce a long list of locations. However, if all locations are not investigated, Authorities may be financing intuitively many low cost treatments which may not give the same overall benefits as a thoroughly researched package of treatments.

internal rate of return

first year rate of return

There has been considerable debate concerning transport economics and evaluating infrastructure investment, but consensus opinion appears to favour benefit-cost ratio for evaluating public works programmes.

The form of the agreed benefit-cost ratio is:

$$\frac{\text{Discounted savings in accident costs and secondary benefits}^{*}}{\text{Discounted capital and maintenance costs}}$$

However, it should be noted that this criteria is not universally accepted. Net present value is sometimes preferred as it measures total benefits. A high first year rate of return has some supporters for road safety initiatives since it ensures an immediate return on capital expenditure.

The research on identification procedures for urban intersections illustrated that the optimal ranking of individual elements of a programme in terms of achieving the maximum net present value for the programme, was a ranking by benefit-cost ratio. A near optimal ranking was achieved when individual elements were ranked by their net present value.

Moreover, the research on rural road sections showed that the methods based on benefit-cost ratio to select from alternative treatments at each identified location resulted in greater economic value than those based on net present value.

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*If a countermeasure implementation has significant impact on delays either by reducing or increasing delays, these should be included in the secondary benefits as either a positive or negative benefit.

Although it is acknowledged that the ranking by benefit-cost ratio tends to assign high rank to countermeasures with a relatively low net present cost, the other potential advantages led to the adoption of benefit-cost ratio as the preferred procedure.

6.3 ECONOMIC CRITERIA

The economic criteria used to measure the economic value of a countermeasure are:

Benefit-cost ratio (BCR), used to determine the appropriate countermeasure from a range of possible treatments, is defined as net present benefit (NPB) divided by the net present cost (NPC)

$$BCR = NPB/NPC$$

The cumulative benefit cost ratio, used to determine the economic value of the programme, is defined as the cumulative net present benefit divided by the cumulative net present cost

$$BCR = \sum NPB/NPC$$

Net present benefit (NPB) is defined as the total value of benefits due to accident loss reduction over a defined period based on an economic discount rate

$$NPB = \sum_{1}^{n} B / (1 + d)$$

where

n is the programme period
d is the discount rate

n should be related to the service life of a treatment with the longest life before re-installation generally being considered. In terms of low cost treatments, 10 years is probably an appropriate service life.

d should be related to the general interest rate applicable at the time of the study.

Net present cost (NPC) is defined as the cost of implementation (C) (discounted if not undertaken in the first year) plus the cost of maintenance (M) over a defined period based on the economic discount rate

$$NPC = C + \sum_{1}^{n} M/(1+d)^n$$

Net present value is defined as the net present benefit minus the net present cost

$$NPV = NPB - NPC$$

6.4 DATA REQUIREMENTS

6.4.1 Costs of Countermeasures

The costs of countermeasure implementation should be based upon actual estimates of each treatment at current prices. However, it is recognised that when a number of possible countermeasures are being considered this may be impractical. In this instance costs can be based on typical treatment costs, updated where necessary to current prices. If possible these typical costs should be calculated from recent implementations in the area under consideration.

If no local data is available the typical unit construction costs on which cost estimates can be based are illustrated in Tables 6.1 and 6.2 for urban and rural areas respectively.

In establishing countermeasures cost it is necessary to consider the service life of countermeasure since this will dictate whether further implementation will be necessary within the programme period.

TABLE 6.1

TYPICAL CONSTRUCTION COSTS FOR COUNTERMEASURES IN URBAN AREAS

	Average Cost $	Units
TRAFFIC SIGNALS		
- New site - Two way road	40,000 - 50,000	Site
- New site - Duplicated carriageway	60,000 -100,000	Site
- Minor remodel	15,000 - 20,000	Site
- Major remodel and minor roadworks	45,000	Site
- New fully controlled turn phase	2,000 - 3,000	Site
- New mast arm	2,000 - 3,000	Site
- Relocate pedestal	500 - 1,000	Site
- Pedestrian signals	20,000	Site
- Signal link, depending on controller capacity	8,000 - 15,000	Site
ROUNDABOUTS		
- Local intersection	10,000 - 15,000	Site
- Secondary arterial/collector intersection	150,000 -200,000	Site
- Primary arterial intersection	300,000 plus	Site
DELINEATION THROUGH INTERSECTION		
- Linemarking, Raised pavement markers	500 - 1,000	Site
PROVISION OF NEW EXCLUSIVE RIGHT TURN LANE, excluding signal works	10,000 - 15,000	Site
RELOCATE ELECTRICITY POLE, depending on voltage transformer on pole	1,000 - 10,000	Site
INSTALLATION OF GUARDRAIL, to protect pole and deflect traffic	100	m

TABLE 6.1 (cont'd)

	Average Cost $	Units
CONVERT 4 LANE INTERSECTION TO 5 LANES, by providing right turn lane for both approaches	2,000	Site
TRUNCATE SERVICE ROAD, road enters carriageway prior to intersection	9,000 - 15,000	Site
SPLITTER ISLAND (2.4m wide)		
- Paved median	250	m
- Landscaped median	150	m
LEFT TURN SLIP LANE, excluding service alterations and land acquisition	15,000 - 22,000	Site
OVERSIZED TRAFFIC CONTROL SIGN	300 - 500	Site
IMPROVE SKID RESISTANCE		
- grooving	7	Sq.m
- resurface over existing asphalt for 3 approach lanes	8,000	Site

NOTE: Costs based on 1985 estimates

SOURCE: Road Traffic Authority, Victoria

TABLE 6.2

TYPICAL CONSTRUCTION COSTS FOR COUNTERMEASURES IN RURAL AREAS

	Costs $	Units	Service Life Years
CONSTRUCTION			
Freeway, 2 lanes	2,500,000	km	30
Dual carriageway, 2 lanes	1,000,000	km	30
Lane widening, 3.0m to 3.7m	180,000	km	30
Sealing shoulder	2	m	5
or	5,000	km	5
Surface shoulder	4	m	30
or	10,000	km	30
DELINEATION			
Barrier line	95	km	0.5
Edgeline	95	km	0.5
Raised reflective pavement markers,	5	each	5
based on 6m spacing	850	km	5
Guideposts,	20	each	15
based on 20m spacing	1,000	km	15
Guardrail	60	m	15
SIGNING			
Reflectorized, 750 x 750mm	150	each	5
Reflectorized, 900 x 900mm	250	each	5
Advance warning signs	300	m sign area	5
LIGHTING			
Linear		km	30
Intersection	15,000	each	30

NOTES: Costs based on 1982 estimates
Costs for delineation signing and lighting include installation costs.

SOURCE: Road Construction Authority, Victoria

6.4.2 Costs of Maintenance

The costs of maintenance again should be based on local estimates at current prices. However, in the absence of local data, typical maintenance costs on which cost estimates can be based are illustrated in Tables 6.3 and 6.4 for urban and rural areas, respectively.

Maintenance costs should only take into account remedial countermeasures and not general roadworks in the area.

6.4.3 Accident Reduction Savings

The savings resulting from the countermeasures are measured by the reduction in accident losses over and above any reduction which would occur in the absence of the treatment.

The accident experience in the investigation period prior to treatment is used to indicate the subsequent expected accident experience.

This investigation period should be as long as possible so that a realistic previous accident record is established. If only a short period (say the two year identification period) is used it may lead to an inflated estimate of savings because the accident experience in this short period may be a chance high (even allowing for critical rate analysis). At the same time the period should be considered so that no major changes at the locations affect the accident history.

If only such a short period is available, Hauer (1980) describes procedures for correcting for the bias, based on the Poisson assumption.

The estimated annual saving from implementing any countermeasure is calculated by multiplying the expected annual losses from the previous accident experience by the estimated reduction factor.

TABLE 6.3

TYPICAL MAINTENANCE COSTS IN URBAN AREAS

	Costs $	Units
TRAFFIC SIGNALS		
Operating Cost - Average	1,200	per annum
- Large	2,000	per annum
Maintenance Cost	1,200	per annum
DELINEATION		
Linemarking	installation cost every twelve months	
Guardrail	replaced upon damage	
SIGNING		
All Signs	replaced upon damage	

Note: Costs based on 1985 estimate

SOURCE: Road Traffic Authority, Victoria

TABLE 6.4

TYPICAL MAINTENANCE COSTS IN RURAL AREAS

	Costs $	Units
CONSTRUCTION		
Pavement	0.20	m
	or 2,000	km
Shoulder	0.20	m
	or 2,000	km
DELINEATION		
Linemarking	installation cost every six months	
Guideposts	replaced upon damage	
Guardrail	replaced upon damage	
SIGNING		
All Signs	replaced upon damage	

NOTE: Costs based on 1982 estimates

SOURCE: Road Construction Authority, Victoria

TABLE 6.6

TYPICAL ACCIDENT REDUCTION FACTORS FOR COUNTERMEASURES IN RURAL AREAS

	Percentage Reduction	Range
Improvement to dual carriageway	30	
Re-construct highway	25	10 - 40
Left turn lane	15	
Right turn lane	40	25 - 60
Acceleration lane	10	
Lane widening	25	
Overtaking lanes	25	
Re-construct intersection	40	
Surface shoulder	30	25 - 40
Widen shoulder	10	
Barrier line	65	
Edgeline-highway or curve	15	
Raised reflective pavement markers	15	
Guardrail	30	10 - 50
Guideposts - highway	25	
- curves	32	
For two lane road		
Advance Warning signs-highway	30	
-intersection	35	
For multi-lane road		
Advance Warning signs-highway	18	
-intersections	9	

NOTE: Range is only given where there are significant differences from the assumed reduction factors

SOURCES: Jorgenson (1966); Laughland et al (1975); Pak-Poy (1974); ADI (1981);

The accident reduction factor for a particular countermeasure is applied only to the intersection or length of road affected by the countermeasure and the accidents at the location. It could be argued that the implementation of certain countermeasures could have a residual effect over a greater area, for example overtaking lanes may reduce frustration levels so that drivers may not attempt to overtake on preceding or succeeding sections. However, the definition of residual effects would be extremely arbitrary and as such should be ignored.

For locations at which more than one countermeasure is recommended the additive effect of the countermeasures should be combined as follows:

$$\text{Expected Accidents} \times \underset{\text{(Countermeasure 1)}}{\text{Accident Reduction}} \times \underset{\text{(Countermeasure 2)}}{\text{Accident Reduction}}$$

6.4.5 Costs of Accidents

The best estimates of costs of Australian road accidents available at this time are those derived by Atkins (1981).* These 1978 costs have been updated to 1984 prices based upon the increase in average weekly earnings, the dominant index in the basic cost parameters used to determine accident costs.

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*These costs are based on historical facts (ex post costs). However, there is a view that society is willing to pay more to prevent future accidents than the cost of past accidents. The value that society is willing to pay has been estimated at 2 or 3 times the ex post cost of an accident of the same type and severity (ex ante costs). If ex ante costs were used it is more likely that proposed treatments would be cost-beneficial. These costs have been discussed by many researchers without determining which is the most appropriate.

In the research for urban intersections, fatal accidents were given a weight equivalent to the cost of such accidents in the derivation of total accident losses. However, when the intersections were ranked in order of the estimated treatment benefits, it was found that the fatal accidents contributed more than one third to the estimated benefits. Since this effect was due to a very limited number of fatal accidents, it was considered that this procedure produced unstable estimates of treatment benefits calculated using this approach.

Accordingly, fatal accidents should be combined with other casualty accidents in the calculation of annual accident losses, and costs assigned on the basis of casualty and property damage only accidents.

The accident costs to be used at 1984 prices:

casualty accidents	$17,100*
property damage only accidents	$ 1,400*

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*Highways Department (South Australia) suggest that these totals are low compared to those derived by the Department: For urban areas, $28,500 for a casualty and $1,420 for a property damage accident and for rural areas $31,000 for a casualty and $2,180 for a property damage accident. These have been obtained by dividing the total reported accident costs by the total number of accidents for each type and adding average insurance payouts for casualty accidents. Different costs may be used but these should be used consistently within specific programmes.

6.5 RECOMMENDED COUNTERMEASURE SELECTION PROCEDURE

6.5.1 Net Present Costs

The net present cost of each treatment at current prices is calculated for the programme period by adding the implementation cost and the discounted re-implementation cost if necessary during the programme period and the discounted maintenance costs.

The programme period is generally ten years as this is compatible with the service life of low cost remedial countermeasures.

For calculation purposes, the interest rate used for discounting future costs can be taken as 10%. However, this should be reviewed frequently by reference to current financial indicators.

6.5.2 Net Present Benefits

The net present benefits of each treatment at current prices is calculated by summing all the discounted annual accident savings for the programme period.

6.5.3 Benefit-Cost Ratio

The benefit-cost ratio is calculated by dividing the net present benefit by the net present cost (Chapter 6.3).

6.5.4 Countermeasure Selection

The appropriate countermeasure, among a number of options identified, is the one with the highest benefit-cost ratio. This becomes the countermeasure adopted in the overall programme for ranking of priorities.

6.6 RECOMMENDED RANKING PROCEDURE

Locations are ranked by the benefit-cost ratio of the selected countermeasure at each site to produce an implementation programme in order of priority.

For each priority rank level, the cumulative net present benefits and cumulative net benefit costs are computed to measure the benefit-cost ratio of implementing the programme to that level.

The locations included in the ranked order are then related to the implementation cost so that, at a fixed implementation budget, the number of locations and the overall benefit-cost ratio are readily determined.

7. MONITORING OF COUNTERMEASURES

One of the principal deficiencies of locational safety programmes has been the inadequate follow up and evaluation of the actual results of implemented improvements. This is essential to monitor the value of the programme, to generate information for methodological improvements and to determine the effects of various countermeasures on reducing accident rates and severity ratios for future reference.

The most appropriate technique for monitoring countermeasures would appear to be a before-and-after study. The Binomial or Poisson test could be used to test the statistical significance of the reduction in the number of accidents.

However, the problem of "regression towards the mean"* inherent in hazardous location identification, and which could confound before-and-after analysis, must be considered. This problem can be resolved by the use of a control group of locations which are also identified as black spots but for which no countermeasures are being implemented. An alternative but similar measure of effectiveness does not require the control group to be accident black spots, only locations of similar characteristics prior to implementation measures. This latter methodology is that suggested by Teale et al (1979) for their recent study.

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*"Regression towards the mean" phenomonon is where individual road locations may have an exceptionally high number of accidents in a given period due solely to chance factors alone. Any subsequent analysis, therefore, would reveal a lesser number of accidents and would more closely approximate the mean value of accidents.

In addition to this research the Final Report of this Study recommended the detailed monitoring of countermeasures as part of the package of additional work necessary. It was suggested that there is a need for a uniform approach to the continual monitoring of countermeasure effectiveness. Without this, there is little sense in instituting identification and correction programmes. A major component of this research would include a review of the existing procedures in Australia and overseas, establishing guidelines for developing a programme and guidelines for the integration of these results into a nationwide data base.

In the interim, for those interested in monitoring countermeasures, a wide range of procedures are discussed in the proceeding of the Esso-Monash Civil Engineering Workshop on Traffic Accident Evaluation held in 1983.

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APPENDIX 1

ESTIMATION OF SYSTEM-WIDE ACCIDENT DATA

1. AVERAGE ACCIDENT NUMBER PER INTERSECTION

If information is not available on the total number of intersections, estimates can be obtained knowing the number (n) of intersections having one or more accidents, and their accident experience. Based on a Poisson model, the average accident occurrence rate (μ) at this truncated set of intersections is related to the rate at all intersections (λ) by the formula:

$$\mu = \lambda/(1 - \exp(-\lambda))$$

Furthermore, the expected number of intersections with one or more accidents is related to the total number of intersections (N) by the formula:

$$Ex(n) = N(1 - \exp(-\lambda))$$

These relationships can be used to estimate the required information using the following procedures.

Average Accident Numbers

The estimated average accident numbers per intersection ($\hat{\lambda}$) are obtained from the average accident numbers at intersections with one or more accidents ($\hat{\mu}$) via the relationship:

$$\hat{\mu} = \hat{\lambda}/(1 - \exp(-\hat{\lambda}))$$

From the available data, $\hat{\mu}$ is calculated and $\hat{\lambda}$ determined by trial-and-error.

Estimated Intersection Numbers

The estimated total number of intersections (N) is calculated from the number of intersections with one or more accidents (n) and the estimated average accident number ($\hat{\lambda}$) via the relationship:

$$\hat{N} = n/(1 - \exp(-\hat{\lambda}))$$

2. ACCIDENT RATES PER EXPOSURE

With limited resources available, it is often not feasible to obtain information on exposure at the total population of intersections. Instead, an average daily exposure can be calculated from a sample of intersections and weighted by the estimated population number ($\hat{N}$).

Estimated accident data rates per exposure are calculated from $\hat{\lambda}$ and estimated annual exposure per intersection.

APPENDIX 2

RESULTS OF ANALYSES OF MONITORING COUNTERMEASURES

TABLE A2.1

CASUALTY ACCIDENT RATES AT SIGNALISED INTERSECTIONS

Intersections Type	No.	Mean Casualty Accidents per 10^7 vehicles entering Before	After	% Change	% Confidence Limits
"T" Junction	9	1.6	1.7	+7%	24% decrease to 52% increase
"Y" Junction	6	1.0	0.9	-12%	49% decrease to 51% increase
Cross-roads	26	4.5	1.6	-64%*	58% decrease to 69% decrease
All Sites	41	3.4	1.5	-55%	49% decrease to 61% decrease

NOTE: *Significant at 90% confidence level

SOURCE: Road Construction Authority (1982)

TABLE A2.2

CASUALTY ACCIDENT RATES AT FIVE LANE INTERSECTION TREATMENTS

Location	% Change in Casualty Accident Rate
At the intersection	2% decrease
On the approaches to the five lane treatments	38% increase*
Both locations combined	10% increase

NOTES: *Significant at the 90% confidence level.

SOURCE: Road Construction Authority (1982)

TABLE A2.3

CASUALTY ACCIDENT RATES AT ROUNDABOUTS IN VICTORIA

Group	Mean Casualty Accidents Per 10^7 Vehicles Entering		% Reduction	90% Confidence Limits
	Before	After		
Minor Residental Streets	7.4	0.3	95%	80%-99%
Collector streets	5.1	0.9	83%	74%-89%
Arterial/Sub-Arterial Roads	2.1	0.8	59%	41%-78%
All Routes	3.1	0.8	74%	66%-80%

SOURCE: Road Construction Authority (1982)

TABLE A2.4

CASUALTY ACCIDENT RATES AT RURAL STAGGERED "T" INTERSECTIONS

No. of Sites	Casualty Accidents Per 10^7 Vehicles Entering		% Reduction	90% Confidence Level
	Before	After		
10	17.4	2.7	85%	70%-92%

NOTE: The typical casualty rate of unsignalised cross-road intersections in rural areas is about 5 casualty accidents per 10 vehicles entering.

SOURCE: Road Construction Authority (1982)

TABLE A2.5

REDUCTION IN CASUALTY ACCIDENT RATE FOR RAISED REFLECTIVE PAVEMENT MARKERS

Accident Type	% Reduction in Casualty Accident Rate	90% Confidence Limits
'Single vehicle' and 'head on' at night	29%*	15%-41%
All night casualty accidents at night	26%*	13%-36%
'Single vehicle' and 'head on', day and night	21%*	10%-30%
'Single vehicle' and 'head on' by day	13%	3% increase to 27% decrease
All casualty accidents by day	7%	7% increase to 18% decrease
All casualty accidents	15%	6%-23%

NOTE: *Significant at 90% confidence level.

SOURCE: Road Construction Authority (1982)

TABLE A2.6

CASUALTY ACCIDENT RATES ON HUME HIGHWAY/FREEWAY SECTION

	WALLAN TO BROADFORD	AVENEL TO TUBBS HILL	VIOLET TOWN TO BADDAGINNIE	OVERALL
Before rate (casualty accidents per 100 mill. vehicle kilometres	45.1	35.9	39.9	41.9 (37.3 - 46.9)*
After rate (casualty accidents per 100 mill. vehicle kilometres	14.1	17.0	28.2	12.5 (10.2 - 15.2)*
Reduction (%)	68%	53%	29%	70%
90% confidence level	61%-74%	Not Significant	Not Significant	63%-76%

NOTE: *90% confidence level for the overall casualty accident rates

SOURCE: Road Construction Authority (1982)

TABLE A2.7

BEFORE AND AFTER CASUALTY ACCIDENTS AND CASUALTY ACCIDENT RATES - LIGHTING INSTALLATION ON PRINCES HIGHWAY EAST

Period	Before Period (3 Yrs)		After Period (3 Yrs)	
	Casualty Accidents	Casualty Accident Rate per 10^7 Veh.Km.	Casualty Accidents	Casualty Accident Rate per 10^7 Veh.Km.
Day	21	6.9	19	7.0
Night	21	27.6	13	18.8
TOTAL:	42	11.1	32	9.3

SOURCE: Road Construction Authority (1982)

6.4.4 Accident Reduction Factors

The derivation of accident reduction factors for each type of countermeasure likely to be used is very difficult. A review of existing information demonstrated that there is limited Australian data available to prepare a comprehensive list of reduction factors (particularly for rural areas) and overseas studies may have to be used to provide some of the required information.

If a countermeasure has been implemented a sufficient number of times in the local area to determine a local accident reduction factor, this should be used.

However, in the absence of local factors, typical accident reduction factors on which to base calculations are illustrated in Table 6.5 for urban roads (based on the work of Nicholas Clark and Associates), and Table 6.6 for rural roads (based on overseas experience).

This remains a topic requiring considerable detailed research and investigation. Therefore, it is important that wherever countermeasures are implemented, their performance should be monitored in detail.

Some of the monitoring studies undertaken and reported by the Road Construction Authority (1982) are illustrated in Appendix 2.

TABLE 6.5

TYPICAL ACCIDENT REDUCTION FACTORS FOR COUNTERMEASURES IN URBAN AREAS

TREATMENT	PERCENTAGE REDUCTION
Convert X to T	47
Median Closure	59
Safety Bars	14
Modify Signals	14
New Signals	19
Roundabout	57
Additional lane at intersection	22
New Channelisation	17
New Signals and Channelisation	40
Modify Signals and Channelisation	16 *
Street Closure	77

* It should be noted that the Nicholas Clark & Associates report suggested that there would be a 20% increase in accidents with modification of signals and channelisation. However, a reappraisal of the data for those intersections included in this sample showed that their data was dominated by a number of intersections in the growth areas of Southern Adelaide whereas there was for this sample a decrease in accidents.

SOURCE: Nicholas Clark & Associates (1984)