# IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS

# FINAL REPORT

*RACV Consulting Services*

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

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IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS: FINAL REPORT


Author(s)

SANDERSON, J.T., CAMERON, M.H., AND FILDES, B.N.

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 the identification and ranking of hazardous road locations throughout Australia. A study was conducted where potential procedures, identified from a detailed appreciation of overseas and Australian studies, were evaluated at urban intersections, urban sections and rural locations to determine preferred procedures. Selection criterion was in terms of accident risk and likely accident reduction and procedures were compared using their relative cost-effectiveness at this task. The study recommended procedures for the identification of hazardous road locations in Australia. A separate volume, Identification of Hazardous Road Locations: Procedural Guidelines, has been prepared for practitioners involved in programmes to identify hazardous road locations.



Keywords Identification, Procedures, Hazards, Roads, Urban, Rural, Intersection, Section, Accident, Numbers, Rates, Reduction, Risk, Exposure, Accident Severity, Countermeasures Cost-Effectiveness

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# 1. INTRODUCTION

In January 1981, the Federal Office of Road Safety commissioned RACV Consulting Services to undertake a study to define a practical and systematic procedure for the identification of hazardous locations throughout Australia.

## 1.1 STUDY OBJECTIVES

The objectives defined by the Federal Office of Road Safety for this project were FOUR fold.

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

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

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

3. 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

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

## 1.2 STUDY PROCEDURE

The study objectives outlined above were subsequently refined to develop a detailed study procedure. The following tasks were then undertaken.

1. Establishing the state-of-the-art of hazardous location identification procedures. A review of the research literature was undertaken to:

   . identify the evaluation techniques which have been used, and to determine their reliability, their acceptance and the administration and organisational requirements.

   . accumulate research findings by others on the effectiveness of countermeasures.

   . gain an insight into on-going research into predictive analysis techniques.

2. Analysis of existing evaluation procedures in use in Australia by reviewing the operations of each State Authority involved in hazardous location research.

3. Preparation of an inventory of existing Australian resources. A detailed assessment of each State's effort in the field of road accident data and analysis was performed which included an appraisal of:

   . the quantity and quality of available road accident data

   . the availability of any other accident-related data

   . data storage, processing and retrieval facilities

   . finance and staffing

   . relationships between agencies.

4. Defining potential identification procedures. The principle objective of the study was to develop an identification procedure which could be implemented immediately. The various techniques available, the techniques presently in

use in Australia and the constraints on data collection and processing, provided a framework in which to assess the range of procedure options that were available.

5. Comparison, selection and testing of the most likely options. Statistical assessment was undertaken to determine which procedure option produced a meaningful result. Each of the options were similarly field tested by:

   . selecting test locations to include a variety of development, terrain and roadway locations.

   . applying each procedure using actual accident records.

   . statistical testing where appropriate

   . traffic management and engineering evaluation of the effectiveness of each measure tested.

   . relative measure comparisons to highlight preferred procedures.

   . in-depth testing of the preferred procedure to develop procedural guidelines.

6. Definition of the scope of predictive analysis. The possibility of extending preferred procedures was investigated so that Authorities concerned with road safety could tackle accident prevention.

7. Preparation of a separate guideline document, outlining preferred procedures for practitioners.

## 1.3 OUTLINE OF THE REPORT

This report evolved from the working documents provided to the Federal Office of Road Safety during the course of the project. To keep the report manageable, it was necessary to include only those features, tables, analyses and formulae that directly bear on the arguments and discussions enclosed. Hence, any repetitiveness of data and calculations is minimised in the interest of simplicity and comprehension.

Readers wishing more detailed background to any of the arguments described are referred to the working documents available at RACV Consulting Services, 123 Queen Street, Melbourne, 3000.

## 1.4 REPORT STRUCTURE

Figure 1.1 shows the overall structure of the Hazardous Location Report. The format is summarised as follows:

- Chapter 2 discusses the identification of hazardous locations and defines the various terminologies used throughout the report.

- Chapter 3 outlines the overseas research into hazardous location procedures.

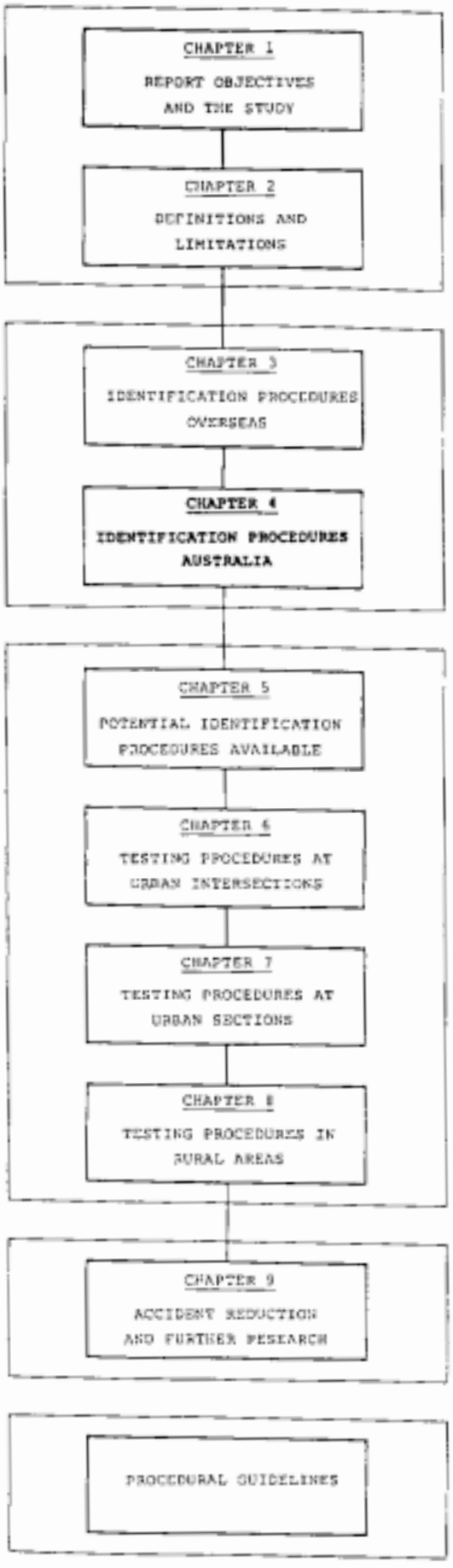
- Chapter 4 summarises the existing investigation procedures in each State in Australia and briefly reviews the existing data available in each State, the data requirements for the proposed procedures, and improvements to data bases necessary to accommodate these requirements.

- Section 5 describes potential procedures available for testing and evaluating hazardous road locations.

- Chapter 6 describes testing procedures for identifying hazardous locations at urban intersections.

FIGURE 1.1

IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS REPORT STRUCTURE



- Chapter 7 describes the testing procedures for identifying hazardous locations on urban sections.

- Chapter 8 describes the testing procedures for identifying hazardous locations in rural areas.

- Chapter 9 includes the recommendations resulting from the testing procedures, reviews overseas and Australian research into accident reduction factors, and describes further research required in hazardous location identification and investigation.

The procedural guidelines for hazardous road identification is a separate document to this study report. Copies are available through the Federal Department of Transport, Federal Office of Road Safety, Canberra, Australia.

# 2. DEFINING HAZARDOUS LOCATIONS

## 2.1 OVERVIEW

Programmes for identifying hazardous locations go under various names, such as "Accident Black Spot Programme", "High Accident Location Programme" and so on. A fundamental assumption of all these programmes is that adverse road design plays a contributory role in the occurrence of a substantial proportion of road accidents. OECD (1976) estimated this proportion as being one-quarter of all road accidents.

Subsequently, it follows that a substantial proportion of accidents could be averted by improving the existing road system. OECD (1976) conservatively estimated this saving as 20 percent. Hills and Jacobs (1981) pointed to increasing evidence from the U.K. and the U.S.A. that low-cost remedial measures, appropriately directed at identified hazardous locations, can be highly cost-effective in reducing accidents.

Acceptance of these assumptions, and of the cost-effectiveness of appropriately directed location treatments, has led to a plethora of hazardous location identification programmes throughout the world. The intention of the remainder of this chapter is to introduce some of the common objectives, concepts and terminologies used before embarking on specific descriptions of procedures in operation overseas and in Australia.

## 2.2 OBJECTIVES

It appears that no existing programme for identifying hazardous locations is concerned solely with identification. However, some Australian programmes tend to see this part of the process as being quite independent of the subsequent investigations aimed at diagnosing accident problems, evaluating countermeasures, and developing implementation priorities.

More commonly, hazardous location programmes have dual objectives of identifying and investigating hazardous locations. Quite often, these objectives can be inter-dependent as, for example, at the Greater London Council (Landles 1979). Here the accident blackspot programme was aimed at identifying locations with sufficient accidents of the same type for which cost effective remedial measures were already available.

The London example illustrates that hazardous location identification programmes can have integrated objectives well beyond merely identifying the location of hazardous parts of the road system.

The general objectives of this type of hazardous location identification programme, therefore, would include:

(i) identification of road locations at which:

- there is an inherently high risk of accident losses, and

- there is an economically justifiable opportunity to reduce this accident risk.

(ii) identification of countermeasures options and priorities which maximise the economic benefits from the programme.

## 2.3 PHASES OF IDENTIFICATION PROGRAMMES

To match these objectives, a hazardous location identification programme needs to include the following phases:

(i) locating high risk locations,

(ii) diagnosis of accident problem(s) at these locations,

(iii) identification of countermeasures(s) to these accident problem(s),

(iv) selecting from countermeasure options and developing countermeasure implementation priorities to maximise the economic benefits from the programme.

Phase (i) will henceforth be called the IDENTIFICATION PHASE, to match the limited objectives of historical hazardous location identification programmes. Phases (ii) and (iii) will be referred to as the INVESTIGATION PHASE, while phase (iv) will be called the PROGRAMME IMPLEMENTATION phase.

It is worth reiterating that these 3 phases need not be independent. The objectives and procedures of the Identification Phase, for instance, can influence the Investigation Phase, and vice versa. However, the main thrust of this project will be directed towards the IDENTIFICATION and PROGRAMME IMPLEMENTATION procedures for hazardous road locations .

## 2.4 DEFINING ROAD LOCATIONS

The first step in identifying hazardous road locations (HRL) is to define a unit of road location. The definition can be specific or broad; the location unit might be an individual site (eg, intersection or short road section), or a route or area.

There are competing objectives in formulating road location definitions. One objective is to maximise the potential number of accidents which occur at each location to minimize chance variation in accident incidence. This usually requires locations to be as large as possible. Another objective is to define each location as specifically as possible so that investigation and treatment of identified hazardous locations is aided. This usually requires locations to be as small as possible.

Intersections are an attractive type of location for use in HRL identification programmes. They are sufficiently specific to aid the investigation phase and usually have the potential for large numbers of accidents. This is particularly true for intersections on major roads.

Road sections between intersections are less attractive locations. Accidents on sections in urban areas occur relatively infrequently and usually do not cluster. This situation does not aid either identification or investigation. To facilitate section identification, it is possible to group contiguous road sections into a single length bounded by major road intersections. This process only requires that sections have the same minor intersection characteristics. Using this definition of a road section, however, the question of whether minor intersections should be considered as part of the section or not is always present.

## 2.5 TYPE OF ROAD LOCATION

The road system is never homogeneous, either in terms of design and construction or the amount of traffic carried. Hence, it would be quite inappropriate to consider all road locations collectively (no matter how defined) in a single HRL identification programme.

A normal regional classification for road location is whether the site is located in an URBAN or RURAL area. In urban areas, it is usual to consider intersection and sections separately. Sections on local streets are seldom considered other than in an "area" definition of location, and only intersections with major roads usually have sufficient accidents to be of interest. In rural areas, however, it is usual to consider intersections and sections together.

Within each classification, there can be further breakdowns if it is useful in the identification phase. Particular locations may have substantially different accident expectations depending on the road hierarchy, intersection configuration, and the presence of traffic controls. These factors then can be used to define sub-systems of the urban intersection classification.

## 2.6 CRITERION FOR HIGH ACCIDENT RISK

Having defined road location, the next step is to define what constitutes a "hazardous location". In general, hazardous locations are normally associated with high risk (or probability) of accident; the higher the risk of accident, the more likely the location will be considered hazardous.

There are two criteria commonly used to indicate high risk. The first is that the number of accidents per unit time is relatively large while the second is a relatively large accident rate. The second accident criterion may be defined in various ways, but essentially is the ratio of the number of accidents to the expected number of accidents under normal circumstances.

The number criterion measures high accident risk per unit time. Risk measured by the rate criterion is related to the type of measure used in its denominator, but in general, measures high risk per opportunity of accident occurrence. Typical denominators in rate criterion are vehicle-kilometres for sections, and the number of vehicles entering at intersections. These denominators are commonly referred to as 'exposure'.

There is little agreement on which type of criterion is most appropriate for identifying hazardous locations. Proponents of the number approach have argued it focusses attention on locations where most accidents occur, and hence, the programme has the most potential to reduce accidents. Proponents of the rate approach, however, argue that it identifies sites where there is something truly unusual, not just a high level of traffic.

In terms of achieving the general objectives of the HRL programme (see Chapter 2.2), there is little difference in the choice of identification criterion, though some practitioners may suggest otherwise. Both approaches can identify locations where treatment could be cost-beneficial. Whether treatment should be implemented, however, and whether this in turn maximally

contributes to the cost-benefitness of the programme, is also related to other identification procedures and to the subsequent investigations carried out.

An open question is whether the number or rate approach, or some alternative or combination of the two, is more effective and efficient in identifying locations where the resources required for subsequent attention are minimised and the economic treatment benefits are maximised. The eventual choice between these alternative dependent variables is usually empirically based.

## 2.7 UNDER REPORTING OF ROAD ACCIDENTS

There is every reason to believe that World-wide accident statistics are conservative. Bull and Roberts (1973) demonstrated that up to one-third of all injuries sustained in car accidents in the UK failed to appear in police notifications, particularly when only one vehicle was involved. Similar results have been found in other countries (McGuire 1973).

Shinar, Treat and MacDonald (1983) also questioned the validity of accident data in the United States. They argued that the least reliable accident reports were those concerned with road characteristics and accident severity.

Given the shortcomings that have been documented in Australian accident reporting (Smith 1976; Hendtlass, Bock and Ryan 1980; Wales 1983) it is most probable that deficiencies also exist in Australian data bases.

How these shortcomings effect hazardous location identification is not clear at this stage. It could be that accidents at some sites are under-reported compared to others; it may also be that under-reporting is general across all sites.

As there is little information about the nature of under-reporting in Australia, it must be assumed that anomalies only influence the absolute numbers of accidents, rather than the

relative accident rates. The possibility that an inconspicuous hazardous site may be overlooked, however, needs to be recognised.

## 2.8 STATISTICAL ASPECTS

As noted previously, it is usual to define a hazardous location as one with a relatively high accident risk. The statistical implications of this definition are similar no matter whether the risk is time-based or accident opportunity based (ie, exposure-based).

It is widely assumed that the number of accidents at a location during a particular period have a Poisson distribution. This is not to say that accident numbers at different locations or at the same location during different periods will appear to come from a Poisson distribution (except under very controlled conditions, as reported by Erlander, Gustavsson and Larusson 1969). Rather, they may appear to come from a mixture of Poisson distributions resembling a Negative Binomial distribution, from which most location-to-location or year-to-year accident numbers appear to come (Hutchinson and Mayne, 1977).

The assumption of the Poisson distribution for accidents at one location during one period appears to be well based (Cameron, 1969), but is not an assumption that can be easily tested.

The mean of the statistical distribution of the number of accidents in a given time interval is:

. the time-based risk by the length of the interval, and also

. the exposure-based risk by the exposure occurring at the location during the time interval.

In either case, a Poisson distribution of the actual number of accidents around the mean is a commonly used model. The mean of the distribution is sometimes referred to as the "expected accident frequency".

From the Poisson model, it is possible to define the statistical distributions of the number of accidents per unit time (mean = time-based risk) and, if exposure is known, of the accident rate per unit exposure (mean = exposure-based risk).

Aided by these statistical distributions, it is possible to calculate (at least approximately) the probability of a given accident number or accident rate at a particular location under the assumption that its risk (time-based or exposure-based) is the same as the average risk for the sub-system of locations. If this probability is small, it is usual to conclude that the risk at a particular location is different from average, where high risks are of particular interest. Of course, chance may have played a role and the risk at the location may not, in fact, be any different from average. This is known as a Type I error.

Similarly, the location may have a high risk, but the observation period was too short or the location was too small, to generate sufficient accidents for identification. This is known as a Type II error. The statistical distributions can also be used to calculate the probability of the Type II error for various levels of risk relative to the sub-system average.

In general practice, however, these statistical tools are not essential components of HRL identification programmes and, therefore, are not always used. There are a number of commonly used alternatives to the procedure of identifying HRL defined as those with accident experience exceeding a level which would be expected with small probability at the average level of risk. These non-statistical alternatives are:

- accident experience exceeding the expected accident experience,

- accident experience exceeding twice the expected level,

- accident experience exceeding some arbitrary level (usually related to the required number of identified locations to match some pre-defined treatment budget).

## 2.9 ACCIDENT SEVERITY

Not all accidents are equally severe. There is a belief that the more severe accidents should be given greater weight in identifying hazardous locations.

There is no agreement regarding how this is best done. One approach is to give each accident a weight representing the average "cost of accident" in the severity category in which it falls. If this is done, fatal accidents receive more than ten times greater weight than that assigned to injury accidents. Hence, this may causes fatal accidents to dominate the identification procedure which results in the identification of spurious locations, that is, those without high accident risk.

A compromise approach is to disproportionately weight the more severe accidents, but not with extreme weights in proportion to the average cost. This is a more common approach and many such weighting systems exist (see Table 2.1). However, because the approach lacks a firm conceptual base, it is not clear how the optimum weights should be derived.

TABLE 2.1

SUMMARY OF AUSTRALIAN ACCIDENT SEVERITY WEIGHTINGS

| | ACT | NSW | QLD | SA[2] | TAS | VIC | WA[3] |
|---|---|---|---|---|---|---|---|
| Fatal accident | 16 | 3 | 4 | 60 | 3 | | 12 |
| Injury crash where a casualty is admitted to hospital | 4 | 1.8 | 3 | 20 | 1 | n/a | 3 |
| Injury crash where a casualty is not admitted to hospital | 4 | 1.3 | 1 | 20 | 1 | n/a | 3 |
| Property damage only | 1 | 1[1] | 1 | 1 | 1 | | 1 |

NOTES: 1. In NSW, this basic factor is tow-away accidents.
2. In SA the weightings are approximately based upon the accident costs included.
3. In WA the weights are generally not used.

SOURCE: State Road and Traffic Safety Authorities, 1982.

## 2.10 ACCIDENT COST

Another reason for taking into account the severity of accidents occurring at a location is related to the economic assessment of a proposed treatment during the investigation phase. The expected accident reduction from the treatment needs to be quantified in monetary terms, and this in turn, is related to the total economic loss of past accidents as a proxy for future expected losses. In this case, it is common to weight accidents of different severity by the average cost in each severity category.

However, there is a view that Society is willing to pay more to prevent future accidents than the cost of past accidents. Costs of past accidents are known as ex post costs. The value that society is willing to pay to prevent a future accident is known as its ex ante value and this has been estimated as 2 or 3 times the ex post cost of an accident of the same type and severity (RACV 1983, Lay 1983). If ex ante values are used, it is more likely that proposed treatment would be judged cost-beneficial during the investigation phase.

It should be pointed out that methods for estimating ex ante values of accidents are poorly developed. Ex post cost give a guide to the lower bound of ex ante values and are more appropriate for the purpose of weighting accidents of different severity in the identification phase.

## 2.11 OTHER ECONOMIC CRITERIA

In making economic decisions regarding which sites and in what order of priority to treat identified hazardous locations, there are two fundamental questions:

. Among a number of different countermeasures at an identified location, which should be chosen?

. Among a number of identified location and chosen treatment combinations, which should be implemented and in what order?

A refinement of this two-stage decision process (first attributed to Jorgensen 1966), is a linear programming method devised by Mahalel, Hakkert and Prashker (1982) which allows the full range of potential treatments at each location to be considered in order to maximize the economic benefits from the programme. This approach produces the optimal economic decision, but Mahalel et al have shown that it is superior only for small treatment budgets ($180,000) and little different to the two-stage process for large budgets ($540,000).

Because the two-stage process is simpler and in more common use, the economic concepts associated with this approach only will be described here.

2.11.1 Location-oriented Criteria

Each potential treatment at an identified location has expected values of:

. Benefits, due to a reduction of future accidents and consequent economic losses, over a number of years; and

. Costs, due to the cost of installation (and, perhaps, re-installation) and the cost of maintenance, if applicable, over a number of years.

The period over which these economic criteria are usually considered is somewhat arbitrary, but is usually related to the longest service life of the treatments being considered (10, 20 or 30 years). A fixed period is used for all treatments.

The value of future benefits and costs are normally discounted to present values using an interest rate usually equated to that available from investment in the public sector.

Currently, an interest rate of 10% is commonly chosen by most Australian States. Methods of discounting have been described by Laughland, Haefner, Hall and Clough (1975).

The present value of total benefits over the period considered is known variously as Net Present Benefits (NPB), Present Worth of Benefits (PWOB), or like terms. Similarly, the present value of total costs is known as Net Present Costs (NPC) or Present Worth of Costs (PWOC).

For comparison between alternative potential treatments at a location, a number of different economic criteria are commonly used:

. Benefit-Cost Ratio (BCR) = NPB/NPC

. Net Present Value (NPV) = NPB - NPC

. First Year Rate of Return (FYRR), which is the present value of benefits in the first year divided by the installation cost.

. Internal Rate of Return (IRR), which is the discount interest rate which, if applied, would result in zero NPV.

Treatments expected to result in BCR less than one, or NPV less than zero, are considered not economically justified. FYRR and IRR are compared with the returns available from alternative sources of public investment and, if the return from treatment is lower, the project is deferred for at least one year.

The most common method in Australia for choosing between alternative potential countermeasures at an identified location is to choose the one with the highest BCR.

### 2.11.2 Programme-oriented Criteria

At the programme level, the constraint of the available budget has an impact on the economic decisions which is not normally felt at the location level.

It is known that a ranking of projects by their individual BCRs produces a programme with maximum economic benefit in terms of cumulative NPV. However, the size of this programme may not be in agreement with the total budget available and some funds may be wasted because the next project in the BCR ranking may be too expensive to include in the programme because the budget would be exceeded.

OECD (1976) recognised the problem and pointed out that the programme of treatment projects may have to be adjusted to make use of all of the available funds. They also saw a need for promoting some projects with favourable long-term effects which could not be quantified for inclusion in cost-benefit calculations. Nevertheless, OECD (1976) endorsed the general principle that "measures are ... put into effect until funds run out, in order of decreasing effectiveness coefficients".

## 2.12 COMMENTS

There are several salient points and concepts defined within this chapter:

- there is a need to assume that adverse road design leads to accidents and low-cost remedial treatments are highly cost effective in reducing accidents.

- the hazardous nature of a road location is closely associated with the risk of road accident.

- Programmes for hazardous road locations should include identification, investigation and implementation phases to maximise the resultant benefits.

- Statistics are more useful for testing the robustness of accident data, rather than for predicting accident rates.

- It is appropriate to apportion extra importance to casualty accidents in determining hazardous road locations.

- Ex post costs have been assumed to have an advantage over ex ante values at this time for accident cost-benefit analysis.

- Benefit Cost Ratio (BCR) is the most common means in Australia for choosing between alternative potential countermeasures.

- There is a need to study the effects of under-reporting of road accidents across Australia and how this influences hazardous road location selection.

# 3. HAZARDOUS LOCATION PROCEDURES OVERSEAS

## 3.1 IDENTIFICATION OF HAZARDOUS LOCATIONS

### 3.1.1 Objectives of Identification Procedures

Concise objectives of identification programmes are relatively rare in the literature. One of the first writers to articulate a clear objective was Hastings (1969) who stated that, "the prime objective is to identify intersections which are not only hazardous but which also have some potential for improvement by engineering methods".

English (1980) stated that "the overall goal is to develop a procedure that will identify hazardous locations (or groups of them) in some rank ordered way such that countermeasure works...will reduce all locations to the same relative risk (low)". While this goal does not appear to acknowledge feasibility or economic aspects, English did imply later that the objective should maximise accident reduction returns per dollar spent.

A more clear statement of objectives is given by Landles (1979) when he wrote that the objective of the Greater London Council Black Spot Team is "to implement quick, relatively inexpensive accident remedial measures to give a minimum first year financial rate of return of 100%". He also indicated that this had proved to be a rather conservative objective as figures for the financial year 1978-1979 indicated a rate of return in excess of 400%.

The UK Institution of Highway Engineers (1980) suggested the following objectives and policy parameters should apply to hazardous location identification and treatment programmes:

. 20% accident reduction by low cost treatment measures

- 50% first year rate of return for treatments to specific sites

- 25% first year rate of return for treatments covering wider areas

- Treatment costs to be less than 5000 Pounds Sterling per site.

In a later document, the Institution of Highway Engineers (undated) attempted to operationalise the above objectives and suggested that, in the early stages of an accident reduction programme, the objective should be to achieve an average first year economic rate of return higher than 50%. This is necessary because in later stages of a programme, schemes will be identified which may not meet the 50% first year return but nevertheless would be still worth implementing.

In summary, it appears that those relatively few writers who have expressed specific objectives for their identification programmes see the need for those objectives to go beyond the identification of hazardous locations and to include a specific economic objective.

### 3.1.2 Compliance with Stated Objectives

Some writers have indicated whether their programme meets the objectives set. An early study of the first 85 sites implemented as a result of the Greater London Council programme, for instance, revealed that an overall reduction in accidents of 37% was achieved (Landles 1979).

Wilson (1977) compared the before and after accident experience at 40 sites in Hertfordshire which had been identified and treated with 40 other untreated accident black spots selected at random. He found an overall accident reduction of 32% at the treated sites, compared to a predicted 33% accident reduction at

treated sites and a 10% accident increase at the untreated sites. In addition, there was a first year economic rate of return of 167% at the treated sites compared with a predicted 50%.

These performance results, however, should be viewed with caution as indicated by the work of Agent, Deacon and Dean (1976). In an initial assessment of approximately 300 rural locations in Kentucky comparing the accident experience in the year immediately before treatment, the authors found total benefit-cost ratios ranging from 5.3 to 6.4 for the treatment programme, depending on the length of the segment used for the identification procedure. However, they recognised that the accidents in the year before treatment may have been artificially high due to chance and, therefore, revised the above to produce a corrected benefit-cost ratio of 2.3 for the whole programme.

The overall conclusion from this review of identification programme objectives is that it is appropriate and feasible to identify locations with inherently high accident risk at which there is an economically justifiable opportunity to reduce this risk. Specific objectives, therefore would be:

- Relatively inexpensive, quickly implemented countermeasures only

- Minimum target economic benefit (dependent on the economic criterion used)

- Minimum target reduction in accident risk.

### 3.1.3 Definition of Locations

There is a range of concepts in the literature for defining road locations. The Institution of Highway Engineers (1980) describe identification procedures in which locations are specific sites (intersections or short road sections) or have broader definitions such as routes or areas, the latter normally being reserved for residential areas.

Once defined, locations are then usually considered in sub-categories of the road system. OECD (1976) suggested that major urban areas, main roads and the remaining classes of the road network should be considered separately.

Zegeer and Deen (1977) have suggested that in urban areas, locations should be classified by their road class. On arterial-collector roads, intersections and mid-block locations should be considered separately, whereas urban freeways need to be considered in one-half mile (0.8 km) segments. English (1980) proposed an alternative categorisation for Australian roads where separate consideration should be given to urban intersections, urban mid-blocks, and rural roads.

There seems to be little agreement in the literature regarding the lengths of road sections considered as a location unit. ADI Ltd. (1981) proposed that one-half kilometre sections should be considered for identifying black spots on rural highways. Agent et al (1976) found that a segment length of 0.3 miles (0.48 km) was considerably superior to a 0.1 mile (0.16 km) segment length.

Zegeer and Deen (1977) examined the effect of a variable section length definition for urban sections, comparing the critical number of accidents necessary to identify a hazardous location. However, this approach may be academic in Australian urban areas if consideration is given to Renshaw and Carter (1980) who propose that boundaries of individual road sections should be defined by a change in some cross-sectional element.

Nicholson (1980) cautions against so called "end effects" (the misclassification of accidents in sections adjacent to high risk sections) and recommends the avoidance of sections shorter than 1 kilometre.

There is little consistency in the literature regarding systems which uniquely identify individual locations. Gibson et al (undated) describe the nature, advantages and disadvantages of four types of location systems:

- Alphabetical (roads listed in alphabetical order including the distance from an intersecting road or landmark)

- Route meterage (major routes divided into fixed intervals by special markers)

- Grid system (based on a national mapping system)

- Node-link system (nodes at major intersections are assigned a unique number and the link between two nodes is described by the two numbers related to the nodes at each end).

Unfortunately, Gibson et al failed to make any recommendations regarding which system was superior for hazardous location identification purposes.

## 3.2 IDENTIFICATION PROCEDURES FROM ACCIDENT RECORDS

The majority of procedures for identifying hazardous locations are based on historical accident record information. Hastings (1969) suggested that the use of accident records is accepted as the most reliable method of identifying unsafe intersections. He claimed that other procedures suffer from "the inherent fault that often apparently hazardous locations are treated with caution by drivers, and as a result relatively few accidents occur".

There are several methods employed for determining hazardous locations from accident records.

### 3.2.1 Number of Accidents

A common method of identifying hazardous sites is simply to rank each by the number of accidents which occurred in some previous period. Agent et al (1976) judged sections of rural highway to be hazardous if there were at least three accidents in a 0.1 mile (0.16 km) section during the last year. However, they found this procedure to be inefficient and likely to identify spurious locations. Zegeer and Deen (1977) used a similar procedure to rank urban road sections, but found it necessary to also make use of the accident rate at the identified locations in establishing their priority order for treatment. There would seem to be some merit in each of these approaches.

### 3.2.2 Accident Rate

Accident rate is another common procedure for ranking hazardous sites. An accident rate is determined by dividing the number of accidents at each location by some measure of the exposure at the location. ADI Ltd. (1981) used accident rate per vehicle kilometre to rank sections of rural highways. Cutts (1973) used the accident rate per exposure to rank intersections to determine those where police enforcement should be directed.

### 3.2.3 Accident Number and Rate Combination

The Institution of Highway Engineers (undated) described the biases inherent in using either the number or rate methods alone. They recommended a combination of the two methods and advocated that a number method should be used for initial selection, with a rate method to determine unusual sites in the initial group and also the priority ranking for treatment. Hastings (1969) described a procedure where the number and rate methods are used simultaneously for ranking urban intersections. The efficacy of using a number and rate combination method needs to be further examined.

Hauer (1980) has shown that this problem is worst for shorter accident histories and for smaller fractions of identified sites considered for treatment. However, he describes procedures for bias correction based on the Poisson assumption. Abbess, Jarrett and Wright (1981) also examined the problem and showed it to be worse for higher accident frequencies in a given year.

The decision criteria for judging which ranking sites should be considered hazardous are not always based on statistical models. English (1980) proposed that the cut-off should be chosen at some point in the ranking where relatively few sites have most of the accidents. OECD (1976) make reference to numerical ranking techniques, apparently similar to the statistical techniques, but which do not attempt to take account of random variation in the numbers of traffic accidents.

### 3.2.7 Exposure Measures

Ranking methods based on accident rates make use of some measure of traffic exposure at the location. The exact nature of this depends on whether the location is a section or an intersection.

For sections, the common method of measuring exposure is total vehicle volumes (sometimes multiplied by the section length to produce a measure of vehicle kilometres). Gibson et al (undated) described a study of the error limits expected from standard procedures for estimating traffic volumes, and discussed the effect of such errors on the rate quality control method.

For measuring intersection exposure, there are many formulae in the literature. Some of these formulae are derived empirically while others are based on the product of intersecting flows at conflict points in intersections.

Three basic measures have been used for measuring exposure. Raff (1953) and Thorson (1969) proposed a sum of the Vehicles Entering the Intersection approach, Chapman (1967) and Bennett and Blackmore (1970) argued for a Product of Conflicting Flows method, while Tanner (1953) suggested the Square Root of the Product of Conflicting Flows was an appropriate measure of exposure.

The most popular measure seems to be the latter, although there is a suggestion that both of the former methods are also viable. Each of these 3 approaches are considered further in Chapter 6.9.

### 3.2.8 Comparison Studies

There have been a number of studies which attempted to compare the efficiency of different identification and ranking procedures. The methods were compared on the basis of the rank order produced, the accident reductions achieved following treatment, and on the actual economic benefits achieved.

Jorgensen (1966) compared five different ranking methods calculated for 176 signalised urban intersections where improvements were subsequently made on four economic criteria. They concluded that on these criteria, rate quality control, number followed by rate (long initial list), and the rate based on sum of the volumes entering the intersection, were preferred.

They also found that the rate followed by number, number, and the rate based on the square root of the product of the volumes entering the intersection, produced relatively poor economic performance.

Jorgensen formed the general conclusion that rate based methods perform generally better than number based methods for identifying hazardous urban intersections.

Renshaw and Carter (undated) compared six different identification and ranking methods for short sections of road across a broad range of road classes. The methods compared were number, number per kilometre, accident rate, accident rate minus the statistical critical value, accident rate minus the sum of the sub-system mean rate plus two standard deviations, and accident rate minus the sub-system mean divided by the standard deviation.

While Renshaw and Carter made a thorough comparison of the rankings produced by the six methods, they did not compare the methods by any final criterion such as economic benefit. Hence, the relative values of the different methods could not be judged.

Deacon, Zegeer and Deen (1975) compared four different identification methods to rank 170 sections of Kentucky rural highways, including equal numbers of recommended and non-recommended sections. The four methods compared were number, accident rate, equivalent property damage only (EPDO) number, and EPDO rate.

Each methods was compared on the basis of cumulative benefit-cost ratio and cumulative net benefits. For rural highway sections, the EPDO number method appeared to perform the best on economic criteria. Moreover, the two number-based methods displayed superior economic performance compared with their corresponding rate-based methods.

McGuigan (1982) compared the relative efficiency of three ranking methods namely number, accident rate and Potential Annual Accident Reduction (PAAR), on their ability to determine the top 20 hazardous urban sections with maximum accident reduction potential. PAAR represents the difference between the observed and expected accident experience calculated from site and traffic flow characterists.

McGuigan found that the PAAR method was the superior ranking method and subsequently argued (McGuigan, 1983) that the use of PAAR is likely to significantly improve the effectiveness of road safety expenditure on identified hazardous locations.

Petersen (1973) has described a so-called "Z-value method" which resembles McGuigan's PAAR, but with an extension of the procedure to incorporate a quality control approach based on a statistical model.

## 3.3 PREDICTIVE MODELS

While Hastings (1969) argued that the use of accident records is generally accepted as the most reliable method of identifying hazardous locations, the approach does have certain limitations. These are summarised below:

- There may be inconsistencies in the accident history of a specific location.
- Historic accident date may not be appropriate for consideration at locations where major physical changes have been implemented.
- Historic accident data may not be appropriate at locations where traffic characteristics have changed.
- Different identification ranking procedures can sometimes lead to different locations being identified.
- Accident records may not be available.

To overcome these limitations, alternative procedures have been considered which identify hazardous locations from particular characteristics generally related to accident occurrence. These characteristics include:

- Traffic volumes

. Traffic conflicts (although these may be represented by traffic volumes)

. Skid resistance

. Speeds

. Sight distances

. Visibility (for night accidents)

Unfortunately, these procedures also have limitations; the major problems being in deriving the relationships between the various parameters, and the considerable research effort necessary to establish these relationships.

### 3.3.1 Mathematical Models

Establishing mathematical functions is often undertaken by considering a number of locations with similar physical characteristics. For such groups, significant relationships between accident details and characteristics can be determined using regression analysis or similar techniques.

A problem with this model procedure, however, is that limited resources only permit limited amounts of data collection, over a restricted set of parameters. Hence, large standard deviations are usual in the regression equation, which tends to invalidate the procedure as a useful predictive tool for identifying hazardous locations. Models derived by Cribbins, Arry and Donaldson (1967) and Sparks (1968) illustrate these shortcomings.

An alternative modelling procedure is to form relationships between accident details and locational characteristics for a single parameter. This type of procedure has been used more successfully to estimate the possible reduction in accidents as a

result of a particular remedial measure. However, because studies such as Fox, Good and Joubet (1979) have illustrated similar problems of bias and validity still exist with this approach, it is also inappropriate for defining hazardous locations in general.

### 3.3.2 Accident Conflict Models

As accidents are a low probability event, there is often insufficient data to derive statistically significant results. One way to overcome this is to consider traffic conflicts as a proxy measure for accidents. By observing the frequency of 'near accidents' such as emergency braking or hurried lane changes, an alternative measure of the hazardousness of a location can be determined.

The technique can provide sufficient data to allow the derivation of a predictive model. However, the collation of this data is extremely resource consuming. While these 'near accidents' are more frequent than actual accidents, they are still relatively infrequent events, and considerable time must be devoted to the observations. Moreover, the collection of the information is also a relatively skilled technique requiring a judgement based on experience.

OECD (1976) however, consider this to be an important direction for future research into accident occurrence. While some of the preliminary research has been undertaken, the development is still in its infancy, and has not been used yet for identifying or ranking hazardous locations. In any event, the main use of the conflict technique seems to be for investigating locations after identification, as a diagnostic technique for determining remedial measures.

### 3.3.3 Subjective Models

It is possible to overcome some of the difficulties in defining mathematical relationships between accidents and road characteristics by using subjective assessment procedures and 'weighting' the importance of the parameters.

Taylor and Thompson (1977), for instance, reported on a group of 'experts' assessments of important road characteristics at hazardous locations. The assumption underlying this approach is that the hazardous ratings provided by the degree of convergence of the individual indicators provides a reasonably accurate prediction of future accident experience.

Unfortunately, however, the methodology adopted by these authors required as much effort in collecting resource data as did the mathematical models. Thus, any advantage of utilizing the combined experience of the experts assessments is offset, to some degree, by the cost required for data collection.

In addition, by not relying on accident data, the methodology, in fact, may be less than useful for determining appropriate countermeasures, since these are usually dependent on accident type. Thus, a new approach to countermeasures identification is necessary if subjective modelling is adopted for identifying hazardous locations.

Taylor and Thompson (1977) also highlighted specific areas with this approach that require additional research and development, indicating that substantial effort is still required to develop a subjective modelling approach for the identification of hazardous road locations.

### 3.3.4 Comments

A predictive technique for identifying hazardous locations would be very useful in that it could potentially establish accident locations. However, the development of such techniques is still in its infancy compared to accident-based techniques, and requires the allocation of considerable resources.

In addition, application of predictive analysis would not entirely overcome the problems of data collection, and in fact, may be more resource consuming by requiring professional experience to assimilate the data. Moreover, the data collected is not as easily adaptable to computer analysis.

The major thrust of predictive techniques at this stage, therefore, appears to be in the investigation of previously identified hazardous locations. Accident conflict modelling and mathematical modelling seem particularly well suited for determining appropriate countermeasures, and may also be useful for evaluating particular parameters and the potential for accident reduction. It is early days in the development of subjective models and considerable research is still required in this area before effectiveness can be fully assessed.

## 3.4 INVESTIGATION OF HAZARDOUS LOCATIONS

There have been many studies overseas which have attempted to identify procedures for carrying out a safety improvement programme. Laughland et al (1975), for instance, identified a management system consisting of the following sequence of events:

. Identify hazardous locations,

. Identify potential corrective improvements,

. Evaluate alternative improvements in terms of effectiveness,

costs, and benefits, and establish priorities for improvements,

. Programme and implement improvement,

. Monitor actual results of implemented improvements, and

. Evaluate the total highway safety improvements programme.

This section summarises the procedures that follow the identification of hazardous locations, and outlines the different criteria used in defining each of the parameters.

### 3.4.1 Identifying Appropriate Countermeasures

It is generally acknowledged that there are considerable difficulties in determining the exact problem at identified hazardous locations. It is difficult, therefore, to select the appropriate countermeasures. To overcome these problems, some studies recommend a detailed systematic analysis of accident data, road characteristics, and traffic information. Such a rigorous analysis takes account of the minimal information usually available at particular locations, and avoids premature conclusions. In addition, the systematic approach enables analysis to be undertaken by unskilled operators, providing the procedure is documented effectively.

The level of formal documentation differs significantly between countries. In the United Kingdom (IHE 1980), for example, the detail is left to the discretion of the engineer, whereas in Canada (ADI 1981), detail has been reduced to a finite number of work-sheets.

### 3.4.2 Steps towards Selecting Appropriate Countermeasures

The procedures outlined by Laughland et al (1975), Missouri State Highway Commission (MSHC) (1975), OECD (1976), Landles (1980) and ADI (1981) systematically follow phases of office

work, site inspection, further detailed analysis if necessary, and finally countermeasure definition.

- Office Work - OECD (1976) summarises the information to be collated in the office to include location type, and specific characteristics of the location, as well as accident history in a specific time period in terms of accident and collision types, number and severity (if possible in monetary terms). This work generally includes collision diagrams and a summary of accident statistics.

- Site Inspections - Site inspections are recommended to review the analysis previously undertaken, complete the inventory of locational data, investigate driver behaviour to establish whether this could be a primary cause of accidents, and finally, to understand any driver's problems by driving through the location.

  Landles (1980) includes a comprehensive list of factors that could be considered during a site inspection. These include such things as physical conditions of the road, amount of signing and other delineation available, and environmental conditions. The full list is included in Figure 3.1.

- In-depth Analysis - If accident causation has not been established following this work, it may be necessary to undertake more detailed studies. For example, speed studies or a more detailed conflict analysis may be required to highlight problems not evident from accident analysis. Finally, it may also be necessary to investigate police reports or talk to police, witnesses or local residents.

  If there is a significant number of accidents, an in-depth study would be resource consuming. Therefore, it may be appropriate to investigate only the dominant accident types since these are commonly addressed by the countermeasures.

# FIGURE 3.1

# 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

LIGHTING
Type Height of columns:-
Position of Columns (show on plan)
Obstruction by foliage

STATUTORY UNDERTAKINGS
Show manhole covers etc on plan

ROAD SURFACE
Type
Condition
Anti-skid treatment (show on plan)

RESTRICTIONS (Show on plan)
Waiting - Meter Zone
Loading - Banned turns
Clearway - Bus Stop Clearway

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

SIGNING (Note on plan)
Type
If illuminated
Foliage obstruction

VISIBILITY
Site lines
Obstruction to view (Post boxes - litter
Concealed entrance bins etc)

SPEED
Limit
85 percentile speed

PUBLIC TRANSPORT
Route Nos
Type of vehicles
Frequency
Location of Stops Shelters Stands etc
Taxi Rank

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

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)

Countermeasure Selection - The identification of the appropriate countermeasures is not documented in the studies investigated. It is generally accepted that the choice of countermeasures will be obvious from the preceding analysis and is normally based on the professional judgement of the investigating officer.

OECD (1976) summarise the 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 judgement..." Laughland et al (1975) states that "Someday we may be able to feed a computer with data on all circumstances and condition 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..."

The literature does provide comprehensive lists of possible countermeasures which can be considered. Perhaps the most comprehensive is that reported by OECD (1976) which list the types of countermeasures in five categories, namely, geometric design, road surfaces, road markings and delineation systems, road signals and furniture, and traffic management. Each countermeasure is then discussed together with its possible use and the accident types which can be avoided by its implementation.

Other comprehensive lists of countermeasures by Barton (1977) and English (1981) are also available in hazardous road locations literature. Sometimes, these include the accident reduction effect expected from the use of these countermeasures, although this is never guaranteed.

### 3.4.3 Economic Evaluation of Countermeasures

The evaluation procedure is necessary to determine which improvement would be the most appropriate for a particular location, and establish the relative priority of all improvements within the available finances.

Landles (1980) states that "there must be a remedial measure that will give a good rate of return and that can be implemented quickly". Bartelsmeyer (1972) suggests that "it is highly desirable that ranking of safety projects should be done so that the high yield improvements will be accomplished first". Graham and Glennon (1975) further emphasise the necessity for ranking by stating that "give first priority to the location that has the highest average annual net return".

OECD (1976) add a further dimension to the ranking procedure by recognising the limitation of budget constraints. It states that "the measure with the highest coefficient of effectiveness will thus be implemented as long as funds last, provided that it attains the minimum effectiveness in the order of their decreasing effectiveness coefficients".

Evaluation in the past has been based principally on economic analysis. While there are numerous concepts and approaches for performing such analyses, Laughland et al (1975) in his review of alternative methods in the USA, suggests that "It is generally agreed that analysis identifying annual benefits and annual costs is acceptable for safety improvement evaluations". This appears to be corroborated by the present literature review, although various studies differ in the treatment of the evaluation parameters.

### 3.4.4 Evaluation Criteria

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

This has not been universally accepted. Laughland et al (1975) suggested that net present value is preferrable for evaluating improvements at a particular location as maximising this criteria will ensure maximum total benefits. IHE (1979) suggests a first year rate of return as its measure of highway safety benefits. Agent et al (1976) also appeared to favour a first year rate of return based on their objectives.

ADI (1981) introduced a further evaluation measure by deriving a cost-effectiveness criterion indicating a relative cost per accident saved; the lower the relative cost, the higher the priority for implementation of the countermeasure.

There is little value in discussing the derivation of particular evaluation parameters in this report, except where these may be used for application in Australia. The specific parameters that have been used in this study are described in detail in the Procedural Guidelines of this report.

### 3.4.5 Programme Priorities

Having established individual economic value and a preliminary ranking of schemes, it is then necessary to determine the programme of priorities for implementation. To undertake this successfully, objectives and policies need to be defined.

Laughland et al (1975) suggested two different approaches may be considered which result in different programmes:

. Select to ensure that maximum benefits are forthcoming at each location which means that schemes with highest net

# 4. HAZARDOUS LOCATION PROCEDURES IN AUSTRALIA

The very existence of this report is indicative of the lack of any previous Australian-wide perspective on hazardous location procedures. Each of the States and Territories in Australia have generally developed their own procedures for the identification of hazardous locations quite independently, although recently there has been discussions between them in an attempt to overcome particular problems.

By necessity, then, a State-by-State analysis was performed in 1982 to define existing measures and problems inherent in the development of a National programme of hazardous road location procedures in Australia. It needs to be recognised that some of this information may have been superceded by more recent events at the time of publication of this report.

## 4.1 IDENTIFICATION OF HAZARDOUS LOCATIONS

Some of the States have been collecting and updating numerical data for hazardous location identification for a number of years. Other States have only recently developed their procedures and are still refining their methods.

In general, the identification procedures adopted by the States are based on accident numbers, although some States have adopted an accident rate method. The individual procedures adopted by each State need to be described in detail.

### 4.1.1 Australian Capital Territory (ACT)

Accident histories of intersections and mid-block locations were computed every three months to determine:

. Ranking of locations based upon the number of accidents

. Ranking of locations based upon accident severity in which

property damage only. Severity rating factors were derived from the cost ratios obtained from the different accident types.

Ranking of locations by accident severity related to exposure indices. These indicies are defined by the total number of vehicles entering each intersection, and the number per million vehicle kilometres for mid-block locations.

. Listing by accident type.

These various factors are combined to produce a list of possible hazardous locations based upon professional judgement and local knowledge. Because ACT is relatively compact, the majority of locations and traffic conditions are well known to the engineering staff involved in this programme.

4.1.2 New South Wales (NSW)

Accident histories are computed every three months by the Traffic Accident Research Unit to determine:

. Accident details by local government area both in plain language and coded detail.

. Accident details by route and section.

This provides the basic accident information to supplement the identification of hazardous locations.

The identification of hazardous intersections by local government is based upon an accident severity ranking where severity is defined as either a fatal crash, an injury crash requiring hospitalization, non-hospital injuries or a tow-away crash.

Accident severity factors were derived from an analysis of the 1979 mass accident records for the Sydney Metropolitan area. The average number of intersection accidents by severity was obtained using an iterative process, where the expected number of intersections with X accidents of a particular severity was subsequently determined. From the model, it was then possible to determine the value of X for which the expected number of intersections was less than 0.5. This value denoted the limit of the number of accidents by severity at an intersection regarded as unusual, and the appropriate weightings for different severities of accidents.

This procedure only recently superceded a numerical analysis in which an intersection was considered hazardous if it experienced 5 recorded crashes in a quarter or 10 recorded crashes in a 12 month period.

A definition for mid-block hazardous locations has <u>not</u> yet been developed because of locational identification problems associated with the existing coding. This was to be pursued following the refinement of the locational identities to the Australian Mapping Grid Reference. However, in the interim, the Department of Main Roads determined hazardous road sections (primarily in the non-metropolitan area) based upon:

. Ranking by accident severity per kilometre

. Ranking by non-intersection accident severity per kilometre.

4.1.3 <u>Queensland (QLD)</u>

Accident histories are computed every three months to determine accident details by district to provide basic accident information. The identification of hazardous intersections or road sections by the Main Roads Department is by district and is based upon:

. Ranking by accident severity in which the severity is

defined by fatal crash, hospitalized injury crash, non-hospital injury crash, injury crash not requiring medical treatment or property damage only.

These factors were derived from the cost ratio of the different accident types.

. Ranking by accident severity related to exposure indices, defined as the number of accidents per total vehicles (or its square root) for intersections, and the number of accidents per one hundred million vehicle kilometres for road sections.

The ranking factors were based upon the five year average severity rating and the last year severity rating, although the five year average was the predominant factor. The selection criteria for inclusion in the intersection ranking list was a severity index of 10 in the last five years or 5 in the last year. For the road section ranking list, the indices were 8 or 4 respectively.

This computerised identification procedure was a recent development and had not been fully utilised, particularly the exposure related ranking facility.

Prior to this more recent development, the State Transport Department prepared a list of hazardous metropolitan intersections manually, using the same severity indices which were used by both the Main Roads Department and the Brisbane City Council. This latter authority, being the main beneficiary of the data, developed a simple computer program to list the accident histories and severity ratings over the last three years, and then ranked the sites based upon the last year's severity rating.

benefits would always be selected. Generally these would be low cost schemes with high benefits.

. Select by benefit-cost ratio at each location to ensure that maximum benefits are derived from the total budget available. This could include more costly schemes with a lower rate of return but with generally longer term benefits.

In an ongoing highway safety planning programme, the second approach (selected by BCR) produces the maximum benefits of the programme. This recognises that hazardous locations programmes can be an integral part of highway improvements, and suggested countermeasures need to be considered in the light of all other construction possibilities.

Both OECD (1976) and Laughland et al (1975) highlight the need for a budget to reflect the funds necessary to accomplish the programme, and recommend performance budgeting techniques which combine work programmes and budget considerations in subsequent decision making.

3.4.6 Monitoring Countermeasure Effectiveness

One of the principal deficiencies of highway safety programmes in the past has been the inadequate follow up and evaluation of the 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 and casualty rates for future use.

The techniques used in monitoring countermeasure effectiveness include before-and-after studies and control group comparisons. However, a formal analysis could be used if performance standards can be established.

ADI (1981) suggested that it is also advisable to monitor the costs of implementing the anlysis procedure. If additional personnel are required, then there could be significant costs associated with its implementation.

### 3.4.7 Comments

Although there is a lack of definitive documentation on the investigation of hazardous locations, and the references which are available tend to be derivatives of each other, the reports do provide a general framework of work to be undertaken. However, it should be noted that there are few authorities which have formalised a hazardous location investigation programme, and for those who have, the majority appear to be based on professional judgment.

Any programme which is developed must be a balance between formalisation and judgement, since in the majority of instances, locational improvements are site dependent and will rely upon the experience gained from previous applications of countermeasures.

### 3.2.4 Reference Values

No matter which ranking method is used, it is common to define a reference value to determine whether a given location is truly different from other locations in the same category. In general, these references are average values of the ranking criterion, calculated over all sites in the same category or sub-system under consideration (e.g. Agent et al, 1976; Zegeer and Dean, 1977; ADI Ltd. 1981).

A refinement of this approach is to derive formulae as functions of traffic flows which represent the expected number of accidents at each specific location for comparison with the observed number. Mahalel et al (1982) constructed expected accident models which included indicies of traffic flows appropriate to the type of road section. Hocherman and Prashker (1983) derived formulae for the expected number of various intersection accidents as functions of the relevant traffic volumes.

### 3.2.5 Severity Weighting

The use of weighting factors to give additional weight to the more severe and more costly accidents is common. Gibson et al (undated) describe procedures for giving additional weight to more recent accidents, accidents involving higher levels of injury severity, accidents involving a greater number of road users, and accidents resulting in a greater level of societal cost. Graham and Glennon (1975) recommend a procedure where fatal and injury accidents are given a greater weight than property damage only accidents, producing a weighted number called the equivalent property damage only (EPDO) number.

ADI Ltd. (1981) recommend a ranking procedure for rural highways in which the accident rate is supplemented by a severity ratio (defined as the number of casualty accidents divided by the total accidents) and if either of these exceeds a critical value the site is considered to be identified as hazardous.

A simple version of severity weighting is to use fatal or injury accidents only in the ranking procedure, and this is commonly done in jurisdictions where only casualty accidents are reliably and consistently reported.

### 3.2.6 Statistical Aspects

Some identification procedures make use of statistical models to assist in setting critical levels for the ranking criteria. Sites which have ranking criteria above the critical level are considered hazardous. These models are usually based on the assumption of a Poisson distribution of the number of accidents.

Wilson (1977) gives a useful description of statistical models in the context of hazardous location identification and draws the analogy with quality control procedures used in industry. Because of this analogy, number and rate methods which make use of statistical methods to set critical values are commonly known as the "number quality control" and "rate quality control" methods, respectively.

When a statistical model is introduced to set critical levels for the ranking criteria, it is necessary to first determine a critical level of accident experience. This assumes a small level of probability that a particular site may not be truly hazardous, and its accident risk is really consistent with the average for all sites in the same category.

If a statistical model is accepted for accidents at road locations, a consequence is the so called "regression to the mean" phenomenon (Hauer, 1980; Abbess, Jarrett and Wright, 1981). In the present context, this means that an individual location at a particular point in time may have an exceptionally high number of accidents due solely to random chance factors. Any subsequent analysis, therefore, would reveal a lesser number of accidents and would more closely approximate the mean value of intersection accidents.

### 4.1.4 South Australia (SA)

The identification of hazardous metropolitan intersections by the Highways Department was by accident cost rate in which accident costs were related to exposure indices. These costs have been determined from general insurance statistics for 1977 and 1978 involving potential conflicts at intersections. The selection criteria for inclusion in the ranking list was at least 5 accidents in the last year.

The identification of hazardous road sections in both metropolitan and rural areas was based upon an accident severity index. In computing this index, each accident was weighted by an appropriate factor of accident type and cost. The estimated property damage cost was used for each type of property damage accident, while Troy and Butlin's (1971) injury costs were used as a basis for determining injury accident weighting factors.

The hazardous road section ranking procedure used by the Highways Department also incorporated the AADT, section length, ten million vehicle kilometres, and accidents by severity.

Programmes were being modified for transfer to a new computer system. Following this change, the analysis was to be undertaken on a quarterly, rather than annual, basis. The modification was to include an additional report identifying location as it accumulated 4 accidents per annum, to provide an early warning of a possible hazardous situation.

In addition, further elementary programmes were being used to identify signal requirements. Based on a 50% reduction in personal injury accidents and 30% reduction in property damage accidents, the savings possible per year were calculated for uncontrolled intersections together with the cost of accidents at each intersection. These figures were then used to rank possible signal installations.

The South Australian Police Department also identified hazardous locations for enforcement programmes. The metropolitan road network was divided into 500 road sections and each accident was allocated to one of these sections. Section analysis was carried out every 3 months by time of day and by day of week to determine enforcement programmes or locations.

4.1.5 Tasmania (TAS)

The identification of hazardous locations was based upon a ranking of accident severity in which severity was defined by fatal crash, injury crash requiring hospitalization, injury crash not detained in hospital, injury crash requiring first aid only, major property damage and minor property damage.

The ranking list also incorporated the number of accidents in each of the severity categories, based upon the last five years' accident totals. This ranking method, however, was variable.

A computerised identification procedure was being developed in Tasmania. When ready for use, it will be extremely flexible, and ranking can be based on location or locational type if required.

4.1.6 Victoria (VIC)

The Road Traffic Authority (RTA) were responsible for all non-designated roads in the State, and determine accident black spots from the number of casualty accidents over the previous year. Whenever possible, accident rates are related to exposure, and accident numbers over the last five year period are also investigated to provide additional information.

The Road Construction Authority (RCA) were responsible for all designated highways in the State, and based the identification of hazardous locations upon:

- Ranking by the number of accidents over the previous four years, where ranking also incorporated the number of casualty accidents in the past eight years.

- A comparison of accident rates in which casualty accidents are related to exposure indicies. These indicies differentiate between urban and rural intersections and road sections, as well as road type and urban development.

These classifications enabled black spots to be ranked on several dimensions so that investigations could be implemented according to a particular need or priority. Since this study, however, RCA's involvement in black spot identification has been substantially reduced.

Accident histories of intersections and mid-block locations are computed annually to provide basic accident details by local government area.

4.1.7 Western Australia (WA)

Accident histories were compiled annually to provide detailed information. The identification of hazardous intersections was carried out using a flexible computer programme which allowed ranking by local government area, accident type, locational type and control type. The programme also has the facility to include a severity index defined by fatal crash, injury crash and property damage only, and a time-based currency factor for the last 4 years' data.

The ranking of hazardous intersections took into account these severity and currency factors. Several ranking lists were produced annually for both metropolitan and rural intersections, and covered a range of accident types, road features, control features, latest controlled installations, accidents by severity for the last year, and the 4 year accident history.

At the time of this review, a method for the identification of hazardous metropolitan mid-block sections had not been defined. However, a method for identification of rural road sections was computed on a trial basis for evaluation. Using this procedure, the actual accident rate is compared to the average rate by type of road, and the difference is costed to produce an accident saving ranking.

### 4.1.8 Other Considerations

In addition to the formal identification procedures outlined above, hazardous locations are also nominated by the public and, in some States, by the police. These public comments are usually investigated within the hazardous locations programmes.

### 4.1.9 Summary

The identification procedure of hazardous road locations have been developed independently within each State or Territory. As a result, there has not been a unified approach to identification procedures in Australia. The differences highlighted earlier are further illustrated in the summary table provided in Table 4.1.

## TABLE 4.1

## SUMMARY OF HRL IDENTIFICATION PROCEDURES IN AUSTRALIA

| State or Territory | Intersections | Sections |
|---|---|---|
| ACT | combination of number of accidents, severity index and severity rate. | combination of number of accidents, severity index and severity rate. |
| NSW | severity index | not applicable |
| QLD | severity index and severity rate. | severity index and severity rate. |
| VIC (RTA) | number of accidents | number of accidents |
| (RCA) | number of accidents and accident rate. | accident rate compared to average values. |
| WA | number of accidents. | accident cost savings (being developed). |
| SA | accident cost rate | accident severity index and accident rate compared to an upper control limit. |
| TAS | severity index | severity index |

## 4.2 INVESTIGATION OF HAZARDOUS LOCATIONS

The identification of hazardous locations is the first phase of improving safety at these locations. A detailed accident analysis is then required to identify major problems and possible traffic management measures to reduce these problems. Where possible, the available countermeasures need to be monitored following their implementation.

These phases have been handled quite differently by the relevant authorities. This section, therefore, avoids discussing the operational aspects of the investigations, and concentrates upon other engineering matters. In this respect, the States are generally unified in their approach, although the depth of the investigations varies considerably.

### 4.2.1 Detailed Accident Analysis

The first step in the analysis of the traffic accident data is to identify the dominant types of accidents and the homogeneity of accidents which point to possible traffic management measures to reduce the problem.

Identification is generally based upon the previous year's accident records. However, this rarely provides sufficient information for detailed analysis so the last three to five years data is often considered.

Identification procedures are usually based upon casualty accidents; property damage only collisions introduce additional complications as they only represent a small percentage of the actual property damage accidents reported.

### 4.2.2 Identification of Countermeasures

Having determined what were the dominant accident factors, the next step in countermeasure identification is to visit the site. Observations of features such as road geometry, superelevation, surface quality, delineation and signing supplement the basic accident data, and can suggest specific countermeasures that may otherwise be overlooked.

Countermeasures are generally based upon the professional judgement of the relevant engineers. In making these judgements, many tend not to rely on a formal detailed analysis involving a range of solutions, but rather, take into account their knowledge of these measures and previous experiences with their use.

### 4.2.3 Economic Evaluation of Countermeasures

The Highways Department in South Australia undertake cost-benefit analysis to rank sites within their departmental budget. The Department of Main Roads in NSW on the other hand, performs cost-benefit analyses to justify expenditure, rather than rank alternative schemes.

The major problem with economic evaluation is determining benefits from the reduction in the number and severity of accidents. These problems arise from difficulties in defining the costs of accidents (even average costs) and the percentage reduction in accidents, for which only the Minor Improvements for Traffic Engineering and Road Safety (MITERS) programme has consolidated reduction factors.

Some of the State Road Authorities have undertaken comprehensive evaluations of traffic management measures to identify accident reduction factors.

### 4.2.4 Monitoring Countermeasure Effectiveness

Monitoring countermeasures is generally undertaken by observing the change in accident numbers from year to year. In addition, comprehensive evaluations are also undertaken when necessary.

There is a need to increase the monitoring of countermeasures, not only to determine the appropriateness of the solution implemented, but also to provide information for future economic evaluation. This will only be achieved by a conscious effort on the part of the relevant authorities in investigating hazardous accident locations.

### 4.2.5 Implementation Constraints

The implementation of countermeasures suffers the same time and cost constraints that all road works appear to suffer; insufficient funding of hazardous road location programmes reduces the number of sites which can be treated in any one year. This can be partially overcome by implementing schemes through general maintenance budgets.

By having to include the cost in future departmental budgets, time constraints are even more critical because the essence of hazardous road location improvements is immediate implementation. Again, inclusion in general maintenance budgets helps overcome the problem to some degree.

These constraints will only be permanently overcome if a sufficiently large budget allocation, covering most of the envisaged schemes, together with a comprehensive programme of identification and investigation procedures, is provided.

### 4.2.6 The Need for Further Research

The whole question of countermeasure selection appears to be very much ad hoc across Australia. There is clearly a need for additional research in this area as a relatively high priority, if long term improvements are to be gained at hazardous locations.

There are 2 immediate needs for additional research into countermeasure selection for hazardous locations in Australia.

- General research into monitoring procedures for evaluating economic effectiveness of countermeasures. While some States are currently involved in monitoring their own black spot programmes, there is no unified approach or established procedures for this activity. Research effort in this area would eventually lead to streamlined monitoring procedures and thus an overall long term improvement in eliminating hazardous road locations.

- Specific research into the individual effectiveness of all known and used accident countermeasures. This research would need to encompass before-and-after accident data (as a crude initial measure of relative effectiveness) as well as performance and behaviour studies of the effects of implementing individual measures. While this latter approach may be less accident related, it will provide a more sensitive assessment of countermeasure improvements, that can be expected. Naturally, both of these approaches need to include cost-benefit considerations.

## 4.3 DATA AVAILABILITY AND REQUIREMENTS

The application of a National identification procedure for hazardous locations would require a compatible data base in each State. The compatibility should be in terms of:

- Consistent accident reporting criteria where the information collected and stored is based on the same procedures in each State.

- Consistent information on the location of accidents in order to attribute an accident to a specific location. This does not necessitate identical location definition for each State, although this would still be desirable.

- Adequate statistics to define the accident parameters. Additional information may also be included in the records at the discretion of each State, if this is desired.

- Traffic volume data for use in the definition of exposure indicies.

- Road characteristics to define location information for each site.

A brief summary of the review of the data bases in each State or Territory is described below.

4.3.1 Interstate Accident Reporting

Table 4.2 illustrates the existing legal requirements for reporting accidents in each State, and the wide variation which exists between them. Although each jurisdiction aims to exclude the least serious accidents from the records by omitting property damage only accidents, this minimum requirement is quite different across the States.

Table 4.3 describes the particular practices adopted by each State in recording accident details. Again, wide variation is also apparent.

## TABLE 4.2

## LEGAL REQUIREMENTS FOR REPORTING ROAD TRAFFIC ACCIDENTS IN AUSTRALIAN STATES

| State or Terriorty | | Road traffic accidents required to be reported to police |
|---|---|---|
| ACT | a) | All accidents |
| NSW | a) | All accidents involving personal injury |
| | b) | All accidents where aggregate property damage exceeds $300 ($50 prior to July 1977). |
| QLD | a) | All accidents involving personal injury |
| | b) | All accidents where aggregate property damage exceeds $1,000 ($300 prior to 1978 : $100 prior to 1976). |
| SA | a) | All accidents involving personal injury and/or injury to an animal. These are reported by the Police. |
| | b) | All accidents where aggregate property damage exceeds $300 ($100 prior to 1980 : $50 prior to 1975). These are reported by drivers involved. |
| TAS | a) | All accidents involving personal injury. |
| | b) | All accidents where there is property damage and the owner is not present. |
| VIC | a) | All accidents involving personal injury. |
| | b) | All accidents where there is property damage or an animal is injured and the owner or owner's representative is not present. |
| WA | a) | All accidents involving personal injury. |
| | b) | All accidents where aggregate property damage exceeds $300 ($100 prior to 1980) or where property damage level is in dispute, or where all interested parties are not present. |

SOURCE: State Road and Traffic Safety Authorities, 1982.

## TABLE 4.3

## PRACTICE FOR REPORTING AND RECORDING INFORMATION ROAD TRAFFIC ACCIDENT DATA BASES IN AUSTRALIAN STATES

| State or Territory | Road traffic accidents recorded |
|---|---|
| ACT | All reported accidents are included on the data base, although minor accidents are not always reported. |
| NSW | Reported accidents involving injury or in which at least one vehicle required towing away (all reported accidents prior to July 1975). |
| QLD | All reported accidents, that is, when PDO exceeds $1,000. |
| SA | All reported accidents for which location is positively identified, an injury is sustained or PDO exceeds $300. (This PDO limit could be replaced by accidents in which at least one vehicle required towing away. |
| TAS | All reported accidents, in which an injury is sustained and all reported PDO accidents. |
| VIC | All reported accidents involving injury and PDO accidents. PDO accidents are predominantly accidents where police contemplate legal action. |
| WA | All reported accidents where an injury is sustained or PDO exceeds $300. |

NOTE: PDO = Property Damage Only.

SOURCE: State Road and Traffic Safety Authorities, 1982.

There is clearly a need to increase the compatibility of accident reporting between States and ensure that interstate casualty accident data is equivalent. While accident investigations are normally based on casualty accidents only, the lesser order accidents can often be important in helping to define problems. Furthermore, not all casualty accidents are necessarily reported as injured parties are often removed from the accident scene prior to the arrival of the police, or taken to private doctors if injuries are only minor.

Hence, there may be a case for including all casualty and property damage only (PDO) accidents on a National data file for hazardous road location identification and investigation procedures. Naturally, the benefits of a fully detailed National data base need to be weighed against the cost of introduction and maintenance.

### 4.3.2 Definition of Accident Locations

Defining the location of accidents is one of the most important aspects in identifying hazardous locations. The definitions presently used for urban accidents in each State or Territory vary considerably, from a full and detailed coding using node and link characteristics in SA and the ACT, to the locational coding based on street names and house numbers in TAS. Details of the procedures in each State and Territory are summarised in Table 4.4.

The location of mid-block and road section accidents is always a problem because of distance coding. This is especially a problem in rural areas where distance can be large and an error of only 100m can make a huge difference in accident location. The only method of overcoming these problems is to provide a unique number for each road section as reference point. One suggestion might be to erect kilometre posts on all major highways.

The use in Tasmania of electricity poles as definition points is useful for either of these measures. These could be utilised directly, or used as a reference for a mapping grid reference system.

### 4.3.3 Details of Accidents

The accident location procedures summarised in Table 4.4 shows varying degrees of refinement in each State or Territory report. It is necessary to consolidate these reporting procedures into a National accident data base if hazardous road locations are to be compared across Australia. A National data base would also be useful for other accident reporting considerations as well.

### 4.3.4 Traffic Volumes

The traffic volume information in each State or Territory differs substantially because of the varying degree of involvement and their geographical size. The information ranges from intermittent counts in some circumstances to comprehensive permanent counting for both metropolitan and rural areas.

It must be recognised that the resources required to collect and maintain a traffic volume data base are considerable. Nevertheless, there is still a need for a comprehensive data base for applying hazardous locations identification procedures. This may necessitate more resources as this information needs to be consolidated on the accident data base.

## TABLE 4.4
## LOCATION DEFINITION PROCEDURES ADOPTED IN AUSTRALIAN STATES

| State or Territory | | Location Definition Procedure |
|---|---|---|
| ACT | I | - by locational coding and street names. |
| | MB | - by locational coding involving street names and distance from nearest street, key point or house number. (ACT are about to change to a node and link system). |
| NSW | I | - by local government area and street names |
| | MB | - by local government area, street name and identifying characteristic or route number. (NSW are considering change to Australian Mapping Grid Reference). |
| QLD | I | - by local government area and street names. |
| | MB | - by local government area and street names - no details recorded of accident site. |
| SA | I & MB | - by unique intersection and link code covering both intersections and sections for rural and urban areas. |
| TAS | I | - by street names only for both urban and rural areas. |
| | MB | - by street names and numbers (urban) or pole numbers (rural). |
| VIC | METRO | - by grid system based on MELWAY street directory. |
| | RURAL | - by grid system based on an assortment of maps. |
| WA | I | - by hierarchy coding of key roads. |
| | MB | - by hierarchy coding and distance from a defined start point of the key road. |

NOTE: I = Intersection
MB = mid-block section

SOURCE: State Road and Traffic Safety Authorities, 1982.

### 4.3.5 Road Characteristics

Each of the States compile a road characteristics data base including road geometry, surface characteristics, skid resistence and physical (roadside) features. These data are usually developed by highway divisions or forward planning groups for their own purposes, and are not necessarily compatible with (or linked to) accident data bases. Western Australia is the only State in which the road characteristics data base is compatible with the accident data base and can be linked.

There is obviously a need for considerable development and commitment of major resources if road characteristics are to be linked with the accident data base.

### 4.3.6 Comment

There are significant differences in the data available in each State or Territory. As previously discussed, there is a need to provide at least compatible records as a basic requirement, although the ultimate objective should be to have one accident record form for the whole of Australia, and identical accident records for all accident types in each State or Territory.

There is also a need to link the various traffic information data bases to the accident records so that information correlation is readily available. Western Australia is the only State to have taken a major step in this direction with the development of the 'Road Traffic Accident Records System (ROTARS), but in 1982, this was still not fully operational in the original form envisaged.

# 5. POTENTIAL HAZARDOUS LOCATIONS PROCEDURES

The review of hazardous location procedures overseas and in Australia clearly identifies the need to consider a range of identification methods, namely:

- ranking procedures
- locational definitions
- measures of exposure
- economic criteria
- identification periods.

Testing of these evaluation procedure options considered identification of hazardous locations for intersections and sections related to urban and rural areas, separately.

The testing strategy adopted concentrated initially on urban intersections, since these locations had been previously identified as a major problem in hazardous location studies. If particular relationships were found to exist at these locations, then these relationships would direct subsequent investigations of urban sections and rural locations.

## 5.1 TESTING PROCEDURES

The 2 approaches of retrospective and prospective analysis are available for use in evaluating identification procedures. The major difference between these two approaches is that the former has the capacity to test the performance of a range of indentification methods against actual economic outcomes, whereas the latter is constrained to comparisons in terms of expected economic outcome.

The detailed considerations of both these procedures are outlined below.

5.1.1 Retrospective Analysis

In retrospective analysis, the basic phases of the study include:

- Selecting a wide-range of previously investigated locations, both with implemented countermeasures and no subsequent action;

- Using a before-and-after accident analysis, determine the benefits resulting from the countermeasure and the dis-benefit from no implementation. Benefit calculations should be based on the difference in actual accidents subsequent to treatment, compared with the number expected without treatment;

- Using each identification method, rank all locations and determine the total benefits for a given number of sites or implementation cost budgets.

The actual economic return is determined and used as the comparison criteria for the identification methods. To undertake such a procedure, it is necessary to have available:

- A large sample of treated and untreated sites;

- Accident histories for each site, with at least one year history before-and-after countermeasure installation;

- Actual costs of implemented countermeasures;

- An estimate of the expected number of accidents for each site if the countermeasure had not been implemented;

- Engineering decisions for the choice of particular countermeasures.

An alternative procedure which determines the expected benefits rather than actual benefits could be considered. In this instance, the benefits would be based on the expected accident reduction and the expected cost of the selected treatment at the time the location was investigated. The expected economic return would be used as the comparison criterion.

5.1.2 Prospective Analysis

In prospective evaluation, the study phases include:

. Ranking all sites by each identification method;

. Selecting the priorities of each ranking;

. Determining countermeasures, if any, for each site and estimating the cost of treatment;

. Computing the expected benefits resulting from the implementation of the countermeasure. Benefit calculations would be based on the estimated accident reduction.

The expected economic return is the comparison criterion for identification methods. To undertake this procedure, it is necessary to have available:

. A sample of potentially hazardous locations compatible with a realistic budget allocation for such improvements;

. Accident histories at each site for at least three years, but preferably five years if no major changes were implemented;

. A record of all improvements over the study period;

. Detailed costs of countermeasures;

Realistic estimates of potential accident reduction.

### 5.1.3 Comparison of Procedures

An accurate retrospective analysis can only be performed when identification and investigation procedures have been undertaken for many years.

In this situation, it provides a rigorous comparison of identification methods, and permits easier analysis of identification procedure elements. Furthermore, it alleviates the need for major investigation at each site to determine appropriate countermeasures. Unfortunately, though, it does require considerable detail on previously investigated schemes including reasons for no treatment.

A retrospective procedure, by definition, can only use existing data and does not provide any new results which may be of value in identifying previous unknown hazardous road locations.

On the other hand, while the prospective analysis can produce usable results in the jurisdiction being studied, additional research resources are needed for problem diagnosis and countermeasure selection which could dictate the identification method.

### 5.1.4 Study Procedures Adopted

On balance then, a retrospective procedure seemed most appropriate for the study of urban intersections, given the relative wealth of data for hazardous road locations in South Australia. However, a prospective analysis was more suited for urban sections and rural locations as data at these locations was less complete and improvements less common than for urban intersections.

## 5.2 SELECTION OF DATA

### 5.2.1 Urban Intersections

South Australia has had a long standing policy towards improving hazardous road locations in the metropolitan area of Adelaide as a result of the Minor Improvements for Traffic Engineering and Road Safety (MITERS) treatment and signalisation programme. As road and traffic data collection in this State is also well advanced, Adelaide was chosen as the appropriate urban area to conduct a retrospective analysis.

### 5.2.2 Urban Sections

It was hoped that a retrospective analysis would also be undertaken for urban sections in South Australia. However, a review of the MITERS sites showed that the urban non-intersection countermeasures were restricted in number because:

. The new pedestrian signals and school pedestrian crossings were not sectional treatments, but rather specific locational treatments. Furthermore, the identification of these locations was not accident-based.

. The new upgraded street lighting schemes covered considerable lengths of the main highways which had not been identified by accidents. While it is natural that the total length had been treated for ease of implementation, this could have been misleading for any accident analysis.

. The traffic signal co-ordination was an intersection treatment programme.

A prospective study, therefore, was decided upon. To keep extraneous influences to a minimum, it was further decided that the consideration of sections would be undertaken using 1983 as the base year to use the existing work of other agencies. The

work on urban sections was undertaken in Victoria to minimise resources.

### 5.2.3 Rural Locations

Because of the relative lack of rural highway improvements for road safety compared with urban installations, it was not possible to consider a retrospective study for rural locations in any State. Moreover, a prospective study in a rural area would require considerable resources in the investigation phase.

Hence, it was decided to undertake the work in the Road Construction Authority's Traralgon division in Victoria to minimise total resource costs. This area provides two different, but nevertheless complementary, highways for which the majority of data was readily available.

### 5.2.4 The Research

The evaluations undertaken in these three areas, namely urban intersections, urban sections and all rural locations, are discussed in the following chapters of this report.