6. TESTING HAZARDOUS LOCATION PROCEDURES AT URBAN INTERSECTIONS

As discussed in Chapter 5.2, Adelaide in South Australia was chosen as the metropolitan area most suited to a restrospective evaluation of urban intersections. This city was well advanced in terms of road treatment and signalisation improvements through the MITERS programe, and provided the most extensive and suitable data base for this study.

6.1 SAMPLE STRUCTURE

A structured sample of some 200 intersections, covering both treated and not treated intersections, was assembled for testing. The sample represented the population of metropolitan intersections on the Adelaide main road network, in terms of intersection geometry and type and presence of traffic control.

The sample was also constructed to be representative of the range of treatments appropriate for the intersections investigated, including the "no treatment" option.

6.1.1 Treated Intersections

The source of the treated intersections sample was the MITERS file of the South Australian Highways Department, covering the period between 1974 and 1978.

Intersections on non-metropolitan and local roads, and other intersections where data was not available, were subsequently removed. This left a sample of 154 treated intersections on the main road network.

Examination of other intersections investigated and treated by the Highways Department or Local Authorities was not considered appropriate, since in these cases, the objective for investigation was not increased road safety but increased traffic movement efficiency.

6.1.2 Untreated Intersections

The source of the sample of investigated-but-not-treated intersections was the investigations files of the South Australian Highways Department. Investigations had been undertaken for a considerable number of locations but predominantly on the local road network.

These intersections, along with 14 intersections in the MITERS programme which had not been treated, formed a data base of 44 untreated (control) intersections on the Adelaide main road network.

Because of the limited number of locations available, it was not possible to obtain a proportionately representative sample of metropolitan intersections on the main road network, in terms of intersection geometry, type and traffic control. The sample, however, did include each category of intersection and traffic control. Table 6.1 illustrates the number of intersections in the sample by intersection type and traffic control.

TABLE 6.1
SAMPLE COMPOSITION FOR
ADELAIDE MAIN ROAD NETWORK

Traffic Control	Intersection Type								
	Cross*			Tee			Total		
	Treated	Not Treated	Total	Treated	Not Treated	Total	Treated	Not Treated	Total
SIGNAL	47	13	60	4	4	6	51	15	66
STOP SIGN	24	5	29	4	1	5	28	6	34
GIVE WAY	3	2	5	8	3	11	11	5	16
NO CONTROL	41	10	51	23	8	31	64	18	82
TOTAL	115	30	145	39	14	53	154	44	198

*includes multi-leg intersections.

6.1.3 Structure of the Intersection Population

There were considerable changes between 1972 and 1979 in the structure of the population of intersections on the main road network. The number of uncontrolled intersections decreased dramatically, while the number of intersections controlled by stop and give way signs increased as a result of the introduction of the priority road system.

The most representative structure of the population was the average for this eight year period. This was approximated by the average 1975/1976 population which represented the identification period for many of the sample intersections. The structure for either 1975 or 1976 was not considered as this was the main period of implementation of a priority road system in Adelaide.

There was no data available for the total population of intersections on the main road network. The best information available from the Highways Department was the number of intersections with one or more accidents per annum classified by intersection type and traffic control. This was used to estimate the total number of intersections on the main road network. The statistical approach adopted for this task is outlined in detail in the Procedural Guidelines from this report.

Table 6.2 illustrates the estimated total number of intersections on the main road network by intersection type and traffic control for each year from 1972 to 1979.

It is worth noting that in the majority of instances, the number of intersections with one or more accidents approximates the total population. For the uncontrolled intersections (and predominantly Tee intersections) however, there were a significant number of intersections without an accident.

TABLE 6.2

ESTIMATED TOTAL INTERSECTIONS ON ADELAIDE MAIN ROAD NETWORK

CROSS INTERSECTION

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	Average
Signals	240	243	246	247	272	284	299	316	268
Stop	79	78	78	103	147	177	210	174	131
Give Way	19	14	25	60	161	224	287	332	140
No Control	731	775	941	842	640	581	431	389	666
ALL	1069	1110	1290	1252	1220	1266	1227	1211	1205

TEE INTERSECTION

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	Average
Signals	42	42	58	62	65	71	80	114	67
Stop	21	22	18	34	118	143	174	116	87
Give Way	22	34	33	159	692	869	1166	1267	530
No Control	1870	1974	2374	2154	1575	1380	1090	1030	1681
ALL	1955	2072	2483	2409	2450	2463	2510	2577	2365

TOTAL INTERSECTIONS

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	Average
ALL	3024	3182	3773	3661	3670	3729	3737	3788	3570

6.1.4 Sample Representativeness

The comparison between the intersections included in the sample and the estimated total population is further illustrated in Table 6.3.

TABLE 6.3

COMPARISON BETWEEN TREATED SAMPLE AND ESTIMATED TOTAL POPULATION OF INTERSECTIONS ON ADELAIDE MAN ROAD NETWORK

Traffic Control	INTERSECTION TYPE								
	Cross			Tee			Total		
	Sample	Total	%	Sample	Total	%	Sample	Total	%
Signals	60	268	22	6	67	9	66	335	20
Stop Sign	29	131	22	5	87	6	34	218	16
Give Way	5	140	4	11	530	2	16	670	2
No Control	51	666	8	31	1681	2	82	2347	3
TOTAL	145	1205	12	53	2365	2	198	3570	5

Note: Cross Intersections include multi-leg intersections

The sample is not representative of the total population as it over-represents the intersections controlled by signals and Stop signs, and under-represents uncontrolled intersections or those controlled by Give Way Signs. In this respect, the sample probably reflects traffic managed intersections, rather than the total available intersection population.

On the other hand, it could be argued that a more representative sample would not necessarily benefit evaluation. Including more intersections with Give Way signs or presently uncontrolled would only introduce low cost treatments and low accident rates. The sample selected, at least, represents sites with a mix of varying cost treatments and a mix of accident numbers and accident rates.

All things considered, the sample provides a sound data base from which to evaluate the different identification techniques.

6.2 DATA STRUCTURE

For each sampled intersection, the data was structured into FOUR categories, namely:

- IDENTIFICATION CODES

- TREATMENT TYPE AND IMPLEMENTATION COSTS. Only parts of this information were considered for intersections investigated-but-not-treated.

- ESTIMATED ACCIDENT REDUCTION FACTORS. This information was not considered in the detail originally intended because reduction factors were not available for each accident type. Furthermore, the information was not relevant for intersections investigated-but-not-treated.

- ACCIDENT AND TRAFFIC VOLUMES. This information was collected for each year between 1972 and 1979, with interpolated traffic volume estimates for those years in which data was not available.

Each of the 4 data categories comprised a number of related independent variables. The format for this data is illustrated by the sample coding form shown in Figure 6.1.

6.3 SYSTEM-WIDE ACCIDENT DATA

System-wide accident data was necessary to compare accident experience of individual intersections with that of the whole system of intersections on the main road network in Adelaide. Information was required in the form of average accident numbers

FIGURE 6.1

HAZARDOUS LOCATION PROCEDURES AT URBAN INTERSECTIONS

CODING FORM

OFFICE OF ROAD SAFETY : RACV CONSULTING SERVICES

HAZARDOUS ROAD LOCATIONS PROJECT

METROPOLITAN INTERSECTIONS

IDENTIFICATION

REF	CARD NO.	INTERSECTION NUMBER	MAIN STREET	MAIN STREET CAT	CROSS STREET NAME	CROSS STREET CAT	LGA	GEOM
EX	1	1051655000	GOODWOOD RD	PA	SPRINGBANK RD	SA	MI	T

TREATMENT IMPLEMENTATION COSTS

REF	CARD NO.	BEFORE CONTROL	TREATMENT			AFTER CONTROL	DATE OF TREATMENT	ESTIMATED IMPLEMENTATION COST	ACTUAL IMPLEMENTATION COST	SERVICE LIFE	MAINTENANCE COST P.A.
EX	2	TS	214	409		TS	78	28600		10	500

ESTIMATED ACCIDENT REDUCTION FACTORS

REF	CARD NO.	ACCIDENT TYPE RO	RA	SS	RE	OTH	SEVERITY PD	PI	F	TOTAL
EX	3									22

ACCIDENT AND TRAFFIC VOLUMES

REF	CARD NO.	YEAR		ACCIDENT TYPE RO	RA	SS	RE	OTH	SEVERITY PD	PI	F	TOTAL	TWO WAY TRAFFIC VOLUMES (AADT) V_1	V_2	V_3	V_4	EXPOSURE	
SG	4	72		0	6	3	7	1	12	5	0	17	19100	10900	25800			CC
SG	5	73		3	11	1	7	0	19	3	0	22	23400	12900	23300			CC
SG	6	74		2	13	3	9	0	24	3	0	27	24450	13400	32700			CC
SG	7	75		1	6	1	9	1	16	2	0	18	23600	14300	33550			EE
SG	8	76		3	11	2	10	2	18	0	0	28	22750	15250	34400			CC
SG	9	77	T	2	26	5	11	0	38	6	0	44	23350	15400	34700			EE
SG	10	78	T	3	23	5	4	1	28	8	0	46	24000	15500	35000			EE
SG	11	79		2	15	5	9	2	28	5	0	33	24600	15600	35200			CC

per intersection and accident rates, categorized by intersection geometry and traffic control, so that comparisons could be made within sub-systems.

Estimates had previously been made of the total number of intersections on the main road network, by category (see Chapter 6.1.3). Information had been obtained on the number of intersections having one or more accidents each year and their accident experience. Based on a Poisson model, the average accident rate for this truncated set of intersections was compared with the rate at all intersections. This process is detailed in the Procedural Guidelines of this report.

Since the sample of investigated intersections was not proportionately representative of the population of intersections on the main road system, it was not appropriate to compare directly the overall system average accident rates with the sample. Instead, the sub-system accident rates were weighted by the sample numbers in each category to produce sample-weighted overall averages.

6.4 ADJUSTMENTS AND PRELIMINARY ANALYSIS

The sample data collected was subjected to particular checks and adjustments prior to ensure accuracy prior to detailed evaluation. These procedures are fully described below.

6.4.1 Data Checking

The integrity of the punched data file was checked by various logical tests on the data, as follows:

- card number in correct sequence?

- reference numbers all the same for each location?

- fourth traffic volume blank for tee intersections?
- accident numbers by type and severity add to total accidents?
- treatment code (T) corresponds to year of treatment indicated on card no. 2?

The final data file satisfied all these logical tests.

6.4.2 Exposure Calculations

The average daily exposure during each of the years 1972 to 1979 was calculated for each sampled intersection using the empirical formula currently used in some Australian States (Chapman 1973) namely:

- for a four way intersection

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

- for a three way junction

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

Where E = exposure
V1-V4 = traffic volumes on each intersection leg

6.4.3 Costs of Treatment

The costs of treatment installation and maintenance in different years of treatment were adjusted to 1978 prices by the BTE road construction index (Bureau of Transport Economics, 1982). This index was considered appropriate because the specific treatments were predominantly minor road construction jobs or signalisation, which included a major construction component. The year 1978 was chosen as the base so that treatment costs would be compatible with the accident cost estimates of Atkins (1981).

The Net Present Cost (NPC) of the treatment in 1978 prices was then obtained for a ten year period by discounting the maintenance costs (and re-installation costs, where necessary during the period). An interest rate of 10% was chosen, for compatibility with the interest rate used by Atkins (1981).

6.4.4 Investigation Costs

An arbitrary investigation cost of $500 per identified intersection (1978 prices) was assumed, following an estimate by Deacon et al (1975). This cost was added to the NPC of each intersection investigated, whether they were treated or untreated. The S.A. Highways Department was unable to supply information to improve this estimate.

6.4.5 Accident Reduction Factors

In specifying the likely accident reduction factors, allowance was made for recording either standard factors by type of accident, severity and total figures, or an estimated accident reduction factor.

The former approach proved to be difficult as standard factors were not always available for the full range of treatments. Moreover, the draft evaluation of the effectiveness of low cost road safety improvements in South Australia undertaken for the Federal Office of Road Safety (Nicholas Clark and Associates 1984) had derived estimated accident reduction factors for countermeasures using the same MITERS data base to this study.

Hence, these estimated accident reduction factors were subsequently used for coding. Table 6.4 lists the estimated accident reduction factors used in this study.

TABLE 6.4

ACCIDENT REDUCTION FACTORS

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

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

SOURCE: Nicholas Clark and Associates (1984)

6.4.6 Benefits of Treatment

The benefits of the intersection treatments were measured by the reduction in accident losses (monetary costs) over and above any reduction which would have occurred in the absence of the treatment.

The two bases for measuring benefits were estimated accident reduction factors, and actual accident loss reductions. These two approaches are described further on. In both methods, the accident experience in the three years prior to treatment was used to indicate expected accident experience in the absence of treatment.

Because of the possibility that intersections investigated may have been identified by chance "high" accident experience, it was necessary to consider the accident trends in the three years prior to treatment.

(a) Accident trends prior to treatment

Intersections treated in 1975 were found to have had a rising trend in accidents during 1972-74 in line with the system-wide experience. Intersections treated during 1976-79, however, had no consistent accident trend prior to treatment.

It was concluded, therefore, that there was no evidence of a "bias-by-selection" effect among the sampled intersections. Nicholas Clark and Associates (1984) also reached the same conclusion after finding that many treated intersections in South Australia could not be chosen by accident criterion alone.

A three year accident experience before treatment seemed adequate for estimating subsequent accident rates.

(b) Benefits based on estimated accident reduction factors

Estimated annual savings were calculated by multiplying the annual losses from accidents averaged over the three years prior to treatment by the estimated accident reduction factor (Table 6.4). For intersections where there was less than three years accident data before treatment, the available years were used instead.

This approach simulates the benefit calculations normally made by a State Road Authority as part of its economic analysis prior to treatment. It was made in ignorance of any future exposure changes at the site and of any system-wide changes in accident rates. However, in deriving the estimated accident reduction factors, allowance had been made for changes by Nicholas Clark and Associates (1984).

In calculating benefits, fatal accidents were given a weight of $178,090 in deriving total accident losses (Atkins 1981). However, when the intersections were ranked in order of the estimated treatment benefits, it was found that the fatal accidents contributed towards 35% of the estimated benefits in the top 20 intersections, and 43% in the next 20. Since this effect was due to only 20 fatal accidents, this procedure produced unstable estimates of treatment benefits.

Accordingly, fatal accidents were pooled with other casualty accidents in calculating annual accident losses, and assigned the following values at 1978 prices:

. Casualty accidents	$14,285
. Property damage only accidents	$1,180

(c) Benefits based on actual accident loss reductions

Using this approach, the estimated annual savings were calculated as the difference between the annual losses averaged over the three years after treatment and the expected annual loss. The expected annual loss was the average annual loss in the three years prior to treatment, adjusted for changes in the intersection exposure and system-wide changes in the loss rate per exposure. For intersections at which there were less than three years data before or after treatment, the available years were used instead.

"Benefits" at untreated intersections were calculated in the same way, by comparing accident losses in the three years before and after 1975 (chosen arbitrarily). This contrasted with the previous approach based on estimated accident reduction factors in which the annual savings at untreated intersections were set equal to zero, by definition.

(d) <u>Discounted benefits</u>

For each approach, the Net Present Benefit (NPB) of the annual savings (assumed constant per year) over a ten year period was calculated by discounting the estimated savings, using an interest rate of 10%. Since the average accident costs were in 1978 prices, NPB was also in 1978 prices.

6.4.7 Economic Criteria

Final criteria used to measure the economic value of each intersection treatment (or no treatment) were:

- Net Present Value (NPV) = NPB - NPC

- Benefit-Cost Ratio (BCR) = $\frac{NPB}{NPC}$

Following ranking of intersections by each identification method (see Chapters 6.5 and 6.6), two complementary economic criteria related to a programme of intersection treatments were also calculated cumulatively by rank:

- Cumulative NPV = Cumulative NPB - Cumulative NPC

- Cumulative BCR = $\frac{\text{Cumulative NPB}}{\text{Cumulative NPC}}$

These measures of economic value of a programme were compared with two measures of the economic cost or budget for providing a programme of HRL identification and treatment:

- Cumulative Installation Cost

- Cumulative NPC

These economic criteria were used to compare intersection identification methods. The comparisons were made in two ways; firstly based on estimated accident reduction factors (Chapter 6.5), and, secondly based on actual accident loss reductions (Chapter 6.6 to 6.10).

6.5 COMPARISON BASED ON ESTIMATED ACCIDENT REDUCTION FACTORS

A large number of combinations of factors related to intersection identification methods were considered in this analysis. These factors included:

- Identification period (1,2 or 3 years)
- Criterion type (numbered-based, rate-based, or combination)
- Reference values (system and sub-system averages)
- Decision levels (maximum treatment budget, or critical statistical values)
- Severity-weighting
- Measure of intersection exposure

Most of these combinations were systematically compared, paying heed to foregoing results. In addition, the optimal ranking which any identification method could achieve was determined from the estimated economic value of each treatment in the sample.

6.5.1 Optimal Ranking

The optimal ranking of individual elements of a programme in terms of achieving the maximum NPV of the programme is by BCR. Figure 6.2 and 6.3 show this ranking.

A near-optimal ranking is also achieved if individual elements are ranked by NPV. Figures 6.4 and 6.5 show near-optimal rankings.

The ranking by BCR tends to assign high rank to intersection treatments with a relatively low NPC, compared with those assigned high rank by NPV.

6.5.2 Identification Period

A three year identification period was initially considered. However, the effects of shorter periods on the identification methods were subsequently evaluated and the results are described in Section 6.9.

For this identification ranking, a full three years of accident and exposure data before treatment was required in the data file. This resulted in the exclusion of 17 intersections treated prior to 1975.

6.5.3 Identification Methods

The accident data used in the comparison of methods was total reported accidents. Methods based on severity-weighting of the accidents were also considered and will be described later in Chapter 6.5.5.

The identification methods were grouped as follows:

- Number-based methods involving total accidents, or total accidents significantly greater than system average.

- Rate-based methods including accident rate (total accidents per exposure), rate significantly greater than the system average, rate minus sub-system average, rate significantly greater than twice system average, and rate minus twice sub-system average. System and sub-system averages from the particular identification years were used for rate-based methods.

FIGURE 6.2

HAZARDOUS LOCATION PROCEDURES AT URBAN INTERSECTIONS

RELATIONSHIP BETWEEN NET PRESENT VALUE AND INSTALLATION COST

RANKING BY BENEFIT - COST RATIO

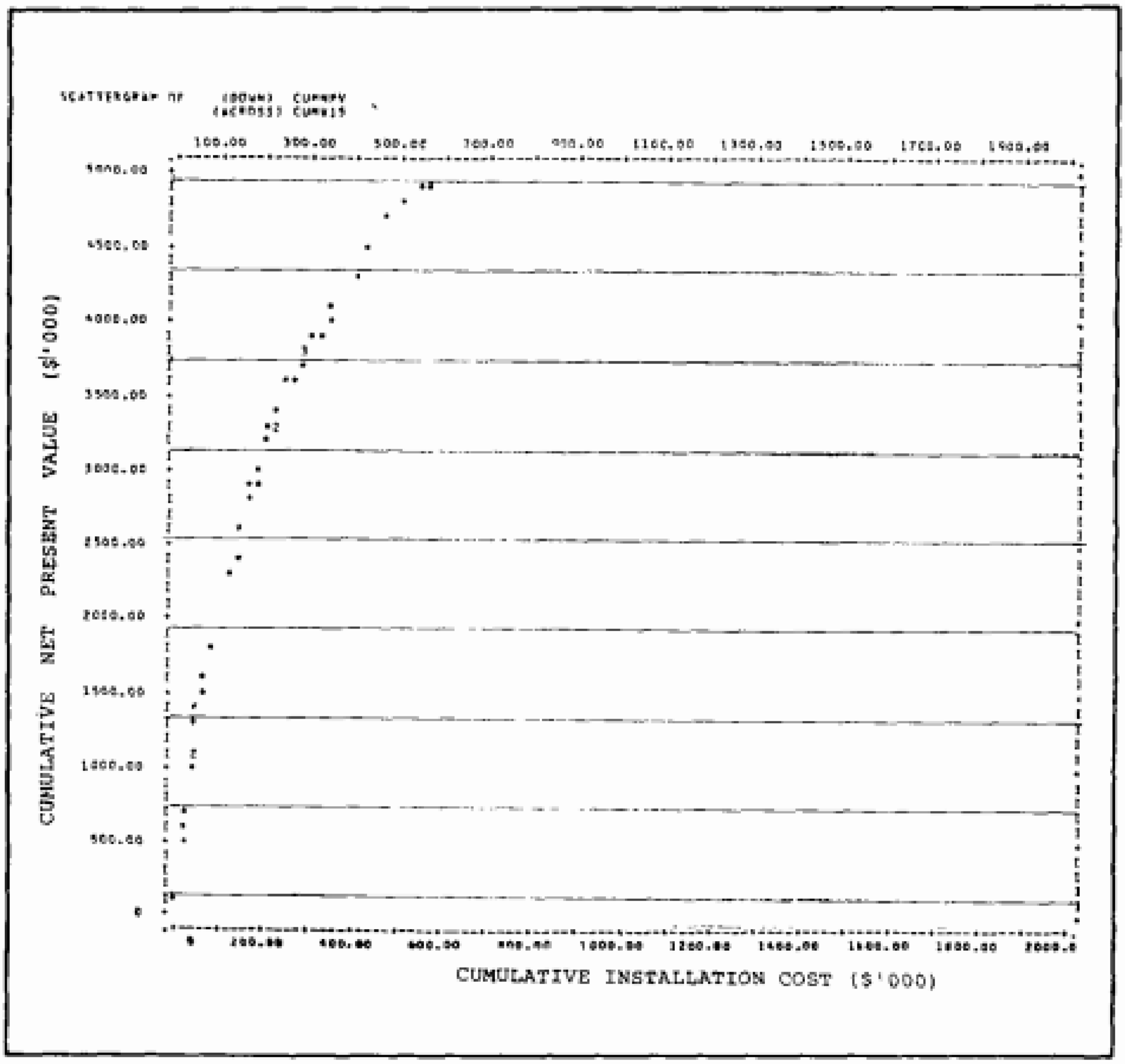


FIGURE 6.3

HAZARDOUS LOCATION PROCEDURES AT URBAN INTERSECTIONS

RELATIONSHIP BETWEEN BENEFIT-COST AND RATIO AND INSTALLATION COST

RANKING BY BENEFIT-COST RATIO

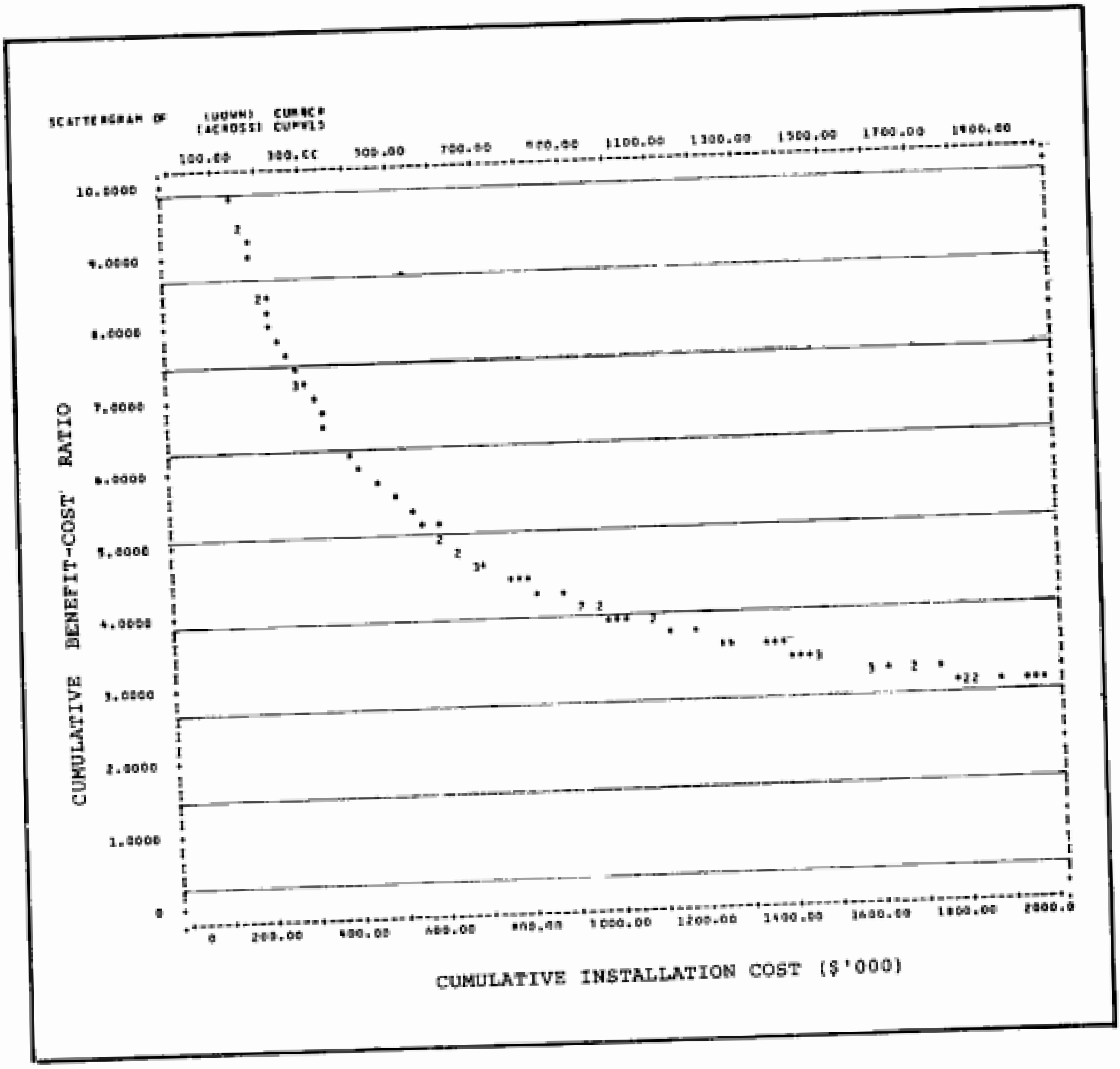


FIGURE 6.4

HAZARDOUS LOCATION PROCEDURES AT URBAN INTERSECTIONS

RELATIONSHIP BETWEEN NET PRESENT VALUE AND INSTALLATION COST

RANKING BY NET PRESENT VALUE

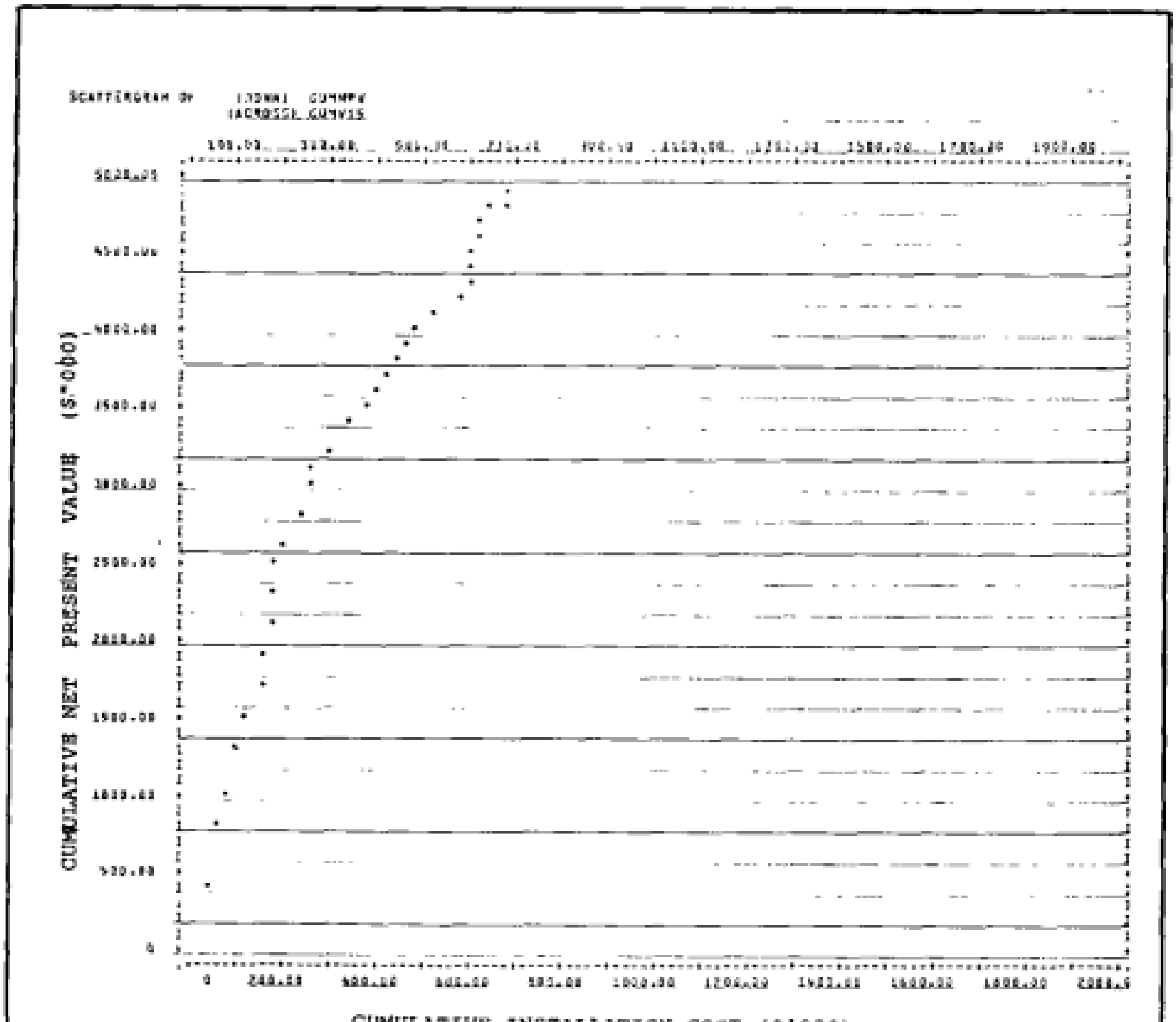
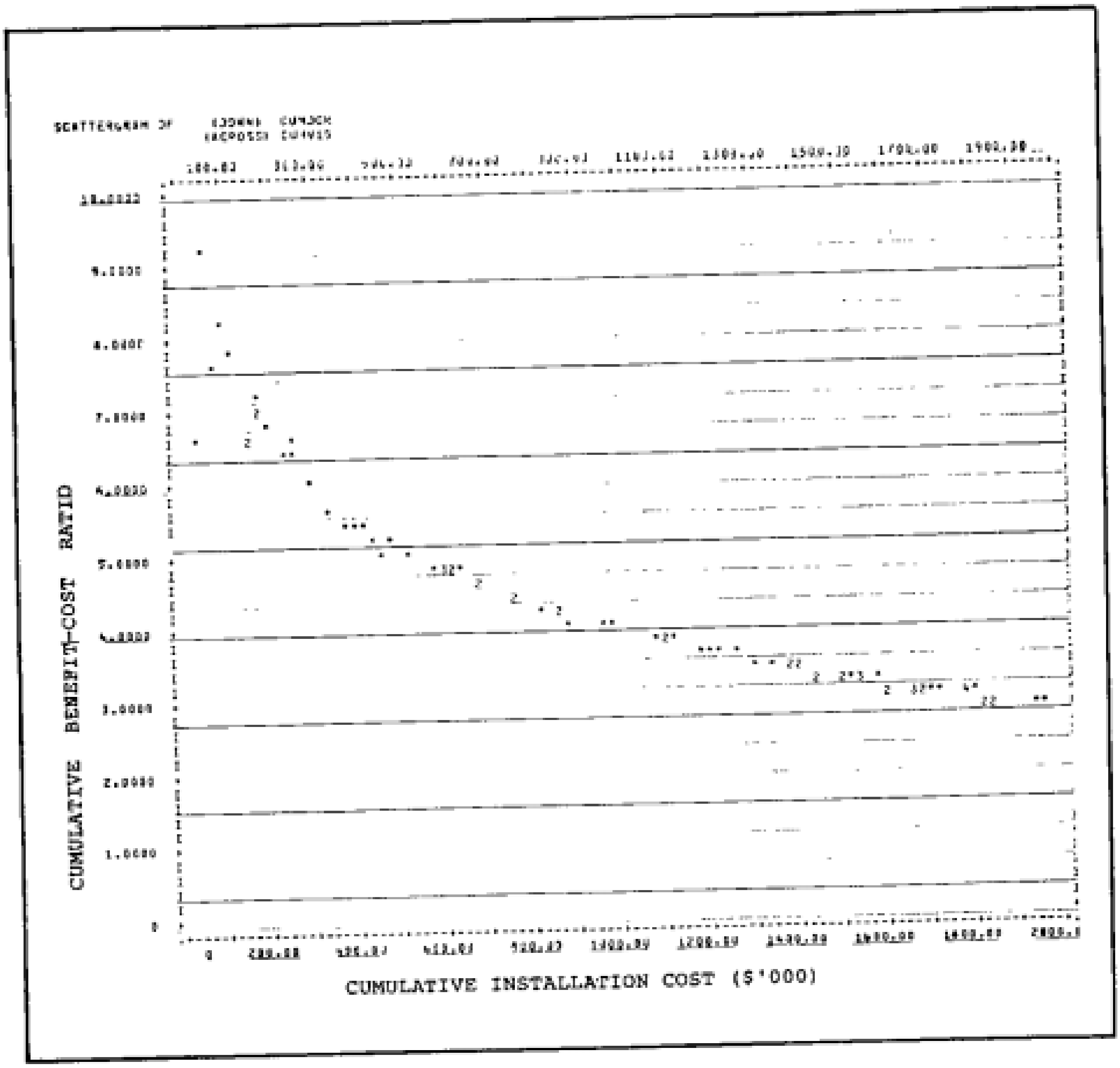


FIGURE 6.5

HAZARDOUS LOCATION PROCEDURES AT URBAN INTERSECTIONS

RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND INSTALLATION COSTS

RANKING BY NET PRESENT VALUE



Combination methods namely accident rate after number (where the criterion in each case was significantly greater than the system average), and accident number after rate (where accident rate was significantly greater than <u>twice</u> system average).

Potential Accident Reduction (PAR) methods, where total accidents minus expected intersection accidents were derived from system-wide accident experience (and, in some cases, from intersection exposure). System-wide accident experience was calculated from either sub-system average accidents, system average accident rate or a sub-system average accident rate.

6.5.4 Statistical Decision Levels

Statistical significance above average for the number and rate-based methods was by derived from critical values ($p<.05$, one-tailed) given by Deacon et al (1975) and found by Jorgensen (1966) to be an accurate approximation to the true critical Poisson distribution values for accident numbers.

It was also planned to derive critical values from Monte Carlo (simulation) methods for linear accident functions with different severity weighted by average costs. These critical values could have been used to judge statistical significance from on accident losses per exposure (see next section). However, the relatively poor performance of these identification methods on economic value criteria, precluded this approach (see Chapter 6.5.6).

6.5.5 Severity-Weighting

Severity-weighting was applied to a subset of identification methods found to have superior performance. The use of casualty accidents alone was interpreted as severity-weighting in these data. In some Australian States, these are the only accident data available which could reliably be used for identification purposes.

The following severity-weighted identification methods were considered:

- Number-based methods comprising total losses (fatal accidents separately weighted), total losses with casualty accidents pooled, and casualty accidents.

- Rate-based methods consisting of loss rate (total losses per exposure), loss rate with casualty accidents pooled, casualty accident rate, casualty accident rate significantly greater than system average, and casualty accident rate significantly greater than twice system average.

- Combination method comprising casualty accident rate after number (in all cases, the criterion was significantly greater than the system average).

6.5.6 Results and Discussion

Tables 6.5 and 6.6 summarize the results for the unweighted and severity-weighted identification methods, respectively. The tables show the cumulative economic value of the intersections chosen in rank order for each method and installation budgets of $0.5 million and $1 million. Extensions of these tables to budgets of $1.5 million and $2 million were also calculated, but have not been included here as they add very little to the outcome.

TABLE 6.5

COMPARISON OF UNWEIGHTED IDENTIFICATION METHODS

(Economic benefits based on estimated accident reduction factors)

RANKING METHOD	$0.5m. INSTALLATION BUDGET Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	$1m. INSTALLATION BUDGET Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Estimated B.C.R of Treatment	469	4,702	5.81	37	995	6,106	3.94	60
Estimated N P.V of Treatment	474	4,098	5 23	22	972	5,521	4.02	40
Total Accidents	478	2,539	3.38	22	996	3,448	2.84	37
Total Accidents Sig.> System Average		As above				As above		
Accident Rate	471	2,861	4.03	20	976	3,892	3.23	31
Accident Rate Sig.> System Average		As above				As above		
Potential Accident Reduction (Sub-Sys.Average No.)	497	2,632	3.52	22	984	3,555	2.91	34
Potential Accident Reduction (Sys.Average Rate)	440	2,374	3.58	17	954	3,463	2.94	31
Potential Accident Reduction (Sub-Sys.Average Rate)	473	2,365	3.34	18	999	3,254	2 82	29
Accident Rate Minus Sub-Sys.Average.(Sig.>)	450	2,758	4.09	18	984	3,599	3.09	31
Accident Rate After Number	447	2,628	3.88	17	995	3,793	3.11	30
Accident Number After Rate	469	2,335	3.44	17	999	3,196	3.86	26
Accident Rate Sig> Twice System Average	450	2,715	3.95	19	972	3,768	3.18	30
Accident Rate Minus Twice Sub-Sys.Average	493	2,591	3.76	17	987	3,400	2.89	32

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure
(c) Unweighted total accidents

TABLE 6.6

COMPARISON OF SEVERITY-WEIGHTED IDENTIFICATION METHODS

(Economic benefits based on estimated accident reduction factors)

RANKING METHOD	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Total Losses	473	2,505	3.48	18	964	4,096	3.13	42
Loss Rate	470	2,276	3.46	18	988	4,328	3.36	41
Casualty Accidents	496	2,224	3.27	16	965	4,238	3.16	41
Casualty Accident Rate	444	2,465	4.14	18	934	4,547	3.62	48
Total Losses (Casualty Accidents Pooled)	489	2,373	3.35	18	942	4,025	3.14	41
Loss Rate (Casualty Accidents Pooled)	441	2,268	3.92	17	926	4,607	3.71	41
Casualty Accident Rate After Number	475	2,162	3.55	14	998	3,870	3.13	34
Casualty Accident Rate Sig.>System Average	444	2,465	4.14	18	918	4,521	3.65	46
Casualty Accident Rate Sig.>Twice Sys.Average		As above			792	3,721	3.63	32

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure
(c) Severity-weighted accidents

6.6 COMPARISONS BASED ON ACTUAL ACCIDENT LOSS REDUCTIONS

For these comparisons, attention was confined to those identification methods displaying superior performance in the earlier work. The following methods were thus compared, each based on a three year identification period. Further details of these methods can be obtained from the preceding discussion.

6.6.1 Number-based Methods

- Total accidents

- Total losses (fatal accidents separately weighted)

- Casualty accidents.

6.6.2 Rate based Methods

- Accident rate significantly greater than system average

- Casualty accident rate significantly greater than system average.

6.6.3 Combination Methods

- Accident rate after number

- Accident number after rate

- Casualty accident rate after number

6.6.4 Potential Accident Reduction (P.A.R.) Methods

- System average rate based on P.A.R.

6.6.5 Optimal Ranking

The optimal ranking of sampled intersections by BCR was difficult using this approach. Among the untreated intersections, there were some which displayed a substantial accident loss reduction after 1975, presumably due to chance. This resulted in a high BCR due to the absence of any treatment costs (apart from the arbitrary investigation cost of $500 assigned to all intersections). Untreated intersections all had a BCR of zero in the comparisons of estimated accident reduction factors (see Chapter 6.4).

Ranking by BCR, therefore, would have produced a number of untreated intersections at the top of the list and this was unrealistic. While it could be argued that any decision not to treat after investigation was a well-based economic decision in these cases, it seemed more appropriate, nevertheless, to produce an "optimal" ranking by NPV. Earlier work had shown this to yield a near-optimal ranking (refer Chapter 6.5.1).

6.6.6 Results and Discussion

Table 6.7 summarizes the identification method comparisons. Among the number-based methods, those using casualty accidents as the identification criterion displayed the best overall performance in achieving a cumulative BCR of 3.15 for $0.5 million installation budget.

TABLE 6.7

COMPARISON OF IDENTIFICATION METHODS

(Economic benefits based on actual accident reductions)

RANKING METHOD	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Actual N.P.V of Treatment	487	5,250	6.66	17	989	7,029	4.72	45
Total Accidents	478	432	1.41	22	996	- 677	0.64	37
Total Losses	473	1,274	2.26	18	964	1,132	1.59	42
Casualty Accidents	496	2,107	3.15	16	965	327	1.17	41
Accident Number after Rate	469	1,520	2.59	17	999	1,831	2.07	26
Accident Rate Sig.>System Average	471	1,819	2.92	20	976	2,433	2.39	31
Casualty Accident Rate Sig.>System Average	444	4,020	6.12	18	918	4,921	3.88	46
Potential Accident Reduction (System Average Rate)	440	1,363	2.48	17	954	685	1.38	31
Accident Rate After Number	447	1,722	2,89	17	995	2,334	2.30	30
Casualty Accident Rate After Number	475	4,195	5.94	14	998	4,411	3.43	34

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure calculation
(c) Actual loss reduction factors
(d) Casualty accidents pooled in economic calculations

For the rate-based methods, casualty accident rate significantly greater than the system average was the best economic performer, producing cumulative BCRs of 6.12 for a $0.5 million budget and 3.88 for a $1 million budget. These economic indicators were not far short of those produced by the "optimal" ranking based on actual NPV of each treatment.

The identification method, based on casualty accidents rather than on total accidents, was also the best performer among the combination methods. Casualty accident rate after number produced a cumulative BCR of 5.94 for a $0.5 million installation budget and 3.43 for a $1 million budget.

Thus, the best combination method appeared to perform almost as well as the best rate-based method, which in turn, displayed the best performance of all the identification methods considered. In all cases, combination methods were not far short of the "optimal" ranking.

However, casualty accident rate after number has a distinct advantage over casualty accident rate as an identification method. In the former, a subset of sites is initially selected for having a casualty accident number significantly greater than the system average, and exposure data need only be collected to facilitate subsequent ranking by casualty accident rate.

The only potential accident reduction method considered, namely that based on the system average rate, displayed relatively poor economic performance and produced a cumulative BCR of only 2.48 for a $0.5 million installation budget.

Examination of the top ranking sites produced by each of the superior identification methods showed that they included sites with BCR less than one (and even negative values in some cases). This undesirable economic outcome could have been anticipated in many instances by calculating the estimated BCR based on estimated accident reduction factors, and the accident experience before treatment. These sites, therefore, would be excluded from treatment in an objective hazardous road location identification and treatment programme.

The effect on the economic performance indicators of excluding anticipated non-economic sites is described below. Attention was confined to the three identification methods found to be the best performers namely casualty accidents, casualty accident rate significantly greater than the system average, and casualty accident rate after number.

6.7 EFFECT OF EXCLUDING NON-ECONOMIC SITES

For this part of the study, sites with an estimated BCR of less than one were excluded before ranking by each of the three identification methods (casualty accidents, casualty accident rate significantly greater than the system average, and casualty accident rate after number).

This procedure ensured that ranked sites would be investigated, that the best treatment was chosen, and that only those sites with estimated BCR greater than one would be treated. Estimated BCR was based on estimated economic benefits from estimated accident reduction factors listed in Table 6.4.

This approach also excluded untreated sites, since their expected BCR was zero in each case.

6.7.1 Optimal Ranking

The exclusion of untreated sites meant that there was no difficulty in using actual BCR to determine the optimal ranking. Previously, when untreated sites were included, the ranking by BCR was headed by a number of untreated sites displaying substantial accident loss reductions after 1975, presumably due to chance.

The optimal ranking of the expected economic sites from actual BCR is shown in Table 6.8 together with the results for each identification method.

TABLE 6.8

COMPARISON OF IDENTIFICATION METHODS FOR SITES WITH EXPECTED BENEFIT-COST RATIO GREATER THAN ONE

(Economic benefits based on actual accident reductions)

RANKING METHOD	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Casualty Accidents	496	2,286	3.34	15	965	1,698	1.87	35
Casualty Accident Rate Sig. > System Average	444	4,186	6.34	15	895	5,365	4.33	35
Casualty Accident Rate After Number	475	4,161	5.91	13	998	5,007	3.76	29
Actual B.C.R of Treatment	497	5,624	6.84	25	975	6,663	4.62	41

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure
(c) Estimated BCR>1 following investigation
(d) Actual loss reduction factors
(e) Casualty accidents pooled in economic conditions

6.7.2 Results and Discussion

With one exception, the economic performance indicators suggested superior performance for each identification method when non-economic sites were excluded. Tables 6.8 and 6.7 compares the performance differences with and without site exclusion. The exception was for casualty accident rate after number with a $0.5 million installation budget in which cumulative BCR was almost identical for the two cases. In the remaining cases, the difference in performance was small for a $0.5 million budget, and not substantial for $1 million budget.

In addition, the optimal ranking was marginally superior for a $0.5 million installation budget, and marginally inferior in the case of $1 million budget.

Based on alternative identification methods, the general conclusion was that the economic benefits from an objective programme (one in which only expected economic sites are treated) are not much greater than those from a programme where all identified sites are treated within practical limits.

While this conclusion is particularly important for small installation budgets, it must be tentative from the data analysed here. There is the possibility that some non-economic sites with high initial ranking have been already excluded from the treatment programme, following informal investigations not included in the Highways Department files.

Based on these findings it was decided not to exclude expected non-economic sites in subsequent comparisons of identification methods.

6.8 STANDARD DEVIATION OF CUMULATIVE BENEFIT-COST RATIO

To strengthen the conclusions from Chapter 6.6, it was necessary to place error limits on cumulative BCR so that any real difference could be determined.

From earlier discussions, cumulative BCR can be seen as a function of accidents and exposure before-and-after treatment, system-wide changes in accident rates, and discount factors. Of these components, chance variation in the accident experience before-and-after treatment seemed to dominate the error variance of cumulative BCR.

Assuming Poisson distributions for the numbers of property damage and casualty accidents and ignoring error variance of the other components, the standard deviation of cumulative BCR was calculated. This was then used to judge whether there were real differences in the economic performance of the three identification methods discussed in Chapter 6.6 as the best performers (casualty accidents, casualty accident rate significantly greater than system average, and casualty accident rate after number).

6.8.1 Results and Discussion

Assuming an error limit on cumulative BCR of twice the standard deviation in each case, it is possible to identify which method is superior. Table 6.9 shows that the number of casualty accidents is a significantly poorer identification method in terms of economic performance than the other methods.

TABLE 6.9

COMPARISON OF IDENTIFICATION METHODS

STANDARD DEVIATIONS OF CUMULATIVE BENEFIT-COST RATIO

(Economic benefits based on actual accident reductions)

RANKING METHOD	\$0.5m. INSTALLATION BUDGET				\$1m. INSTALLATION BUDGET			
	Cumulative Installation Cost(\$000's)	Cumulative NPV (\$000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost(\$000's)	Cumulative NPV (\$000's)	Cumulative BCR	No. Sites
Actual N.P.V. of Treatment	487	5,250	(0.61) 6 66	17	989	7,029	(0.41) 4.72	45
Casualty Accidents	496	2,107	(0.77) 3.15	16	965	327	(0.55) 1.77	41
Casualty Accident Rate Sig.>System Average	444	4,020	(0.68) 6.12	18	918	4,921	(0.49) 3.88	46
Casualty Accident Rate After Number	475	4,195	(0.69) 5.94	14	998	4,411	(0.47) 3.43	34

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure calculation
(c) Actual loss reduction factors
(d) Casualty accidents pooled in economic calculations
Note: Figure in brackets is standard deviation of cumulative BCR.

There is no significant difference in economic performance between the other two methods, although casualty accident rate significantly greater than the system average appears to be marginally superior. Any difference, however, must take account of the cost of collecting exposure data.

Hence, the casualty accident rate after number method is preferred, since it substantially reduces the need for collecting exposure data, and its economic performance is not significantly poorer than the casualty accident rate significantly greater than the system average method.

6.9 EFFECT OF SHORTER IDENTIFICATION PERIODS

So far, only a three year identification period has been considered in the comparisons of identification methods. The effects of using one and two year periods were also examined for each of the three identification methods. The use of shorter identification periods allowed some additional sites to be included in the analysis which had not been previously considered.

The periods for calculating economic criterion based on accident experience before-and-after treatment, remained unchanged for these comparisons (see Chapter 6.3).

6.9.1 Results and Discussion

Tables 6.10 and 6.11 show the results for two and one year identification periods, respectively. These can be compared with Table 6.9 for three year identification periods.

TABLE 6.10

COMPARISON OF IDENTIFICATION METHODS BASED ON A TWO YEAR PERIOD

(Economic benefits based on actual accident reductions)

	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
RANKING METHOD	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Casualty Accidents	491	1,912	(0.77) 2.79	21	942	907	(0.53) 1.47	36
Casualty Accident Rate Sig. > System Average	451	4,346	(0.65) 6.31	19	991	4,330	(0.47) 3.54	42
Casualty Accident Rate After Number	472	4,250	(0.68) 5.90	14	964	3,538	(0.51) 3.04	34

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure calculation
(c) Actual loss reduction factors
(d) Casualty accidents pooled in economic calculations
Note: Figure in brackets is standard deviation of cumulative BCR

TABLE 6.11

COMPARISON OF IDENTIFICATION METHODS BASED ON A ONE YEAR PERIOD

(Economic benefits based on actual accident reductions)

	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
RANKING METHOD	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Casualty Accidents	445	1,128	(0.79) 2.20	16	983	493	(0.50) 1.24	40
Casualty Accident Rate Sig. > System Average	449	3,564	(0.60) 5.41	15	991	3,451	(0.46) 2.99	36
Casualty Accident Rate After Number	445	3,488	(0.60) 5.44	13	987	2,931	(0.46) 2.70	30

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) South Australian intersection exposure calculation
(c) Actual loss reduction factors
(d) Casualty accidents pooled in economic calculations
Note: Figures in brackets is standard deviation of cumulative BCR

For any given identification method and installation budget, the cumulative BCR appears to decrease monotonically with decreasing identification period. However, the differences between cumulative BCR in this relationship are not statistically significant.

For a $0.5 million installation budget, there is little advantage in using a three year identification period against two years, for either the casualty accident rate significantly greater than system average, or the casualty accident rate after number.

6.10 EFFECT OF INTERSECTION EXPOSURE MEASURE

So far, only the intersection exposure measure employed by the SA Highways Department (Chapter 6.4.2) has been considered in comparing identification methods.

The available literature on measuring intersections exposure showed there were three basic measures in use, namely the sum of vehicles entering the intersection, the product of conflicting flows, and the square root of the product of conflicting flows. The most popular measure was the latter, although research indicated that both of the former methods are also viable.

For the purpose of examining the effect of the intersection exposure measure on the identification methods, therefore, the sum of entering volumes and the product of conflicting flows were included for comparison with that used by the Highways Department (square root of the product of conflicting flows).

The total vehicles entering the intersection was approximated by dividing the total vehicles on each leg by 2. The product of conflicting flows was then calculated, using the South Australian formula without the square root. The definition of the product formula for T-junctions is not standardized in the literature. However, retaining the South Australian formula approach ensured compatability.

It was not necessary to examine the effect of the intersection exposure measure on the casualty accident identification criterion, since this method does not employ exposure.

In the comparisons carried out in this analysis, the economic criterion continued to be based on the SA Highways Department method, since this was relatively insensitive to the chosen exposure measure compared with the relative sensitivity of the identification measure. In each case, ranking was based on a three year identification period.

6.10.1 Results and Discussion

Tables 6.12 and 6.13 show the results for the product measure and the sum of entering volumes measure, respectively. These can also be compared with Table 6.9 for the equilavent Highways Department measure of intersection exposure.

The square root of the product of conflicting flows measure consistently produced the highest cumulative BCR's for a given identification and installation budget. The product measure results in relatively poor economic performance for each of the two identification methods, especially for a $0.5 million installation budget. The sum of entering volumes measure produced lower cumulative BCR's than the SA measure, but the difference is not statistically significant.

TABLE 6.12

COMPARISON OF IDENTIFICATION METHODS BASED ON THE PRODUCT MEASURE OF INTERSECTION EXPOSURE

(Economic benefits based on actual accident reductions)

RANKING METHOD	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Casualty Accident Rate Sig. > System Average	456	2,835	(0.59) 4.41	36	976	3,667	(0.42) 3.09	58
Casualty Accident Rate After Number	478	2,772	(0.68) 4.28	16	946	3,712	(0.49) 3.19	34

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) Product method intersection exposure
(c) Actual loss reduction factors
(d) Casualty accidents pooled in economic calculations
Note: Figures in brackets is standard deviation of cumulative BCR

TABLE 6.13

COMPARISON OF IDENTIFICATION METHODS BASED ON THE SUM OF ENTERING VOLUMES MEASURE OF INTERSECTION EXPOSURE

(economic benefits based on actual accident reductions)

RANKING METHOD	$0.5m. INSTALLATION BUDGET				$1m. INSTALLATION BUDGET			
	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites	Cumulative Installation Cost($000's)	Cumulative NPV ($000's)	Cumulative BCR	No. Sites
Casualty Accident Rate Sig. > System Average	495	4,225	(0.69) 6.20	17	953	4,175	(0.49) 3.32	46
Casualty Accident Rate After Number	489	3,657	(0.72) 5.04	16	979	2,219	(0.54) 2.19	40

IDENTIFICATION METHODS BASED ON
(a) 3 years identification period
(b) sum of entering volumes intersection exposure
(c) Actual loss reduction factors
(d) Casualty accidents pooled in economic calculations
Note: Figures in brackets is standard deviation of cumulative BCR

6.11 CONCLUSIONS

The following conclusions were reached from the retrospective evaluation of identification methods applied to urban intersections on the Adelaide main road system:

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

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

3. The best number-based identification method (casualty accident number) identified sites with significantly lower benefit-cost ratios than the identification methods described in 1 and 2 above.

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

5. For a $0.5 million installation budget, there is no advantage in using a three-year identification period over two years, for either of the identification methods

described in 1 and 2 above. However, identification periods as short as one year should be avoided, and for a $1 million installation budget, three years is still preferred.

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

7. TESTING HAZARDOUS LOCATION PROCEDURES ON URBAN SECTIONS

A prospective analysis was decided on for urban sections as discussed in Chapter 5. The year 1983 was chosen as a base year for 2 reasons:

- To keep extraneous influences to a minimum,
- To enable the work of other agencies to be used in this study.

7.1 DEFINITION OF A SECTION

The traditional method of identifying metropolitan non-intersection locations is based on mid-block locations between minor intersections. These lengths are generally short and they require a substantial number of accidents to be individually identified as hazardous locations.

However, this may not be the most suitable means for identifying hazardous sections. A number of adjacent mid-blocks could all exhibit similar numbers and types of accidents. On their own, they may not be hazardous, but together, would indicate a length of road which has an accident problem.

The South Australian Highways Department has recognised this identification problem. They define hazardous road sections as a length of road between <u>major</u> intersections, and include all mid-block lengths between those locations. In other words, they <u>exclude</u> minor intersection accidents. However, this also has problems in that many of the hazards may be specifically related to the minor intersections along that length of road.

The most recent work undertaken in Victoria by the Road Traffic Authority identified high accident road sections by considering the total number of accidents between major intersections, including those at minor intersections. A consequence of this approach is that minor intersections are identified by both the intersection identification programme and the road section identification programme if adjacent intersections have similar accident problems.

One of the main questions addressed by this research, therefore, was what constituted an appropriate definition for hazardous urban sections.

7.2 STUDY OBJECTIVES

The study, therefore, was undertaken in two phases, namely:

- Establishing an appropriate definition for urban sections
- Evaluating identification methods.

In addition, the urban intersection conclusion that casualty accident data only (not total accidents) would not detract from the identification procedure was also tested for urban sections. Unfortunately, this test could not be fully definitive as only a proportion of PDO accidents are reported in Victoria.

7.3 STUDY AREA

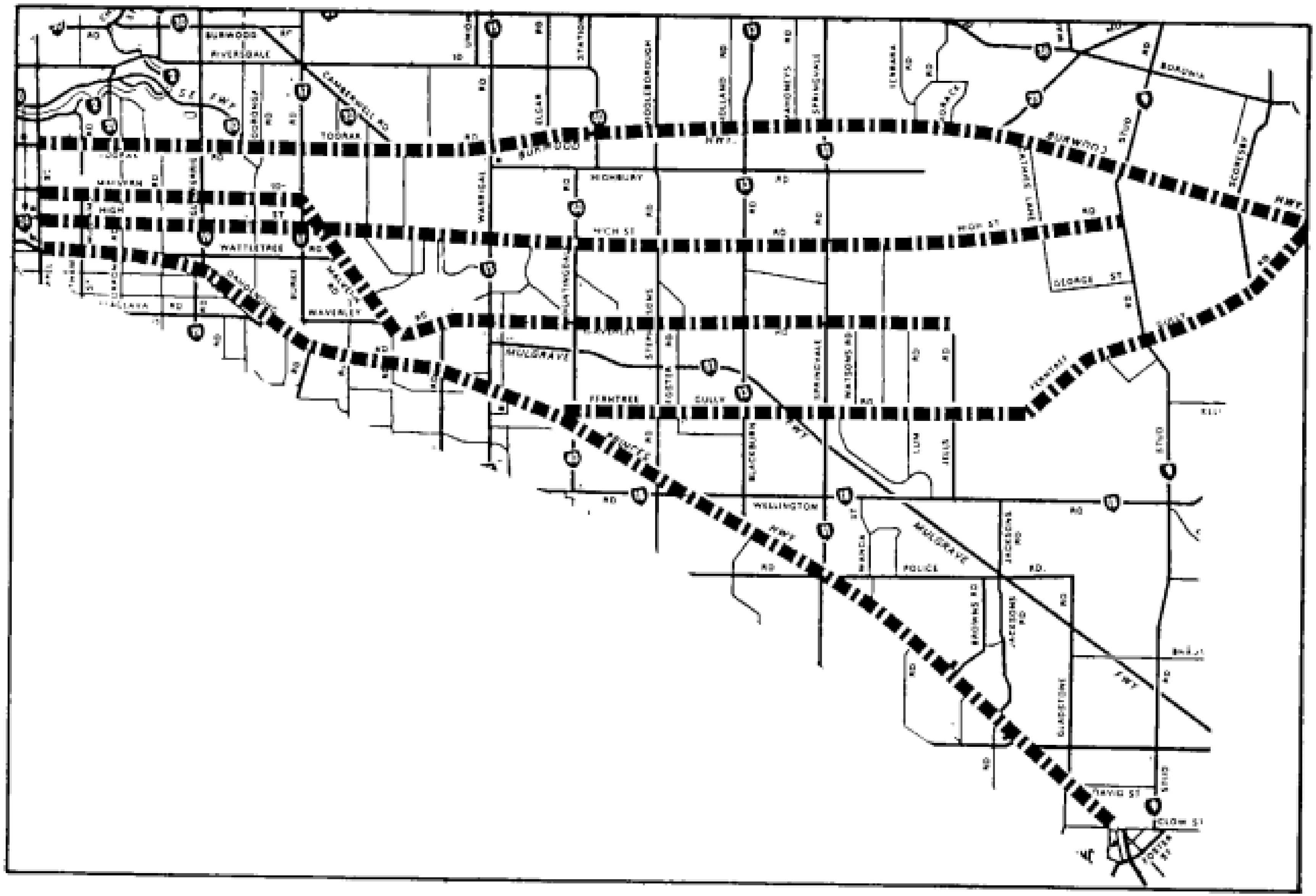
The evaluation of identification procedures was based on five major roads in the eastern suburbs of Melbourne shown in Figure 7.1, namely:

- Toorak Road and Burwood Highway from its intersection with Punt Road to its junction with Ferntree Gully Road (26 kms).
- High Street and High Street Road, from Punt Road to its junction with Stud Road (22 kms).
- Commercial Road, Malvern Road and Waverley Road from Punt Road to its junction with Jells Road (20 kms).

FIGURE 7.1

HAZARDOUS LOCATION PROCEDURES ON URBAN SECTIONS

ROUTE IDENTIFICATION



- Dandenong Road and Princes Highway from Punt Road to its intersection with Cleeland Street, Dandenong (26 kms).

- Ferntree Gully Road, between Princes and Burwood Highways (17 kms).

These roads were chosen because they provide a representative variety of typical road types. Of the total 111 kms, there were:

- 20 kms of two-way road with tram operation;

- 43 kms of two-way road without tram operation, mainly 4 lanes but occasionally 6 lanes wide; and

- 48 kms of multi-lane divided highways.

In the subsequent analysis, this road categorisation was used along with the individual characteristics.

7.4 ACCIDENT DATA

Casualty and property damage only (PDO) accident data for these roads was provided by the Road Traffic Authority (RTA). The initial data was for each RTA classified link and included all necessary information for initial identification. In subsequent analysis, road sections were formed which generally comprised RTA links, although in some cases, these links were divided into smaller road sections.

The road information provided for the six year period from 1977 to 1982 was tabulated for easy reference. Separate tabulations were prepared for the sections including and excluding minor intersection accidents.

7.5 TRAFFIC VOLUMES AND EXPOSURE CALCULATIONS

Traffic volume counts are continuously recorded by the Road Construction Authority and local municipalities in these areas. From these combined resources, it was possible to determine 12 hour counts on the majority of sections studied for either 1982 or 1983. Where volumes were not available, adjacent traffic volumes were used to estimate approximate volumes.

These 12 hour two-way traffic volumes were then converted to 24 hour volume by multiplying by a factor of 1.10. This figure is generally used by the Road Authorities in Victoria in deriving AADT volumes from these counts. The volumes were then incorporated in accident tabulations.

Estimates of annual vehicle kilometres for the sections were determined by multiplying the daily traffic volume by the length of the section and then by 365.

7.6 IDENTIFICATION PROCEDURE

Detailed evaluation of the identification procedures for the urban intersections suggested that the casualty accident number and casualty accident rate methods were the most appropriate procedures. These measures were used as the basis for all subsequent evaluation.

7.7 SECTION DEFINITION

The initial phase of the urban section study was to determine whether to include or exclude minor intersection accidents.

The accident rate per kilometre and accident rate per million vehicle kilometres were calculated for each section of road including and excluding minor intersection accidents. The sections were then ranked from highest to lowest, and the top 20 sections identified by each calculation method. Table 7.1 illustrates these comparisons in the number of accidents per kilometre and per million vehicle kilometres.

Using the number of accidents per kilometre, seventeen of the sections were included in the top 20, no matter whether minor intersection accidents were included or excluded. Similarly, when using the number of accidents per million vehicle kilometres, fifteen of the sections ranked highly by both methods.

Since these lists are basically the same, it was decided that future analysis should include minor intersection accidents for completeness.

7.8 ACCIDENT DEFINITION

The next stage of the evaluation was to determine whether the identification procedures should include only casualty accidents or all reported accidents.

Casualty and total reported accident rates per kilometre and per million vehicle kilometres were calculated for each section including minor intersection accidents. Sections were then ranked from highest to lowest. The top 20 casualty accident and total reported accident sections were again compared. This comparison is illustrated in Table 7.2.

For kilometre figures, seventeen sections were identified by both casualty and total reported accidents. Similarly, using million vehicle kilometre figures, eighteeen of the sections were identified by both methods.

Since the section rankings are basically the same, it was concluded that casualty accidents only should be used in the subsequent analysis. Although these represent only one-half of the accident data, they do provide a more definitive assessment of the risk of accident involvement, as records in Victoria do not consistently include property damage only (PDO) accidents.

TABLE 7.1

COMPARISON OF SECTION DEFINITIONS

(INCLUDING AND EXCLUDING MINOR INTERSECTIONS)

BASED ON DIFFERENT IDENFICATION METHODS

	IDENTIFICATION METHOD			
	Number of Accidents Per Kilometre		Number of Accidents Per Million Veh. kms.	
	Included	Excluded	Included	Excluded
Toorak Rd-Punt Rd to Chapel St	1	1	1	10
Princes Hwy-Chadstone Rd to Warrigal Rd	2	2	-	5
Malvern Rd-Chapel St to Williams Rd	3	4	2	2
Princes Hwy-Warrigal Rd to Ferntree Gully Rd	4	7	-	19
High St-Chapel St to Hotham St	5	3	2	1
Princes Hwy-Chapel St to Hotham St	6	11	-	-
Princes Hwy-Belgrave Rd to Chadstone Rd	7	6	-	13
Toorak Rd-Summerhill Rd to Highfield Rd	8	16	-	-
Malvern Rd-Punt Rd to Chapel St	9	5	4	3
Toorak Rd-Williams Rd to Grange Rd	10	12	7	9
Malvern Rd-Wattletree Rd to Waverley Rd	11	9	-	-
High St-Summerhill Rd to Warrigal Rd	12	8	-	14
Princes Hwy-Chadstone Rd to Warrigal Rd	13	10	-	-
Princes Hwy-Heatherton Rd North to South	14	-	11	-
High St-Kooyong Rd to Glenferrie Rd	15	13	5	6
Burwood Hwy-Warrigal Rd to Elgar Rd	16	14	19	-
High St-Malvern Rd to Glen Iris Rd	17	-	14	-
Princes Hwy-Hotham St to Orrong Rd	18	18	-	-
High St-Orrong Rd to Kooyong Rd	19	-	9	15
High St-Williams Rd to Orrong Rd	20	-	8	20

continued

TABLE 7.1 (continued)

	IDENTIFICATION METHOD			
	Number of Accidents Per Kilometre		Number of Accidents Per Million Veh. kms.	
	Included	Excluded	Included	Excluded
Malvern Rd-Tooronga Rd to Burke Rd	-	15	14	11
Waverley Rd-Warrigal Rd to Huntingdale Rd	-	17	6	4
High St-Punt Rd to Chapel St	-	19	10	7
Princes Hwy-Gladston Rd to Cleeland St	-	20	-	-
High St-Glenferrie Rd to Tooronga Rd	-	-	12	-
Malvern Rd-Glenferrie Rd to Tooronga Rd	-	-	16	12
Malvern Rd-Williams Rd to Orrong Rd	-	-	13	-
Waverley Rd-Huntingdale Rd to Stephensons Rd	-	-	17	8
Malvern Rd-Kooyong Rd to Glenferrie Rd	-	-	18	18
High St-Tooronga Rd to Burke Rd	-	-	20	-
Toorak Rd-Glenferrie Rd to S.E Freeway	-	-	-	17

TABLE 7.2

COMPARISON OF ACCIDENT DEFINITIONS

(TOTAL REPORTED OR CASUALTY ACCIDENT ONLY)

BASED ON DIFFERENT IDENFICATION METHODS

	IDENTIFICATION METHOD			
	Number of Accidents Per Kilometre		Number of Accidents Per Million Veh. kms.	
	Reported	Casualty	Reported	Casualty
Toorak Rd-Punt Rd to Chapel St	1	4	1	3
Princes Hwy-Tooronga Rd to Waverley Rd	2	2	-	11
High St-Chapel St to Williams Rd	3	5	2	1
Princes Hwy-Warrigal Rd to Ferntree Gully Rd	4	6	-	-
Malvern Rd-Chapel St to Williams Rd	5	3	2	2
Princes Hwy-Chapel St to Hotham St	6	1	-	-
Princes Hwy-Williams Rd to Grange Rd	6	10	7	6
Princes Hwy-Chadstone Rd to Warrigal Rd	8	13	-	-
Malvern Rd-Punt Rd to Chapel St	9	7	4	4
Toorak Rd-Summerhill Rd to Highfield Rd	10	12	-	-
Malvern Rd-Wattletree Rd to Waverley Rd	11	16	-	-
High St-Summerhill Rd to Warrigal Rd	12	9	-	18
Princes Hwy-Heatherton Rd North to South	13	-	11	-
High St-Kooyong Rd to Glenferrie Rd	14	-	5	15
Burwood Hwy-Warrigal Rd to Elgar Rd	15	11	19	15
Princes Hwy-Belgrave Rd to Chadstone Rd	16	8	-	-
High St-Malvern Rd to Glen Iris Rd	16	13	14	14
Princes Hwy-Williams Rd to Orrong Rd	18	15	8	7
High St-Orrong Rd to Kooyong Rd	19	-	9	9
Princes Hwy-Gladstone Rd to Cleeland St	20	17	-	-

continued

TABLE 7.2 (continued)

	IDENTIFICATION METHOD			
	Number of Accidents Per Kilometre		Number of Accidents Per Million Veh. kms.	
	Included	Excluded	Included	Excluded
High St-Williams Rd to Orrong Rd	-	18	-	-
High St-Glenferrie Rd to Tooronga Rd	-	19	12	8
Waverley Rd-Warrigal Rd to Huntingdale Rd	-	20	6	5
High St-Punt Rd to Chapel St	-	-	10	15
Malvern Rd-Williams Rd to Orrong Rd	-	-	13	18
Malvern Rd-Tooronga Rd to Burke Rd	-	-	14	10
Malvern Rd-Glenferrie Rd to Tooronga Rd	-	-	16	18
Waverley Rd-Huntingdale Rd to Stephensons Rd	-	-	17	13
Malvern Rd-Kooyong Rd to Glenferrie Rd	-	-	18	18
High St-Tooronga Rd to Burke Rd	-	-	20	11

This is also the case in all other States and Territories except the ACT.

This analysis, therefore, corroborated the urban intersection evaluation of identification procedures which also suggested that the use of casualty accidents alone would not detract from the identification results.

7.9 AVERAGE ACCIDENT STATISTICS

The average casualty accident statistics including minor intersections accidents were calculated for each route, road type and in total for accident per kilometre and accidents per million vehicle kilometres. These are illustrated in Table 7.3.

TABLE 7.3
AVERAGE ANNUAL ACCIDENT STATISTICS
CASUALTY ACCIDENTS
INCLUDING MINOR INTERSECTION ACCIDENTS

Road (Type)	Accidents per km	Accidents per million vehicle km
Burwood Hwy	3.39	26
Waverley Road	3.33	45
High Street	3.87	51
Ferntree Gully Rd	2.23	24
Princes Hwy	4.40	28
Tram Routes	5.99	76
Two-way Roads	2.57	30
Dual carriageway	3.50	24

7.10 <u>INDIVIDUAL SECTION ACCIDENT STATISTICS</u>

The critical accident rate per kilometre and critical accident rate per million vehicle kilometres were calculated from the average casualty accident statistics (Chapter 7.9) using the method referenced by Jorgensen (1966) and Deacon et al (1975), namely:

$$CR = A + 1.645\sqrt{\frac{A}{M}} + \frac{1}{2M} \quad \text{(see footnote *)}$$

where

- CR is the critical rate
- A is the average casualty accident rate per exposure
- M is the measure of exposure
- 1.645 is based on a 95% confidence limit, implying a 5% chance that the intersection may be indicate a significantly high rate of accident even though it is not specifically hazardous. Deacon et al (1975) provides alternative values of this constant for differing confidence limits.

These critical accident rates were then compared to the actual casualties expressed as an appropriate rate for each individual section.

The sections identified by reference to the total accident rates per kilometre and by accident rates specific to the road type (tram, two-way, and dual carriageway) are listed in Table 7.4. Sections identified in a similar way, but based on accident rates per million vehicle kilometres, are listed in Table 7.5.

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*This formula was adapted from original analyses performed by Rudy (1962) and Morin (1967). Formula derivations can be obtained from these original references.

TABLE 7.4

CRITICAL SECTIONS BASED ON ACCIDENTS PER KILOMETRE

Rank	Route	Link	Type	Common
TOTAL RATE				
1	Princes Hwy	Chapel St - Williams Rd	Dual	
2	Princes Hwy	Tooronga Rd - Waverley Rd	Tram	
3	High St	Chapel St - Williams Rd	Tram	*
4	Burwood Hwy	Punt Rd - Chapel St	Tram	*
5	Waverley Rd	Chapel St - Williams Rd	Tram	*
6	Princes Hwy	Warrigal Rd - Ferntree Glly Rd	Tram	
7	Waverley Rd	Punt Rd - Chapel St	Tram	*
8	Princes Hwy	Chadstone Rd - Warrigal Rd	Dual	
9	High St	Summerhill Rd - Warrigal Rd	Two Way	*
11	Burwood Hwy	Warrigal Rd - Elgar Rd	Dual	*
TYPE RATE				
1	Princes Hwy	Chapel St - Williams Rd	Dual	
6	Princes Hwy	Warrigal Rd - Ferntree Glly Rd	Dual	
8	High St	Chadstone Rd - Warrigal Rd	Dual	
9	High St	Summerhill Rd - Warrigal Rd	Two Way	*
11	Burwood Hwy	Warrigal Rd - Elgar Rd	Dual	*
13	High St	Malvern Rd - Glen Iris Rd	Dual	
20	Waverley Rd	Warrigal Rd - Huntingdale Rd	Two Way	*

NOTE: Sites identified by a * are those ranked critical by either accident per km or accident per million vehicle kilometers (ie: common to both Table 7.4 and 7.5).

Type specifies the road hierarchy including two way, dual highway or two way with public transport (tram).

TABLE 7.5

CRITICAL SECTIONS BASED ON ACCIDENTS PER MILLION VEHICLE KILOMETRES

Rank	Route	Link	Type	On Both Lists
TOTAL RATE				
1	High St	Chapel St - Williams Rd	Tram	*
2	Waverley Rd	Chapel St - Williams Rd	Tram	*
3	Burwood Hwy	Punt Rd - Chapel St	Tram	*
4	Waverley Rd	Punt Rd - Chapel St	Tram	*
5	Waverley Rd	Warrigal Rd-Huntingdale Rd	Two Way	
6	Burwood Hwy	Williams Rd - Grange Rd	Tram	
7	High St	Williams Rd - Orrong Rd	Tram	
8	High St	Glenferrie Rd-Tooronga Rd	Tram	
15	Burwood Hwy	Warrigal Rd - Elgar Rd	Dual	*
18	High St	Summerhill Rd-Warrigal Rd	Two Way	*
TYPE RATE				
1	High St	Chapel St - Williams Rd	Tram	
5	Waverley Rd	Warrigal Rd-Huntingdale Rd	Two Way	*
15	Burwood Hwy	Warrigal Rd - Elgar Rd	Dual	*
18	High St	Summerhill Rd-Warrigal Rd	Two Way	*
23	Waverley Rd	Chapel St - Williams Rd	Dual	
28	Prince Hwy	Gladstone Rd-Cleeland St	Dual	

NOTE: Sites identified by a * are those ranked critical by either accident per km or accident per million vehicle kilometers (ie: common to both Table 7.4 and 7.5).

Those sections identified by reference to the specific road type rates are included with those identified by reference to the total rates, in terms of both accidents per kilometre and accidents per million vehicle kilometres. This is directly comparable with the urban intersection evaluation, where it was found that component rates gave similar identification results to total rates.

The identified sections based on both measures are listed in Table 7.6. This shows that both methods identified the same 6 sections from the possible 10 sections considered.

Those sections in which the actual accident rate in terms of accidents per kilometre and million vehicle kilometres is above the critical rate, therefore, were considered worthy of detailed investigation.

TABLE 7.6

CRITICAL SECTIONS BASED ON TOTAL RATES

Rank	Route	Link	Type	On Both Lists
BASED ON ACCIDENTS PER KILOMETRE				
1	Princes Hwy	Chapel St - Williams Rd	Dual	
2	Princes Hwy	Tooronga Rd-Waverley Rd	Tram	
3	High St	Chapel St - Williams Rd	Tram	*
4	Burwood Hwy	Punt Rd - Chapel St	Tram	*
5	Waverley Rd	Chapel St - Williams Rd	Tram	*
6	Princes Hwy	Warrigal Rd-Ferntree Gly Rd	Tram	
7	Waverley Rd	Punt Rd - Chapel St	Tram	*
8	Princes Hwy	Chadstone Rd - Warrigal Rd	Dual	
9	High St	Summerhill Rd - Warrigal Rd	Two Way	*
11	Burwood Hwy	Warrigal Rd - Elgar Rd	Dual	*
BASED ON ACCIDENTS PER MILLION VEHICLE KILOMETRES				
1	High St	Chapel St - Williams Rd	Tram	*
2	Waverley Rd	Chapel St - Williams Rd	Tram	*
3	Burwood Hwy	Punt Rd - Chapel St	Tram	*
4	Waverley Rd	Punt Rd - Chapel St	Tram	*
5	Waverley Rd	Warrigal Rd - Huntingdale Rd	Two Way	
6	Burwood Hwy	Williams Rd - Grange Rd	Tram	
7	High St	Williams Rd - Orrong Rd	Tram	
8	High St	Glenferrie Rd - Tooronga Rd	Tram	
15	Burwood Hwy	Warrigal Rd - Elgar Rd	Dual	*
18	High St	Summerhill Rd - Warrigal Rd	Two Way	*

NOTE: Sites identified by a * are those ranked critical by either accident per km or accident per million vehicle kilometers (ie: common to both the upper & lower sections of this table).

7.11 INVESTIGATIONS

The value in continuing to investigate the accident record of each identified location, and to identify possible traffic management solutions was questionable; there would probably have been insufficient differences along these lengths to allow a meaningful comparison of the two identification methods. Moreover, the continuation of the work depended upon the availability of resources to provide detailed environmental information on the 600 accidents at these identified sections.

It was decided, therefore, that benefits resulting from the investigations were marginal and not sufficient to justify the work. Hence, the evaluation did not undertake an investigation of each location, and did not provide economic comparisons of the identification methods.

7.12 CONCLUSIONS

The following conclusions were reached from the evaluation of identification methods, applied to urban sections in the eastern suburbs of Melbourne.

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

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

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

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

It was not possible to check the economic benefits of each identification method because of the external resources necessary to provide the accident location information.

8. TESTING HAZARDOUS LOCATION PROCEDURES IN RURAL AREAS

A prospective evaluation was decided on for evaluating hazardous roads in rural locations because of the relative lack of rural highway improvements for road safety compared with urban locations. To minimise resource effort and cost, the work was carried out in the Road Construction Authority's Traralgon Division in Victoria.

8.1 SITE SELECTION

The Traralgon Division of the Road Construction Authority provides two different, but complementary, highways with suitable data.

- Princes Highway East is the main highway from Melbourne through Gippsland. It links the important country centres of Warragul, Moe, Morwell, Traralgon, Sale and Bairnsdale, and continues on to the NSW Border. Within the Traralgon Division, there were differing road characteristics, including freeways, dual carriageways and high quality two lane roads, with varying traffic volumes.

- South Gippsland Highway is the main coastal road from Melbourne to Sale, linking the important country centres of Korrumburra, Leongatha, Foster, Wilsons Promontory, Welshpool, Alberton and Yarram. Within the Traralgon Division, this road provided varying qualities of two lane road with medium to low traffic volumes.

8.2 ACCIDENT DATA

The Road Construction Authority has developed a computer program for rural investigations which lists the accidents on each highway by road section and intersection, defined as a kilometre distance from a control point.

This information for the two highways from July 1978 to June 1982 was plotted as a strip map for easy reference. Figure 8.1 is a typical illustration of this map.

Following the identification of rural hazardous sections and intersections, RCA provided a summary of the accidents at each identified location for the same four year period from which it was possible to identify the accident report form number (see Figure 8.2). The relevant accident data were subsequently provided by RTA for the detailed examination. This is discussed further in Chapter 8.7.

8.3 TRAFFIC VOLUMES AND EXPOSURE CALCULATIONS

8.3.1 Road Sections

RCA undertake annual traffic volume surveys each year on the main Victorian highways. This does not provide detailed traffic volumes for each section of the highway but rather, an historic record for a selected number of locations (10 on the Princes Highway East and 9 on the South Gipplsand Highway).

From these locations, 12 hour two-way traffic volumes for each section of both highways were derived. These were assumed to represent the traffic volumes in 1980 which was the mid point of the accident data collection period, 1978 to 1982. It should be noted that the annual variation over this period was relatively low.

The 12 hour two-way traffic volumes were converted to 24 hour, two-way volumes using the factor of 1.25 which is generally used by the RCA for deriving AADT volumes from these counts.

8.3.2 Intersections

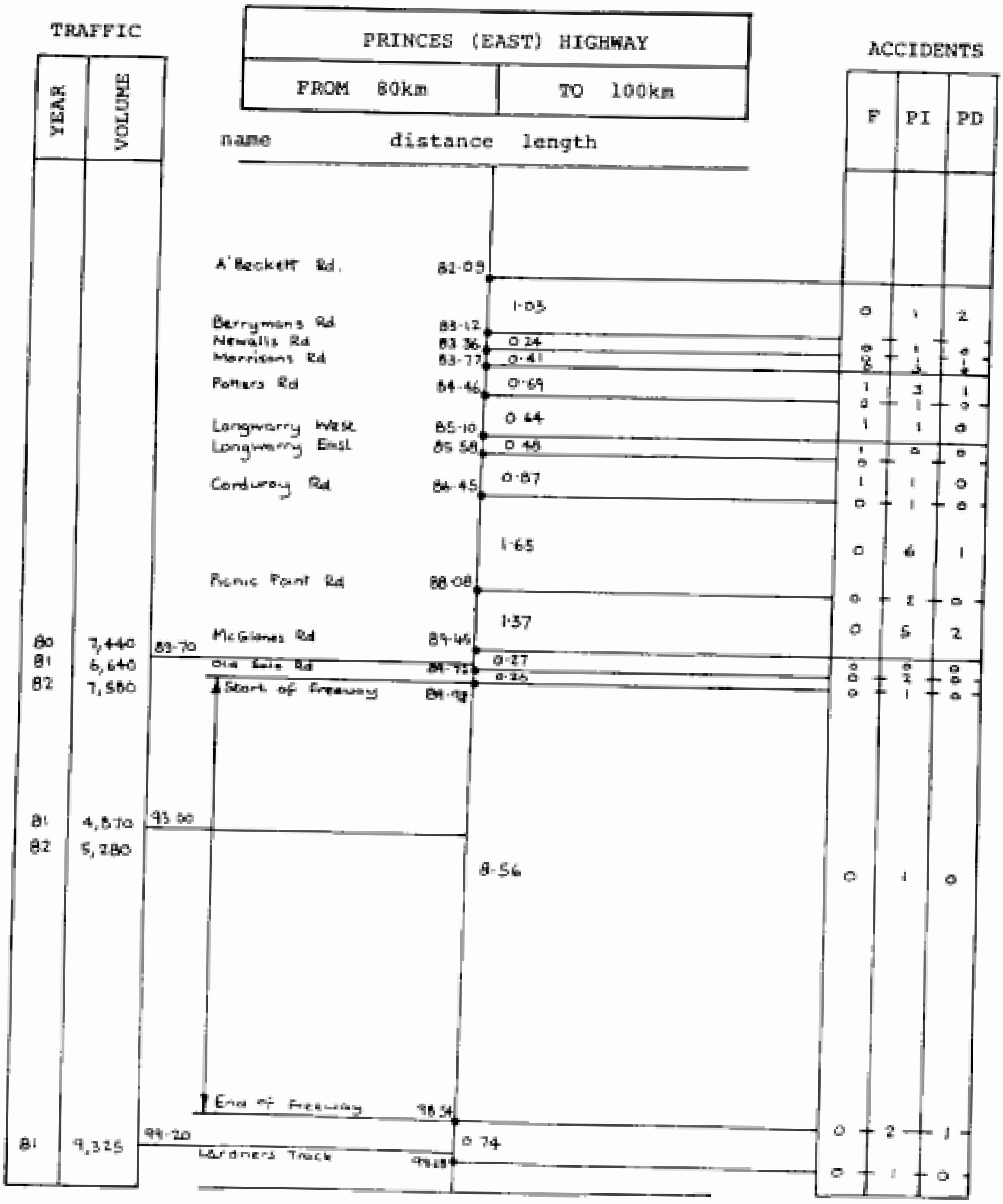
The traffic volumes on the main cross roads were provided by the relevant local government authorities.

The exposure estimates for the intersections were determined using the South Australian formula (Chapter 6.4.2.).

FIGURE 8.1

HAZARDOUS LOCATION PROCEDURES IN RURAL AREAS

SAMPLE ACCIDENT STRIP MAP



NOTES: All traffic volumes are 12 hour (7.00 am - 7.00 pm)

FIGURE 8.2

HAZARDOUS LOCATION PROCEDURES IN RURAL AREAS

SAMPLE ACCIDENT RECORD SHEET

MIDBLOCK ACCIDENTS 4 YEARS TO 6 1982

RACV STUDY TRARALGON DIVISION PHE BLACKSPOTS

KILOM	MICRONU	ACCNO	CONTL	SEV	NUM	DATE	TIME	ROAD	LITE	ROADNAME		ROADNAME	REFERENCE	LGA
86.4	1221107	35541	15	2	61E	10 12 81	1350	1	1	PRINCES HWY		CORINBUY RD	3750HG805	
88.06											TO-	PICNIC POINT RD	3750B0809	852
86.4	1222085	37686	15	2	83W	06 12 81	1930	1	1					
88.06														852
86.4	1020937	02901	15	2	77W	01 02 81	0230	1	5					
88.06														852
86.4	0231119	34673	15	2	84	12 12 80	1830	1	1					
88.06														852
86.4	0072275	13089	15	2	85	08 05 80	1710	1	1					
88.06														852
86.4	0011583	01501	15	2	82	13 01 80	0545	1	5					
88.06														852
86.4	9090487	10022	15	3	51	11 04 79	1530	1	1					
88.06														852
* *														
88.0	2091127	14032	15	2	04E	14 05 82	0120	2	5	PRINCES HWY		PICNIC POINT RD	3750B0809	
89.43											TO-	MC GLONES RD	3750C0807	852
88.0	2051633	11725	15	2	51SE	27 04 82	1610	2	1					
89.43														852
88.0	2021667	03356	15	2	85W	10 02 82	0930	1	1					
89.43														852
88.0	0230215	33128	15	3	44	23 10 80	1430	2	1					
89.43														852
88.0	0120557	20130	15	2	63	04 07 80	1320	2	1					
89.43														852
88.0	9111535	19052	15	3	63	28 06 79	1440	2	1					
89.43														852
88.0	8220821	40147	15	2	82NW	15 12 78	0150	1	5					
89.43														852
* *														
108.7	2100863	14786	15	3	51E	06 06 82	0020	1	5	PRINCES HWY		RHODES RD	1292AC101	
107.14											TO-	MILMA-MONA VISTA RD	3970K1901	862
108.7	1190125	30590	15	3	61SE	03 10 81	0940	2	1					
107.14														862
108.7	1170505	24362	15	2	44E	11 09 81	1515	1	1					
107.14														862
108.7	1090701	14970	15	3	60E	25 05 81	1555	2	1					
107.14														862
108.7	0240645	20613	15	1	80	09 07 80	1150	3	1					
107.14														862
108.7	9230739	39215	15	2	85	15 12 79	2145	2	5					
107.14														862
108.7	9171599	29400	15	3	65	24 09 79	2300	1	5					
107.14														862
108.7	9110439	19126	15	3	84	23 05 79	1730	2	2					

SEV	CONTL	ROAD	LITE
1=FATAL	4=PED SIGS	1=DRY	1=DAYLIGHT
2=PERS INJ	5=PED XING	2=WET	2=DUSK,DAWN
3=PROP DAM	6=L X GATES	3=MUDDY	3=DARK,SL ON
	7=L X LIGHTS	4=SNOW,ICE	4=DARK,SL OFF
CONTL	13=SCH-FLAGSL		5=DARK,NO SL
14=SCH-NO FG	15=NO CONTROL		6=DARK,SL UNK

8.4 IDENTIFICATION PROCEDURES

The identification analysis for urban intersections suggested the most appropriate procedures for rural areas were the accident number and accident rate methods, especially those based on casualty accidents.

On rural sections, the number method was corrected for section length, and the accidents restricted to casualty accidents (the Victorian records do not always include property damage only (PDO) accidents). The previous analyses suggested this would not detract from the rural identification procedures.

8.5 AVERAGE HIGHWAY ACCIDENT STATISTICS

8.5.1 Road Sections

The average casualty accident statistics were calculated for each highway separately using casualty accidents per kilometre and casualty accidents per million vehicle kilometres.

These averages were intended to be used as reference values for individual accident rates on rural sections. It was necessary, therefore, to eliminate urban area accident locations. The definition of an urban area was derived from the accident mapping classification, where rural areas were deemed to finish at the nearest designated urban area intersection. The only exception to this was on the Princes Highway East where the Freeway in the Moe urban area was included.

The Princes Highway East consisted of <u>three</u> highway types, namely 25.7 km of freeway, 7.0 km of dual carriageway and 60.8 km of two-way road. However, the use of this categorisation was unnecessary as the dual carriageway was only one section and did not provide comparative statistics. Moreover, the use of this categorisation did not provide superior identification for urban intersections.

The section statistics provided failed to identify all intersection accidents. Procedures have been used by the authorities to allocate intersection accidents to sections, but this was not appropriate for this research project. Hence, rural intersections were treated separately in this evaluation.

The average annual accident statistics are summarised in Table 8.1.

TABLE 8.1
AVERAGE ANNUAL ACCIDENT STATISTICS
RURAL SECTIONS

Highway	Casualty Accidents per km	Casualty Accidents per km
Princes Highway East	0.40	0.15
South Gippsland Highway	0.16	0.25

8.5.2 Intersections

The average casualty accident statistics were calculated for each highway using casualty accidents per intersection and casualty accidents per million vehicles exposure.

The casualty accidents per intersection are based on 38 intersections on the Princes Highway East (excluding the grade separated intersections on the freeway sections), and 130 intersections on the South Gippsland Highway.

It was not possible to obtain the traffic volumes for all these 168 cross routes readily. A sample of intersections was selected, therefore, in which accidents were higher than the critical number. This sample included 11 sites on the Princes Highway East which had two or more accidents, and 14 sites on the South Gippsland Highway which had more than one accident. Average exposure was available for each intersection and was applied to all sample intersections.

The average annual accident statistics calculated are summarised in Table 8.2.

TABLE 8.2
AVERAGE ANNUAL ACCIDENT STATISTICS
RURAL INTERSECTIONS

	Casualty Accidents per intersection	Casualty Accidents per million vehicles
Princes Highway East	0.61	0.085
South Gippsland Highway	0.12	0.073

8.6 CRITICAL ACCIDENT RATES

8.6.1 Road Sections

The accident rate per kilometre and accident rate per million vehicle kilometres were calculated for each section of the highway, and sections were then ranked from highest to lowest rate. The critical accident rates were subsequently calculated.

Those sections where the actual accident rate is above the critical rate were investigated in detail. These are listed in Table 8.3.

TABLE 8.3

SECTIONS IDENTIFIED FOR INVESTIGATION

SECTION	ACCIDENTS/km			ACCIDENT RATE		
	Actual	Critical	Rank	Actual	Critical	Rank
PRINCES HIGHWAY EAST						
Newall Rd-Morrisons Rd	1.83	1.51	1	0.53	0.51	2
Morrisons Rd-Potters Rd	1.45	1.20	3	0.42	0.41	4
Corduroy Rd-Picnic Pt.Rd	0.92	0.88	6	-	-	-
Picnic Pt.Rd-McGlones Rd	0.91	0.93*	7	-	-	-
Nilma Bona Vista Rd - Rhodes Rd	0.93	0.88	5	-	-	-
Railway Viaduct Rd - Lloyd Rd	1.53	0.99	2	0.45	0.44	3
Haunted Hills Rd - Morwell Bypass Rd	-	-	-	0.31	0.26	6
Morwell Bypass Rd - Morwell Bridge Rd	1.15	1.01	4	0.56	0.41	1
Sale Cowwarr Rd - Hopkins Rd	-	-	-	0.38	0.39*	5
SOUTH GIPPSLAND HIGHWAY						
Hookers Rd-McKenzies Rd	0.66	0.43	4	0.72	0.59	6
Goldies Rd-Roy St	0.50	0.45	6	-	-	-
Jeetho Rd - Bena Kongwak Rd	1.21	0.42	2	1.32	0.57	3
Bena Kongwak Rd - Bena Poowang Rd	1.67	0.93	1	1.83	1.19	1
Cahills Outlet Rd - Barnes Rd	0.98	0.86	3	-	-	-
Carmodys Rd - Gwther Siding Rd	0.44	0.43	8	-	-	-
Dorans Rd-Grip Rd	0.45	0.44	7	0.65	0.66*	7
Edeys Rd-Pound Rd East	0.57	0.48	5	0.83	0.72	4
Old Sale Rd-Cascade Rd	-	-	-	0.79	0.72	5
Cascade Rd-Carrajung Woodside Rd	-	-	-	1.77	1.46	2

* Although the actual are less than the critical rate, the comparison is sufficiently close to warrant investigation.

8.6.2 Intersections

Accident rates per intersection, accident rate per million vehicles, and critical rates were calculated in a similar way for the intersections. Those intersections where the actual number or rate was above the critical number or rate were considered further. These are listed in Table 8.4.

TABLE 8.4

INTERSECTIONS IDENTIFIED FOR INVESTIGATION

INTERSECTION	ACCIDENT NUMBER		ACCIDENT RATE	
	Actual	Critical	Actual	Critical
PRINCES HIGHWAY EAST				
Picnic Point Rd	-	-	1.00	0.67
Bloomfield Rd	3	2.39	-	-
Kennys Rd	-	-	1.00	0.67
Moir Rd	-	-	0.58	0.49
Railway Viaduct Rd	-	-	0.71	0.54
Coonoc Rd	4	2.39	0.57	0.33
SOUTH GIPPSLAND HIGHWAY				
Goldies Rd	-	-	1.37	1.29
Koonwarra Inverloch Rd	2	1.19	0.97	0.62
Barry Rd	2	1.19	0.58	0.46
Holmans Rd	-	-	2.74	2.20
Boundary Rd	-	-	2.24	1.84

8.7 INVESTIGATIONS

The accident report forms were studied in detail and the accidents located on black spot maps. In addition, accident summary sheets were prepared for each location (see Figure 8.3). These included accident details such as number, date, time, light conditions, road conditions, and accident severity, together with a brief summary of possible accident causes.

The location of accidents on the road sections was relatively precise for short lengths, where the Police used a nearby intersection as a reference point. However, on long sections of road, the location data was less accurate because many accidents occurred at relatively large distances from the nearest intersection. The location of these accidents, however, did not interfere with the investigation of particular lengths of roads.

The freeway between Haunted Hills Road and the Morwell By-pass on the Princes Highway proved the most difficult section to locate accidents. This was because of its length and the lack of identifiable reference points.

8.7.1 Survey of Sites

In addition to obtaining these accident details, a survey of the characteristics of each section of the road was undertaken. This information formed the basis for detailed inspections of accident location to determine the most likely countermeasures.

FIGURE 8.3

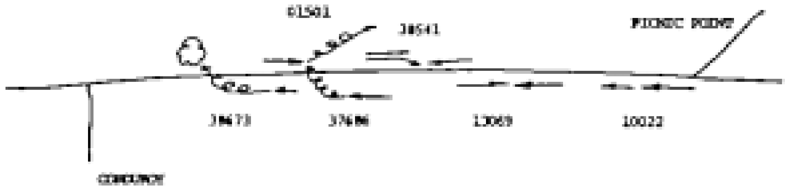
HAZARDOUS LOCATION PROCEDURES IN RURAL AREAS

SAMPLE ACCIDENT SUMMARY SHEET

LOCATION

CORDUROY

PICNIC POINT



Accident No	38673	61501	37686	38541	10022	13069
Date : Day	12:12:80 Fri	13:01:80 Sun	06:12:81 Sun	10:12:81 Thur	11.04.79 Wed	08:05:80 Thur
Time:Light	18:30 Day	05:45 Night	19.30 Day	13·50 Day	15:30 Day	17:10 Day
Weather	DRY	DRY	DRY	DRY	DRY	DRY
SEVERITY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY	PERSONAL INJURY
	200m East of Corduroy Westbound vehicle lost control on gravel shoulder swerved across the carriageway and struck tree 45m away.	300m East of Corduroy Eastbound vehicle veered onto gravel shoulder and lost control, struck post.	300m East of Corduroy Westbound vehicle swerving to avoid vehicle unparking on north shoulder, lost control on gravel shoulder and swerved across the road.	400m East of Corduroy Eastbound vehicle overtaking another vehicle saw approaching vehicle, braked lost control and side-swiped vehicle.	500m West of Picnic Point Westbound vehicle ran into rear of stationary vehicle awaiting direction from flagman at roadwork.	Undefined Location Eastbound vehicle collided with westbound vehicle which had lost control. Vehicle ran off road into paddock.

The inspections were undertaken by two experienced traffic engineers who suggested a range of probable countermeasures. At many of the locations, there was an obvious countermeasure to alleviate the problem. To minimise bias, care was taken to ensure that the engineers were unaware of the method of identification for each section, although experienced traffic engineers would have little trouble in summising this.

To further control for bias in selecting countermeasures, the traffic engineers' recommendations were discussed with RCA Divisional Office engineers in Traralgon. In most instances, the recommendations were unchallenged, but some were rejected because:

- Schemes were unable to meet necessary standards, e.g. guardrail or embankments of insufficient elevation

- Schemes were politically unacceptable, e.g. right-turn treatments for private properties

- Schemes were not in accord with RCA practice, e.g. lighting in rural highway sections.

It should also be noted that some of the recommended countermeasures would not have been considered in practice by RCA because the sections investigated were to be duplicated in the immediate future. This did not interfere, however, with the final list of recommended countermeasures in this project.

8.8 COST OF TREATMENT

8.8.1 Costs of Implementation

Treatment installation costs were based on unit treatment costs provided by the RCA. These unit costs were derived from recent work undertaken in the Traralgon Division.

A factor for maintenance cost was also included for the various treatments, based on assumptions of construction, line marking, and guide post and sign replacements demands. Maintenance costs were only taken into account for the remedial countermeasures and not for general roadworks.

8.8.2 Costs of Investigation

It was not possible to include an arbitrary investigation cost for rural investigations, as a realistic estimate was not available and could not have been derived without considerable work. Moreover, inclusion of an investigation cost for rural investigations would have had only marginal effect.

8.8.3 Net Present Cost

The net present cost (NPC) of each scheme was calculated over a period of 10 years, discounting for re-installation and maintenance costs at 10% per annum.

8.9 BENEFITS OF TREATMENT

8.9.1 Accident Reduction Factors

The derivation of accident reduction factors for each of the treatments proved difficult. There is insufficient Australian data available to prepare a comprehensive list, and overseas studies only provided some of the required information. The major problem with the overseas literature was the ambiguous definition of the countermeasure accident reduction factors.

Accident reduction factors, therefore, were accepted as reported in the literature. Where there was a range of countermeasures for a particular treatment, this was noted (Table 8.5). For marginal benefit-cost ratios, the range of factors available determined whether to accept a higher accident reduction factor or not.

TABLE 8.5

ASSUMED ACCIDENT REDUCTION FACTORS

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

NOTE: 1. Range is only given where there are significant differences from the assumed reduction factors

The accident reduction factor for a particular countermeasure was applied to the length of road (identified section or part thereof) effected by that countermeasure and likely to influence the accidents occuring over that length of road. It could be argued that the implementation of certain countermeasures could generalise over a greater length of road. Overtaking lanes, for example, may reduce the level of frustration so that drivers do not attempt to overtake along succeeding sections. However, identifying these effects would be arbitrary, and as such, were ignored in this analysis.

For locations where more than one countermeasure was recommended, their joint effects were assessed as follows:

Expected Accidents x Accident Reduction (Countermeasure 1) x Accident Reduction (Countermeasure 2)

It was assumed that the accident reduction factors determined for total accidents would similarly apply for the casualty accidents investigated in this study.

8.9.2 Expected Number of Accidents

The expected number of accidents per annum was assumed to be the average of the four year identification period, for the whole length of a section, or part of a section where a particular countermeasure was recommended.

8.9.3 Cost of Casualty Accident

The cost of a casualty accident from the investigation of the urban intersections was that derived by Atkins (1981) in 1978 costs. As a cost update for 1982 was not available at the time of this analysis, an estimate was assumed, based on the rise in Average Weekly Earnings which, according to McLean (1980) and Somerville (1981) is the dominant index in the parameters used to determine accident costs.

8.9.4 Net Present Benefits

The net present benefit (NPB) of the expected accident reduction of each scheme was calculated over a period of 10 years at a discount rate of 10% per annum.

8.10 ECONOMIC CRITERIA

The criteria used to measure economic value of each treatment included the Net Present Value (NPV) and Benefit-Cost Ratio (BCR).

The selection of the appropriate treatment from a range of possible treatments could be based on either the NPV or the BCR for each treatment. Therefore, evaluation of identification methods considered both criteria.

8.10.1 Evaluation Procedure

After ranking treatments by each identification method, the two complementary economic criteria of cumulative NPV and cumulative BCR related to the programme of treatments, were calculated and ranked (see Chapter 6.4.7).

These measures of the economic value of a programme were then compared using the cumulative NPC as a measure of the economic cost or budget for a programme of hazardous road location identification and treatment.

The economic criterion for individual locations and the programme of treatments was then used to compare the different identification methods.

8.11 RESULTS AND DISCUSSION

The factors used in the evaluation of identification methods for rural sections were:

- Number-based, rate-based, or a combination method (either number followed by rate, or rate followed by number).
- Referenced to sub-system averages or system-wide averages.
- Based on treatment selection criterion using either BCR or NPV.

The identification methods for sections were compared on the basis of treatment budgets of $25,000 and $50,000 (see Table 8.6). In addition, comparison was made for a budget of $21,150 and $42,300 (Table 8.7) as these represent a statewide budget for rural roads of $0.5 million and $1 million respectively (since these roads in the Traralgon area represent some 4% of the designated state highways).

Figure 8.4 shows the comparison between the number and rate identification procedures for BCR and NPV selection criteria. The accident number method for BCR treatment selection identified more sites for both $50,000 and $25,000 treatment budgets. Moreover,this approach was also superior for Statewide budgets of $0.5 million and $1 million.

In addition, accident rate comparisons resulted in significantly lower BCRs than accident numbers, and combination methods were not superior to either of the separate approaches. Methods based on BCR for countermeasure selection produced greater economic values than those using NPV.

TABLE 8.6

COMPARISON OF IDENTIFICATION METHODS

TREATMENT BUDGETS $25,000 AND $50,000

RANKING METHOD	$25,000 TREATMENT BUDGET				$50,000 TREATMENT BUDGET			
	CUM NPC	CUM NPB	CUM BCR	No Sites	CUM NPC	CUM NPB	CUM BCR	No. Sites
(1) Number/km (selection criteria BCR)	21,500	285,560	14.28	5	43,200	466,590	11.80	10
(2) Number/km (selection criteria NPV)	22,950	228,280	10.95	4	39,700	316,210	8.96	6
(3) Rate (selection criteria BCR)	20,200	116,590	6.77	4	47,750	359,120	8.52	9
(4) Rate (selection criteria NPV)	23,800	122,760	6.16	4	49,400	368,630	8.46	8
(5) Number/km - sub system average (BCR)	23,150	235,060	11.15	5	---------- As (1) ----------			
(6) Number/km - sub system average (NPV)	---------- As (2) ----------				---------- As (2) ----------			
(7) Rate - sub system average (BCR)	22,350	180,040	9.06	5	---------- As (3) ----------			
(8) Rate - sub system average (NPV)	---------- As (4) ----------				---------- As (4) ----------			
(9) Number/Rate (BCR)	---------- As (1) ----------				------ Not Applicable ------			
(10) Number/Rate (NPV)	---------- As (2) ----------				47,350	349,740	8.39	7
(11) Rate/Number (BCR)	20,200	323,850	17.03	6	------ Not Applicable ------			
(12) Rate/Number (NPV)	15,850	125,820	8.94	3	47,350	349,740	8.39	7

TABLE 8.7

COMPARISON OF IDENTIFICATION METHODS

TREATMENT BUDGETS $21,150 AND $42,300

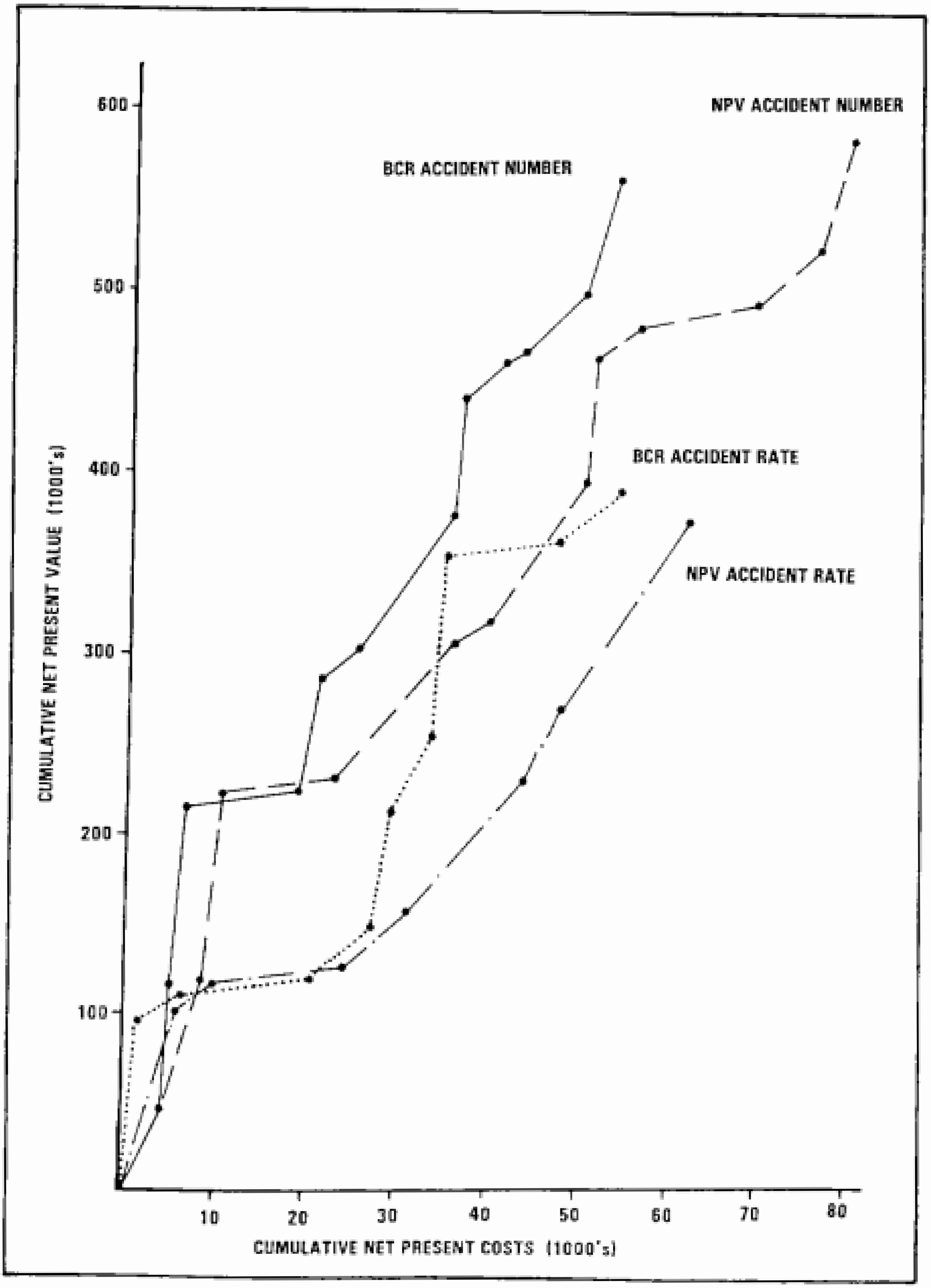
RANKING METHOD	$21,150 TREATMENT BUDGET				$42,300 TREATMENT BUDGET			
	CUM NPC	CUM NPB	CUM BCR	No. Sites	CUM NPC	CUM NPB	CUM BCR	No. Sites
(1) Number/km (selection criteria BCR)	19,350	222,110	12 48	4	41,350	457,970	12 07	9
(2) Number/km (selection criteria NPV)	10,200	220,090	22 58	3	39,700	316,210	8 96	6
(3) Rate (selection criteria BCR)	20,200	116,590	6.77	4	35,000	350,930	11.03	8
(4) Rate (selection criteria NPV)	9,700	115,920	12 95	3	30,650	152,900	5 99	5

FIGURE 8.4

HAZARDOUS LOCATION PROCEDURES IN RURAL AREAS

COMPARISON OF NUMBER AND RATE IDENTIFICATION PROCEDURES

FOR BCR AND NPV SELECTION CRITERIA



8.12 CONCLUSIONS

The following conclusions were reached from the prospective evaluation of identification methods applied to rural sections on the Princes and South Gippsland Highways in the Traralgon Division of the RCA:

1. The identification method based on "accident number related to distance" identified a list of sites with a higher benefit-cost ratio for treatment budgets up to $50,000.

2. The identification method based on "accident rate" identified lists of locations with significantly lower benefit-cost ratios compared with the "accident number related to distance" for all treatment budgets.

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

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

It was not possible to compare the identication methods for the intersections because of insufficient data.

9. RECOMMENDATIONS AND FURTHER RESEARCH

9.1 RECOMMENDATIONS

The research undertaken on testing potential hazardous location procedures in the 3 study areas of urban intersections, urban sections and rural locations has highlighted preferred procedures and recommendations for identifying hazardous road locations. These are summarised below.

9.1.1 Urban Intersections

The following recommendations were reached from the retrospective evaluation of identification methods applied to urban intersections on the Adelaide main road system.

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

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

The best number-based identification method (casualty accident number) identified sites with significantly lower benefit-cost ratios than the identification methods described above.

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

For a $0.5 million installation budget, there is no advantage in using a three-year identification period over two years, for either of the identification methods described in 1 and 2 above. However, identification periods as short as one year should be avoided, and for a $1 million installation budget, three years is still preferred.

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

9.1.2 Urban Sections

The following recommendations were reached from the evaluation of identification methods applied to urban sections in the eastern suburbs of Melbourne.

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

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

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

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

It was not possible to check the economic benefits of each identification method because of the external resources necessary to provide the accident location information.

9.1.3 Rural Locations

The following recommendations were reached from the prospective evaluation of identification methods applied to rural sections on the Princes and South Gippsland Highways in the Traralgon Division of the RCA.

The identification method based on "accident number related to distance" identified a list of sites with a higher benefit-cost ratio for treatment budgets up to $50,000.

The identification method based on "accident rate" identified lists of locations with significantly lower benefit-cost ratios compared with the "accident number related to distance" for all treatment budgets.

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

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

It was not possible to compare the identication methods for the intersections because of insufficient data.

9.2 ACCIDENT REDUCTION FACTORS

It has been noted on several earlier occasions that there is insufficient data available on the potential accident reduction capabilities of most countermeasures.

It is essential in investigating hazardous road locations that countermeasure selection be based on their cost effectiveness. Hence, identifying potential accident reduction factors is imperative for any road improvement programme.

9.2.1 Study Limitations

No attempt has been made to prepare a consolidated list of accident reduction factors and their cost effectiveness as this is beyond the scope and resources of the present study. However, there is an obvious need for a major study to investigate and prepare such a list.

The literature review at the commencement of this study revealed several references to countermeasures and their accident reduction potential. It would be inexcusable not to include these references here, although it should be recognised that the list is not necessarily complete, and overseas information may not be totally relevant. This review is a logical starting point for any subsequent research in this area.

9.2.2 Overseas Studies

A number of overseas studies of hazardous locations have included accident reduction factors. These were:

Evaluation of Criteria for Safety Improvements on Highways (Jorgensen 1966) which details urban and rural factors by road type, number of lanes, and accident severity.

- California Division of Highways (Laughland et al 1975).
- Missouri State Highways Department (Laughland et al 1975) which details factors by accident type.
- South Africa (Brown 1972).
- Texas State Highway Department which details rural factors.
- Low Cost Roadway Safety Improvements in Canada (ADI 1981) which details rural factors by accident severity and, in some instances, accident type.
- Kentucky State Highways Department (Agent et al 1976).

Care must be taken in reviewing this information in that the same data source are frequently cross referenced in each of these studies. Most of this information is also referenced in the Pak-Poy (1974) Study.

9.2.3 Australian Studies

Nicholas Clark and Associates (1984) reviewed countermeasure effectiveness in their evaluation of the effectiveness of low cost traffic engineering projects. This remains the most comprehensive report available in Australia.

Recently, some State Road Authorities have also undertaken a number of 'before-and-after' studies to evaluate particular countermeasures.

(a) Specific Accident Countermeasures

The Road Construction Authority in Victoria have prepared casualty accident reduction factors for:

Rural freeways

- Rural staggered-Tee intersections
- Rural raised reflective pavement markers
- Urban signalised intersections
- Urban roundabouts
- Urban right turn lanes
- Urban lighting improvements

The Road Traffic Authority in Victoria have evaluated the casualty accident reduction at urban roundabouts by accident type.

The Main Road Department in Western Australia have evaluated the effect of urban signalised intersections, urban channelised intersections, regulatory sign control, and pedestrian median islands.

(b) General Countermeasure Studies

In addition to these specific studies, research projects have been undertaken into general aspects of traffic engineering to establish their role in road safety, without necessarily determining specific accident reduction factors. These include, for example:

- Safety implications of geometric standards (McLean 1980)
- Road curve geometry and driver behaviour (Good 1978)
- Delineation of rural roads and curve negotiation at night (Triggs, Harris and Fildes, 1979; Fildes, 1979).
- Literature review of rural road delineation (Hall, 1979)

- Nighttime single vehicle accidents on rural road curves - the problem and potential countermeasures (Johnston 1981)

- The visual factor in accident prevention (Cole and Johnston 1979)

- Conspicuity of traffic control devices (Cole and Jenkins 1978)

- Measures of visibility and visual performance in road lighting (Hall and Fisher 1978)

- Collisions with utility poles (Fox et al 1979)

These and similar studies could form the basis of a general list of accident reduction factors in Australia.

(c) An Attempt at Countermeasure Evaluation

Pak-Poy (1974) have prepared a consolidated list of accident reduction factors presently used in Australia for the evaluation of low cost traffic engineering and safety projects. However, the majority of references upon which these factors are based are overseas studies, many of which have been detailed earlier. The data, therefore, may not be directly relevant to the Australian environment. In the absence of the major investigative study, this list and recent local evaluations could be used to indicate potential accident reductions.

9.2.4 COMMENTS

In the absence of a general list of accident reduction factors available in Australia, the use of particular countermeasures can be determined by a simple comparison of the factors outlined above with a particular emphasis on the Australian data.

Although these factors may not be directly comparable because of the different environments from which they are derived, extreme accuracy of the factors is not really essential in investigating relatively low cost remedial measures. However, for high cost remedial measures, it may be necessary to consult the original references to determine whether a higher level of accuracy and comparability will be possible.

Until definitive factors are available, however, investigations involving accident reduction factors may use lists such as those suggested by OECD (1976) involving pessimistic, normal and optimistic values.

9.3 RESEARCH REQUIRED

Throughout this report, there have been several references to particular aspects of hazardous road location procedures that require further research. This section summarises these requirements to provide direction on future research into identifying and investigating hazardous road locations in Australia.

In many instances, these requirements are interdependent, hence the items have been listed in a suggested order of importance, and constitute a possible programme for on-going research in this area.

9.3.1 Data Base Compatibility Across States and Territories

By far, the most impending need for the identification of hazardous road locations is for a qualitative improvement in State-wide data bases of traffic and casualty accident data.

The procedures established and used in each State have been arrived at independently and are at differing stages of development. Hence, those States or Territories that have less developed data bases and archiving facilities are less able to take full advantage of road improvement funding, and could make less rational decisions on road improvement programmes.

In addition, the development of state-wide data bases needs to be progressing towards the establishment of single comprehensive national data base including traffic characteristics, road construction planning information and accident records. A National data base of this type is not only essential for long term efficiencies in identifying hazardous road locations, but also for many other road safety improvement programmes.

9.3.2 Countermeasures and Accident Reduction

The primary objective of this project was to establish a model for identifying hazardous road locations in Australia. Throughout the study, countermeasure selection has had a substantial influence on identification procedures. Yet, the selection of countermeasures and their expected accident reduction potential is not well developed in this country. It would now seem appropriate to extend the hazardous road location research into the investigation phase and look at the question of how this process can be improved.

There are several aspects of the hazardous road location investigation procedures that require further research. These are described in more detail below.

9.3.3 Countermeasure Usage

An Australia-wide assessment is required of road safety countermeasures in current use, with particular attention to which treatments are the most popular for specific hazardous situations.

This inventory needs to be compared with other overseas treatment lists, and would form the basis for improved investigation procedures at hazardous locations, and for subsequent research.

9.3.4 Countermeasure Effectiveness

Having established a comprehensive list of commonly used and alternative road safety countermeasures, the next step is to address their individual potential for accident reduction. A preliminary evaluation of countermeasure effectiveness in terms of accident data, and an ongoing assessment of hazardous road location programmes provides valuable long term data.

However, it should be recognised that accident data is generally a crude measure of driver performance. Behavioural and road performance studies such as those described in Chapter 9.2.3 are more likely to highlight the full extent of countermeasure effectiveness.

These studies often include on-road, off-road, and simulation tasks; Forbes (1972) and Chapanis (1967) discuss the relative merits and limitations of these experimental approaches to road research. This research can provide valuable insights into countermeasure potential for accident reduction.

9.3.5 Monitoring Countermeasure Effectiveness

The need for a uniform approach to the continual monitoring of countermeasure effectiveness is obvious. There is little sense in instituting hazardous road identification and correction programmes without on-going assessment of their cost effectiveness.

A major component of this research would entail a review of existing procedures in Australia and overseas, establishing guidelines for developing a programme in Australia, and how best to integrate this monitoring procedure into a nation-wide data base.

9.3.6 Under-Reporting of Road Accidents

There is a growing concern in Australia that the extent of under-reporting of road accidents is significant. If this is the case, a full account of road accidents is not presently available to the community or those responsible for road safety improvement.

Chapter 2.7 discussed likely implications of under-reporting of accidents on hazardous road location identification. If under-reporting is general across each State, it will have little effect on the ranking of hazardous location sites. However, if there are particular regions in which accidents are heavily under-reported, the possibility exists of a particularly hazardous site being overlooked. Hence, there is a need to understand the nature of any under-reporting bias and how it effects the identification of hazardous locations.

9.3.7 Predictive Modelling Techniques

There was considerable discussion of the use of accident conflict models and subjective assessment models for hazardous road identification (Chapter 3.3). The OECD (1976) considered this to be an important direction for future research into accident occurrence.

Whether statistical modelling techniques can ever be sufficient and efficient predictors of hazardous road locations is questionable. However, these methods do seem to have potential use in hazardous road investigations, and research is still required to develop these techniques into effective tools for use by engineers charged with improving road hazards.

REFERENCES

ABBESS, C., JARRETT, D. and WRIGHT, C.C. (1981). Accidents at black spots: Estimating the effectiveness of remedial treatment, with special reference to the "Regression-to-Mean" effect. Traffic Engineering and Control, 22, 535-543.

ADI Limited (1981). Manual of low cost roadway safety improvements for rural highways. Road and Motor Vehicle Traffic Safety Branch, Transport Canada, Ottawa.

AGENT, K.R. (1982). Traffic accident rates in Kentucky (1980). Kentucky Department of Transportation, Kentucky. Report No. FHWA-KY-82-12.

AGENT, K.R., DEACON, J.A. and DEEN, R.C. (1976). A High-accident Spot Improvement Program, Transportation Engineering Journal of ASCE, 102, 427-445.

ATKINS, A.S. (1981). The economic and social costs of road accidents in Australia. Office of Road Safety Report No. CR21, Department of Transport, Canberra.

BARTELSMEYER, R.R. (1972). A System to Identify Hazardous Locations and Elements. Traffic Quarterly, 26, 5-13.

BARTON, E.V. (1977) Designing safety into the road system. Traffic Control and Road Accident Seminar, Caulfield Institute of Technology, Victoria, Australia.

BROWN, R.J. (1972). The identification and improvement of accident black spots. National Institute of Road Research, South Africa.

BULL, J.P. and ROBERTS, B.J. (1973). Road accident statistics - A comparison of police and hospital information. Accident Analysis and Prevention, 5, 45-54.

BUREAU OF TRANSPORT ECONOMICS (1982). BTE road construction price indicies:1969-70 to 1980-81, Report 49, Bureau of Transport Economics, Canberra.

CAMERON, M.H. (1969). Accident risks - concept and analysis. M.Sc. thesis, University of Melbourne.

CHAPMAN, R. (1973) The concept of exposure, Accident Analysis and Prevention, 5, 95-110.

CHAPANIS, A. (1967). The relevance of laboratory studies to practical situations, Ergonomics, 10(5), 557-577.

COLE, B.L. and JOHNSTON, A.W. (1979). The visual factor in accident prevention. Department of Optometry, University of Melbourne.

COLE, B.L. and JENKINS, S.E. (1978). Conspicuity of road traffic devices. Australian Road Research Board Internal Report AIR218-1.

CRIBBINS, P.D., ARRY, J.M. and DONALDSON, J.K. (1967). Effects of selected roadway and operational characteristics on accidents on multilane highways, Highway Research Record No. 188. Washington, USA.

CUTTS, J.C. (1973). The Metropolitan Police accident intelligence system. PTRC Summer Annual Meeting, July.

DEACON, J.A., ZEGEER, C.V. and DEEN, R.C. (1975). Identification of hazardous rural highway locations. Transportation Research Record No. 543, Transportation Research Board.

ENGLISH, N. (1980). Study strategy: Identification of hazardous road locations. Report to Office of Road Safety, Department of Transport Australia. Nelson English, Loxton and Andrews Pty. Ltd., Melbourne.

ENGLISH, N. (1981). Guide for the selection and evaluation of countermeasures at hazardous locations. Prepared for Road Safety and Traffic Authority, Victoria.

ERLANDER, S., GUSTAVSSON, J. and LARUSSON, E. (1969). Some investigations on the relationship between road accidents and estimated traffic. Accident Analysis and Prevention, 1, 17-64.

FAIGIN, B.M. (1976). 1975 Societal costs of motor vehicle accidents, NHTSA.

FILDES, B.N. (1979). Delineation of rural roads at night: The effect of visual blurring and luminance changes on estimating curve direction, Unpublished B.Sc (Honours) Dissertation, Monash University, 1979.

FOX, J.C., GOOD, M.C. and JOUBET, P.N. (1979). Collisions with utility poles. Office of Road Safety, Report No. CR1, Department of Transport, Canberra.

FORBES, T.W. (1972). General approach and methods, in Forbes TW (Ed), Human Factors in Highway Traffic Safety Research, New York:Wiley.

GIBSON, R.A. (undated). Critical accident rates:An application for state highways. Unpublished paper, Ministry of Transport, New Zealand.

GOOD, M.C. (1978). Road curve geometry and driver behaviour. Australian Road Research Board. Special Report No. 15.

GRAHAM, J.L. and GLENNON, J.C. (1975). Identification analysis and correction of high accident locations. Mid-West Research Institute, Missouri, USA.

HALL, R.R. (1979). The delineation of rural roads and curve negotiation at night. Australian Road Research Board Internal Report AIR267-1.

HALL, R.R. and FISHER, A.J. (1978). Measures of visibility and visual performance in road lighting. Australian Road Research Board Report No. 74.

HASTINGS, K.C. (1969). Low cost safety improvements at major intersections in large cities. Paper presented to Highways and Traffic Branch, Victoria Division, The Institution of Engineers, Australia.

HAUER, E. (1980). Bias-by-selection: Over estimation of the effectiveness of safety countermeasures caused by the process of selection for treatment. Accident Analysis and Prevention, 12, 113-118.

HENDTLASS, J., BOCK, I. and RYAN, M. (1980). Drink-drive countermeasures in Victoria, Australia. Draft Report to Road Safety and Traffic Authority, Victoria.

HILLS, B.L. and JACOBS, G.D. (1981). The application of road safety countermeasures in developing countries. Traffic Engineering and Control, 22, 464-468.

HOCHERMAN, I. and PRASHKER, J.N. (1983). Identification of high risk intersections in urban areas. Proceedings, PTRC Summer Annual Meeting, July.

HUTCHINSON, T.P. and MAYNE, A.J. (1977). The year-to-year variability in the numbers of road accidents. Traffic Engineering and Control, 18, 432-433.

INSTITUTION OF HIGHWAY ENGINEERS (1980). Synopsis of Guidelines for Accident Reduction and Prevention in Highway Engineering. The Institution of Highway Engineers, London.

INSTITUTION OF HIGHWAY ENGINEERS (undated). Guidelines for Accident Reduction and Prevention in Highway Engineering. The Institution of Highway Engineers, London.

JOHNSTONE, I.R. (1981). Nighttime single vehicle accidents on rural road curves - The problem and potential countermeasures. Australian Road Research Board Internal Report AIR361-1.

JORGENSEN, R. (1966). Evaluation of criteria for safety improvements on the highways. Roy Jorgensen and Associates, and Westat Research Analysts, Inc.

LANDLES, J.R. (1980). Accident remedial measures. Proceedings, PTRC Summer Annual Meeting.

LANDLES, J.R. (1979). London's blackspot program. Transportation Research News, 82, 2-5.

LAUGHLAND, J.C., HAEFNER, L.E., HALL, J.W. and CLOUGH, D.R. (1975). Methods for evaluating highway safety improvements. NCHRP Report No. 162, Transportation Research Board.

LAY, M.G. (1983). Evidence to Social Development Committee Inquiry into Road Safety in Victoria. Parliament of Victoria.

McLEAN, J.R. (1980). The safety implication of geometric standards. Paper presented at Workshop on Economics of Road Design Standards. Canberra, May.

McGUIGAN, D.R.D. (1983). Expenditure on remedial measures - Value for money. PTRC Seminar on Road Safety, April.

McGUIGAN, D.R.D. (1982). Non-junction accident rates and their use in "black spots" identification. Traffic Engineering and Control, 23, 60-65.

McGUIRE, F.L. (1973). The nature of bias in official accident violation records. Journal of Applied Psychology, 57, 300-305.

MAHALEL, D., HAKKERT, A.S. and PRASHKER, J.N. (1982). A system for the allocation of safety resources on a road network. Accident Analysis and Prevention, 14, 45-56.

MISSOURI STATE HIGHWAY COMMISSION, (1975). Identification, analysis and correction of high accident locations. Missouri, USA.

MORIN, D.A. (1967). Application of Statistical Concepts to Accident Data. Highway Research Record 188.

NICHOLAS CLARK & ASSOCIATES, (1984). The evaluation of the effectieness of low cost traffic engineering projects. Office of Road Safety. Report No. CR22, Department of Transport, Canberra.

NICHOLSON, A.J. (1980). Identification of hazardous locations. PRU Newsletter No. 66, Ministry of Transport of Transport, New Zealand.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, (OECD) (1976). Hazardous road locations: Identification and countermeasures. OECD Road Research Group, France.

PETERSEN, K. (1973). Selection of accident black spots on highways in Denmark through the years 1967-1971. PTRC Accident Analysis Seminar, June.

PAK-POY AND ASSOCIATES, (1974). Evaluation of low cost traffic engineering and safety projects. Prepared for the Commonwealth Department of Transport and Commonwealth Bureau of Roads, Canberra.

RENSHAW, D.L. and CARTER, E.C. (1980). Identification of high hazard locations in the Baltimore Country road-rating project. Transportation Research Record No. 753, Transportation Research Board.

ROYAL AUTOMOBILE CLUB OF VICTORIA (RACV) (1983). Submission to the Social Development Committee Inquiry into Road Safety in Victoria.

RUDY, B.M. (1962). Operational Route Analysis. Highway Research Board Bulletin 341.

SHINAR, D., TREAT, J.R. and McDONALD, S.T. (1983). The validity of police reported accident data. Accident Analysis and Prevention 15, 175-191.

SMITH, D.I. (1976). Official driver records and self reports as sources of accident and conviction data for research purposes. Accident Analysis and Prevention 8, 207-211.

SPARKES, J. (1968). The Influence of highway characteristics on accident rates. Public Works Vol 99, No. 3, Washington, USA.

SOMERVILLE, C.J. (1981). The Cost of Road Accidents. Road Accident Research Unit, University of Adelaide, South Australia.

TAYLOR, J.I. and THOMPSON, H.T. (1977). Identification of hazardous locations:Executive summary. Federal Highway Administration, Report No. FHWA-RD-77-81, Washington, USA.

TEALE, G., MACLEAN, S., CLARK, N. and GIPPS, P. (1979). Study design for the evaluation of the effectiveness of MITERS - type projects - Technical report. Office of Road Safety Report No. CR8, Department of Transport, Canberra.

TRIGGS, T.J., HARRIS, W.G. and FILDES, B.N. (1979). Delineation on rural roads at night: A laboratory based study of curve direction estimation. Australian Road Research Board Internal Report AIR266-2.

TROY, P.N. and BUTLIN, N.G. (1971). The Cost of Collisions, Melbourne; Cheshire.

WALES, S. (1983). Early intervention in Alcoholism. Bachelor of Medical Service Thesis. University of Melbourne.

WILSON, J.L.S. (1977). <u>Computer Programes for Accident Prevention</u>. Hertfordshire Country Council, Hertfordshire U.K.

ZEGEER, C.V. and DEEN, R.C. (1977). Identification of hazardous locations on city streets. <u>Traffic Quarterly</u>, <u>31</u>, 549-570.