Keywords

Poles, accident patterns, accident causation, road geometrics, skid resistance, pavement deficiencies, tyre pressures, vehicle handling, predictive modelling, cost-effectiveness, counter-measure program, summary report.

Abstract

This report summarizes the objectives, methodology, findings and recommendations of a study of collisions with utility poles. In a survey of accidents, information on site characteristics and accident severity was obtained. Randomly-selected samples of sites and vehicles provided control information. An accident-predictor model which identifies accident risk on the basis of site measurements has been derived. The model was used in conjunction with estimates of the costs of accidents to show that a number of remedial treatments are warranted.

NOTE: This report is disseminated in the interest of information exchange. The views expressed are those of the authors and do not necessarily represent those of the Commonwealth Government.
COLLISIONS WITH UTILITY POLES

SUMMARY REPORT

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February, 1979

Project Sponsor:

Office of Road Safety,
Commonwealth Department of Transport.
PREFACE

This study has shown that urban roadsides in Australia are made unnecessarily hazardous by the presence of badly located, unyielding utility poles. About one in ten urban road fatalities results from a collision with a pole. The cost to the community is enormous, both in terms of human suffering and wasted resources. Given the will to do it, cost-effective means are available to effect tangible reductions in this toll. A program of loss-reduction is made feasible by the fact that pole collisions do not occur randomly - the small proportion of poles involved in the majority of accidents can be identified from simple site measurements. Further, the particular factors contributing to a high accident risk can be determined and proven remedial measures are available for immediate implementation.

This situation confronts all users of the road reserve with their joint responsibilities. In particular, policy-makers concerned with pole utilization must acknowledge that their decisions affect public safety and well-being; they must take more account of the effect of their actions. The investment of funds by governments in remedial programs would yield economic and general welfare benefits far in excess of expenditure.
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1. INTRODUCTION

This summary report is a self-contained statement of the major accomplishments of the study 'Collisions With Utility Poles' which was carried out in the Department of Mechanical Engineering, University of Melbourne for the Office of Road Safety, Department of Transport over the period 1976-78. Unencumbered by the rigor and detail of the main contract report*, it is directed at the general interest reader and policy makers at all levels of government, road and traffic authorities and utility supply authorities. The study objectives, methodology, results and findings are summarised and recommendations are made for remedial action.

2. PROJECT OBJECTIVES

The present study differs from most 'in-depth' accident studies previously reported in that it has concentrated on a particular type of accident. Resources were concentrated in this way to enable the collection of sufficiently large accident and control samples for detailed, and statistically reliable, investigations of causes and consequences. The study had the following broad objectives:

(a) To carry out an accident survey, to provide the detailed information on pole crashes which is not available in the regularly-reported accident statistics.

(b) To develop a statistical predictor model which allows the identification of accident risk from measurements of site characteristics.

(c) To further investigate loss reduction measures available for utility pole collisions.

(d) To obtain cost data for application to benefit-cost analyses of proposed remedial measures.

* Report No. CR 1 : Collisions With Utility Poles (February 1979, xiv + 423 pp) is available from the Director, Road Safety Information Service, Office of Road Safety, Commonwealth Department of Transport, G.P.O. Box 1839 Q, Melbourne, Victoria, 3001.
Figure 1  A map of Melbourne, showing the urban statistical division and the area covered by the survey.
3. PROJECT ORGANIZATION

The project consisted of five distinct phases covering a period of 33 months. Table 1 lists the phases, their duration and the number of workers involved at each stage.

TABLE 1

PROJECT TIMING AND PERSONNEL

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Duration (Months)</th>
<th>Number of Full-Time Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization of data collection network and development of instrumented road survey vehicle</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Accident survey</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Random site survey planning and execution</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Coding of data</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Analysis and report preparation</td>
<td>9</td>
<td>1</td>
</tr>
</tbody>
</table>

Data collection and analysis were primarily concerned with the engineering aspects of collisions with utility poles (defined here to include power and telegraph, luminaire, traffic signal and tramway poles). To ensure that the accident survey encompassed all accident severities ranging from property-damage-only (PDO) to fatal injury, a rapid notification network based on tow-truck operators was established. It can be seen from Figure 1 that this network covered virtually all of the Melbourne metropolitan area (excluding the Mornington Peninsular). During the survey period, from 7 July 1976 to 7 March 1977, a total of 879 pole accidents were investigated.

It was found that, for the purposes of the present study, little additional information could be obtained by attending the crash scene immediately after notification compared with approximately 12 hours later (i.e., typically, the next morning). This meant that one, centrally-placed research team was able to cover the whole survey area,
Figure 2 A site involved in two fatal crashes within eight days. In both cases the road was wet and the impacts resulted in only 'scruffing' of the pole.

Figure 3 The driver of this vehicle was killed in a frontal collision with the pole shown in Figure 2.
a task which would otherwise have been impossible because of the size of the area and the frequency of accidents.

Information supplied by the towing operators, usually within minutes of a crash, included the accident location, time of day, weather conditions and whether ambulance attendance was required. The ambulance services in turn provided details of casualty occupants, which enabled the acquisition of detailed injury reports from the hospitals.

Accident-involved vehicles were photographed and inspected within 24 hours, usually at a towing yard or panel shop. Measurements of vehicle damage, occupant space penetration and tyre characteristics were obtained, together with estimates of damage costs.

During the initial site inspection and photography, the accident sequence was reconstructed from physical evidence (vehicle and pole damage, skid marks, debris, etc.) and from tow-truck operators' reports. **Damage to the pole and its utilities and the pole material, size and function** were also noted during the initial site inspection. However, to improve the efficiency of the detailed site data collection process, a number of sites in a given area were allowed to accumulate before they were revisited. Typically, this resulted in a delay of two weeks between the accident and the detailed measurement of site characteristics such as roadway width, curvature and gradient, pavement skid resistance, lateral offset of the pole and so on.

Figure 2 shows members of the survey team at a fatal accident site. The survey vehicle used to make automatic measurements of roadway curvature and cross-fall is at the left of the picture. Vehicles which collided with this pole are shown in Figures 3 and 4, together with a hospital report detailing the fatal injuries sustained by one driver.

Control information on vehicle and site characteristics was obtained by repeating the appropriate measurements for randomly-selected samples of 795 pole sites and 627 vehicles. Without these data few useful inferences could have been made about the factors determining accident occurrence or severity. **To ensure adequate representation of major road sites in the random pole sample (because**
Figure 4  Vehicle damage and driver injuries resulting from another fatal collision with the pole shown in Figure 2.
most accidents occurred at such sites), the sample was stratified into five 'data groups' for subsequent statistical analysis:

- **MNI** - Major road non-intersection
- **MINI** - Minor road non-intersection
- **MJMJ** - Intersection of major roads
- **MJMI** - Intersection of major and minor roads
- **MIMI** - Intersection of minor roads.

The proportion of random pole sites in each data group was chosen to be the same as that for the accident sample. The random vehicle sample was obtained from vehicles stopping at five petrol stations in a variety of socio-economic areas around Melbourne. This sample primarily provided information about the distribution of tyre characteristics in the vehicle population.

Accident cost data obtained and their sources are summarized in Table 2.

**TABLE 2**

**ACCIDENT COST DATA COLLECTED**

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical and hospital, by injury severity</td>
<td>Motor Accidents Board</td>
</tr>
<tr>
<td>Pole/utility damage</td>
<td>Supply Authorities</td>
</tr>
<tr>
<td>Vehicle damage</td>
<td>Vehicle repairers, tow-truck operators</td>
</tr>
<tr>
<td>Vehicle market value</td>
<td>National Auto Market Research</td>
</tr>
</tbody>
</table>

In addition, costs of various remedial programs were obtained from utility supply authorities, road authorities, councils and various equipment and materials suppliers.
Figure 5  Distribution of pole accidents by accident severity and accident sequence. In a primary pole collision, a pole is the first object struck by an errant vehicle. A pole collision subsequent to a vehicle-vehicle collision is classified as a 'secondary' pole collision.

Figure 6  Accident frequency rises sharply when the pavement skid resistance (being measured here with a pendulum tester) is not maintained at a satisfactory level.
4. EXTENT OF THE PROBLEM

Comparison with Road Safety and Traffic Authority (RoSTA) data on casualty accidents in which a pole was the first object struck, showed that the present eight-month survey, which included 31 fatalities and 374 injured persons, achieved a 65 percent coverage of all personal injury pole accidents and a complete coverage of fatal pole accidents in the Melbourne metropolitan area. The coverage of tow-away PDO accidents was assumed to be 65 percent also. Within the study area the accident coverage was estimated to be 90 percent.

Whereas RoSTA's data (based on police reports) refer to primary pole collisions only, 15 percent of the cases in the present survey involved secondary pole collisions which were judged to have made a significant contribution to the severity of the accident. Including these collisions, it is estimated that pole accidents in the Melbourne metropolitan area result in 45 fatalities and 785 injured persons annually. These figures represent approximately 9.4 percent and 5.9 percent of the respective totals for all road accidents in Melbourne. The RoSTA data show that primary pole collisions account for 45 percent of fatal fixed-object collisions and 52 percent of personal injury fixed-object collisions.

For the whole of the State of Victoria, primary collisions with poles resulted in 54 fatalities and 813 non-fatal injuries in 1976 (5.8 percent and 4.6 percent of the State totals). Corresponding data for the rest of Australia are generally lacking. In New South Wales, primary pole collisions accounted for 6.1 percent of all road fatalities in 1973; in South Australia the figure was 6.4 percent in 1972. It is clear that collisions with poles represent a national problem of some magnitude.

5. GENERAL CHARACTERISTICS OF POLE ACCIDENTS

The accident sample was classified according to whether the pole impact was the primary or secondary collision, and according to the level of injury to the worst-injured occupant. Figure 5 shows this breakdown, with accident severity described as Fatal (F), personal injury only (PI) or property damage only (PDO). The classification of the accident
Figure 7 Distribution of pole accidents by road features and impact sequence.
sample by road features and impact sequence is shown in Figure 7. The distribution of pole accidents by road class* and road features into the five data groups used for statistical analysis is shown in Figure 8. Classes 6 and 7 (denoted 'major' roads) refer to arterial and collector roads, while class 8 (denoted 'minor' roads) refers to residential streets.

A number of characteristics of pole accidents which emerge from the accident sample are:

(a) In terms of the number of fatal accidents per 100 casualty accidents, pole accident severity is 1.5 times greater than the average over all metropolitan accidents.

(b) Seventy percent of the accidents studied resulted in property damage only.

(c) The majority (82 percent) of the accident sample came from major roads (CBR Class 6 or 7).

(d) Sixty-eight percent of the accidents were at non-intersection sites; nearly half of these involved horizontal curvature of the road.

(e) The majority of the accident sites (90 percent of major road sites and 99 percent of minor road sites) were in 60 km/h speed limit zones. Eight percent of the major road accident sites were in 75 km/h speed limit zones with the remaining two percent being in 100 km/h zones.

(f) More accidents occurred on Sunday morning between midnight and 3 a.m. than in any other three-hour period during the week. In terms of the number of vehicles on the road the greatest risk of a pole accident occurs between 3 a.m. and 4 a.m. Fifty percent of the accidents studied occurred in the hours of darkness.

(g) Typically, two out of three vehicles running off the roadway do not collide with poles. Thus poles cannot be regarded as providing an effective 'protection' for pedestrians or abutting properties. Despite this, fewer than 1 in 200
Figure 8  Distribution of pole accidents by Commonwealth Bureau of Roads (CBR) road class.

Figure 9  Side impacts with poles are particularly severe. The driver of this car was killed instantly when it hit a timber power pole.
pedestrian fatalities occur off the carriageway. Hence the removal of poles, or their replacement with frangible designs, would not result in a perceptible increase in hazard to pedestrians. It should be noted that pole accidents are most likely to occur at times of day (and under weather conditions) when pedestrian traffic is lightest.

Pole accidents are four times more likely to occur when the roads are wet than when they are dry. Thirty-eight percent of the accident sample arose from wet road accidents.

The majority of poles hit at curved-road sites were on the outside of the bend. The proportion was reduced when the roads were wet, apparently because of a change in the loss of control mechanism.

Sixty-nine percent of the accidents involved frontal impacts. Side and oblique impacts were generally more severe than frontal impacts because of higher occupant space penetration. A strong relationship between level of injury and depth of intrusion was found. Despite the increased severity of side and oblique impacts, sixty-five percent of casualties arose from frontal impacts.

Pole material and function seem to be unrelated to accident occurrence and have only a slight effect on accident severity. This is because all poles presently in service are effectively rigid.

Sixty-one percent of the casualty occupants were male and typically in the age group between late teens and early twenties.

Nearly half of the injuries sustained were classified as minor. The most common injury location was the head, face and neck region (45 percent), followed by the upper torso (15 percent).

In frontal impacts the life-threatening injuries were fairly evenly divided between the head and neck, the upper torso and abdominal regions. In side impacts they were concentrated more on the head and neck and upper torso areas.
Figure 10 Relative risk versus pole lateral offset - MNI data group
6. POLE ACCIDENT OCCURRENCE AND SEVERITY AS RELATED TO SITE, VEHICLE AND POLE CHARACTERISTICS

6.1 Site Characteristics Related to Pole Accident Occurrence

As previously stated, a major aim of the study was the determination of a statistical model which would allow the identification of variations in accident probability as a function of measurable pole site characteristics. To this end measurements of roadway, traffic and pole placement variables were made at a sample of sites at which pole accidents had occurred, and at a control group of randomly-selected pole sites. To ensure that subsequent statistical analysis was possible, the 'random' sample was stratified according to site description (intersection/non-intersection) and road class. Accordingly, the analysis of the effects of site characteristics on pole accident occurrence was carried out within these data groups.

The statistical analysis was based on the concept of 'relative risk' which measures the accident involvement of poles with a given site attribute relative to their numbers in the population of all poles. For example, Figure 10 shows the variation of relative risk with the attribute 'lateral offset' (the distance of the pole from the kerb line) for major road, non-intersection sites. It can be seen that the risk rises sharply for offsets less than 3 m; poles at the kerb line are over three times more likely to be involved in an accident than those more than 3 m away.

The final model allows the calculation of the expected annual accident rate for a given site as a function of measured site characteristics. For the major road non-intersection model, the following data are required:

- $|K_{MAX}|$: Maximum horizontal curvature upstream of the pole.
- AADT: Annual average daily traffic.
- ST: Pavement skid resistance (measured by pendulum test).
- LO: Lateral offset of pole.
- W: Road width (for undivided roads only).
- DC: Distance between the pole and the start of the curve.
- PD: Pavement deficiencies (corrugations etc.).
- e: Superelevation at curve.
- OIB: Pole on the inside/outside of bend.
Figure 11 Case Study B.1.

Figure 12 A combination of curvature, incorrect camber, low skid resistance and corrugations in the road surface caused seven pole accidents in eight months at this site. The predictor model developed in this study allows identification of such high risk sites and the nature of the required remedial action.
This model was highly successful in discriminating between poles at risk: the range of risks identified was of the order of 1000:1; site characteristics associated with only 10 percent of the poles in the population were found in 50 percent of the accident sites. For the minor road non-intersection model the corresponding figure was 65 percent of accident sites.

The groups of poles subsequently shown to afford the greatest opportunity for cost-effective remedial action are those at non-intersection major road sites and at the intersection of major roads. For the latter group the data required for the predictor model are:

- **AADT**: Annual average daily traffic for both roads.
- **ST**: Pendulum skid test.
- **G**: Grade into the intersection.
- **DV**: Roads divided/undivided.
- **LO**: Lateral offset of the pole.
- **IT**: Intersection type.

It can be seen that these variables largely describe the characteristics of the intersection. Apart from its lateral offset, there is little to distinguish the accident risk of one pole from another at the intersection of major roads.

In the main contract report a 'User's Manual' is provided to aid in the application of the statistical predictor model. Three case studies are presented which cover the range of most possible applications, and are worked out step-by-step. The first of these case studies may be summarized as follows:

The case study involves the road layout depicted in Figure 11. The vehicle shown is travelling in such a direction that it has to negotiate a right-hand curve. Clearly, there are a number of poles at risk in a situation such as this, and all poles in the vicinity of the curve need to be examined. The risk changes for each pole as a function of its position in relation to the curve. The model should be applied to each pole in turn, producing a total relative risk for each one. These can then be used in the calculations of accident probability which are required for decisions concerning possible remedial treatment.
For this example, the pole marked with an "X" in Figure 11 is analysed, with the direction of travel of the vehicle as shown. The subject pole is not close to an intersection and, as it is adjacent to a major road, it is classified as a member of the MNI data group. As such, it has an accident risk of 4.36 relative to the average for all poles. This is shown in Table 3, together with the relative risks determined from the User's Manual figures and tables indicated for each of the site characteristics.

A total relative risk (TRR) is obtained as the product of all the individual relative risks: $TRR = 141.6$. That is, the subject pole is 141.6 times more likely to be involved in a collision than average.

The average accident frequency for all poles in Melbourne is estimated to be $3.785 \times 10^{-3}$ per annum. Hence the expected accident rate for the subject pole is

$$E[a] = 141.6 \times 3.785 \times 10^{-3} = 0.536 \text{ accidents per annum.}$$

The probability of one or more accidents occurring in a year (assuming a Poisson distribution) is 0.415. That is, there is a 41.5 percent chance that the subject pole will be involved in a collision during a one-year period.

This information may then be used with a cost-benefit model to decide on what course of remedial action is warranted, as is illustrated in Section 9 of this summary report.

**TABLE 3**

**MNI MODEL - CASE STUDY B.1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>RR</th>
<th>Source(1)</th>
</tr>
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<tbody>
<tr>
<td>Data Group</td>
<td>MNI</td>
<td>4.36</td>
<td>T/B.2</td>
</tr>
<tr>
<td>$</td>
<td>X_{MAX}</td>
<td>$</td>
<td>0.012</td>
</tr>
<tr>
<td>AADT</td>
<td>17500</td>
<td>1.24</td>
<td>F/B.5</td>
</tr>
<tr>
<td>ST</td>
<td>45</td>
<td>1.50</td>
<td>F/B.6</td>
</tr>
<tr>
<td>LO</td>
<td>0.20</td>
<td>1.38</td>
<td>F/B.7</td>
</tr>
<tr>
<td>W</td>
<td>12.4</td>
<td>1.32</td>
<td>F/B.8</td>
</tr>
<tr>
<td>DC</td>
<td>110</td>
<td>1.12</td>
<td>F/B.9</td>
</tr>
<tr>
<td>PD</td>
<td>Corrugations</td>
<td>2.00</td>
<td>T/B.3</td>
</tr>
<tr>
<td>e</td>
<td>Negative</td>
<td>1.20</td>
<td>T/B.4</td>
</tr>
<tr>
<td>OIB</td>
<td>Outside</td>
<td>1.15</td>
<td>T/B.5</td>
</tr>
</tbody>
</table>
6.2 Accident Severity as a Function of Site Characteristics

Levels of occupant injury and vehicle damage were compared for the three major site categories:

(a) Curved road non-intersection sites.
(b) Straight road non-intersection sites.
(c) Intersection sites.

It was found that accidents on curves were slightly more severe than on straight roads because of an increased number of side impacts on curves. The crashes with poles in both non-intersection categories were considerably more severe than those at intersections. Damage to poles and their associated utilities did not vary between site classifications.

6.3 The Effect of Vehicle Characteristics on Accident Occurrence

There is a lack of detailed information on the distribution of vehicle characteristics in the population of vehicles on the road. Because of this lack the analysis of the effect of vehicle characteristics on accidents was somewhat limited. To overcome the deficiency, in part, a random survey of vehicles was made, concentrating on the measurement and recording of tyre variables. The distributions of vehicle make, year of manufacture and body style in the random sample were found to be very similar to those in Australian Bureau of Statistics (ABS) figures for all vehicles on register in Victoria, suggesting that the tyre characteristics measured were representative of the general population.

A number of tyre-related variables had a significant effect on accident occurrence:

(a) Relative accident involvement increased markedly for tread depths less than 3 mm, particularly on wet roads. It was found that a vehicle with a tread of only 0.5 mm was about 15 times more likely to be involved in an accident than one with 5 mm tread depth (see Figure 13).

(b) The effects of under- and over-inflation of tyres relative to specifications was investigated from the point of
Figure 13 Relative risk versus the average front tyre tread depth for wet and dry roads.
view of the influence on vehicle handling characteristics known to be important to driver/vehicle performance. A strong relationship was found between average pressure margin (the difference between observed and specified inflation pressure averaged over all four wheels) and accident occurrence. Average pressure margin is related to the response time of the vehicle to steering inputs. General under-inflation (associated with longer response time) is associated with a higher accident risk (Figure 14).

Vehicle understeer/oversteer, on the other hand, is sensitive to the difference between the front and rear tyre cornering stiffnesses and, hence, to the front-rear pressure margin (FRPM). A positive FRPM indicates that, compared with the specified balance between front and rear tyre pressures, the front tyres are over-inflated, leading to a reduction in the amount of understeer or possibly the production of oversteer characteristics.

The data showed that deviations in FRPM in both directions caused an increase in accident involvement; the effect of reduced understeer being associated with increased hazard for curved sites was particularly strong. As with the average pressure margin, a substantial proportion of the accident vehicles had hazardous deviations of tyre pressures from the specified levels.

(c) Tyre construction. Compared with other tyre factors the effect of tyre construction on accident risk was relatively weak. Radial-ply tyres proved marginally 'safer' than cross-ply or recapped tyres.

6.4 Accident Severity as a Function of Vehicle Characteristics

The only vehicle characteristic analysed which had a significant effect on accident severity was the vehicle mass. Reduced vehicle mass was associated with higher injury levels and slightly less pole and utility damage.
Figure 14 Relative risk versus the overall average tyre pressure margin for all accidents.
6.5 Accident Severity as a Function of Pole Type

All the poles in the present study were effectively rigid. No difference in accident severity, as measured by injuries and vehicle damage, was detected between poles classified by material or function. The level of damage to the pole and its utilities did vary with pole classification however.

7. THE COST OF POLE ACCIDENTS

A review of the available literature revealed a wide range of accident cost estimates, particularly with regard to assigning a value to the loss of life, largely dependent on the inclusion or non-inclusion of the loss of future production associated with permanent disability or death.

Three broad philosophies relating to the costing of road accidents emerged from the literature. The societal cost associated with each level of the Abbreviated Injury Scale* was calculated for the three costing philosophies, using local data collected in this study where possible and employing Faigin's study for the U.S. Department of Transportation# as a guide otherwise. The calculations may be regarded as under-estimates as they make no allowance for intangibles such as pain and suffering.

If the loss in societal welfare is measured in terms of consumption of current resources and foregone production, the cost to the community of a fatality is estimated to be $204 600. The annual cost of pole accidents in the Melbourne metropolitan area, according to the same costing philosophy, is estimated to be $23 million and average cost per tow-away accident is $11200.

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* The Abbreviated Injury Scale, 1976 Revision. American Association for Automotive Medicine, 1976.

Figure 15  Mean cost ($ thousand) per accident, based on total accident cost components, by impact direction.

Figure 16  Estimated annual cost ($million) in Melbourne metropolitan area based on total accident cost components, by impact direction.
Considering the effect of impact direction on the vehicle on societal costs, it was found that:

(a) Side and oblique impacts have a higher mean cost per accident than frontal impacts if the value of lost production is accounted for.

(b) Because of their greater frequency, the bulk of the societal costs result from frontal impacts. However, there are significant gains to be made from side impact crashworthiness improvements as well.

These findings are illustrated in Figures 15 and 16.

8. PERFORMANCE OF ALTERNATIVE LOSS REDUCTION MEASURES

The term 'loss reduction' is taken here to refer to a lowering of the societal cost of pole accidents, the emphasis being on the cost to the community as a whole rather than costs to specific groups or individuals. Loss reductions at a particular accident 'black spot' can be achieved by a reduction in accident severity or probability or both. An analysis of available loss reduction measures revealed that:

(a) The most effective method of loss reduction in relation to pole accidents is (obviously) pole removal. As with other methods, however, the benefits must be weighed against the costs.

(b) The installation of crash barriers or attenuators would not be an effective loss-reduction measure for pole accidents in the urban road system.

(c) Crashes with breakaway or wrap-around luminaire poles produce significantly lower societal costs than those with rigid luminaire poles. It has been the South Australian Highways Department's experience that such savings can be achieved at little or no extra cost to the authority owning and installing the poles (see Figures 17-19).
Figure 17  An unnecessarily rigid luminaire support on a freeway median.

Figure 18  The driver of this car was killed in a collision with the luminaire support shown in Figure 17. All such poles should be made to yield safely (such as in figure 19).
Figure 19 A number of proven designs for breakaway or frangible luminaire supports exist. This 'wrap-around' type brings the vehicle to rest safely. Breakaway luminaire supports, mandatory on U.S. Federal-aid highways and widely used in Adelaide, have reduced casualties without additional costs to the supply authority.
The arguments sometimes advanced against pole removal, or the use of breakaway poles, suggesting that this would involve unacceptably hazardous secondary collisions, danger to pedestrians, or increased cross-median collisions, have been shown to be unfounded. Such effects, if any, would be insignificant compared with the reduction in the severity and cost of pole accidents.

Based on the results of preliminary scale model tests, a scheme for modifying timber, cable-supporting utility poles has a significant potential for loss reduction.

Substantial improvements in vehicle crashworthiness in pole impacts do not appear feasible at current levels of technology, and within societal constraints on cost and consumption of material and fuel resources.

Resurfacing and re-aligning the road can also provide societal returns for high-risk locations. The 'Shellgrip' resurfacing technique appears to provide an accident-reducing treatment which maintains its effectiveness over a long service life.

9. THE EVALUATION OF SELECTED LOSS REDUCTION PROGRAMS

The application of benefit-cost methodologies to the evaluation of alternative treatments to alleviate the pole accident problem was investigated. The practical application of the information gathered together in this study with respect to accident probability, costs and treatment effectiveness, in conjunction with the selected benefit-cost measures, was demonstrated by way of a number of illustrative examples. Several conclusions emerged:

(a) The greatest opportunity for cost-effective remedial programs exists for poles beside mid-block sections of major roads (MNI data group): Fifty-six percent of pole accidents occur with poles in this group, and the predictor model allows the identification of the small proportion of poles which account for the majority of accidents.
(b) On average, poles at the intersection of major roads have the highest risk of accident involvement of any of the data groups. Selective treatment of poles at an intersection is hindered by the inability to discriminate large variations in risk. However, the number of such intersections is relatively small (in Melbourne there are 813) and the predictor model should allow the priority ranking of intersections for remedial treatment.

(c) When applied to the MNI data group, the 'average approach' to benefit-cost analysis (which attempts to assess the value of particular treatments for large numbers of sites) indicates that there are a number of treatment options which would return significant net societal benefits, and are worthy of investigation on a site-by-site basis. This is demonstrated in Table 4, where the costs and benefits of several programs of selective pole removal or modification in Melbourne are estimated. It can be seen, for example, that when accidents are costed according to the resultant consumption of current resources and foregone production, there would be justification for removing 1510 power poles and undergrounding their conductors. The cost of carrying out such a program would be about $7.55 million, but would return economic benefits to the community over 15 years with a present worth of $16.4 million. In addition, the pain and suffering associated with 4 fatalities and 66 injuries would be prevented every year. The other treatments listed in Table 4 return even greater net benefits.

(d) Because the factors contributing to risk, the practical feasibility of various treatments, and the costs and benefits of such treatments all vary from site to site, each candidate site must be investigated individually to determine the performance of alternative remedial treatments. When a number of sites have been so investigated, the choice of the 'best' treatment at each will be determined, in part, also by the amount of capital funds available.
### TABLE 5

**BENEFIT-COST ANALYSIS (1) OF ALTERNATIVE REMEDIAL TREATMENTS OF CASE STUDY B.1**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of Treatment ($)</th>
<th>Present Worth of Benefits ($)</th>
<th>Net Discounted Present Value ($)</th>
<th>Annualized Net Benefit ($)</th>
<th>Benefit/Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road reconstruction with plant-mix</td>
<td>70 000</td>
<td>498 000</td>
<td>427 000</td>
<td>47 000</td>
<td>7.1</td>
</tr>
<tr>
<td>Road reconstruction with Shellgrip (2)</td>
<td>100 000</td>
<td>641 000</td>
<td>541 000</td>
<td>60 000</td>
<td>6.4</td>
</tr>
<tr>
<td>Resurfacing with Shellgrip (3)</td>
<td>31 000</td>
<td>406 000</td>
<td>375 000</td>
<td>41 000</td>
<td>13.1</td>
</tr>
<tr>
<td>Convert 5 luminaires to 'breakaway'</td>
<td>3 750</td>
<td>191 000</td>
<td>187 000</td>
<td>21 000</td>
<td>50.9</td>
</tr>
<tr>
<td>Convert 5 luminaires to 'wrap-around'</td>
<td>3 750</td>
<td>305 000</td>
<td>301 000</td>
<td>33 000</td>
<td>81.3</td>
</tr>
</tbody>
</table>

(1) Interest rate = 7 percent per annum; service life = 15 years.

(2) Because of the different service lives associated with the Shellgrip surface and the reconstructed pavement, the cost of treatment includes the present worth of a second Shellgrip application in the ninth year.

(3) The analysis includes a second application of Shellgrip in the ninth year, making a total service life of 16 years.
(e) The particular accident costing philosophy adopted will have a significant effect on the warrants for remedial action and the choice of treatment to be applied.

TABLE 4

COSTS AND BENEFITS ($ MILLION) ASSOCIATED WITH SOME ALTERNATIVE REMEDIAL PROGRAMS FOR THE MELBOURNE METROPOLITAN AREA

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of Poles Treated</th>
<th>Cost of Program</th>
<th>PWB (1)</th>
<th>NDPV (2)</th>
<th>Casualties saved per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground power lines</td>
<td>1 510</td>
<td>7.55</td>
<td>16.40</td>
<td>8.85</td>
<td>4</td>
</tr>
<tr>
<td>Convert luminaires to 'breakaways'</td>
<td>15 515</td>
<td>11.64</td>
<td>28.80</td>
<td>17.16</td>
<td>8</td>
</tr>
<tr>
<td>Convert luminaires to 'wrap-around'</td>
<td>16 585</td>
<td>12.44</td>
<td>35.43</td>
<td>22.99</td>
<td>9</td>
</tr>
<tr>
<td>Modify timber power poles</td>
<td>8 347</td>
<td>5.84</td>
<td>14.43</td>
<td>8.59</td>
<td>9</td>
</tr>
</tbody>
</table>

(1) PWB - present worth of benefits accruing over the installation service life (15 years, 7 percent per annum interest rate)

(2) NDPV - net discounted present value

All benefit calculations include costs associated with crash damage to the installation and secondary collisions.

In the main contract report benefit-cost analyses are worked out for several case studies to illustrate the practical application of the accident and cost data gathered in this study. Table 5 shows the results of such an analysis for the site illustrated in Figure 11. A number of treatment options were costed for this site and the accident predictor model used to predict any consequent changes in accident frequency (including single-vehicle accidents on the curve where a pole is not involved). Data on the performance of pole modification treatments were used to estimate changes in accident severity. All of the treatments listed in Table 5 result in substantial net benefits to the community.
10. RECOMMENDATIONS

It has been demonstrated that significant societal savings, both in terms of life and limb and consumed resources, could be made through the implementation of known remedial measures at selected sites on urban roads. In order that these potential savings may be realized, the following recommendations are made:

1. Central government should establish a policy on the costing of accidents and allocate funds for remedial programs which will result in net societal gains. Mechanisms should be established for ensuring that costs and benefits are equitably shared.

2. A central co-ordinating body in each State should be given responsibility for implementing the following program of remedial action, concentrating initially on the major road system:

   (a) Compile an inventory of pole site characteristics coded for computer analysis.

   (b) Apply the accident predictor model to rank sites in order of accident probability.

   (c) Starting with the highest ranked sites automatically generate a list of candidate remedial treatments which appear warranted for each site, based on the site characteristics making the greatest contribution to risk, and average treatment costs.

   (d) From site inspection determine the practicability of the candidate treatments and any special site requirements and costs.

   (e) Apply benefit-cost analyses to the selected treatments.

   (f) Within the context of available funds, select and implement the combination of sites and treatments which will result in the greatest societal benefits.
3. 'Black spot' poles identified during the accident survey and/or from accident records should be investigated immediately. As a matter of on-going policy, all pole collisions should be investigated with a view to remedial site treatment.

4. As a further matter of policy, all luminaire poles requiring replacement, either due to crash damage or routine maintenance, should be replaced with 'breakaway' or 'wrap-around' designs. These poles should also be installed as part of a selective program using the method of recommendation 2.

5. For new installations:

(a) Breakaway or wrap-around luminaire supports should be mandatory.

(b) The undergrounding of conductor cables should always be considered, taking into account the expected accident cost savings and aesthetic benefits.

(c) Poles which are required should be offset at least 3 m from the road edge and should not be placed on the outside of curves or near curve entry and exit points.

(d) Horizontal road curves should have a radius exceeding 200 m and should be accompanied by appropriate super-elevation.

(e) Four-lane, two-way roads should preferably be divided.

(f) Pavement skid resistance should be maintained to give a pendulum skid test value greater than 50, and the road surface should be free from corrugations and other defects.

5. Strictly on a safety basis, the minimum legal tread depth for tyres should be 3 mm. Investigations of the economic consequences of such a standard should be made. As the relationship between lower tread depths and increased accident involvement was found to be quite strong even on dry roads, enforcement of the tread depth limit could well result in the detection of other accident-related driver or vehicle characteristics.
7. A substantial proportion of accident-involved vehicles have handling characteristics that have been dangerously degraded through use of improper inflation pressures. Efforts should be made to educate drivers and garage attendants on the importance of maintaining tyre pressures at the levels recommended by the vehicle manufacturer.