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Abstract

This report summarizes the objectives, methodology, findings and recommendations of a study of collisions with utility poles. In a survey of accidents, inform- ation on site characteristics and accident severity wa 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 mode was used in conjunction with estimates of the costs of accidents to show that a number of remedial treatments are warranted.

COLLISIONS WITH UTILITY POLES

SUMMARY   REPORT

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February, 1979

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.

CONTENTS

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, Univers-
ity of Melbourne for the Office of Road Safety, Department of Trans-
port 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 avail-
       able for utility pole collisions.

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

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* Report No. CR 1 : Collisions With Utility Poles (February 1979,
  xiv + 423 pp) is available from the Director, Road Safety Informat-
  ion Service, Office of Road Safety, Commonwealth Department of
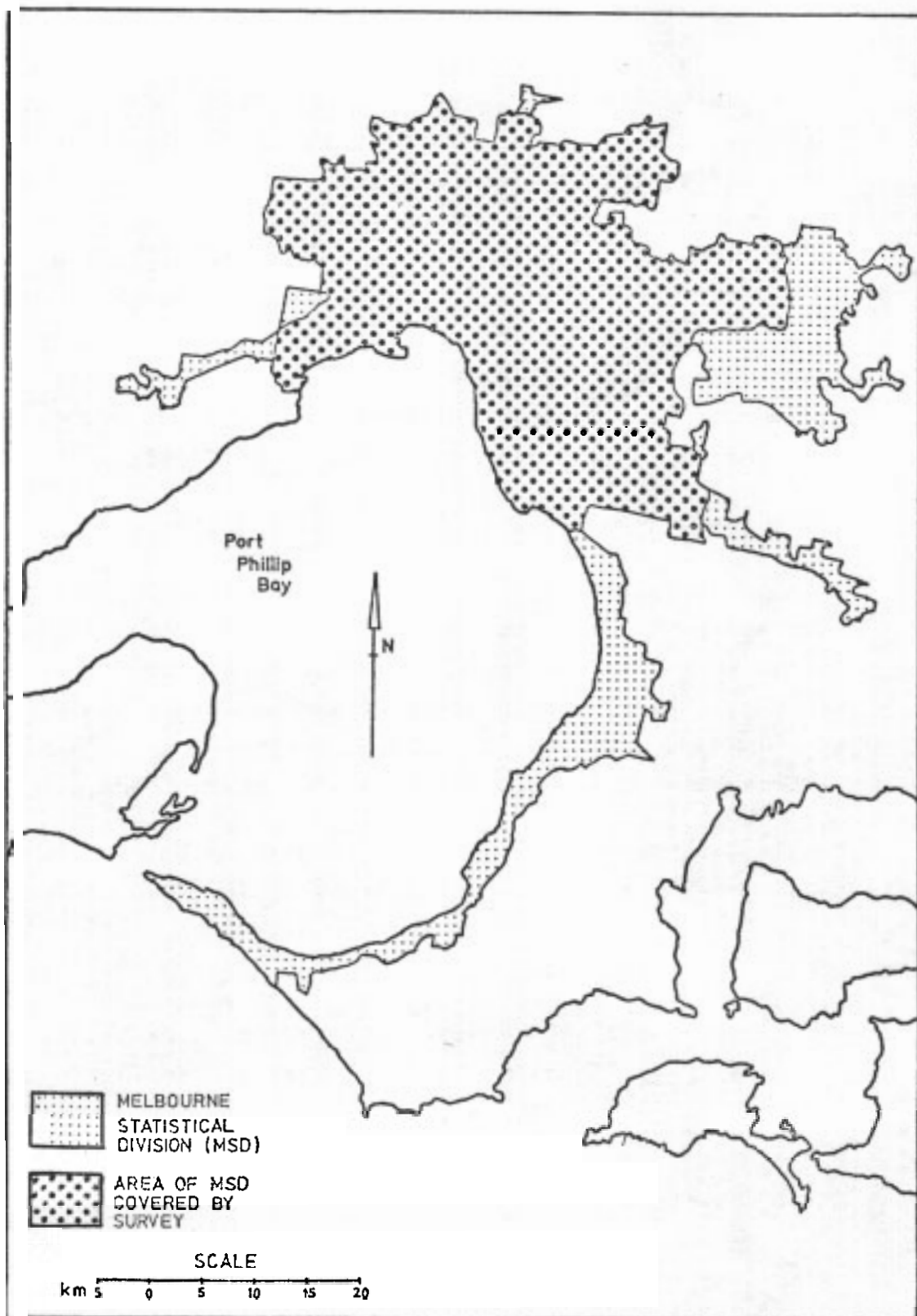 Transport, G.P.O. Box 1839 Q, Melbourne, Victoria, 3001.

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

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

        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 estab-
lished.   It can be seen from Figure 1 that this network covered
virtually all of the Melbourne metropolitan area (excluding the Morn-
ington 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
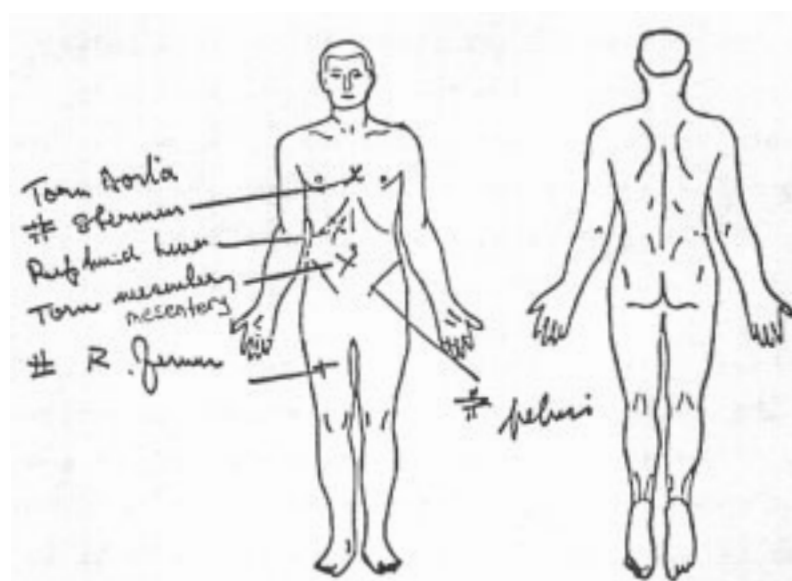
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Figure 4 Vehicle damage and driver injuries resulting from another
fatal collision with the pole shown in Figure 2.

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

Cost Item	Source
Medical and hospital, by injury severity	Motor Accidents Board
Pole/utility damage	Supply Authorities
Vehicle damage	Vehicle repairers, tow-truck operators
Vehicle market value	National Auto Market Research

In addition, costs of various remedial programs were obtained from utility supply authorities, road authorities, councils and various equipment and materials suppliers.

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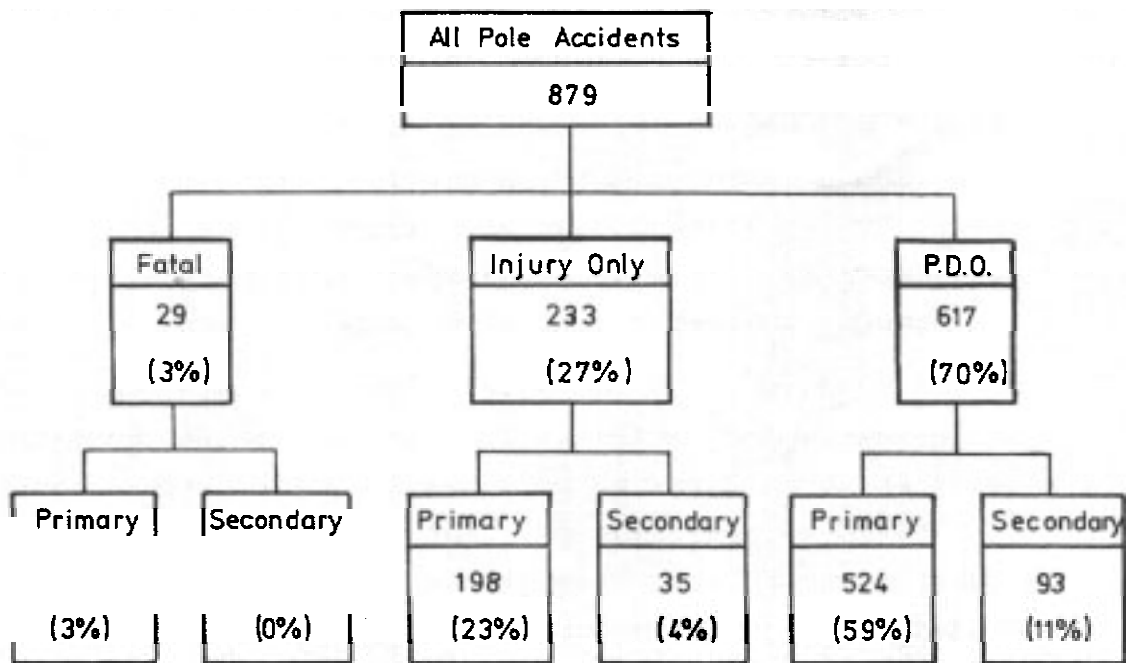
Figure 5 Distribution of pole accidents by accident severity and accident sequence. In a primary pole collision, a pole is the first object struck by an errant vehicle. A pole collision subsequent to a vehicle-vehicle collision is classified as a 'secondary' pole collision.

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 fatal-
ities 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
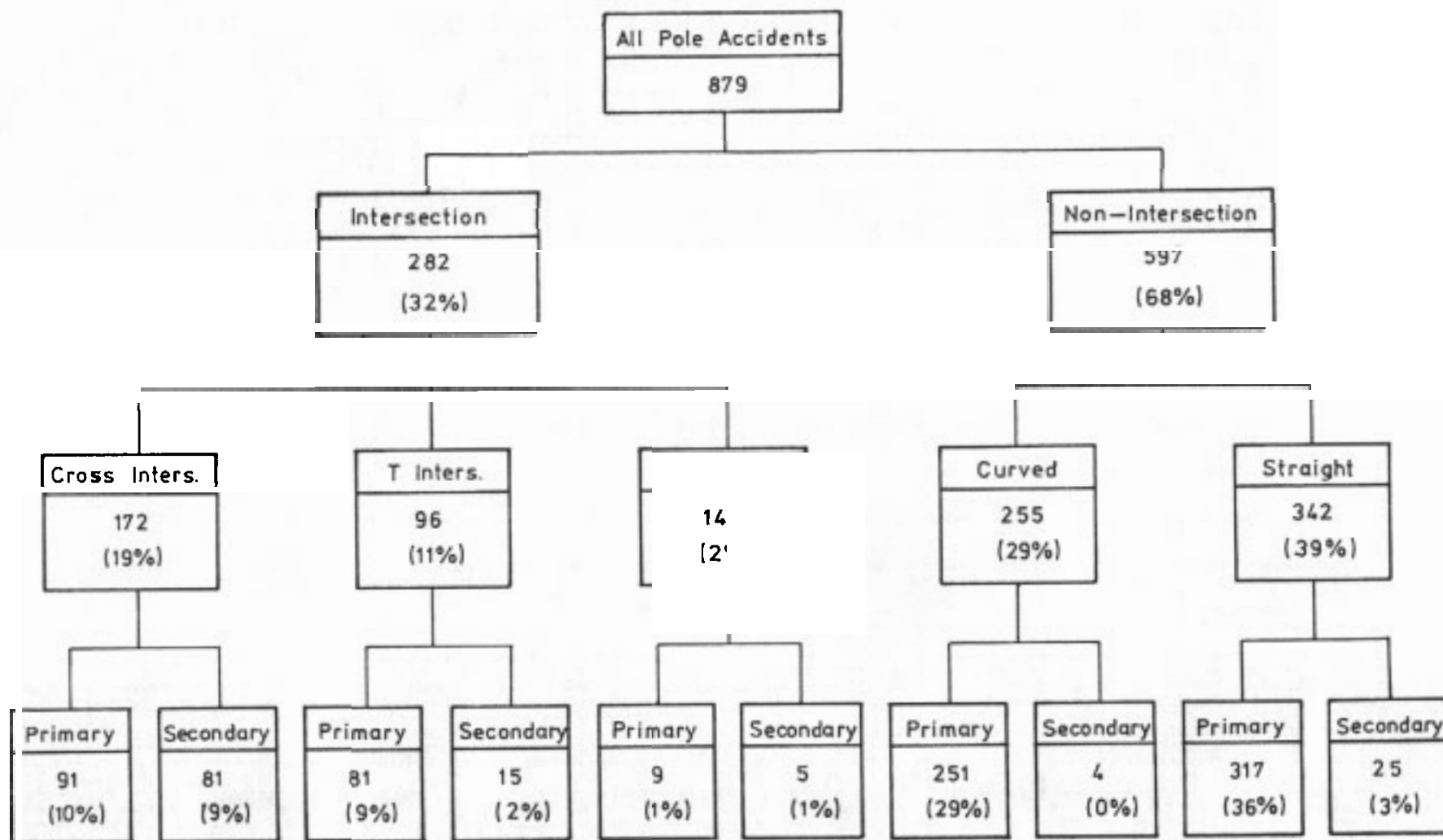(PI) or property damage only (PDO). The classification of the accident

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 <u>not</u> collide with poles. **Thus poles cannot be regard**ed as providing an effective 'protection' for pedestrians or abutting properties. Despite this, fewer than 1 in 200

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                    ┌─────────────────────┐
                    │  All Pole Accidents │
                    ├─────────────────────┤
                    │         879         │
                    └─────────────────────┘
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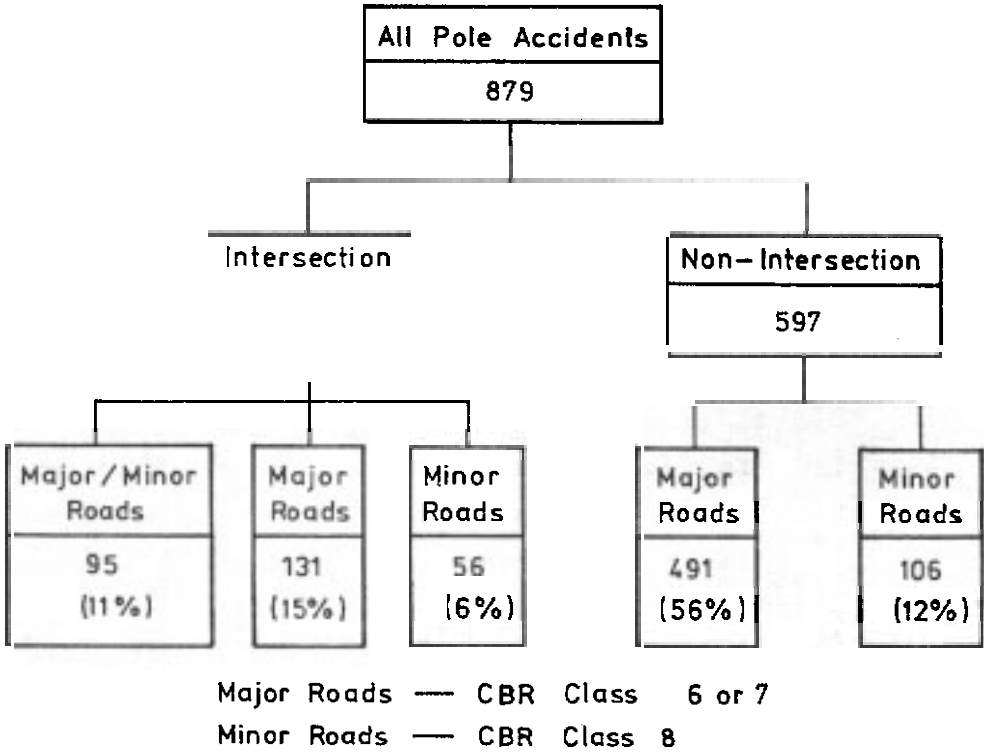
Figure 8   Distribution of pole accidents by Commonwealth
Bureau of Roads (CBR) road class.

Major Roads —— CBR Class 6 or 7
Minor Roads —— CBR Class 8

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 accid-
ents are most likely to occur at times of day (and under
weather conditions) when pedestrian traffic is lightest.

(h) 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.

(i) 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.

(j) 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.

(k) Pole material and function seem to be unrelated to accident
occurrence and have only a slight effect on accident sever-
ity. **This is because all poles presently in service are**
effectively rigid.

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

(m) 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).

(n) 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 concentrat**ed
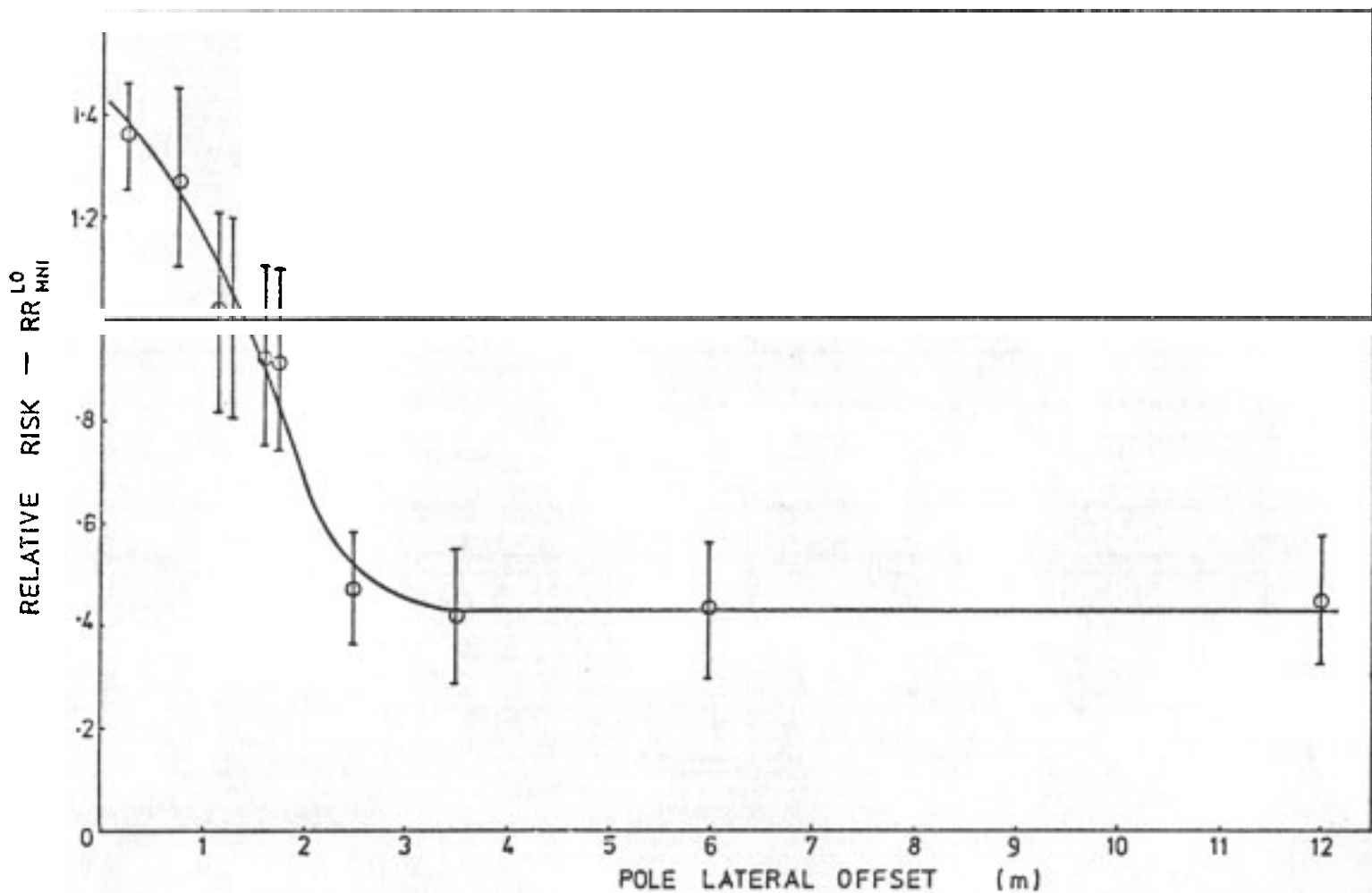more on the head and neck and upper torso areas.

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 vari-
ations 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. Accord-
ingly, 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 charac-
teristics. 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.

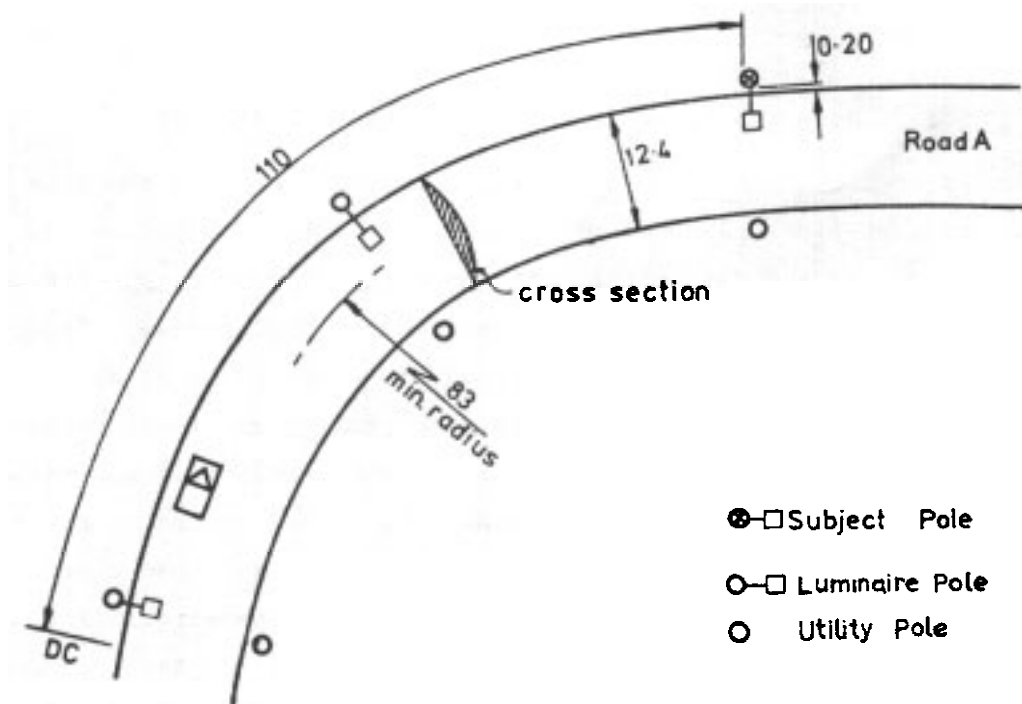OIB   Pole on the inside/outside of bend.

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 3.785×10^{-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

Variable	Value	RR	Source[1]
Data Group	MNI	4.36	T/B.2
$\lvert K_{MAX} \rvert$	0.012	3.10	F/B.4
AADT	17500	1.24	F/B.5
ST	45	1.50	F/B.6
LO	0.20	1.38	F/B.7
W	12.4	1.32	F/B.8
DC	110	1.12	F/B.9
PD	Corrugations	2.00	T/B.3
e	Negative	1.20	T/B.4
OIB	Outside	1.15	T/B.5

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 classi-
fications.

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 Stat-
istics (ABS) figures for all vehicles on register in Victoria, suggest-
ing 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 relat-
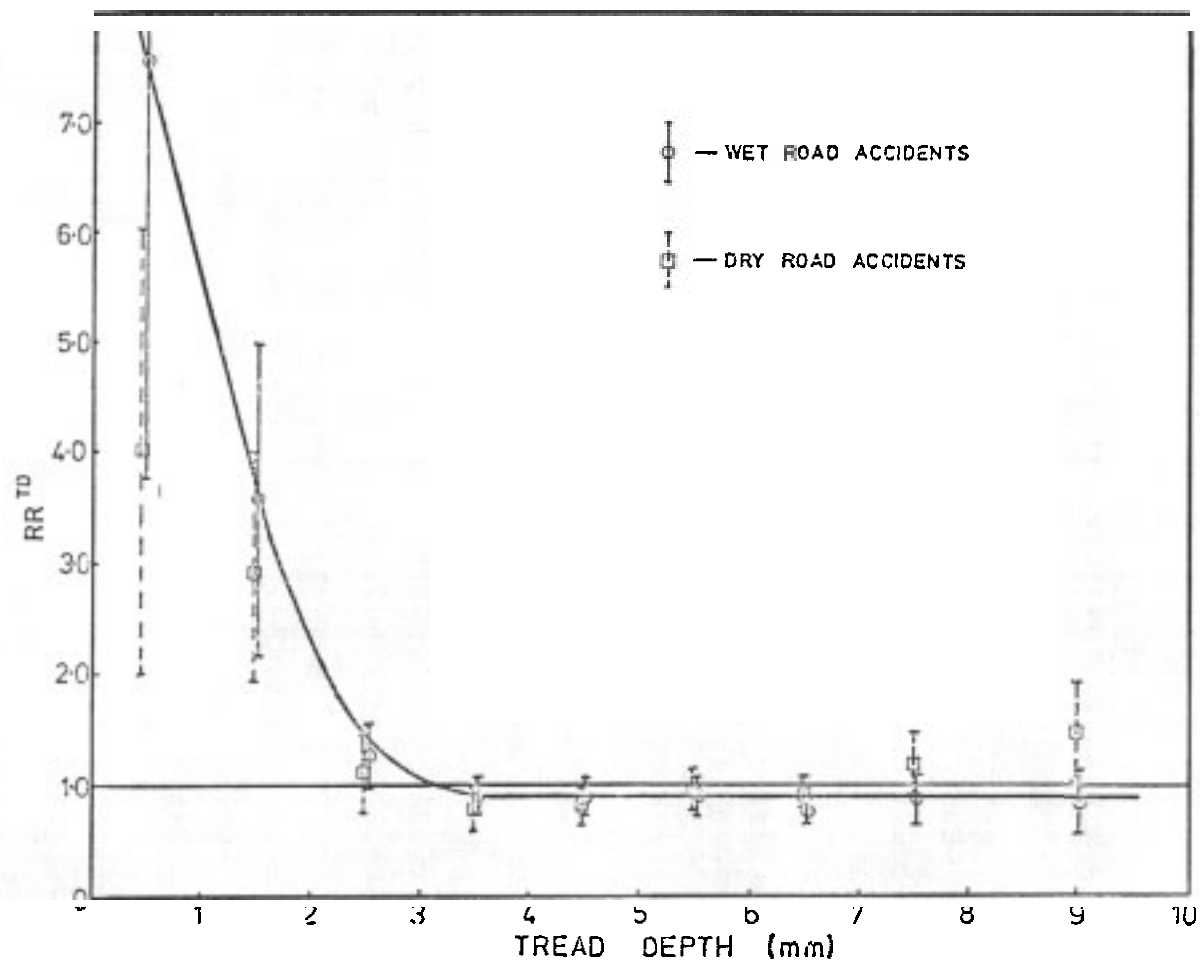   ive to specifications was investigated from the point of

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.
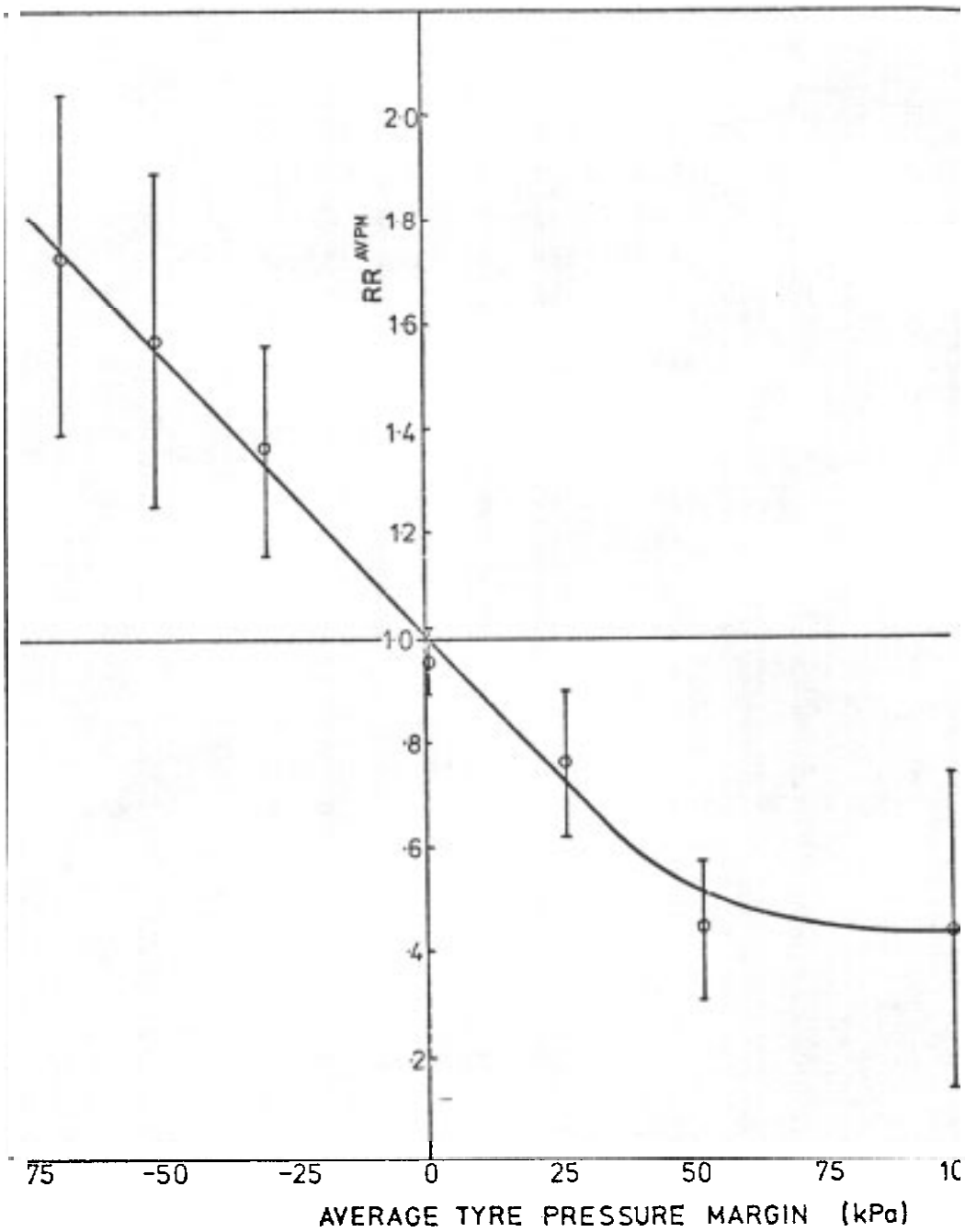
Figure 14   Relative risk versus the overall average tyre
pressure margin for all accidents

6.5   Accident Severity as a Function of Pole Type

All the poles in the present study were effectively rigid. No differ-
ence 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 accid-
ents 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 con-
sumption 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 aver-
age cost per tow-away accident is $11 200 .

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

[#] 1975 Societal Costs of Motor Vehicle Accidents, by B.M. Faigin.
    United States Department of Transportation, National Highway Traffic
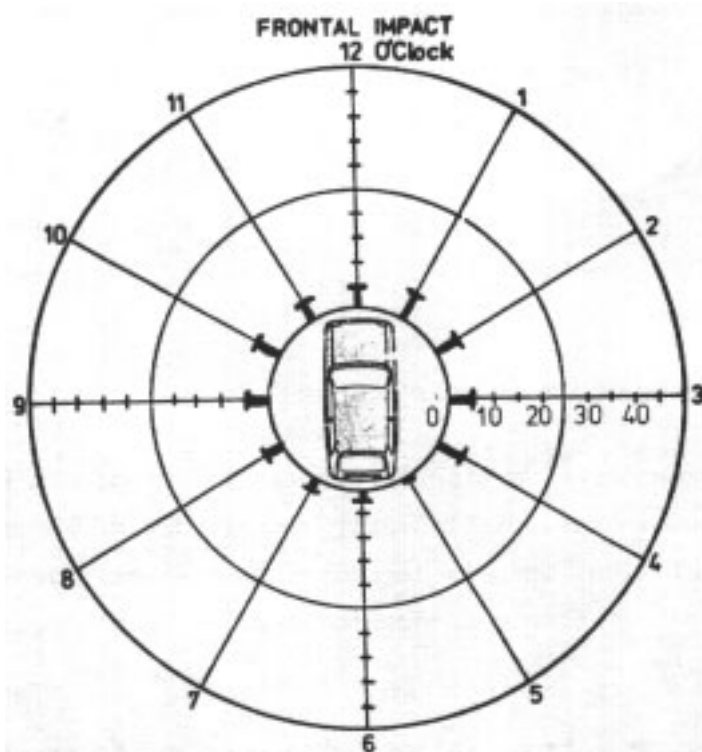   Safety Administration, 1976.

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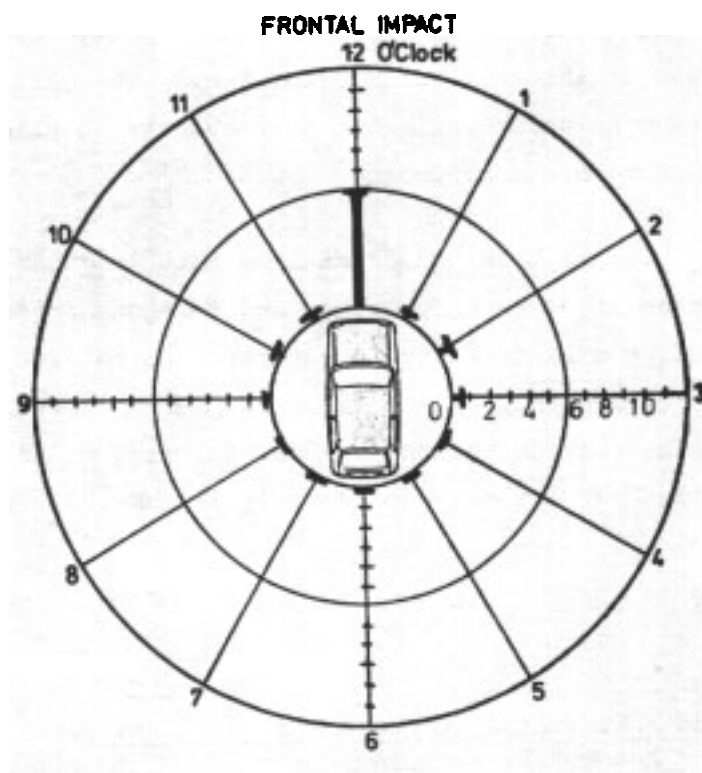

Figure 16 Estimated annual cost ($million) in Melbourne metropolitan area based on total accident cost components, by impact direction.

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.

(d) 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.

(e) 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.

(f) 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.

(g) 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

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

(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

Treatment	No. of Poles to be Treated	Cost of Program	PWB (1)	NDPV (2)	Casualties saved per annum	
					Fatalities	Injuries
Underground power lines	1 510	7.55	16.40	8.85	4	66
Convert luminaires to 'breakaways'	15 515	11.64	28.80	17.16	8	122
Convert luminaires to 'wrap-around'	16 585	12.44	35.43	22.99	9	161
Modify timber power poles	8 347	5.84	14.43	8.59	9	72

(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 treat-
ments 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 inves-
      tigated 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 out-
            side 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.

6.   Strictly on a safety basis, the minimum legal tread depth for
      tyres should be 3 mm . **Investigations of the economic con-**
      sequences of such a standard should be made. **As the relation-**
      ship between lower tread depths and increased accident involve-
      ment was found to be quite strong even on dry roads, enforce-
      ment 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 recomm-
      ended by the vehicle manufacturer.