RESEARCH REPORT **88/095b/2**

SOUTH AFRICAN ROADS BOARD
RESEARCH AND DEVELOPMENT ADVISORY COMMITTEE

The revised K21: Identification and improvement of hazardous locations

RESEARCH DONE FOR
AND ON BEHALF OF THE
SOUTH AFRICAN ROADS BOARD BY
DIVISION OF ROADS AND TRANSPORT TECHNOLOGY
CSIR
P O BOX 395
PRETORIA
March 1991

TITEL/TITLE THE REVISED K21: IDENTIFICATION AND IMPROVEMENT OF HAZARDOUS LOCATIONS

VERSLAG NR: REPORT NO:	ISBN:	DATUM: DATE:	VERSLAGSTATUS: REPORT STATUS:
88/09b/2		March 1991	Research Report

NOAK NR/RDAC NO: 88/095b/2

GEDOEN DEUR:
CARRIED OUT BY:
Division of Roads and Transport
Technology, CSIR
P O Box 395
Pretoria
0001

OPDRAGGEWER:
COMMISSIONED BY:
Chief Director : National Roads
P O Box 415
PRETORIA
0001

OUTEUR(S):
AUTHOR(S):

R A Opperman
A H Upton

NAVRAE:
ENQUIRIES:
Navplan
Private Bag X5
ALKANTRANT
0005

SINOPSIS:

Die doel van hierdie handleiding is om 'n praktiese en maklike metode daar te stel om gevaarkolle in 'n gegewe area te identifiseer en te prioritiseer asook om riglyne te bied vir die bepaling van die mees koste-effektiewe herstelmaatreëls vir 'n spesifieke gevaarkol.

Die handleiding is gebasseer op die bekende WNNR Tegniese Handleiding K21, wat in 1972 gepubliseer is. Alhoewel 'n baie eenvoudiger benadering tot die identifisering van gevaarkolle asook stap-vir-stap prosedures vir die ondersoek daarvan en die bepaling van die voordele/koste-verhoudings van moontlike verbeterings in hierdie handleiding gegee word, is baie van die inligting vervat in die oorspronklike dokument, hierin herhaal.

Ten einde die gebruiker behulpsaam te wees, word 'n lys gegee van botsingspatrone, die waarskynlike oorsake daarvan en algemene teenmaatreëls. Verder word die verbeterings vir verskillende tipes botsings beskryf en 'n aanduiding gegee van die mate waartoe dit die botsings sal verminder. Opgegradeerde botsingskostes en eenheidskostes van padvebeterings, sowel as 'n voorbeeld van die berekenings met betrekking tot die analisering van 'n gevaarkol, word ook gegee.

SYNOPSIS:

The purpose of this manual is to provide a practical and easy-to-use method for identifying and prioritising hazardous locations in a given area, and to provide guidelines for establishing the most cost-effective remedial measures for a specific site.

This manual is based on the well known CSIR Technical Manual K21, published in 1972. Although a much more simplified approach towards the identification of hazardous locations, and step-by-step procedures regarding the investigation of such sites as well as determining the benefit/cost ratio's of possible improvements are given in this manual, much of the information contained in the original manual is repeated in this document.

To assist the user, a list of collision patterns, their probable causes and general countermeasures are given. Furthermore the improvements recommended for various types of collision are described and an estimate is given of the degree to which these improvements could reduce collisions. Also included are updated collision costs and unit costs of road safety improvements as well as an example of the calculations regarding the analysis of a hazardous location.

TREFWOORDE:
KEYWORDS: Hazardous locations; Elimination; Road safety; Remedial measures.

LIST OF CONTENTS

CHAPTER 1: INTRODUCTION

Since the publication of the original **K21** (CSIR Technical Manual K21 "The identification and improvement of collision black spots") in 1972, requests have been received by the CSIR for a more practical and easy-to-use manual. This revised publication aims to achieve this, and is particularly aimed at smaller local authorities.

During the compilation of the Revised K21, much consideration was given to the feedback and inputs received from eleven provincial and local authorities with regard to shortcomings of the old K21, such as criteria for defining hazardous locations, basis for prioritisation, systems for recording data, period before and after taken into consideration for establishing success rates, and success rates of various remedial measures implemented.

The experience gained by CSIR research personnel from in-depth investigations of nine hazardous locations in various parts of the country also provided invaluable background knowledge for designing this new manual.

Although this manual is based on the original K21, a much more simplified approach towards the identification and prioritisation of collision hazardous locations in a given area, is adopted. This method comprises the keeping of proper records, identifying the worst locations purely on the basis of **NUMBER** of collision occurrences, and listing the locations in order of priority according to the **EQUIVALENT ACCIDENT NUMBER (EAN)**. This is followed by a step-by-step procedure on how to investigate these locations and also six easy steps for the calculation of benefit/cost ratio's in order to select the improvements which will be the most cost effective in reducing collisions. Finally, guidelines regarding follow-up studies to ascertain the actual effect of the improvements that have been carried out, are given.

Whilst much of the information contained in the original manual is repeated in this document, it has been updated and expanded in order to be as practical and useful as possible.

CHAPTER 2: COLLISION DATA

This manual does not prescribe a specific system for the collection of collision data and leaves it to the discretion of the authority concerned to utilise its own established method. The CSIR may be approached to assist any authority in installing an appropriate system if required.

It is recommended however that the following minimum data are utilised for this purpose:

- Number of collisions over time
- Types of collisions
- Severity of collisions
- Location of collisions
- Date and time of collisions
- Cause of collision (if possible)

2.1 NUMBER OF COLLISIONS OVER TIME:

It is recommended that a time period of at least one year be used when applying collision data for any location as seasonal effects must be taken into account. (It should, however, be borne in mind that data collected over a long period may be invalidated by changing environmental and traffic conditions).

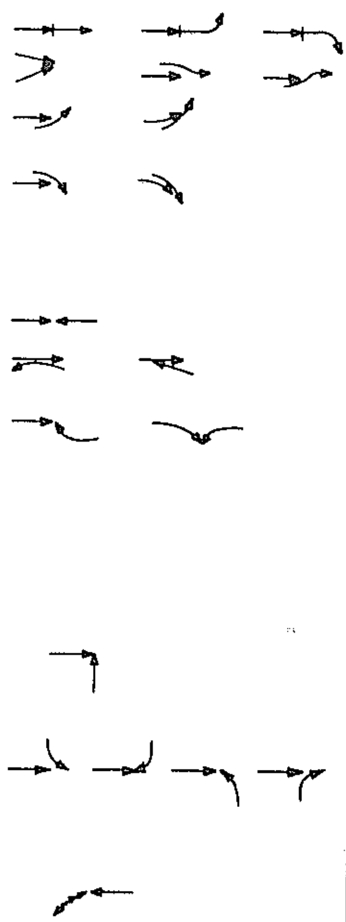
2.2 TYPES OF COLLISIONS

There are 19 categories of collisions which the SA Police use on the Collision Report Form (SAP 352A) according to the type of vehicle(s) involved, viz:

- Motor car, station wagon;
- Combi, mini-bus;
- Light delivery vehicle, "bakkie", panel van;
- Heavy commercial vehicle (above 3500kg GVM);

- Articulated vehicle;
- Passenger bus, Trolleybus;
- Motor cycle, scooter, autocycle;
    - (i) 50cc and below
    - (ii) Above 50cc
- Pedal cycle;
- Animal-drawn vehicle;
- Tractor or mobile equipment;
- Other road vehicle;
- Vehicle unknown;
- Train;
- Pedestrian;
- Animal;
- Road sign, post, tree;
- Building, bridge;
- Other fixed object; and
- No collision (vehicle overturned, etc).

Collisions which involve two or more motor vehicles are further sub-divided according to the relative movements of the vehicles just prior to the collision. These groupings of two or more motor vehicle collisions, and their sub-divisions, are defined in Figure 1.



DESCRIPTION OF COLLISION	DIAGRAM	CODE
BOTH FROM SAME DIRECTION		
Rear-end		1
Sideswipe		2
Turning left from wrong lane		3
Turning right from wrong lane		4
FROM OPPOSITE DIRECTION:		
Head-on		5
Sideswipe		6
Turning right in face of on-coming traffic		7
APPROACHES AT AN ANGLE OR AT RIGHT ANGLES:		
Both travelling straight		8
One or both turning		9
REVERSING		0

FIGURE 1: Codes for relative movements in two motor-vehicle collisions.

NOTE: Collision with parked vehicle to be classified under "single motor vehicle" collision.

2.3 SEVERITY OF COLLISION:

The severity of a collision is defined by the casualty class into which it falls. The following definitions are used by the S A Police who have, in most cases, the responsibility of preparing the initial collision reports.

(i) **Fatal Injuries** are injuries that cause immediate death, or death within a period of six days as a direct result of the collision.

(ii) **Serious injuries** include fractures, concussions, severe cuts and lacerations, shock necessitating medical treatment and any other injury necessitating hospitalisation or confinement to bed.

(iii) **Slight injuries** include cuts and bruises, sprains and slight shock not requiring hospital treatment.

(iv) **Damage only:** Collisions in which there is no personal injury but damage to property.

2.4 LOCATION OF COLLISIONS:

The precise location of collisions should be pin-pointed as accurately as possible, using such information as road names (intersections), street address numbers, road numbers and kilometre markers.

2.5 DATE AND TIME OF COLLISIONS:

It is important to establish the date, day and time of collision occurrences in order to reveal trends.

2.6 DATA RECORDS

It is suggested that the most simple and effective method of collision data recording is the use of pin-maps of the relevant area, together with collision diagrams of all sites listed as hazardous locations. More sophisticated systems are, however, available.

All data should be up-dated at weekly or monthly intervals.

An example of a motor vehicle collision report form which can be used to record information with regard to individual collisions on a continuous basis, which will eventually form the data base in respect of specific sites to be investigated in detail, is shown in Appendix A.

CHAPTER 3: IDENTIFICATION AND PRIORITISATION OF HAZARDOUS LOCATIONS.

There are many possible ways of defining and therefore identifying hazardous locations (such as collision rates, benefit-cost considerations, etc.) but it is suggested that only the number and severity of the collision occurrences at a particular site be considered in order to decide whether or not it qualifies as a hazardous location. The collision history at the site in question is expressed as a factor known as the **equivalent accident number** by application of the "weighted number method".

This method recognises collision severity as a prime factor in the selection of sections, spots or intersections for investigation. To accomplish this a weighting is assigned to each collision according to the severity of injury. This weighted total, the **E A N**, is then used to compare different sites. The E A N should be for a minimum period of one year or the average for a number of years.

The following weighting is recommended for calculation of the **E A N**:

Fatal collisions	**12**
Injury collisions	**3**
Damage only collisions	**1**

This manual does not prescribe an **E A N** that should be regarded as the lower cut-off point for a site to be classified as a hazardous location, but suggests that any site within the area under consideration with an abnormally high **E A N** should be classified as a hazardous location.

Prioritisation should be in order of the highest **E A N** to the lowest.

CHAPTER 4: INVESTIGATION OF HAZARDOUS LOCATIONS

Once they have been listed in order of priority, as many of the locations as can be dealt with practically by the authority concerned should be investigated more thoroughly.

The following investigation procedure is suggested:

(i) Draw up a collision diagram (if not already existing) for the site under investigation;

(ii) Examine collision data on the collision diagram for trends;

(iii) Visit the site, do conflict studies, and conduct visual observation to establish traffic patterns, driver behaviour and any environmental factors which may affect safety.

Some of the questions which should be considered are:

- Are the collisions caused by physical conditions of the road or its immediate environment and can these conditions be either eliminated or corrected (e.g. possible low skid resistance)?

- Are the existing signs, traffic signals and road markings doing the job for which they were designed, or is there a possibility that they contribute to collisions?

- Is traffic properly channelised so as to minimise the occurrence of collisions?

- Could collisions be prevented by banning certain traffic movements, such as right turns?

- Can part of the traffic be diverted to other streets where the collision potential is lower?

- Is there a high incidence of night-time collisions, indicating the need for special night-time protection such as the improvement or installation of street lighting, better control of traffic signals, or reflectorized signs or markings?

- Does parking in the area contribute to collisions by reducing the width of the road or by causing sight obstructions at intersections?

- Do the advance warning signs give adequate notice of route changes so that proper lanes may be chosen well in advance of the intersection?

- Do conditions show the need for additional traffic law enforcement?

(iv) Draw conclusions regarding causative factors.

CHAPTER 5: DETERMINATION OF BEST SOLUTION FOR HAZARDOUS LOCATION.

- Identify possible remedial measures (see Appendix B which gives examples of typical remedial measures and may be used as a guideline).

- Establish benefit/cost ratio for each possible solution. (Appendix F shows an example of how to calculate a benefit/cost ratio as explained below).

Steps:

i) Determine the collision costs at the site under consideration by multiplying the number of collisions with the unit costs of these collisions. (See Appendix C which gives collision costs).

ii) Determine the annual benefit by multiplying the relevant total annual costs with the percentage by which the collision rate is expected to drop resulting from the remedial measure (see Appendix B, Table 4, which gives expected benefit [i.e reduction in collisions]).

iii) Establish the initial capital cost of the improvement (Appendix D gives approximate costs of typical remedial measures) as well as the annual maintenance cost (if applicable). Convert the initial capital cost into an annual cost by multiplying it by a capital recovery factor (see Appendix E), and add this to the annual maintenance cost.

iv) Calculate the ratio of benefits to costs by dividing the total annual benefits (from ii above) by the total annual costs (from iii above).

v) Select the improvement showing the biggest benefit/cost ratio for implementation.

vi) Re-calculate the benefit/cost ratio of the remedial measure chosen using actual costs and not the typical costs shown in Appendix D.

- Having established the benefit/cost ratio for each of the hazardous sites they are then ranked in order of ratio size with the largest ratio at the top of the list. Improvements should now be carried out in strict list order until the funds are expended.

CHAPTER 6: FOLLOW-UP STUDIES

When improvements have been carried out it is particularly desirable to carry out follow-up studies on the same basis as the studies undertaken before the improvements. This is necessary on two counts:

(i) Unforeseen problems may show up which make minor adjustments necessary such as, for example, the re-timing of traffic control signals.

(ii) Examination of collision records under the new conditions may point to the necessity for new or further modifications.

The first part of the follow-up study can be made almost immediately by a visit to the site of the improvement. As the conditions prior to the improvement are known, it should be possible to assess the effect of the improvement subjectively. The results of before-and-after studies should be subjected to a test of statistical significance; that is, any apparent change in the number of collisions should be tested to see if that change could have arisen by chance. Statistical tests of significance usually assess results at the 5 per cent level of probability, that is a change is significant at this level if the odds are 19 to 1 against it occurring by chance.

In order to be able to draw reliable conclusions when collision numbers are tested it is necessary to use the numbers of collisions that have occurred over at least a two year period. Using before-and-after periods of the same length the following method can be used to test the statistical significance of the improvement.

If b is the number of collisions that occurred before an improvement and a the number of collisions that occurred in an equal and comparable period after an improvement, then if the reduction in collisions $(b - a)$ is greater than $2\sqrt{(a + b)}$, the change is statistically significant at the 5 per cent level. It can therefore be concluded that the improvement in the collision record is due to the engineering alterations that have been carried out.

If, however, there is a general upward or downward trend in collisions during the period of investigation it is necessary to use as a control the number of collisions that occurred at similar sites which were not affected by safety improvements. For testing the statistical significance at the 5 per cent level the following formula is used:

$$N\left[\left(\frac{b}{a+b} - \frac{c}{c+d}\right) X \left(\frac{b}{b+c} - \frac{a}{a+d}\right)\right] > 3,8$$

where

$a =$ number of collisions that occurred after the improvements at the site
$b =$ number of collisions that occurred before improvements at the site
$c =$ number of collisions that occurred before improvements at the control site
$d =$ number of collisions occurred after the improvements at the control site
$N =$ total number of collisions i.e. $(a + b + c + d)$

If the left hand side of the formula is greater than 3,8, the change is statistically significant at the 5 per cent level.

The use of this formula does not necessitate before-and-after periods of equal length but it should not be used if the smaller of the amounts $(a + b)$ and $(c + d)$ when multiplied by the smaller of the amounts $(b + c)$ and $(a + b)$ is less than 5N.

If a particular type of collision is being investigated then the collisions recorded at the control sites should be of a similar type.

Because collision numbers are small in statistical terms, it is necessary to take collision records over a long period (2 years) before firm conclusions can be made on the success of the measure adopted. It should be borne in mind that it is only by keeping detailed collision records after carrying out road safety improvements that the success in effecting greater safety can be measured. The collision record therefore needs to be studied at regular intervals, say every 6 months, to determine whether or not further measures are required.

CHAPTER 7: CONCLUSION

This manual is intended to be used as a guide in the process of applying a simple systematic approach to the identification, prioritisation and rectification of hazardous locations.

Many of the larger local authorities which are able to afford specialist personnel and other costly resources have developed their own, more sophisticated diagnostic systems and the authors of this work do not want to give the impression that these well established procedures are in any sense invalid or inferior.

The purpose of this manual is to provide a simple and inexpensive system by which collision hazards may be identified and rectified, particularly for those local authorities which do not have dedicated resources, thus enabling them to make use of local and state funding for the enhancement of their road infrastructure.

CHAPTER 8: ACKNOWLEDGEMENTS

The authors wish to thank the following organisations for the close cooperation which was afforded them during the course of the investigation of hazardous locations in their respective areas of jurisdiciton:

- South African Police;
- Cape Provincial Administration;
- Natal Provincial Administration;
- Borough of Pinetown;
- Municipality of Worcester; and
- Durban Corporation.

The authors also wish to thank the Road Engineer's Department, Cape Provincial Administration for their input in this manual regarding collision-patterns and general countermeasures.

CHAPTER 9: BIBLIOGRAPHY

1. AUTOMOTIVE SAFETY FOUNDATION, Traffic control and roadway elements - their relationship to highway safety, U.S. Automotive Safety Foundation in cooperation with U.S.A Bureau of Public Works, 1970.

2. BROWN, R.J, The identification and improvement of accident black spots, National Institute for Road Research, Technical Manual K21, Pretoria, CSIR, 1972.

3. SA ROADS BOARD, CB-Roads Manual and Program. 1992.

4. GLENNON, J.C. & TAMBURRI, T.N, Objective criteria for guardrail installation, HRR 174 Highway Reseach Board, National Research Council, U.S.A, 1967.

5. GREAT BRITAIN, Ministry of Transport, Instructions for using portable skid resistance tester, Road Research Laboratory, Road Note No 27, London, HMSO, 1960.

6. GREAT BRITAIN, Ministry of Transport and Scottish Development Department, Urban traffic engineering techniques, London H.M.S.O, 1965.

7. GREAT BRITAIN, Ministry of Transport, Cobbe, B.M. & Webster, F.F, Traffic signals, Road Research Laboratory, R.R. Technical Paper No 56, London, HMSO, 1966.

8. GREAT BRITAIN, DSIR, Road Research Laboratory, Research on road safety, London, HMSO, 1963.

9. GREAT BRITAIN, Ministry of Transport, Roads in urban areas, London, HMSO, 1966.

10. GREAT BRITAIN, DSIR, Road Research Laboratory, Research on road traffic, London, HMSO, 1965.

11. GREAT BRITAIN, Ministry of Transport, Technical Memorandum, No H8/69, Criteria for the provision of pedestrian subways or bridges, London, HMSO, 1969.

12. JORDAAN, P.W. An improved collision severtity module for CB-ROADS, Project Report PR 91/230/1, Jordaan & Joubert Inc., Pretoria, South Africa, March 1992.

13. HOBBS, F.D. & RICHARDSON, B.D, Traffic Engineering Volumes 1 and 2, London, Pergamon, 1967.

14. JORGENSEN, R. & ASSOCIATES, Evaluation of criteria for safety improvements on the highway, A report to the USA Department of Commerce, Bureau of Public Roads, Office of Highway Safety, 1966.

15. LITTLE, A.D, Cost effectiveness in traffic safety, New York, A Praeger Ltd, 1968.

16. MICHIE, J.D. & CALCOTE, L.R, Location, selection and maintenance of highway guardrails and median barriers, National Cooperative Highway Research Program Report No 54, Highway Research Board, National Academy of Sciences - National Academy of Engineering, 1968.

17. MORDEN, C.H, An Estimate of the cost of road traffic collisions in South Africa for 1988, Research Report DPVT/64, CSIR, Pretoria, June 1989.

18. ODENDAAL, J.R, Road traffic accident case studies in the Republic of South Africa Report VI, National Institute for Transport and Road Research, Technical Report RU/8/76, CSIR, Pretoria, April 1976.

19. OPPERMAN, R.A, Gevallestudie: Le Sueurstraat tussen Buitekant- en Durbanstraat, Technical Report DPVT/C 61.2, CSIR, Pretoria, March 1989.

20. OPPERMAN, R.A, Gevallestudie: Sampsonstraat tussen Le Sueurstraat en Breëriviersingel, Worcester, Report DPVT/C 61.3, CSIR, Pretoria, March 1989.

21. OPPERMAN, R.A en NOTHNAGEL, A, Gevallestudie: N1 Kraaifontein tussen Bellville en Paarl, Kaapprovinsie, Report DPVT/C 61.7, CSIR, Pretoria, March 1990.

22. RIBBENS, H, Guidelines for setting speed limits, Technical Report RV/19, CSIR, Pretoria, February 1986.

23. RIBBENS, H, Die subsidieskema vir die uitskakeling van gevaarkolle - Nuusbrief 1988, CSIR Brochure DPVT/G1, CSIR, Pretoria, July 1988.

24. * SOUTH AFRICA, South African road traffic signs manual, Second Edition, CSIR Manual K55, UDC 656.1.054/057 (680), Pretoria, 1986.

25. SOUTH AFRICA, Technical methods for highways, Special methods for testing roads, Draft TMH 6, Pretoria, South Africa, 1984.

26. SOUTH AFRICA, Technical recommendations for highways, Geometric Design of Rural Roads, TRH 17, Pretoria, South Africa, July 1988.

27. SOUTH AFRICA, Technical recommendations for highways, Surfacing seals for rural and urban roads, Draft TRH 3, Pretoria, South Africa, July 1986.

28. UNITED STATES OF AMERICA, Institute of Traffic Engineers, Manual of traffic engineering studies, 3rd Edition, Washington D.C. 20036, 1964.

29. UPTON, A.H and OPPERMAN, R.A, Case study: The intersection of Old Main Road and Crompton Street, Pinetown, Technical Report DPVT/10, CSIR, Pretoria, June 1988.

* An updated version is presently being prepared by Department of Transport.

30. UPTON, A.H, The intersection of St Johns Avenue and Bamboo Lane, Pinetown, Report DPVT/C 61.1, CSIR, Pretoria, September 1988.

31. UPTON, A.H, Case Study: The intersection of Umgeni and Goble Roads, Durban, Report DPVT/C 61.4, CSIR, Pretoria, August 1989.

32. UPTON, A.H, Case Study: A section of Umgeni Road opposite the Umgeni Railway Station, Durban, Report DPVT/C 61.5, CSIR, Pretoria, March 1990.

33. UPTON, A.H, Case Study: The R613 Highway, Pinetown Section, Report DPVT/C 61.6, CSIR, Pretoria, March 1990.

34. UPTON, A.H, Case Study: Umgeni Road - Durban Station, Report DPVT/C 61.8, CSIR, Pretoria, March 1991.

35. VISSER, A.T. and WALKER, R.N, Skid resistance and noise generation of surfaces, Report RR 179, National Institute for Transport and Road Research, CSIR, August 1974.

36. VISSER, A.T. and MARAIS, G.P, A state-of-the-art review of factors that effect the skid resistance of roads and airfields, Report RR 385, National Institute for Transport and Road Research, CSIR, August 1984.

37. WIUM, D.J.W, Traffic accident records, National Institute for Road Research, Pretoria, CSIR, June 1968.

38. WIUM, D.J.W, Determination of accident patterns for hazardous locations on roads, Unpublished Report RT/3/68, National Institute for Road Research, Pretoria, CSIR, June 1968.

39. WIUM, D.J.W, Black spots, accident patterns and preventive measures, Report RT/4/70, National Institute for Road Research, Pretoria, CSIR, 1970.

40. SABS, Code of Practice for Public Lighting, C 098-1967, Pretoria, 1967.

APPENDIX A:

MOTOR VEHICLE COLLISION REPORT: HAZARDOUS LOCATION

MOTOR VEHICLE COLLISION REPORT: HAZARDOUS LOCATION

A. DESCRIPTION OF COLLISION LOCATION.

1. Local Authority
2. Location code of collision site
3. Road name or number ____________________
4. _____Kilometers N E S W from ____________________
5. at intersection with ____________________

B. LOCATION COLLISION RECORD.

1. Number of collisions over last 12 month period __________
2. Collision rate (if available) ____________________/10^6 km
3. Have any improvements been effected to this location during the last 3 years. YES ☐ NO ☐
4. Collision rate prior to improvement __________

C. ROAD-USER DETAILS.

	A	B	C
Name			
Sex			
Age			
Race			
Address			
Telephone			
Licence code			
date of iss			

D. VEHICLE DETAILS.

	A	B	C
Vehicle type			
Model			
Year of manuf.			
Reg. plate			
General condit.			

E. CONDITION OF ROAD-USERS.

1. Did any driver or pedestrian appear to be under the influence of alcohol or drugs. YES ☐ NO ☐
2. A B or C ____________________
3. Were any tests performed. YES ☐ NO ☐
4. Nature of test. ____________________
5. Reading (if applicable) ____________________
6. Did any driver or pedestrian appear to be ill or infirm, or have any physical impairment YES ☐ NO ☐
7. A B or C ____________________
8. Specify ____________________

F. CONDITION OF VEHICLES.

1. Did any of the vehicles involved appear to have any mechanical defects. YES ▒ NO ▒
2. A B or C ______________________________
3. Specify ______________________________
____
(If tyre related, state condition of all tyres on offending vehicle, and tread-depth.)
4. Were any mechanical tests performed on any of the vehicles involved. YES ▒ NO ▒
5. A B or C ______________
6. Nature of test ______________________________
7. Authority conducting test ______________________
8. Result of test ______________________________

G. ENVIRONMENTAL CONDITIONS.

1. Day of accident ▒ time ▒ date ▒
2. Weather conditions:
   Dry clear ▒ Dry mist ▒ Dry smoke ▒ Strong wind ▒
   Light rain ▒ Heavy rain ▒ Lightning ▒ Hail ▒
3. Temperature:
   Very hot ▒ Hot ▒ Cool ▒ cold ▒ very cold ▒
4. Visibility:
   Day good ▒ Day poor ▒ Dusk good ▒ Dusk poor ▒
   Dark good ▒ Dark poor ▒
5. Is road-user's view of other road traffic obstructed or impaired in any direction. YES ▒ NO ▒
6. Give precise details ______________________________
____
____
____
____
____
7. What could be done to rectify this problem. ______
____
____
____
____
____
____
8. What is the speed limit at this location. ___________KPH
9. Would a change in this limit improve the safety of traffic movement. YES ▒ NO ▒
10. Suggested speed limit ______________________________

H. ENGINEERING CONDITIONS.

1. Road markings:
   Paint, clear ☐ Paint, indistinct ☐

   Reflective, clear ☐ Reflective, indistinct ☐

   Other (specify) ______

   Clear ☐ Indistinct ☐

   None ☐

2. Traffic signals:
   Working ☐ Not working ☐ Faulty ☐ Flashing ☐

   Confusing ☐ Inadequate ☐ None ☐

3. Road signs:
   Non-reflective, clear ☐ Non-reflective, indistinct ☐

   Reflective, clear ☐ Reflective, indistinct ☐

   Confusing ☐ Damaged ☐ Displaced ☐

   Inadequate ☐ None ☐

4. Road surface:
   Tarmac, high skid-resistant ☐ Tarmac standard ☐

   Tarmac smooth ☐ Tarmac slippery ☐ Chip/spray ☐

   Concrete ☐ Unpaved ☐

5. Condition of road surface:
   Excellent ☐ Good ☐ Rutted ☐ Pot-holed ☐

   Worn ☐ Severely damaged ☐ Contaminated ☐

6. Is the engineering of the road in any way hazardous to the passage of traffic. YES ☐ NO ☐

7. Specify ____

8. What improvements could be made to the engineering of the road ____

I. DESCRIPTION OF ACCIDENT.

Give a full description of the collision, stating such details as probable speed of each of the vehicles involved, direction of travel and speed of impact.

J. DIAGNOSIS OF CAUSE.

State what is in your opinion the PRIMARY CAUSE of this collision, and any other factors which may have contributed to the collision occurrence.

K. RECOMMENDED ACTION.

What action do you recommend should be taken to improve the safety of this spot.

L. COLLISION DIAGRAM.

Draw, as accurately as possible, a plan diagram of the collision site, including all roadside features,(lamp poles, traffic signals, roadsigns etc) and road markings. Mark the direction of travel of all vehicles/pedestrians, as well as the point/s of impact.

N

FULL NAMES OF INVESTIGATING OFFICIAL

DESIGNATION

....

DATE

APPENDIX B

SOME RECOMMENDED IMPROVEMENTS

SOME RECOMMENDED IMPROVEMENTS:

In this Appendix some ways in which hazardous locations can be improved in relation to the type of collision and the effect these improvements may have in reducing the number of collisions, are discussed.

The need for road alterations does not necessarily imply that the road design was initially below standard, although it may have become so owing to changing traffic or other conditions. In fact, re-examination of the road and traffic conditions is a continuous task and the duty of the engineer. Determining corrective measures can in some instances be relatively easy while in other much analysis and thought have to be applied.

The following recommendations for dealing with various collision types are only a general guide as each collision situation is unique, and in consequence no hard and fast rules can be made for its solution.

1 PEDESTRIAN COLLISIONS

The fact that almost fifty per cent of all road fatalities in South Africa are pedestrians makes the improvement of pedestrian facilities of the utmost importance.

The conditions under which pedestrian and pedal cyclist facilities should be provided, are set out in the CSIR publication TRH 17 "Geometric Design of Rural Roads".

Below are some of the suggested methods for reducing pedestrian collisions:

1.1 <u>Pedestrian refuges</u>

Pedestrian refuges have considerable safety value on carriageways that are over 13 metres wide, and their provision can often obviate the need for pedestrian subways. Refuges should be at least 1,5 metres wide (preferably 2m) and should only be built if the widths remaining to traffic are sufficient for two through traffic lanes. Refuges are a simple form of channelisation which allow pedestrians to cross one traffic stream at a time without to any great extent affecting the traffic capacity.

Research has shown that the risk to a pedestrian on a pedestrian crossing without a refuge is 50 per cent higher than on one with a refuge. It is estimated that the provision of a refuge will reduce the number of pedestrian collisions at a particular location by as much as 30 per cent.

1.2 Pedestrian crossing (controlled)

A further measure to consider is the provision of signal-controlled crossings. The signalling apparatus can be a separate installation for pedestrians, or incorporated into the traffic signal at a road junction. There are considerable disadvantages in providing pedestrian phases at very busy intersections. The reduction in time available for vehicular movements often necessitates substantial lengthening of the cycle time with the result that pedestrians do not wait for the period allotted to them and cross during the traffic phase.

When the number of pedestrians crossing a street between intersections exceeds 200 per hour in any four-hour period during a normal day and the vehicular traffic in both directions exceeds 400 vehicles per hour, the installation of traffic and pedestrian control signals is justifiable. The conditions which warrant the installation of pedestrian phases into existing signal-controlled intersections are given in Section 3.3.2 of the SA Road Traffic Signs Manual.

The expected effect of this type of provision is a reduction of 10 per cent in total collisions. Even though pedestrian safety is improved there is often an increase in vehicular collisions at such intersections.

1.3 Subways and footbridges

Pedestrian subways or footbridges provide the most satisfactory means of crossing roads and such measures should be considered, especially on fast roads where misjudgments of traffic gaps tend to occur, and on roads carrying high volumes of traffic. As there is often difficulty in ensuring full usage of the pedestrian facility, it is desirable to have a clear knowledge of pedestrian movements so that the bridge or subway is sited to cater for the maximum number of pedestrians. It is possible, with the use of guard fencing and the proper location of footpaths, to ensure that the time taken by pedestrians to use the facility is no longer than that for crossing on the surface.

Subways offer about half the rise and fall required by bridges and although subways can become very expensive in urban areas where the diversion of many services may be involved, they are generally to be preferred. To facilitate easy access to wheelchairs or prams it is desirable to provide ramps with a gradient of about 1 in 10.

If absolute use of the new facility is achieved then pedestrian collisions will of course be reduced by 100 per cent. Besides the savings in collision costs, bridges or subways result in the additional benefit of increased traffic capacity at intersections.

1.4 Sidewalks

Collisions to pedestrians can be reduced by providing sidewalks which encourage pedestrians not to walk in the road. These sidewalks should always be constructed where there is a concentration of pedestrians such as near shops, bus stops and routes to schools and places of employment. Justification for the construction of such sidewalks depends on the vehicle-pedestrian conflict, which is reflected in their volumes and the type of road in question. Table 1 is a guide to the limiting values for the provision of a sidewalk either on one side or on both sides of a road:

Table 1: Warrants for Sidewalks

Sidewalk	Average daily traffic (i.e average weekday) (ADT)	Pedestrian Flow (per day)	
		Road Design Speed or speed limit 60 to 80 km/h	Road Design Speed or speed limit 80 to 120 km/h
On one side	400 to 1 400 > 1 400	300 200	200 120
On both sides	700 to 1 400 > 1 400	1 000 600	600 400

In areas where pedestrian movements are likely to be heavy, attention must be paid to the capacity of the sidewalk which must be sufficient to prevent pedestrians from walking in the road. The capacity of open footpaths may be taken as 25 persons per minute per 0,6 metres width of pavement after deducting a 0,9 metre width in shopping areas and 0,45 metres elsewhere.

It is difficult to determine the effect on pedestrian collisions of providing footpaths, but as a guide, there should be a total elimination of collisions as far as pedestrians walking in the road is concerned.

1.5 Pedestrian Barriers

Pedestrian barriers can be used to prevent the indiscriminate crossing of major routes and also opposite exits from schools and recreation grounds to prevent children from running heedlessly into the road.

The overall effect on collisions is difficult to assess, but there should be at least a 75 per cent drop in the particular pedestrian collisions associated with children.

Note: The use of video cameras have proved extremely effective in identifying pedestrian and traffic movements during peak hours, especially at intersections, since these can be analysed later on a "freeze frame" basis.

2 PEDAL CYCLE COLLISIONS

On roads carrying between 20 and 70 pedal cyclists, travel in one direction during any one hour of the day, a Class 3 cycle lane (cycle lane on paved shoulder) should be provided. When the paved road shoulder is used as a cycle lane it becomes a traffic lane and should therefore be appropriately marked. If a hard gravel shoulder is provided next to the cycle lane, a cycle lane width of 1,2 metre would suffice, but for a soft shoulder or sloped drop-off a 1,5m wide cycle lane is recommended.

Where these tracks cross side streets care must be taken with the design or there is a danger of increasing cyclist collisions. If there is insufficient room to provide a separate cycle track consideration should be given to the widening of the nearside traffic lanes to 4,5 metres and using an edge marking to provide a separate lane for cyclists.

This type of facility can reduce pedal cycle collisions by up to 30 per cent.

3 SINGLE VEHICLE COLLISIONS

There are a number of ways by which single vehicle collisions can be reduced and some of these are discussed below.

Discussion of road signing and marking will be left to the section on general improvements.

3.1 Resurfacing

Skidding is often one of the factors which contributes to single vehicle collisions on rural roads and necessitates an investigation into the condition of the road surface. The resurfacing of curves and lengths of road will be considered now and resurfacing at urban intersection approaches will be dealt with under the heading Two Vehicle Collisions.

As it is impossible to decide how slippery a road is by inspection, use has to be made of mechanical aids. For hazardous spots it is recommended that the British Road

Research Laboratory *Portable Skid Resistance Tester* (also known as the "Pendulum Tester") be used. This apparatus provides a simple, but reliable routine method of checking the skid resistance of road surfaces. The normal test procedure is to take readings at five points in the nearside wheeltrack, which is about 0,45 metre from the road edge, and to space these at between 5 to 10 metre intervals along the road under test. The mean of these readings gives a representative value of skid resistance, which is defined as approximately 100 times the coefficient of friction.

The procedure for measuring the frictional properties of a road surface using the Pendulum Tester is described in the CSIR publication Draft TMH6 "Special methods for testing roads[24]".

If knowledge is required of the skid resistance over a long section of road or on a high-speed road then it is recommended that the measurements be taken with some mobile apparatus, such as the single-wheel brake-force trailer or a Sideway Force Coefficient Routine Investigation Machine (SCRIM).

From experiments carried out overseas it has been found that there is a very large increase in the risk of skidding when the skid resistance value (SRV), as measured with a Portable Skid Resistance (Pendulum) Tester is less than 45, or if a Sideway Force Coefficient Routine Investigation Machine (SCRIM) is used, the sideway force coefficient (SFC) is less than 0,40. In Table 2 certain minimum values of skid resistance as measured by these two methods are given for various road categories.

Table 2: Suggested minimum values of Skid Resistance

Category of site	Type of site		Minimum Skid Resistance		
			SCRIM		Pendulum
			S.F.C.	Test Speed (km/h)	S.R.V.
A	Most difficult sites:				
	(i)	Traffic circles			
	(ii)	Bends with radius less than 150m on unrestricted roads			
	(iii)	Gradients of 5% (1 in 20) or steeper or longer than 100m	0,55	50	65
	(iv)	Approaches to traffic signals on unrestricted roads			
B	Average sites:				
	(i)	Freeways and other high speed roads i.e. speeds in excess of 95 km/h	0,50	50	
	(ii)	National roads and heavily trafficked urban roads (i.e. greater than 2 000 vehicles per day)	0,45 0,50	80 50	55
C	Other sites:				
		Straight roads with easy gradients and curves without intersections and free from any feature such as mixed traffic especially liable to create conditions of emergency	0,40	50	45

For sites falling under category A and B where the speed of traffic is high i.e. in excess of 95 km/h, an additional requirement is an absolute minimum "texture depth" of 0,65 mm, with a preferable minimum of 1,0 mm. Details of the measurement of texture depth as well as the use of the Portable Skid-Resistance Tester are given in RRL Note No. 27[4].

Details of resurfacing criteria are given in the CSIR publication Draft TRH3 "Surfacing seals for rural and urban roads[27]".

The resurfacing of slippery curves has reduced collisions on some roads by as much as 80 per cent whilst collisions on straight sections of some rural roads have been reduced by up to 40 per cent by surface treatments.

3.2 Realignment of road

In certain cases the alignment of a road is a contributory cause of collisions. The realignment required may be horizontal, vertical or a combination of the two, but in most cases the remedy will be more costly than other alternatives.

On some roads the realignment of horizontal curves has brought about a decrease of as much as 70 per cent in the number of collisions and the improvement in the superelevation of a curve has reduced collisions in some rural areas by up to 60 per cent. The use of barrier lines to overcome vertical alignment problems has also reduced collisions by up to 60 per cent.

3.3 Bridge widening

Often in rural areas the carriageway on either side of a bridge has been widened to cater for modern requirements whilst the bridge itself has been left as it was, with the result that the parapets become obstructions within the carriageway. The problem can be overcome in two ways: (a) either the bridge can be widened, an expensive procedure if the bridge is of any size, or (b) the parapets can be well delineated; this although less costly, does not entirely remove the hazard.

The widening of a bridge can bring about a reduction of up to 70 per cent in the number of collisions, whilst reductions of up to 40 per cent have been recorded as a result of improvements in the delineation of a bridge.

3.4 Guardrails

It has been found from research carried out in the USA that the following features warrant the provision of guardrails: embankments, roadside obstacles, narrow medians and shoulders.

a) Embankments: Research has shown that the need for a guardrail along an embankment can be determined from a simple diagram (Figure 1). The curve approximately represents the line of equal collision severity for different combinations of embankment heights and slopes. A reduction in collisions of up to 30 per cent has been experienced where guardrails have been used on embankments.

b) Roadside obstacles: It is recommended that if, for practical or economic reasons, a 10 metre zone, measured from the edge of the pavement, cannot be cleared of roadside obstacles, a guardrail may be warranted. The reason that 10 metres is chosen as the zone width is that 80 per cent of off-the-road collisions occur within 10 metres of the pavement edge. Reductions in collisions of the order of 10 per cent can be expected if the roadside is cleared of all obstructions.

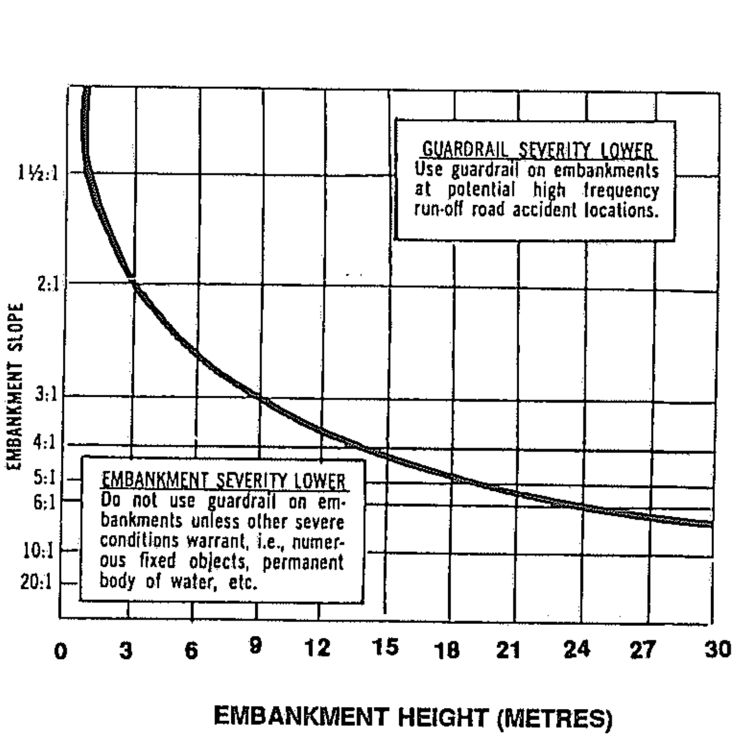


Figure 1: Severity comparison of embankments for guardrail

Source: *"Objective criteria for guardrail installations" - J.C Glennon & T C Tamburri HighwayResearch Record 174, 1967, p. 192.*
(By kind permission of the authors)

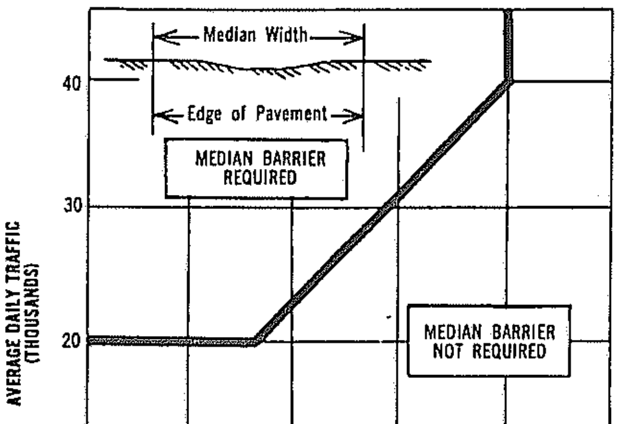


Figure 2: Median barrier requirements

Source: *"Location, selection and maintenance of highway guardrails and median barriers" - N C H R P Report 54, 1968, p. 5.*
(By kind permission of the authors)

c) Median barriers: On heavily-travelled multi-lane highways with narrow traversable medians the probability of a vehicle crossing the median into the opposing traffic stream tends to be high. Studies, into the effectiveness of a continuous median barrier,have shown that although the installation of a median barrier results in a decrease in the number of major and fatal collisions, there is an increase in the total number of reported collisions. The extent of these changes in collision types and rates varies with traffic volumes, median width and barrier characteristics. A possible warrant for median barriers is given in Figure 2. Note that the median barriers are NOT recommended for highways with traffic volumes below 20 000 VPD or medians wider than 12 metres.

3.5 Shoulder improvements

In rural areas the stabilisation of the road shoulder can reduce the number of collisions caused by a vehicle running off the road. If the shoulder is stabilised then the driver's area of recovery after an initial error is significantly increased. This type of improvement can bring about as much as a 30 per cent reduction in the number of collisions.

Another shoulder improvement is that of widening to a minimum width of 3 metres so that the largest vehicles can be accommodated. Many collisions have been the result of vehicles that are parked on the shoulder, but which protrude into the carriageway. The reduction in collisions due to shoulder widening is of the order of 5 per cent.

4 TWO (OR MORE) VEHICLE COLLISIONS

Although most of the recommendations that apply to single-vehicle collisions also apply to two-vehicle collisions, there are also certain remedies that apply only to collisions involving two vehicles. Most of these remedies are in connection with the improvement of intersections where a large percentage of collisions involving two vehicles occur. The traffic engineering techniques that can be used to assist in the reduction of two vehicle collisions are discussed below.

4.1 Declaration of priority

It is essential that the driver is given guidance as to which is the major road at an uncontrolled intersection; this is especially necessary in urban areas where priorities are less obvious. There are two main types of priority control signs that can be used for this purpose; the yield sign and stop sign. Details of the conditions warranting the use of these signs are given in Section 1.2.2 and 1.2.5 of the SA Road Traffic Signs Manual[24].

Conditions which warrant the installation of a four-way stop sign are:

a) the interim period between the time when traffic control signals are found to be warranted and their actual installation;

b) where there have been five or more collisions in a 12-month period which might have been eliminated had there been a four-way stop installation;

c) where the traffic volume entering the intersection from all approaches exceeds an average rate of 500 vehicles per hour for a period of 8 hours;

d) where combined vehicular and pedestrian volume from the minor leg of the intersection exceeds 200 units per hour during the same 8-hour period as in (c) and the delay to minor road vehicles is at least 30 seconds per vehicle during the hour of maximum traffic;

e) when the 85-percentile speed of the major road exceeds 65 km/h and the minimum vehicular volume warrant is reduced to 70 per cent of the figures given in (c) and (d).

Studies indicate that four-way stops work to the best advantage when the flows on the two cross roads are approximately equal.

The use of priority signing systems can reduce collisions at intersections by up to 50 per cent.

4.2 Installation and improvement of traffic control signals

Although the installation of traffic control signals where they have not been used previously is usually based on traffic flow data, collision data can also be used at sites where delays on the minor road are so long that drivers begin to take advantage of very small gaps in the traffic stream at yield or stop signs. The conditions warranting the installation of traffic signals because of the incidence of collisions are given in Section 3.2.9 of the SA Road Traffic Signs Manual[24].

Where possible the aim should be four signal heads for each intersection approach, with additional overhead lights at very busy sites. It is essential that large lenses be used to make the signals clearly visible and that hoods be provided above the lens to overcome the effect of strong sunlight which reduces the luminosity of the signals. Backing boards are sometimes required for the signal heads particularly where there is a tendency for the lights to merge into a background of neon advertising signs, or sunrise or sunset, etc. The colour of these backing boards should be black. Details of traffic signal-head locations are given in Section 3.2.16 of the SA Road Traffic Signs Manual[24].

The installation of new traffic control signals often has the effect of reducing injury collisions by as much as 50 per cent. Improvements to existing installations in the form of additional lights, larger lenses and backing boards have been found to reduce collisions by up to 30 per cent.

4.3 Traffic-control signal cycle times

The control of traffic movement depends on the correct setting of signal cycle times. This is important if collision risk is to be kept to a minimum at intersections. It is recommended that provisions be made for the clearance of the intersection by having the cycle set so that there is at least five seconds of "inter-green time" i.e. the time between the end of one green phase and the start of the next in a two phase system. The use of an all-red period of one or two seconds duration has been found to be very effective in reducing collisions, especially right angle collisions.

At an intersection where there is a heavy right-turning movement from one approach it may be necessary to introduce either an advanced phase or an extended green phase. Details of how the signal cycle can be set to produce these facilities together with phasing in general are given in Sections 3.2.11 - 3.2.13 of the SA Road Traffic Signs Manual.

The use of these facilities can bring about a reduction of as much as 40 per cent in the collisions at traffic-signal controlled intersections.

4.4 Right-turn facilities

Other than the traffic-signal phasing techniques mentioned above there are other facilities for dealing with heavy right-turning movements at intersections. Where the road is of sufficient width (9 metres) the provision of a lane exclusively for right-turning traffic can be made. Both drivers who do right-turns and those that drive straight-ahead should however be made fully aware of the function of this facility by the use of road markings, including lane lines and arrow heads, and adequate advance warning signs.

Where the lay-out of the intersection is not straightforward, channelisation can usually be effected by traffic islands or less frequently, white lines. A thorough knowledge of the collision patterns and traffic movements is required before the planning of a channelisation scheme is attempted.

One method of overcoming the problem of right-turning traffic is its prohibition; however care must be taken that the problem is not just passed to the next intersection. It may well be that by banning right-turns at one intersection, they can be dealt with more adequately at the next because there is extra road space etc.

Separate lanes for right-turning vehicles and channelisation schemes have reduced collisions by as much as 20 per cent whilst the prohibition of right-turning vehicles has reduced the number of intersection collisions by as much as 40 per cent.

4.5 Intersection lay-out improvements (rural)

One simple method of intersection improvement in rural areas is to increase the visibility of the minor road driver by the acquisition of land and the realignment of fence lines. The aim should be to create a triangular piece of roadside measuring 10 metres x 150 metres devoid of all view obstructions, on both sides of the minor road.

A more expensive treatment is the staggering of cross roads, which often entails substantial carriageway reconstruction. There is often argument as to which way to stagger the intersection but it is recommended that drivers crossing the main road should turn right from the minor road and then left into the other leg of the minor road. This method removes the dangerous manoeuvre of a right-turn having to be made from the major road, and which might entail not only the realignment of the minor road but also the widening of the major road. If the volume of traffic is sufficient the construction of a traffic circle or mini-circle should be considered, but it is important that such a feature in a rural area should be well illuminated.

Some benefit can be gained by the construction of acceleration and deceleration lanes, although research in the U.K. has shown that acceleration lanes can be a source of collisions owing to their misuse by drivers.

Visibility improvements at a rural intersection have been found to reduce injury collisions by as much as 30 per cent. The staggering of a cross-road can bring about a 60 per cent reduction in collisions whilst the traffic circle improvement can reduce injury collisions by up to 50 per cent. The provision of acceleration and deceleration lanes at intersections can reduce collisions by up to 10 per cent.

4.6 Resurfacing at intersection approaches (urban)

As resurfacing criteria for curves and road sections were dealt with earlier, the question of approaches to intersections in urban areas is discussed in this Section.

Approaches to traffic signals, traffic circles and pedestrian crossings in urban areas are subject to much wear from the braking action of vehicles. It is therefore important that such sites should be surfaced with a material that not only has an initial high minimum skid resistance (65 measured by RRL portable skid tester), but that this high value should be maintained over a long period of time.

The use of high skid resistance road surfacing material can bring about a reduction in the number of collisions associated with intersections of the order of 60 per cent.

4.7 Widening of carriageway

The optimum lane width for both capacity and minimum collision occurrence criteria is 3,7 metres or a single carriageway width of 7,4 metres. There are still many roads where the carriageway is only 5,5 metres wide. Therefore, if there is a collision record on such a road, widening should be considered.

The expected effect of widening a single carriageway road from 5,5 to 7,4 metres would be a reduction in collisions of as much as 30 per cent. A reduction of this order can also be achieved by the construction of a dual carriageway over any section of road that is heavily overloaded.

5 GENERAL IMPROVEMENTS

The possibility of collisions occurring can be reduced by improving three general facilities, namely, speed limits, road signs and road markings.

5.1 Speed limits

The criteria for safety speed regulations are based upon the need to provide the driver with adequate time to reduce speed, to make decisions and to react when he encounters hazards. It is difficult to lay down definite warrants for the maximum speed at any point on the road network but the following factors should be reviewed when ascertaining the correct speed limit:

(a) 85th Percentile speed of traffic;

(b) Collision rat;

(c) Stopping sight distance;

(d) Pedestrians and cyclists;

(e) Parking and loading manoeuvres;

(f) Access to bounding properties;

(g) Intersections;

(h) Width of road without central median;

(i) Clear roadside area.

Guidelines for setting speed limits are given in the CSIR publication Technical Report RV/19, and general regulations for the design, setting and location of speed limit signs are given in Section 1.2.17 of the SA Road Traffic Signs Manual.

Overseas research has shown that the use of speed limits in built-up areas can reduce collisions by as much as 25 per cent.

5.2 Road signing

The regulations for road signs are classified into three groups namely: Regulatory (R series), Danger Warning (W series) and Information (G series). These are very well covered in the new SA Road Traffic Signs Manual and there is no point in repeating the information in this manual.

It is probably worth emphasizing some aspects of direction signing which are part of the Information series of signs. A collision is often the result of a person changing lane suddenly because there was no prior warning that a change of route would be required at the intersection he was approaching. Continuity of place names on direction signs is essential if hesitancy, and thus collision vulnerability, on the part of the driver is to be reduced at intersections. Often the situation arises that having followed a certain place name for some distance, on arrival at the next intersection that place name is not mentioned on the direction signs.

The installation or improvement of well-designed and correctly sited signs can reduce collisions by up to 30 per cent.

5.3 Road markings

Part 2 of the SA Road Traffic Signs Manual adequately covers the subject of road traffic markings. Some aspects to which particular attention should be paid are: broad stop lines, lane and centre lines, direction arrows, and, in rural areas, edge markings, all of which assist the driver to maintain his correct position on the road, especially at night. Consideration should be given to the use of reflectors and reflectorised paints on busy roads where there is a likelihood of dazzle from oncoming traffic.

Experience has shown that well-maintained road markings can help to reduce road collisions by as much as 15 per cent.

6 NIGHT TIME COLLISIONS

An adequate level of street lighting has been shown to have an effect on urban collisions, especially those which involve pedestrians. The lighting of streets is a specialized subject, so much so that many large authorities appoint a street lighting engineer. Such a person should be consulted, otherwise, help should be sought from the local electrical engineer. The best reference to street lighting standards is SABS C 098-1967 Code of Practice for Public Lighting, which gives recommendations for various types of road.

Street lighting installations at intersections have been found to reduce night time collisions by as much as 40 per cent.

7 OTHER COLLISIONS

7.1 Animal collisions

In rural areas where there is a high occurrence of collisions in which animals are involved, it has been found that the erection of roadside fencing will reduce these collisions by up to 90 per cent. The fences should be erected at least 2 metres back from the road edge.

7.2 Train collisions

Because of the usually disastrous consequences of collisions which involve trains it is important that rail/road level crossings are well signposted. Also it is essential that the motorist when nearing a crossing should have a clear view of an approaching train. Two distances, one measured on the railway and the other on the highway define the visibility triangle, and Table 3 provides distances for defining the visibility triangle for selected highway vehicle and train speeds. It is recommended that the visibility triangles in each quadrant of the crossing be clear of sight obstructions.

Table 3: Required visibility triangle distances (metres) for combinations of highway and train vehicle speeds

Train Speed Km/h	Highway Speed in km/h					
	30	50	60	80	100	120
	Distance along railway from crossing (metres)					
30	50	54	55	60	69	80
50	83	90	92	100	115	134
60	100	108	110	120	138	160
80	133	144	147	160	184	214
100	167	180	183	200	230	267
120	200	216	220	240	276	320
140	234	252	256	280	322	273
	Distance along highway from crossing (metres)					
	30	70	90	140	210	300

Note: Distance along the highway is taken from the minimum stopping distance

8 SUMMARY

The recommended improvements for reducing the various collision types which have been discussed above are summarised in Table 4 together with their expected effect in reducing the number of collisions.

Table 4: List of improvements to hazardous locations and their expected effect

	TYPE OF IMPROVEMENT	APPROX. PERCENTAGE
	PEDESTRIAN COLLISIONS	
1	**Pedestrian refuge**	30
2	**Pedestrian crossing (uncontrolled)**	30
3	**Pedestrian crossing (controlled)**	10
4	**Subways and bridges**	(Ped only) 100
5	**Sidewalks**	(Ped only) 100
6	**Pedestrian barrier**	(Ped only) 75
	PEDAL CYCLE COLLISIONS	
1	**Construction of cycle tracks**	(Ped cycle only) 30
	SINGLE VEHICLE COLLISIONS	
1	**Resurfacing**	
	(a) Slippery curves	80
	(b) Road sections	40
2	**Realignment of road**	
	(a) Horizontal curves	70
	(b) Superelevation improvement	60
	(c) Barrier lines on vertical curves	60
3	**Bridge widening etc.**	
	(a) Bridge widening	70
	(b) Improved bridge delineation	40
4	**Guard rails**	
	(a) Embankments	30
	(b) Roadside obstacles	10
5	**Shoulder improvements**	
	(a) Stabilisation	30
	(b) Widening	5
	TWO (OR MORE) VEHICLE COLLISIONS	
1	**Declaration of priority**	50
2	**Traffic control signals**	
	(a) Installation	(Injury col) 50
	(b) Improvements	30

	TYPE OF IMPROVEMENT (Two or more vehicle collisions: continued)	APPROX. PERCENTAGE REDUCTION (%)
3	**Signal Cycle Times**	40
4	**Right-turning facilities**	
	(a) Separate lanes	30
	(b) Channelisation	20
	(c) Banning	40
5	**Intersection improvements**	
	(a) Visibility	(Injury col) 30
	(b) Staggering of cross-roads	60
	(c) Traffic circle construction	(Injury col) 50
	(d) Acceleration and deceleration lanes	10
6	**Resurfacing at intersection approaches**	60
7	**Widening of carriageway**	30
	GENERAL IMPROVEMENTS	
1	**Speed limits**	25
2	**Road signing**	30
3	**Road markings**	15
	NIGHT-TIME COLLISIONS	
1	**Street lighting at intersections**	40 (Night-time col)
	OTHER COLLISIONS	
1	**Animal Fences**	(Animal col) 90

NOTE: The figures given in the above table are from United Kingdom statistics. Further research is needed to substantiate these figres for the RSA context.

To conclude this section on recommended improvements, the following pages provide a list of collision patterns, their probable causes and general countermeasures.

GENERAL COUNTERMEASURES FOR COLLISION PATTERNS AND THEIR PROBABLE CAUSES		
Collision-pattern	**Probable cause**	**General Countermeasures**
Right-angle collisions at unsignalised intersections	Restricted sight distance	Remove sight obstructions Restrict parking near corners Install stop signs (see S.A.R.T.S.M.) Install/Improve street lighting Reduce speed limit on approaches * Install signals (see S.A.R.T.S.M) Install yield signs (see S.A.R.T.S.M) Channelise intersection
	Large total intersection volume	Install signals (see S.A.R.T.S.M)
	High approach speed	Reduce speed limit on approaches
Right-angle collisions at signalised intersections (Continued)	Poor visibility of signals (Continued)	Install advance warning devices Install 300mm signal lenses Install overhead signals Install visors Install backing boards Improve location of signal head Add additional signal heads Reduce speed limit on approaches
* Spot speed study should be conducted to justify speed limit reduction		

(2)

Collision-pattern	Probable cause	General Countermeasures
	Inadequate signal timing	Provide all-red clearance phases/increase all-red time Install signal actuation Retime signals Provide progression through a set of signalized intersections (synchronize signal sets) Introduce right turn phase
	Proceeding against the red	Enforcement or increase length of all-red
Rear-end collisions at unsignalised intersections	Pedestrian crossing	Install/improve signing or marking of pedestrian crosswalks Relocate crosswalk
	Driver not aware of intersection	Install/improve warning signs
	Slippery surface	Overlay pavement Provide adequate drainage Reduce speed limit on approaches * Provide "slippery when wet" signs
	Large numbers of turning vehicles	Create left- or right-turn lanes Prohibit turns Increase curb radii

* Spot speed study should be conducted to justify speed limit reduction

(3)

Collision-pattern	Probable cause	General Countermeasures
Rear-end collisions at signalised intersections	Poor visibility of signals	Install/improve advance warning signs Install overhead signals Install 300mm signal lenses Install visors Install backing boards Relocate signals Add additional signal heads Remove obstacles Reduce speed limits on approaches *
	High approach speeds	Reduce speed limits on approaches *
	Inadequate signal timing	Retime signals Provide progression through a set of signalised intersections
	Pedestrian crossings	Install/improve signing or marking of pedestrian crosswalks Provide pedestrian phase
	Slippery surface	Overlay pavement Provide adequate drainage Reduce speed limit on approaches * Provide "slippery when wet" signs

* Spot speed study should be conducted to justify speed limit reduction

(4)

Collision-pattern	Probable cause	General Countermeasures
	Unwarranted signals	Remove signals
	Large Turning volumes	Create left- or right-turn lanes Prohibit turns Increase curb radii
Pedestrian collisions at intersections	Restricted sight distance	Remove sight obstructions Install pedestrian crossings Improve/install pedestrian crossing signs
	Inadequate protection for pedestrians	Add pedestrian refuge islands
	Inadequate signals	Install pedestrian signals
	Inadequate signal phasing	Add pedestrian phase Change timing of pedestrian phase
	School crossing area	Use school crossing guards (Scholar Patrol)
Pedestrian collisions between intersections	Driver has inadequate warning of frequent mid-block crossings	Prohibit parking Install warning signs Lower speed limit Install pedestrian barriers Improve signal visibility
	Pedestrians walking on roadway	Install sidewalks
	Long distance to nearest crosswalk	Install pedestrian crosswalk Install pedestrian actuated signals

* Spot speed study should be conducted to justify speed limit reduction

(5)

Collision-pattern	Probable cause	General Countermeasures
Right-turn collisions at intersections	Large volume of right turns	Provide right-turn signal phases Prohibit right turns Reroute right-turn traffic Channelise intersection Install stop signs
	Restricted sight distance	Remove obstacles Install warning signs Reduce speed limit on approaches
	High approach speeds	Reduce speed limit on approaches
Left-turn collisions at intersections	Short turning radii	Increase curb radii
Fixed-object collisions	Objects near travelled way	Remove obstacles near roadway Install barrier curbing Install breakaway feature to light poles, signposts, etc. Protect objects with guardrail
	High speeds	Protect objects with guardrail
Fixed-object collisions and/or vehicles running off roadway	Slippery pavement	Overlay existing pavement Provide adequate drainage Reduce speed limit * Provide "slippery when wet" signs
* Spot speed study should be conducted to justify speed limit reduction		

(6)

Collision-pattern	Probable cause	General Countermeasures
	Roadway design inadequate for traffic conditions	Widen lanes Relocate islands Adjust camber
	Poor delineation	Improve/install pavement markings Install roadside delineators Install advance warning signs (e.g curves)
Sideswipe collisions between vehicles travelling in opposite directions or head-on collisions	Roadway design inadequate for traffic conditions	Install/improve pavement markings Channelise intersections Remove constrictions such as parked vehicles Install median divider Widen lanes
Collisions between vehicles travelling in same direction such as sideswipe, turning or lane changing	Roadway design inadequate for traffic conditions	Widen lanes Channelise intersections Provide turning bays Install/improve pavement lane lines Remove parking Reduce speed limit *
Collision with parked cars or cars being parked	Large parking turnovers	Prohibit parking Change from angle to parallel parking Peak "no stopping" restrictions Create off-street parking Reduce speed limit

* Spot speed study should be conducted to justify speed limit reduction

(7)

Collision-pattern	Probable cause	General Countermeasures
	Roadway design inadequate for present conditions	Widen lanes Change from angle to parallel parking Prohibit parking
Night collisions	Poor visibility	Install/improve street lighting Install/improve delineation markings Install/improve warning signs
Wet pavement collisions	Slippery pavement	Overlay existing pavement Provide adequate drainage Reduce speed limit * Provide "slippery when wet" signs
Collisions at railroad crossings	Restricted sight distance	Remove sight obstructions Install train actuated signals Install stop signs Install gates Install advance warning signs

* Spot speed study should be conducted to justify speed limit reduction

APPENDIX C:

COLLISION COSTS AS DETERMINED BY THE CSIR

COLLISION COSTS

Severity of collision	Average costs per collision
Fatal	R323 820
Serious injury	R 87 884
Slight injury	R 28 807
Damage only	R 8 714

Calculation of average accident costs in accordance with CB-roads, by Prof P W Jordaan.

Note: Assuming an average inflation rate of 14,53 % over the six year period since 1987, the values in the above table have been calculated to the 1987 values by the application of a factor of 2,2569 (= $1,1453^6$).

APPENDIX D:

SOME TYPICAL EXAMPLES OF THE UNIT COST OF ROAD SAFETY IMPROVEMENTS

SOME TYPICAL EXAMPLES OF THE UNIT COST OF ROAD SAFETY IMPROVEMENTS (COSTS AS AT MARCH 1991)

	Type of Improvement	Unit cost (Rand)	Unit
1	Pedestrian refuge (1.5 metre wide)	180	m
2	Pedestrian crossing (uncontrolled)	15	m^2
3	Pedestrian crossing (signal controlled)	25 000	set
4	Bridge (2 metres wide)	4 000	m
5	Subway (3 metres wide)	2 700	m
6	Footpath (2 metres wide)	80	m
7	Guard fence	80	m
8	Construction of cycle track (3 metres wide)	130	m
9	Direction road signs	325	m^2
10	Flashing road sign	3 000	each
11	Road marking	2	m
12	Resurfacing: Single seal	5	m^2
13	Resurfacing: Double seal	10	m^2
14	Realignment of road	2 00	m^2
15	Bridge widening	2 000	m^2
16	Guardrail	75	m
17	Shoulder improvements	150	m
18	Stop sign (includes "Yield" sign)	360	set
19	New traffic control signals	350 000	set
20	Channelisation	120	m^2
21	Visibility improvement at junction	30	m^2
22	Staggering of cross-road	200	m^2
23	Provision of acceleration and deceleration lanes	200	m^2
24	Widening carriageway from 5,5m to 7,3m	600	m
25	Widening to dual carriageway	1 600	m
26	Provision of street lighting	2 400	pole

APPENDIX E:

RECOVERY FACTOR TO CONVERT CAPITAL COST TO ANNUAL COST

RECOVERY FACTOR TO CONVERT CAPITAL COST TO ANNUAL COST

Service life of improvement in years	Recovery Factor for Various Interest Rates										
	5%	6%	7%	8%	9%	10%	12%	15%	17%	20%	25%
1	1,05	1,06	1,07	1,08	1,09	1,10	1,12	1,15	1,17	1,20	1,25
2	0,54	0,55	0,55	0,56	0,57	0,58	0,59	0,62	0,63	0,65	0,69
3	0,37	0,37	0,38	0,39	0,40	0,40	0,42	0,44	0,45	0,47	0,51
4	0,28	0,29	0,30	0,30	0,31	0,32	0,33	0,35	0,36	0,39	0,42
5	0,23	0,24	0,24	0,25	0,25	0,26	0,28	0,30	0,31	0,33	0,37
10	0,13	0,14	0,14	0,15	0,16	0,16	0,18	0,20	0,21	0,24	0,28
15	0,10	0,10	0,11	0,12	0,12	0,13	0,15	0,17	0,19	0,21	0,26
20	0,08	0,09	0,09	0,09	0,11	0,12	0,13	0,16	0,18	0,21	0,25
25	0,07	0,08	0,09	0,09	0,10	0,11	0,13	0,15	0,17	0,20	0,25
30	0,07	0,07	0,08	0,09	0,10	0,11	0,12	0,15	0,17	0,20	0,25

APPENDIX F:

EXAMPLE: CALCULATIONS REGARDING THE ANALYSIS OF A HAZARDOUS LOCATION

EXAMPLE: CALCULATIONS REGARDING THE ANALYSIS OF A HAZARDOUS LOCATION

To illustrate the procedure required in analysing a hazardous location, an example of a four-way intersection controlled by traffic control signals has been prepared.

IDENTIFICATION OF COLLISION SITES

Assume the following list of the collision sites in a certain area has been compiled. The **number of collision occurrences** at each site has been used as criterion of severity.

List of collision sites:

Location:	Number of collisions over a two year period:
Site A	51
Site B	49
Site C	46
Site D	31
Site E	16
Site F	9
Site G	9
Site H	7
Site I	7
Site J	6
Site K	3
Site L	2
Site M	1
Site N	1

LISTING OF LOCATIONS ACCORDING TO EAN

The local authority concerned decides to consider the first ten sites on this list for possible classification as hazardous locations.

For each of these sites the EAN (equivalent accident number) is being calculated and a new priority list in order of the highest EAN to the lowest is drawn up:

List of ten worst locations according to EAN:

Location:	EAN
Site C	110
Site A	98
Site D	87
Site B	85
Site E	37
Site G	21
Site F	15
Site H	11
Site J	8
Site I	7

The local authority now decides to classify the first four sites as hazardous locations and to investigate them more thoroughly.

The calculations with regard to the site at the top of the list, Site C, will be shown.

The EAN of 110 for this site in the above list, was calculated as follows:

Severity of collision:	Weighting according to type of collision:		Number of collisions over period under consideration:		
Fatal	12	X	4	=	48
Injury	3	X	10	=	30
Damage only	1	X	32	=	32
			Total	**=**	**110**

INVESTIGATION OF HAZARDOUS LOCATION

An examination of the collision diagram and collision summary (see Figure 1, page F-8) showed that:-

i) Of the 46 collisions, 17 involved rear-end collisions, which were equally spread between the east, west and south approaches;

ii) Of the 46 collisions, 12 involved collisions between right-turning and straight-ahead vehicles, half of which involved turning right from west to south;

iii) Of the 46 collisions, four involved right-angle collisions;

iv) None of these collisions involved skidding on wet roads;

v) Less than one third (15 of the 46) of the collisions occurred during the hours of darkness. It therefore appears that there is no particular need for improved street lighting;

vi) There were no pedestrian collisions.

By observing the traffic at the actual site the significance of some of the collision data may become evident. There are essentially two methods of carrying out field observations namely, as a vehicle operator and secondly, as an observer on foot at various vantage points in or near the intersection.

Using a combination of these two methods at various times of the day the following points were observed:

i) Because the main road is a dual-carriageway and therefore average vehicle speeds are high, it is considered that the rear-end-collisions on the east and west legs of the intersection could be due, in part, to the fact that there is in effect only one signal head at the entry to the intersection because the other signal is not located on the central reservation but far over on the righthand side;

ii) It was observed on approaching the intersection from the south that the signal head on the near side is partly hidden by trees and only becomes visible when the driver is close to the intersection. The other signal head governing this approach is in the north-east corner of the intersection and has a background of advertising lighting which makes visibility difficult during the hours of darkness;

iii) There is a heavy turning movement from west to south during the evening peak period and drivers, because of long delays accept short gaps;

iv) There is an inter-green period of four seconds. This is the period between the end of one green phase and the start of the next. Some drivers travelling in a north/south direction i.e. across the junction, sometimes experienced difficulty in clearing the junction in this time although generally it appeared to be adequate.

RECOMMENDED IMPROVEMENTS

These findings and a study of traffic volume, including turning movements, signal-cycle times and the approach speed of vehicles lead to the conclusion that the following remedial actions are needed to improve the safety of the intersection:

i) The rear-end collisions can be reduced by additional signal heads in the median islands. The installation of an additional south-facing robot head in the south-west corner of the intersection and the cutting back of the trees in line with the west side of the southern leg, will allow south-north traffic a better view of the signal on that side of the road;

ii) Collisions with right-turning vehicles from west to south can be reduced by extending the green phase;

iii) Right-angle collisions can be reduced by the introduction of an all-red period of two seconds.

ESTABLISHING OF BENEFIT/COST RATIO FOR RECOMMENDED IMPROVEMENTS

Determine the collision costs at the site by multiplying the number of collisions with the unit costs of these collisions. (See Appendix C).

Severity of collision	Unit costs of collision		Number of collisions over period under consideration		Collision cost
Fatal	R 323 820	X	4	=	R1 295 280
Serious injury	R 87 884	X	3	=	R 263 652
Slight injury	R 28 807	X	7	=	R 201 649
Damage only	R 8 714	X	32	=	R 278 848
			Total	=	R 2 039 429

The total collision costs at this site over a two year period is in the order of R2 039 400, therefore the annual collision costs is about R1 019 700.

As a result of the planned remedial measures, the collision rate is expected to drop in the order of 30% (see Appendix B, Table 4). Therefore the annual benefit is expected to be 30% of R1 019 700; i.e:

R1 019 700 (30/100) = R305 910

Suppose the initial capital cost of these improvements is being calculated at R32 500 (Appendix D gives approximate costs of typical remedial measures), and the annual maintenance cost at R6 000. The total annual cost of the improvement can now be calculated by converting the initial capital cost into an annual cost by multiplying it by a capital recovery factor (see Appendix E), and adding this to the annual maintenance cost.

If the service life of this improvement is taken as ten years and an interest rate of 15% is used, the recovery factor is 0,20.

Therefore the annual cost of these improvements is:

(R32 500 X 0,20) + (R6 000) = R12 500

The ratio of benefits to costs is calculated by dividing the total annual benefits by the total annual costs:

B/C ratio = R305 910/R12 500:1
= 24:1

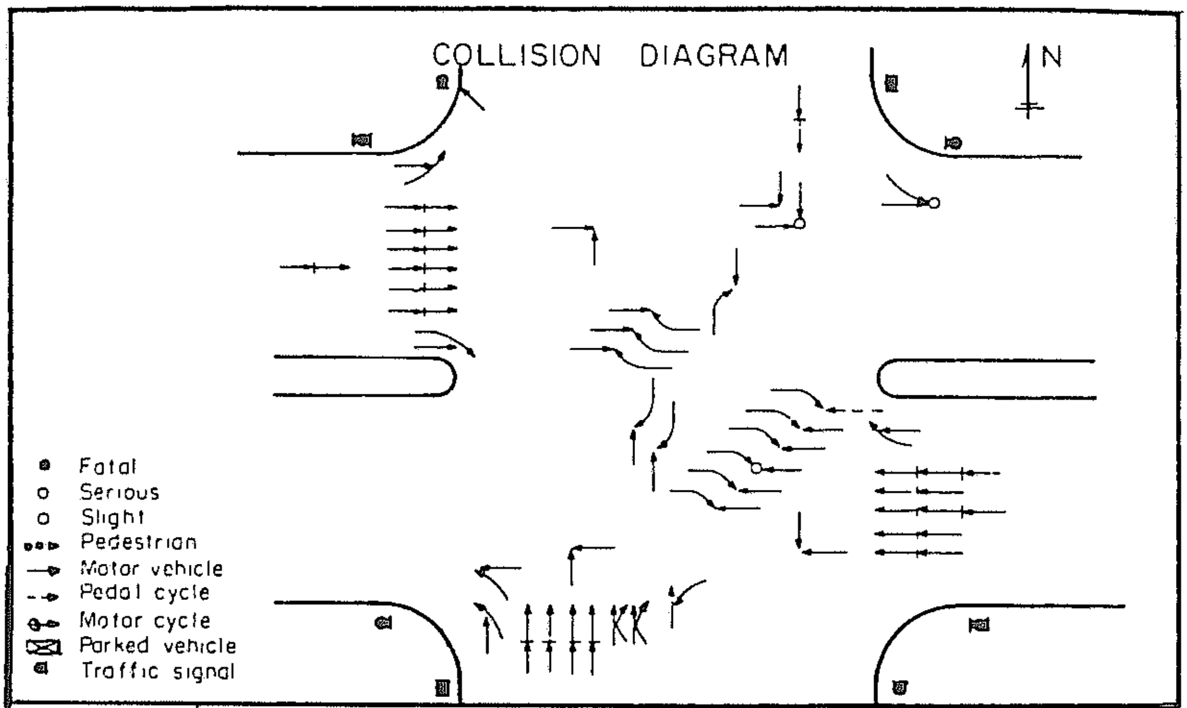
If alternative remedial measures were applicable, the improvement showing the biggest B/C ratio should be selected for implementation.

These results have to be compared with all the other hazardous sites which have been subjected to the same cost effectiveness study.

FOLLOW UP STUDY

If the result of this particular collision study puts this site at the top of the priority list of collision spots studied and the recommended improvements are subsequently carried out, there is no reason why this particular site should be excluded from further study.

As soon as the improvements have been completed the site should be visited by the same engineer who carried out the original field study so that the immediate effects can be assessed. When the collision record for the two year period after completion of the improvement has been compiled, statistical tests of significance should be used to assess the true worth of the improvements.



DATA	TYPE OF COLLISION									Total
	Pedes trian	Pedal cycle	One motor vehicle	Two motor vehicles					Other	
							Other			
DEGREE:										
Fatal					3	1				4
Serious injury				1	2					3
Slight injury					4	1	1		1	7
Damage only		1	1	16	3	2	8		1	32
Total		1	1	17	12	4	9		2	46
YEAR:										
1966		1	1	6	6	3	3		1	21
1967				11	6	1	6		1	25
DAY:										
Weekdays		1	1	8	10	1	8		1	29
Saturdays				8		1	1		1	12
Sundays				1	2	2				5
TIME:										
0-6 am					1					1
6-9 am				4	1		1			6
9-12 am				2	1	2	2			7
12-3 pm				5	1		2			8
3-6 pm			1	1	3	1	2		1	9
6-9 pm		1		5	4	1	2			13
9-12 pm					1				1	2
VISIBILITY:										
Daylight		1	1	12	8	2	6		1	31
Darkness				5	4	2	3		1	15
Skidding on wet road										
Swerving										

Figure 1: Collision pattern summary example for an intersection