UNITED NATIONS
ECONOMIC COMMISSION FOR AFRICA

ROAD SAFETY MANUAL ON LOW - COST ENGINEERING COUNTERMEASURES

PRACTICAL GUIDELINES TO IMPROVE ROAD SAFETY IN AFRICA

PREPARED FOR 2nd AFRICAN ROAD SAFETY CONGRESS,
ADDIS ABABA 16-20 OCTOBER 1989
Road accidents are becoming increasingly severe in Africa in terms of fatalities, injuries, and property damage. While industrial countries have been able to check and even reverse the rising trend of traffic accidents, their incidence and severity are becoming very alarming in our region. Developing countries will be able to reduce road accidents only when they decide to design and implement appropriate and effective counter measures.

One of the recognized measures for enhancing road safety anywhere is the physical, engineering improvement of hazardous road sections. And in Africa, the most practical engineering measures are those that can be implemented at low cost.

In its continued effort to publicize the menace of road accidents in Africa, the United Nations Economic Commission for Africa organized in 1989, in collaboration with the Organization for Economic Co-operation and Development and OECD member countries like Finland, the Second African Road Safety Congress, and one of the recommendations of that Congress was to produce a manual for low-cost engineering measures.

This manual presents, in a simple and understandable form, low-cost engineering measures to improve road safety. It is for me an honour to urge everyone involved in road safety work in Africa to put the manual to the test and not to hesitate to put forward suggestions and recommendations to ECA which would be utilized to improve subsequent editions.

I am indebted to all those who participated to make the Second Congress highly successful, and especially to the Government of Finland, FINNIDA and FINCONSULT who, in addition to the preparation of quality papers presented at the congress, co-operated and contributed, financially and otherwise to the successful production of this useful technical document for Africa.

Adebayo Adedeji
UN Under-Secretary-General
and Executive Secretary of ECA
# ROAD SAFETY MANUAL ON LOW-COST ENGINEERING COUNTERMEASURES

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INTRODUCTION

Number of accidents is growing steadily in developing countries. In many countries it tends to dominate the statistics as a cause of untimed death. According to the police statistics about 90% of these accidents are mainly caused by a human factor: negligence, speeding, loss of control, rushing on to the road etc. However, whenever an accident occurs, there are always the three main factors involved, the driver, the vehicle and the environment.

If the environment did not have any impact on the road safety, the accidents should be distributed randomly along the road. However there are certain sites where several accidents occur while there are only few in other locations. These sites are called dangerous locations or accident black spots because statistically they can be proved out to be more accident prone than the other road sections.

Several international experiments in developed and in developing countries have shown that by improving the dangerous locations a significant accident reduction can be achieved. Even 80...90% of accidents can disappear. It is known that the total cost of accidents are very high: in a country with 200 000 vehicles they are estimated to cause annual losses of 50-150 Million US$. Subsequently the savings in accident costs are often so high that any investment will be paid back in months.

This Manual has been prepared by Finnconsult for The Economic Commission for Africa in connection with the 2nd Road Safety Congress of Africa. Because the effect of the countermeasures has mostly been estimated by using material from several countries, a programme of continuous follow up is recommended. This will facilitate updating the manual and further ensure that the correct measures will be chosen and that the economic calculations will be reliable.
A. DEFINING DANGEROUS LOCATIONS

A.1 General

In order to improve road safety by low cost engineering countermeasures the most important task is to find out the dangerous locations; the second task is to define the correct countermeasures. The location is the key question - if it is not right the countermeasure can never be correct. People often call some locations dangerous because they are frightened when passing them. Some people call a site dangerous because of traffic jams. However those locations are not always accident prone. They might look dangerous and people just become careful. Whatever the reasons, the only correct way to find dangerous locations is to collect and analyse accident data. When the location is defined there are several ways to find out the causes of the accidents.

The accident data is normally collected by the police. The police may have several registers such as

- Daily registers covering all crimes, accidents etc.
- Accident register books containing list of all fatal, injury and non-injury accidents.
- Accident files with accident investigation and statements of those involved including detailed information and material for the court process.
- Form for an accident report (Appendix 1) which is supposed to be filled for every accident registered by Police.

In order to organize a national road safety plan it is necessary to create a system to collect and analyse accident information. Cooperation between several officials is needed: The Police, the road authorities, land-use planners, automobile associations etc. The base of an accident information system lies on the data collected by the local police at site. This is why the key personnel in accident collection are the policemen.

An example of an organized accident data collection could be as follows. A copy of the police form, filed by the local and central police authorities is sent to the road authority (e.g. Ministry of Transport), where a Road Safety Unit (RSU) keeps an Accident Register and Analysis System (ADS). This register serves both local studies and overall statistics for the whole country. The traffic and road engineers can use this information to find out dangerous locations or for other planning purposes. While carrying out a road safety study, it is still necessary for go through both the statistics of the local police and that of RSU in order to get a comprehensive idea of the problem. The continuous cooperation with the Police is of great importance.

General statistics of the whole study area are useful for comparing the general situation with that of the dangerous locations. The general statistics should normally be provided by the data systems located in RSU.
A.2 Accident Data Collection

There are two main reasons to start a road safety study:

- A district/location/town etc. is felt to be accident prone. Thus a road safety study is launched to curb the situation.

- In a certain limited location several serious accidents have occurred within a relatively short period.

The main difference of the two cases is that in the latter the location is defined but in the former case some general studies must precede the actual analyses and designs.

In both cases the location to be studied must be defined, i.e. to outline the area, roads etc. Preliminarily the accident material shall be picked out of the data systems.

In any accident collection system there are shortages which make it difficult get all of the information. So there must be a way to estimate the real situation. The total number of accidents must be found out and compared with the detailed information. The best way to achieve this target is to compare the accident material in the Police Accident Register Books or other daily registers covering all the accidents in the area to be studied. If the accident data system covers over 70% of all accidents, it is not very important to collect more data from the Police records. Otherwise an exercise at police station(s) or headquarters must be carried out.

The accident data collection shall be done by going through the accident files. It is useful to pick up the data on a certain form (see Appendix 1 and 2) unless such one does not exist. The information should be easily added in to the AD-system from these forms. There are two main phases to be carried out:

1) going through the Accident Register Books of Police (summaries of the records) in order to pick up the accident file numbers by roads. It might be necessary to pay attention to the fact that some recording systems include separate books for fatal, injury and non-injury accidents and further for e.g. such accidents with drunken driving and/or government vehicles involved.

2) After defining the study locations, the files must be collected and the data moved on the mentioned forms (or copied if they already exist) for further analyses.

There can be certain problems in getting hold of the files because the case can be in court, sent to other stations etc. However, at least 3/4 of the accidents should be available.

Past experience in accident data collection has proved out that 250-600 accidents can be collected by one man in a month. The time required depends on wheather the file must be gone through or there exists already one accident data form filled.
The most important data to be collected of each accident is:

- date, day and time of accident
- the location of the accident
- how it happened: driving directions, points of impact, speeds, apparent causes, including statements of participants
- vehicles involved: types (e.g. van, lorry), vehicle condition and damage.
- number of victims, ages, seriousness
- road weather and illumination conditions
- accident type

Some information of the accidents and/or dangerous locations can additionally be received by interviewing the police officers, who registered the accidents.

A.3 Preliminary analyses

The preliminary analyses is to define dangerous road sections, and dangerous locations. To find out the dangerous road sections it is enough to use the data of the accident register books - detailed information is absolutely necessary. However more detailed data may be useful. Each road section should be handled as a unit. The necessary data for each road section consists of:

1. The name of the section
2. The length in kilometres
3. The total number of accidents
4. The number of victims classified according to seriousness (fatalities, serious and slight injuries)
5. Annual average daily traffic (AADT) if available.

The total number of accidents and casualties is one measure of danger. Other indicators which can be worked out to for each section are:

6. Accident density (accidents per kilometre)
7. Accident rate (accidents per $10^6$ veh.kilometres)
8. Fatality / casualty rate (fatalities or all casualties per $10^6$ veh.km)

The accident density (accident/km) is considered to be the best measure of the dangerousness. The accident rate indicates the relative dangerousness, and subsequently it might be more useful, if notable changes in traffic volumes is expected in the near future. However, the accident preventive work is aimed at reducing real accidents, therefore the absolute number of accidents is more important than the relative one.

**Accident density** is calculated by Formula (1)

\[
U_d = \frac{U}{L \times n},
\]

where

- $U_d$ = accident density (acc/km)
- $U$ = TOTAL number of accidents
- $L$ = the length of the road section in kilometres
- $n$ = number of years or the coverage coefficient

The factor $n$ is 'number of years', if 100% of accidents have been located. However this not always the situation and the number of years must be multiplied by
the share of located accidents. E.g. in a case of 72% of accidents located and the accident material has been collected from one year \( n = 0.72 \). If the period covers two years \( n = 2 \times 0.72 = 1.44 \), if three \( n = 3 \times 0.72 = 2.16 \) etc.

**Accident rate** is calculated by Formula (2)

\[
U_r = \frac{U \times 10^6}{L \times n \times AADT \times 365}
\]

where

\( U_r \) = accident rate (acc/10\(^6\) veh.km)

\( AADT \) = average annual daily traffic

for \( U, L, n \) see Formula 1

Fatality or casualty rate (density) can be calculated by replacing accidents (\( U \)) with number of fatalities or casualties. These indices can be used when working out priorities, implementation programmes etc.

It is best to document the accident rates and densities both in tables and drawings. An example is in Figure 1.

After calculating the accident densities in different parts of the road network, it is possible to choose the road sections for more detailed analyses. This phase requires the collection of sufficient accident information to construct a pin map. The prerequisite is that each accident can be accurately located. This kind of pin map (Figure 2) should be maintained for each location/town etc. to follow the situation afterwards.

According to studies (1983-87) in Eastern Africa the average accident rate was 4-5 accidents per million vehicle-km on main roads. According to the available information accident rate seems to be of the same level in rural roads and even in urban main roads.

The information of accident rates can be used to find out accident black spots. The road shall be divided in sections. Both average accident rate (\( U_r \)) and that for each section are calculated. If the accident rate of a road section is higher than 1.3 \( U_r \) or 1.65 \( U_r \), the section can be considered dangerous by 90% (or 95%) confidence level. Here \( U_r \) may also be the average accident rate for the respective road class. The absolute figures are estimated to be 5.6 and 7.3 accidents per 10\(^6\) vehicle kilometres. If an accident rate is very low, e.g. less than 2, a significant accident reduction might be difficult to achieve, even in cases where the absolute number of accidents is high.

Average accident densities on rural main roads are about 2 accidents per km. In main streets of big cities the respective figure is about five times higher. In urban areas the average accident density can be assumed to be 7-8 acc/km in bigger cities and about 5 acc/km in town areas in average. To define a dangerous road section, figures in Table 1 can be used as a basis.
Table 1: Critical accident densities of a road location by the population of area

<table>
<thead>
<tr>
<th>Town size (1000's)</th>
<th>Critical accident density (acc./km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90% Conf. level</td>
</tr>
<tr>
<td>Rural roads</td>
<td></td>
</tr>
<tr>
<td>2-15</td>
<td>4</td>
</tr>
<tr>
<td>20-90</td>
<td>7</td>
</tr>
<tr>
<td>100-500</td>
<td>17</td>
</tr>
<tr>
<td>&gt;500</td>
<td>22</td>
</tr>
</tbody>
</table>

Figure 1: Accident densities in central Nairobi network (1984-85 average).
Figure 2a: A pin map gives roughly out the location of accidents.

Figure 2b: Standard markings of a pin map

The standard markings indicate the main types and the seriousness of the accidents. This helps to identify the problem.
Example:

A main road of a big city is divided into several sections of 250 meters. Table 1 indicates that a location is dangerous if the number of accidents is at least 28...31 accidents per km. This is equivalent seven accidents per a quarter kilometre or 250 meters. In Figure 2 the accident black spots are:

- Junction of Muthaiti Avenue
- Junction of Ole Sangale/Gandhi Avenue
- Agip Petrol Station
- Junction of Mbagathi Way

The surroundings of Airport junction and The Memorial site should also be studied.

When an accident black spot has been identified, the accident material must be studied carefully. The things to be checked are the detailed location and the type of accident. Attention should also be given to possible countermeasures.
B. ACCIDENT ANALYSES

B.1 Background

In the former chapter there has been described how to identify the accident black spots or dangerous locations. The accident data collection has been aimed at facilitating the identification of total number of accidents in road sections and the sites of accident accumulation as well. The next step is to find out the main causes of accidents, also other factors affecting on them, and solutions for how to prevent accidents in future.

The accident analysis needs reliable and accurate data. It is important to know not only the location but also how the accident happened: from where to where the participants moved, which type of role other road users played in the event etc.

Further it is important to have enough material. There must be a statistical corpus for the analysis. It is typical to a dangerous location that certain types of accidents appear repeatedly. It is these accidents which can be eliminated with low cost engineering countermeasures.

It is very important to have two or more site visits during the course of the analysis and design. Behind the office desk it is very difficult to see the real problems. To back up the accident material a conflict study can be carried out.

B.2 Accident Causes and Possible Improvements

In order to identify good preventive countermeasures there must be a clear idea of why the accidents have occurred. Because an accident is a result of several unlucky factors, it is not enough to study only who was guilty and why, but also traffic environment, driving speeds and lines, pedestrian movements etc.

Accident analysis should be started by collecting or moving the material on a summary sheet, referred to as a Collision Diagram. There are two main aspects to this job as:

- to have the accidents on a large scale map so that the accumulation spots within a road section or junction can be recognized. This will give a clear picture of what has happened.

- to get a summary by years, accident types and victims. This will indicate the causes and trends, and provide a basis for the analysis of the efficiency estimates of different countermeasures.

Using the collisions diagram (Appendix 2) the main types of accidents can be seen, sometimes even the main causes of accidents are evident. It is also good to go through the possible statements of police concerning the causes of accidents. If the description of accident including vehicle movements is properly done, useful background information can be got out of them. A list of accident causes can be prepared to assist the final work.

When studying the accident causes special emphasis shall be put on facts which indicate something about the environment. There are several types of statements like "negligence while driving", "rushing on to the road" or "careless behaviour" which have no value to the analysis. It is normal that an accident has a connec-
tion to some of these. However, it must be found out why the accident took place at that special site - accident black spot- not anywhere, because most probably driver's "negligence" has existed for a longer time.

The following section lists some of the most common accident causes, and pointers, which can assist us to find sound solutions to the existing problems:

**Pedestrians**

- rushing on the street  
  - From which direction?  
  - Need for fencing?

- illegal crossing  
  - Are there correct crossing facilities? Are they in correct place?

- diagonal crossing  
  - Are the crossing sites painted?  
  - Can the crossing opportunities be limited?

- walking along road  
  - Footpaths? Fencing?

- crossing between parked vehicles  
  - Is parking well organized?  
  - Are the pedestrian crossings painted?

- ignoring pedestrian  
  - Is the zebra crossing situated, where crossing the pedestrians are?

**Drivers**

- speeding/high speed  
  - Driving direction? Long distance traffic?  
  - Too steep downhill section? Straight sections?  
  - Bottlenecks? Speed limit signs?

- wrong lane usage  
  - Lane markings? Arrows?  
  - Are the lanes continuous?

- heedless of crossing pedestrians  
  - Are there zebra crossings?  
  - Proper signs?

- wrong driving lines  
  - Is the area too wide? Junction form?  
  - Lane markings? Bus stops? Potholes?  
  - Is there need for a median island?

- wrong overtaking  

- cutting across a curve  
  - Curve radius/speed limit? Warning signs? Speeds?

**Other Factors**

- jump on red lights  
  - Are signals well visible?  
  - Are indications clear?

- heedless on signals  
  - Are timings correct?  
  - Could audiosignals be useful?

- loading on street  
  - Bus stops and lay-bays? Pedestrian routes?
B.3 Field Studies

Field visits are necessary to get a correct idea of the dangerous location. A visit can be most productive, if it is properly arranged. Things to be analyzed should be thought out before hand. Additionally there are also studies which can be carried out during the visits.

The field visits have three main aims:

1) To give an idea of the physical dimensions, road signs, obstructions etc. at the dangerous location.

2) To find out problems in driver behaviour, traffic volumes, risk areas etc. by observing the traffic.

3) To supplement the information which the accident material has given of accident causes and possible remedies. Conflict studies can be carried out in this connection, too.

During the first visit it is recommendable to draft a map of the site, or to complete and update an existing map. It is good to have a tape measure which is (10...) 20 meters long. The widths and lengths of islands, junction angles and road widths shall be measured, and also sites of poles which are close to the road. Pedestrian paths, fences, access roads, bus stops and pedestrians' attractions (such as kiosks) can be drawn on the map. An example of measurements is shown in Figure 3.

1. Define and measure a basic line and point opposite to the minor road junction
2. Measure the access roads: place and width
3. Measure the alignment of the major road
4. Measure the width of the major road at the same sites as above
5. Measure the minor road islands, widths and important curvature points
6. Fix the approach curve or alignment of the minor road

(7. Measure other important things as road signs, fences, foot paths, poles and big trees, bus stops etc.)

Figure 3: Example of field measurements and the construction of the junction
During field visits two types of information should be collected: one consists of physical form, equipment, pavement etc., which can possibly affect an accident. The other is traffic operations.

Sometimes the vehicle movements indicate possible reasons for danger. Traffic flows can also be studied; especially such phenomena as speeds and delays, waiting times, crossing sites and routes of pedestrians. The results of the studies can be inserted on the map. These studies help in finding out realistic solutions in order to improve the situation.

In the Tables 2 and 3, there is a check list for a dangerous location to be used during field studies.

These checklists are designed to be used during the field studies to find out which problems are possibly the causes of accidents. The operational observations often give information of problems within certain limited areas in junction. Those areas or "points" (see Figure 4) where traffic flows merge, cross or diverge are called conflict points. If, in some of these points, the time gap between two vehicles is very small (e.g. 0.9 sec), the situation can be described as a conflict. They can be classified to be slight or serious conflict or an almost-accident.

During a conflict study the conflicts are registered by conflict points and seriousness, by vehicle type, time etc. Additionally the traffic flows should be counted. The result of the study - the number of various conflicts - can be handled as an additional "almost accident" material to assist in planning of the countermeasures.

![Figure 4: Conflict points of 3-leg and 4-leg junction and a simple roundabout](image-url)
Table 2. Physical checklist

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<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Observer</th>
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<tr>
<td>1. Have accidents been caused by physical conditions of the road such as sight obstructions or blind corners or wrongly sited islands, road signs or adjacent property and can these be corrected?</td>
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<td>2. Is street alignment inadequate?</td>
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<td>3. Are lane widths inadequate? (turning lanes: minimum 3.0m) (other lanes: &quot; 3.25m)</td>
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<td>4. Should pedestrian crossings be relocated/repainted?</td>
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<td>5. Are the road signs inadequate in terms of their message, size, placement or conformity?</td>
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<td>6. Are the signals inadequate in terms of their placement, conformity, number of signals heads or timing?</td>
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<tr>
<td>7. Are road markings inadequate in terms of their clarity or locations</td>
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<tr>
<td>8. Is traffic properly channelized to minimize occurrence of accidents</td>
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<td>9. If the nighttime accidents represent a considerable proportion, is the street lighting and the number of reflectors adequate?</td>
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<td>10. Are parking arrangements adequate? if not - is there a need for obstructions, limitations, islands etc?</td>
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COMMENTS

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Table 3. Operational checklist

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<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Observer</th>
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</thead>
<tbody>
<tr>
<td>1. Do obstructions block the driver's view of oncoming vehicles</td>
<td></td>
<td></td>
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<tr>
<td>2. Do drivers respond incorrectly to signals, signs or other control devices?</td>
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<tr>
<td>3. Do drivers have trouble finding the correct path through the location?</td>
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<tr>
<td>4. Are vehicle speeds high? Speed differences? If yes: Driving direction?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Are there violations of parking or other traffic regulations</td>
<td></td>
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<td>6. Are vehicles delayed? Can the delays be reduced?</td>
<td></td>
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<tr>
<td>7. Are there traffic flow deficiencies or traffic conflict patterns associated with turning movements?</td>
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<tr>
<td>8. Would one-way operation make the location safer?</td>
<td></td>
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<tr>
<td>9. Is the traffic volume causing problems?</td>
<td></td>
<td></td>
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<tr>
<td>10. Do pedestrian movements through the location cause problems?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Is there need for (a) efficied/selective enforcement (b) effective/selective maintenance</td>
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COMMENTS
C. DESIGNS

During the course of his analysis the planner should draft solutions to solve the problems, not only to identify them. The draft solutions should be the basis for final designs. The design process will be carried out in two phases:

1. The preliminary design stage
2. The final design

During the preliminary design stage the planner creates 1-5 sketch drawings of how the dangerous locations could be improved. The ideas should be based on the analysis:
   e.g. if the high driving speeds have caused accidents
   - how to reduce speeds, or
   if crossing pedestrians are the most common victims
   - how to improve pedestrian safety.

These designs do not need to be very accurate, but they should be sufficient for cost estimates and to show environmental impact and the likely effect on accidents, as well.

<table>
<thead>
<tr>
<th>Problems</th>
<th>What to do</th>
<th>How to do</th>
</tr>
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<tbody>
<tr>
<td>Pedestrian</td>
<td>Warn, Inform</td>
<td>signs, markings</td>
</tr>
<tr>
<td>Driver</td>
<td>Facilities</td>
<td>resealing lanes, walkways</td>
</tr>
<tr>
<td>Others</td>
<td>Limitations</td>
<td>bus stops etc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fences, barriers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>islands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bumps etc.</td>
</tr>
</tbody>
</table>

**ALTERNATIVE SOLUTIONS**

**Benefits/Costs**

**Recommendation and Realization**
The draft solutions have to be evaluated by comparing the efficiency or benefits versus costs. Appendix 3 gives a rough estimate of how many accidents can be removed by different types of countermeasures. The information should be collected on an efficiency estimate sheet to carry out the calculations (Figure 5).

The comparison between the different solutions will be the basement for the recommendation. If the most efficient alternative is not feasible, a solution in line with the environment or budget restraints is to be chosen.

During the process of choosing a solution, it may be necessary to base the final proposal on a compromise of 2...3 preliminary ones.

Figure 5 gives an example of a final drawing.

Figure 6: An example of an accident prone location and a proposed solution for improving it.

For the final designs it is necessary to provide not only drawings but also to define typical details. Additionally, a list of quantities shall be prepared for cost estimates and the follow-up.
The Efficiency Estimate Sheet should be filled by each alternative separately. The figures are based on the collision diagram and the designs. In the following there are short explanations of each line to be filled out:

**material:** The accident material defined by accident type.

**aver./year:** Estimated annual number of accidents, average per year during the study period. The figures can be derived from those on the former line based on the length of the time period and the coverage (see A.3).

**countermeasures:** List of the proposed countermeasures.

**probability accidents remaining**

From the list in Appendix 3 estimates of potential accident reduction can be highlighted. E.g. a refuge crossing is estimated to reduce 40% of accidents. Thus there will be 60% of accidents remaining and the figure "60" should be placed in the column.

**cost estimate:** Estimated cost of each countermeasure (col.1).

**relative %:** This figure is calculated from the columns above by multiplying the probability percentages. E.g. Pedestrian crossing (60%), raised zebra (30%), and speed reduction (95%) give the total of 17.1% (60% x 30% x 95%) of remaining accidents. Note that the column 'total' cannot be got otherwise but by calculating first the absolute total and then - backwards - the relative share (percentage).

**absolute :** The remaining number of accidents by type: multiply the average number of accidents from the second line (aver./year) with the relative % to get an estimate for the remaining ones.

**reduction:** The figures above indicate the remaining accidents and thus the reduction is the difference between 'aver./year' and 'absolute'.

**accident**

Estimates for unit costs (US$) are in column 1 in parenthesis. If national accident cost estimates are not available the figures can be used. They are based on 1989 cost level and respond 500-600 US$ Gross National Product(GNP) per capita. In case GNP is much higher or lower a new estimate can be calculated by changing accident costs respectively. However, vehicle-costs can be used fixed. Third column 'victims/veh' means the number of victims or vehicles. 'Cost' in the fourth column will be calculated by multiplying the numbers with the unit costs. Unit cost/accident is acquired by dividing the total with the number of accidents. Note that the original accident material from the line (A) must be used here.

**economic effects:** The formulae for the three indexes are indicated on the sheet. Estimated annual savings and benefit/cost refer to the first year savings while the estimated savings/3 years describe the whole return of the investment.
### ROAD SAFETY COUNTERMEASURE EFFICIENCY ESTIMATE

**location**

### ACCIDENTS

<table>
<thead>
<tr>
<th>ACCIDENT TYPE</th>
<th>1 loss of contr</th>
<th>2 pedes acc.</th>
<th>30-32 chang of lanes</th>
<th>33 nose to tail</th>
<th>4 cross driv. direc</th>
<th>5 head on coll.</th>
<th>64 bic./hand-cart</th>
<th>6 other accid</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(A)</td>
</tr>
<tr>
<td>aver/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PROPOSED COUNTERMEASURES

<table>
<thead>
<tr>
<th>countermeasure</th>
<th>Probability of accidents remaining after each countermeasure (%) by accident type</th>
<th>cost estim</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

remaining accidents per year (calculated from above):

| relative%      |                                                                                 |            |
|                |                                                                                 |            |
| absolute       |                                                                                 |            |
| reduction      |                                                                                 |            |

### ACCIDENT COSTS

<table>
<thead>
<tr>
<th>Acc. unit cost</th>
<th>Number of victims/veh</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>(30 000)</td>
<td>fatalities</td>
<td></td>
</tr>
<tr>
<td>(600)</td>
<td>serious inj</td>
<td></td>
</tr>
<tr>
<td>(50)</td>
<td>slight inj.</td>
<td></td>
</tr>
<tr>
<td>(2200)</td>
<td>damaged veh</td>
<td></td>
</tr>
</tbody>
</table>

average cost of one accident = AC/A

### ECONOMIC EFFECTS

<table>
<thead>
<tr>
<th>estimated annual savings</th>
<th>AR x UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>estimated savings/3yrs x</td>
<td>3 x ES - 1.45 x CE</td>
</tr>
<tr>
<td>benefit / cost (1st year)</td>
<td>ES / CE</td>
</tr>
</tbody>
</table>

Figure 5: An efficiency estimate

^1 15% interest
D. ACCIDENT PREVENTIVE COUNTERMEASURES

D.1 General

Road safety depends much on the traffic environment. Sometimes the cause of accident also derive from other factors. Sometimes the driver’s expectations conflict with the environment (e.g. through traffic on local roads). Sometimes reasons of danger may be in a road section before the actual accident black spot. All measures, which have an impact on the environment can also influence road safety. These measures do not only include reconstruction but also road maintenance and police enforcement.

In the following chapter various countermeasures have been listed, which can be used in accident prevention work. This list has been prepared to assist finding the correct measures for each road safety problem. There are two ways of studying the accident black spots: one from the environmental point of view and the other from the main accident types. The circumstances should also be studied: the designer should ask, whether there are measures that can improve the situation during difficult environmental circumstances as heavy rain, darkness etc. This is of great importance especially when a great deal of accidents occur during these circumstances (e.g. in rainy season).

D.2 Accident types, causes and countermeasures

Proposals for possible accident preventive countermeasures have been listed by accident type. The accident types are classified as follows:

(1) single vehicle accidents
(2) Pedestrian accidents (vehicle(s) and pedestrian)
(3) Several vehicles - driving in the same direction
(4) " " - in converging directions
(5) " " - in opposite driving directions
(6) Other accidents

Possible causes of accidents are based mainly on accident analysis in Africa and Scandinavia, also on those in other Europe and USA.
(1) Single vehicle accidents

Subtypes: 11. Loss of control
12. Collision at an obstacle on Road

![Diagram of single vehicle accidents]

Causes
- high speed
- tiredness, darkness
- potholes or bad surface
- steep gradients
- attempts to avoid a head-on-collision or similar accident

Countermeasures
- Improvement of geometry
  * elimination of small curves
  * correction of gradient
  * widening of the road at a curve
- Improvement of visibility
  * removal of bushes etc.
  * lighting
  * reflective studs or poles
- Softening of the environment
  * removal of obstacles, or moving them more far away from the road
  * reforming of slopes, drainage culverts etc.
  * widening of rock cuttings, toe walls etc.
- Improvement of sealing
  * filling of potholes and repairing of damaged edges
  * roughening of too smooth pavement
- Improvement of markings
  * edge and/or centre lines
  * junction markings
- Road signs
  * speed limits
  * warning of bend, slippery surface, junctions,
    pedestrian crossing, animals, children etc.
  * information signs or directional hazard markings e.g. background plates at sharp bends or junctions
- Speed limiting measures
  * bumps or raised zebra crossing(s)
  * rumble strips
  * active police enforcement
(2) Pedestrian accidents

Subtypes

21-22 Pedestrians walking along the road in direction /
towards the traffic
23 Pedestrians crossing the road
24-25 Pedestrian(s) standing on/by the road

Causes

- negligent crossing/walking
- undefined crossing sites
- narrow road
- poor visibility

Countermeasures

- Improvement of pedestrians'/cyclists' facilities
  * widening/construction of shoulders
  * construction of separate footways
  * painting of edgelines in order to separate shoulders

- Speed limiting measures
  * speed limit signs
  * constructive speed limiting measures
  * active police enforcement

- Improvement of visibility
  * parking prohibition
  * removal of sight limiting obstacles, plants etc.
  * construction of pedestrian bay within street parking
  * lighting (especially of crossing sites)
  * use of pedestrian reflectors

- Limiting pedestrian movements by fences or guardrails

- Improvement of crossing sites
  * (re)paint of a zebra crossing and provide of signs
  * provide rumble strips on both sides of a zebra crossing
  * erect warning signs for a pedestrian crossing (outside City Centre)
  * construct pedestrian refuge with road signs
  * provide a line of reflective studs on both sides of a zebra crossing
  * construct raised zebra crossing (with warning signs)
  * construct level-separated crossing
(3) Accidents between vehicles driving in the same direction

Subtypes

31 Changing lanes or collision while overtaking
32 Single vehicle turning
33 Rear collision (nose-to-tail)

Causes

- ignoring lane markings
- lack of turning lanes
- overtaking at a junction
- overtaking without due free distance
- restricted visibility at junction
- too short amber period at traffic light signals
- lack of bus stops
- high speeds
- careless driving
- damaged edges/potholes on the road
- lack of proper signal indication
- ignoring a STOP or GIVE WAY-sign
- parking/stopping in the middle of road

Countermeasures

- Improvement of road markings/signs
  * (re)painting of lane marking
  * painting of continuous yellow line at junction and/or its continuation
  * erect warning signs of junctions/potholes
  * erect road signs to prohibit parking/turning
  * rumble strips for warning purposes

- Rearrangement of junctions/access roads
  * removal of junctions by constructing a parallel road
  * prohibit turning movements by central island
  * provide turning lanes
  * provide channelization at the junction

- Improvement of road conditions
  * pavement patching/resealing
  * access control
  * provide bus bays
(4) Accidents Between Vehicles Travelling in Converging Directions

Subtypes

41 Crossing vehicles only
42 All vehicles turning
43 Single vehicle turning

Causes

- poor visibility
- high speeds
- steep gradients
- wet road
- incorrect driving along preselection lanes
- junction lacking proper markings
- crossing without due care
- short junction distances
- minor junctions along main road
- wrong timing of traffic light signals (too short amber)

Countermeasures

- reduction of the number of junctions along the road
  * access control
  * construction of a parallel road
  * construction of a level-separated crossing

- Improvement of the visibility of a junction
  * remove bushes and trees, enlarge cuttings
  * construct center islands on road
  * erect warning signs and/or improve markings
  * change the junctions to better locations e.g. away from sharp bends, brows of a hill etc.

- Improve traffic control
  * GIVE-WAY or STOP-sign and markings
  * provision of traffic signals (if urban area)
  * provision of background plate for signal heads
  * speed limit signs and/or road markings
  * relocation of road sign(s)
  * (re)painting of road markings and lane indication arrows
  * construction of rumble strips within chevron or hatched marked area

- Improve junction lay-out
  * add turning lanes
  * construct directive islands with mandatory road signs
  * change junction angle and widen shoulders

- Lighting

- Police enforcement
(5) Accident between vehicles travelling in opposite directions

Subtypes

51 Overtaking accidents
52 Turning off the road
53 Other head-on-collision

Causes

- high speeds
- careless overtaking/driving
- sinkings of the pavement
- faulty estimate of speed
- steep hills with slow heavy traffic
- short straight road section following a long hilly and curvy one

Countermeasures

- Improvement of the alignment
  * improve sight distances by improving geometry or/and by clearing bushes etc. obstructions
  * increase number of sections with opportunity for safe overtaking
  * construct overtaking/crawling lanes

- Improvement of control
  * warning signs of bend, junction, narrow road etc.
  * painting edge and centre lines
  * pass to the right sign, if median exists
  * prohibit overtaking
  * speed limit and active police enforcement

- Improvement of the road surface
  * pothole patching
  * repair of damaged edges

- Improvement of possibilities to estimate speeds and distances correctly
  * plant trees/bushes at certain intervals
    \( \geq 6 \text{ m distance from road edge} \)
  * use of 'safety' roadside poles with reflectors
  * use of reflective studs

- constructive methods (at junction)
  * median island or rumbled chevron markings
  * widening of lanes/shoulders
  * construction of a dual carriage way

- Use of headlights (also during the daytime)
(6) Other accidents

Subtypes:

61 Falling passenger
62 Collision with an animal
63 Collision with a stationery vehicle
64 Collision with handcarts
65 Railway crossing accident
66 Undefined bicycle accident

Causes

- overloading
- inadequate sight distance
- driving busdoors open
- incorrect parking
- no warning triangle
  at a stopped vehicle

- speeding
- inadequate control measures
- narrow road
- limited visibility
- inadequate bicycle/pedestrian facilities

Countermeasures

- Speed reducing measures
- fencing
- warning signs
- construction of bicycle/pedestrian ways
- removal of kerb stones at a bicycle route / road crossing
- Improvement of railroad crossings
  * reduce the number of crossings
  * equip crossings with safety measures as warning signs, signals, audiosignals, barriers
  * improve visibility
  * provide lighting
  * erect warning signs / stop sign
- Construction of shoulders
- Removal of bushes etc. from the road side
- Police enforcement
- Effective maintenance
D.3 Environmental Factors

Certain countermeasures are linked to the road environment and some special circumstances. The following list by road locations gives examples of such countermeasures.

- Straight sections
  * improve driver’s ability to estimate speeds and distances
  * measures to prevent the driver from falling asleep (like rough surface on shoulders)
  * access control or removing junctions
  * softening of the road environment
  * speed limits, road markings

- Junctions
  * remove access roads within at least 40m from the junction
  * change the junction to an acceptable location from a place with sharp bend/steep gradient/restricted sight/brow of a hill
  * provide signs and road markings
  * provide traffic light signals if necessary (normally only in urban areas)
  * widen the main road with extra 2.5 m
  * provide the junction with 1.5 m wide shoulders
  * use hazard marking signs as warning measures
  * change junction angle to 80...100°
  * provide channellization/islands
  * provide adequate turning lanes
  * construct grade separated crossing

Figure 7: Hazard marking signs can improve road safety significantly
- Bends:
  * improve the alignment by reducing sharp bends
  * warning of junctions, narrow bridges etc.
  * improve visibility
  * repair gradients
  * improve optical guidance
  * separate opposite directions with a median island
  * lighting and/or reflectors and/or guardrails
  * rumble strips together with warning signs

Serious accidents in certain road sections occur during some special weather or lighting conditions:

**Darkness**
- better lighting
- reflective studs and markings
- reflective road side poles
- Hi-intensity reflective road signs
- provision of pedestrian ways
- reflective painting of kerb stones
- set of reflectors at critical kerb points
- erect pass to the right sign

**Fog**
- provision of reflective studs or safety posts
- abrade surface
- light shoulders (e.g. of white stone or concrete)

**Rain**
- abrade surface
- correction of gradients
- improvement of ditches
- improvement of shoulders
- fill in surface depressions and patch potholes
D.4 Examples

The countermeasures here have been classified according to accident type. All the countermeasures are examples of different and various solutions. The planner has to apply these carefully and critically, trying to find out the causes of accidents and to design each solution as a tailor-made solution to the actual problems.

It is important to notice that some of the countermeasures mentioned in chapter D.2 are quite expensive. Some of them also demand comprehensive designs and long construction time. In the following pages there are mainly such countermeasures, which are not very costly and which can be implemented in a certain standard designs, which are used repeatedly are described in detail in Appendix 5.
One cause of loss of control accidents can be a junction, which is not easily observed by main road traffic. It can be behind a curve, brow of a hill or bushes and trees. Road signs, markings, clearing of plants make it easier to be recognized.

See also Figure on page 42
<table>
<thead>
<tr>
<th>Accident type</th>
<th>LOSS OF CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location type</td>
<td>Sharp bend</td>
</tr>
<tr>
<td>Aim</td>
<td>Warn, improve visibility</td>
</tr>
</tbody>
</table>

1. Signs

![Sign Diagram]

Rumble strips can be used to give more emphasis to the warning sign (App. 5/3). In a very problematic case bumps can be used to slow down speeds. The first bump should always be placed in the straight section and be preceded by a set of rumble strips.

2. Widening, improving edges, improving gradients

If the road is narrow and curve radius small, the road should be widened for several reasons:

- big vehicles need more space
- centrifugal force increases lateral movement at the cross-section; additional space will reduce accidents
- transition from straight to curve affects vehicle movement
- 1.5m (>1m) shoulder width is recommended in these cases. In order to clarify the situation edgelines should be painted.
<table>
<thead>
<tr>
<th>Accident type</th>
<th>LOSS OF CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location type</td>
<td>Sharp bend</td>
</tr>
<tr>
<td>Aim</td>
<td>Warn, reduce speeds</td>
</tr>
</tbody>
</table>

- 1-2 sets of rumble strips

<table>
<thead>
<tr>
<th>speed limit =</th>
<th>$v_1 = 50 \text{ km/h}$</th>
<th>$d_1 = 50 \text{ m}$</th>
<th>$d_2 = 20 \text{ m}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$70 \text{ km/h}$</td>
<td>80 m</td>
<td>40 m</td>
<td></td>
</tr>
<tr>
<td>$90 \text{ km/h}$</td>
<td>140 m</td>
<td>60 m</td>
<td></td>
</tr>
<tr>
<td>$110 \text{ km/h}$</td>
<td>220 m</td>
<td>80 m</td>
<td></td>
</tr>
</tbody>
</table>

Additionally to road signs, bumps can be used to slow down speeds before a dangerous bend etc. The following rules should be noted:

1. Warning signs concerning the hazard (here: 'bend') and bumps should be erected, both with hi-intensity reflection properties.
2. 1-2 sets of rumble strips should be before the bumps.
3. The bumps should be situated far enough from the hazard to avoid loss of control. They should be painted white with reflective paint.
4. Both directions should be taken into account.
Accident type: LOSS OF CONTROL

Location type: Sharp bend, darkness

Aim: Warn, improve visibility

Reflective markings, studs, poles and road signs help the driver in finding his way even in poor conditions as darkness, rain etc. Reflective kerb stone reduce accidents caused by collision with the island.
<table>
<thead>
<tr>
<th>Accident type</th>
<th>LOSS OF CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location type</td>
<td>Straight, bend</td>
</tr>
<tr>
<td>Aim</td>
<td>Reduce seriousness of accident</td>
</tr>
</tbody>
</table>

Road side construction should be designed to be smooth and accident preventive, so that if an accident occurs damage would be minimal.

The dangerous area is within 9 meters of the road. The most dangerous zone reaches from road edge to 3.5m distance (see below). No hard obstacles should be placed closer than 1.8m from the roadside.

![Graph showing Relative Risk vs Distance (m) from the road]

- Relative Risk
- No road signs or similar
- Distance (m) from the road

---

Insert graph showing Relative Risk vs Distance (m) from the road.
Improvement of road safety within a town centre mostly means reduction of speeds and improvement of pedestrian crossings. The following aspects should be noticed:

1. A speed limit sign should be placed where the actual town centre begins, just before the pedestrian traffic volumes grow high.

2. 1-2 sets of rumble strips should be placed before raised zebra crossings and/or bumps.

3. Raised zebra crossings (see Appendix 5/4) should be situated so that they serve pedestrian routes and are in 50-70m intervalls.

4. Road side parking should be removed and direct access to shops by car eliminated. It should be replaced by one-way service lanes with exit/entry junctions only.
Large junction areas, especially in town centers cause a mixing of vehicles and pedestrians. Reduction of the number of crossing sites has two advantages:

1. Drivers have less sites where they have to worry about pedestrians.

2. The more pedestrians there are per crossing site the safer the crossing is.

Pedestrian refuges make it easier and safer to cross. While planning the arrangements, special attention should be paid to the location of the crossing sites; they must be placed where most pedestrians use them naturally.
Along high speed roads the only way to really improve pedestrian safety is to construct a pedestrian network with grade separated crossings. While working out the designs we have to remember that pedestrians will use the shortest possible route. Vertical distances should be emphasized by multiplying them by ten. The total distance is calculated by adding the lateral distance to this product. By comparing the distances the routes used by pedestrians can be found out.

Example 1:

a) alt.1: grade separated

\[ d_1 = 6 \text{m} \quad d_2 = 28 \text{m} \quad d_3 = 3 \text{m} \]

Total distance:

\[ 6 \times 10 + 28 + 3 \times 10 = 118 \text{m} \]

b) alt.2: no grade separation

The vertical distance is \( d_4 = 3 \text{m} \) added with two ditches of 1m which make the total: \( (3 + 2 \times 1) \times 10 + 28 = 78 \text{m} \).

Conclusion: The bridge will not be used, because the distance through it is considerably longer than that on the level.

Example 2:

a) Alt.1: Distance through the grade separated crossing is about 20m (d2)

\[ d_1 = 3 \text{m} \quad d_2 = 18 \text{m} \]

Conclusion: Everybody uses grade separated crossing.
Reduction of junctions along main roads is a key measure to improve road safety. Parallel roads serve local pedestrian traffic, as well. For the needs of pedestrians and cyclists it is worth to continuing parallel routes even longer than is necessary for vehicular traffic. The plan should be prepared carefully to eliminate through traffic from these roads, and to limit the speeds. The best solution is to design access roads shorter than 500m (preferably 200m). Bumps and special speed reducing measures can be used if necessary. When re-organizing the road network junctions junctions should be mainly designed as T-type ones.
Overtaking lane improves road safety for two main reasons:
It provides an area for safe overtaking and reduces queuing. Both features improve safety not only in the overtaking lane but also in sections after the lane.
A number of accidents is caused by speed differences which are due to vehicles turning out of the main road. Along major roads this turning movement, preceded by decleration, is quite rare - thus oncoming drivers are not prepared to slow down. The hazard can be reduced by constructing special turning lanes for minor road traffic and by painting clear lane markings with directional arrows. Wide junction areas should be limited with islands or chevron markings.

Special danger is caused by a left turning vehicle waiting in the middle of the road: most of the moving vehicles do not realize that it is standing stopped until they are quite close. A left turning lane improves road safety efficiently.
<table>
<thead>
<tr>
<th>Accident type</th>
<th>V E H I C L E S Travelling In Converging D I R E C T I O N S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location type</td>
<td>Junction</td>
</tr>
<tr>
<td>Aim</td>
<td>Reduce number of crossings</td>
</tr>
</tbody>
</table>

4-leg junctions of crossing main road often form a major hazard. One effective, although rather expensive solution is to construct a grade separated crossing.

Complete junctions should be constructed on the road which has less traffic. On the main road it is recommended to place a median at the directional junctions.
Accident type
VEHICLES Travelling In Converging DIRECTIONS

<table>
<thead>
<tr>
<th>Location type</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction</td>
<td>Improve visibility</td>
</tr>
</tbody>
</table>

EXAMPLE 1: Remove plants, trees and bushes, and other obstacles

EXAMPLE 2: Change junction site and illuminate the junction

The yellow line should start before the brow of the hill. The warning sign should also be placed there.

EXAMPLE 3: Chevron markings can be provided with rumble strips. Strips keep vehicles away from these areas, which may be important for e.g. visibility. The bump at the minor road entry guarantees low speed (almost stop) of the approaching vehicles.

Chevron markings with rumble strips

Islands can be used to force vehicles to the best possible angle to allow good visibility at the approach.
Some accidents like "changing lanes", "nose-to-rear" and even "pedestrian crossing" are linked to a large, non-chanellized and poorly marked junction area. The safety can be improved a lot by adding island(s), organizing bus stops, limiting pedestrian movements and improving markings. The following rules shall be noted:

1. Bus stops should be placed after the junction in the driving direction.

2. Pedestrian crossings should be made as short as possible and preferably split in two by an island.

3. A minor road vehicle should meet the main road in about a 90° angle.

4. Driving lanes between kerb stones should be at least 4.5m wide unless there is a special need for reducing speeds.
**Accident type**

<table>
<thead>
<tr>
<th>VEHICLES Travelling In Opposite DIRECTIONS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Location type</th>
<th>Road section</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Reduce speed differences</td>
</tr>
</tbody>
</table>

A staggered speed limit system where each road section is individually studied and the safe speed is indicated by signs will improve safety significantly. If an efficient police enforcement programme is carried out together with the system results will be even better. The speed limit can be defined from existing speeds and the other circumstances as follows:

1. Speeds should be studied and a speed distribution chart drawn. The basic speed should be taken as 85% speed (85% of drivers using speed below this). Technically it is taken from cumulative speed distribution chart where the curve cuts the 85% line.

2. The preliminary speed limit is that with full 10 below 85% speed (e.g. if V85 = 84 km/h, the speed limit is 80 km/h)

3. If there are relatively many access road junctions and pedestrians along the road the limit should be dropped by 10 km/h (exceptionally by 20%). However the limit should be at least V50 or 50% speed. Otherwise the limit will be unrealistically low. At traffic light signals the limit should not be higher than 70 km/h.

% of drivers exceeding speed

<table>
<thead>
<tr>
<th>% of drivers exceeding speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>15%</td>
</tr>
<tr>
<td>50%</td>
</tr>
<tr>
<td>85%</td>
</tr>
</tbody>
</table>

84 km/h

50 km/h 100 speed

Speed limit signs should be situated 30-50m after each public road junction.
<table>
<thead>
<tr>
<th>Accident type</th>
<th>VEHICLES IN OPPOSITE DIRECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location type</td>
<td>Road section</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Some serious accidents between vehicles in opposite driving directions occur at straight road sections with reasonable good visibility. Reasons can include the following:

1. There is a potential need of overtaking after a long curvy section. This can be reduced by overtaking lanes (pg. 37).

2. The road is too straight and clear to allow drivers to estimate the speed and distance of oncoming vehicles correctly. Planting of trees etc. can help in this situation. The trees should be a minimum of 5m from the road.

3. There might also be a minor depressed section, where vehicles are not easily visible. This kind of problem needs partial reconstruction of the road. Safety poles and speed limit signs can also be useful.

Changing of the road’s vertical alignment and creating some horizontal curvature will make the road more interesting for driver. This will reduce the potential risk of the driver falling asleep and thus improve road safety.
Accident type
VEHICLES Travelling In Opposite DIRECTIONS

<table>
<thead>
<tr>
<th>Location type</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction</td>
<td>Eliminate wrong routes</td>
</tr>
</tbody>
</table>

The cheapest method to channellize a junction is to paint turning lanes and chevron markings.

Sometimes on major high speed roads chevron markings are ignored by drivers overtaking along the markings. This can be highly risky as there can be slow vehicles turning in the junction area. A relatively effective way to eliminate this is to add rumble strips to the chevron markings. These strips should be placed at every second painted strip and be about 2cm high. (See Appendix 5/6)

"No overtaking"-sign with a "junction ahead"-sign should be placed before the junction.
| Type of injury: F=fatal S=serious S=slight |
| sex: M=male F=female |
| Position in vehicle: FS=front seat RS=rear seat ST=standing inside OB=on open body |
| Use of safety belt: U=used N=not used |

**Appendix 1**

**ROAD ACCIDENT REPORT**

<table>
<thead>
<tr>
<th>Police Division</th>
<th>Location type: [ ] junction [ ] pedestrian crossing [ ] road/street section</th>
</tr>
</thead>
<tbody>
<tr>
<td>day</td>
<td>date</td>
</tr>
<tr>
<td>total</td>
<td>number of damaged vehicles</td>
</tr>
<tr>
<td>name of town</td>
<td>location:(nearest known place and distance)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant 1</th>
<th>name and address of driver/owner</th>
<th>vehicle type: [ ] govt. [ ] comp. [ ] private</th>
</tr>
</thead>
<tbody>
<tr>
<td>driving licence no.</td>
<td>[ ] valid [ ] non-v</td>
<td></td>
</tr>
<tr>
<td>insurance comp.</td>
<td>ins.no.</td>
<td></td>
</tr>
<tr>
<td>road licence no.</td>
<td>[ ] valid [ ] non-v</td>
<td></td>
</tr>
<tr>
<td>damages of vehicle</td>
<td>[ ] serious [ ] slight</td>
<td></td>
</tr>
<tr>
<td>road works at the accident site:</td>
<td>[ ] yes [ ] no</td>
<td></td>
</tr>
<tr>
<td>road was</td>
<td>[ ] wet [ ] dry</td>
<td></td>
</tr>
<tr>
<td>illumination:</td>
<td>[ ] daylight [ ] night time</td>
<td></td>
</tr>
<tr>
<td>traffic light signals</td>
<td>[ ] operating [ ] not oper. [ ] no</td>
<td></td>
</tr>
<tr>
<td>weather:</td>
<td>[ ] clear [ ] cloudy [ ] foggy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant 2</th>
<th>name and address of driver/owner</th>
<th>vehicle type: [ ] govt. [ ] comp. [ ] private</th>
</tr>
</thead>
<tbody>
<tr>
<td>driving licence no.</td>
<td>[ ] valid [ ] non-v</td>
<td></td>
</tr>
<tr>
<td>insurance comp.</td>
<td>ins.no.</td>
<td></td>
</tr>
<tr>
<td>road licence no.</td>
<td>[ ] valid [ ] non-v</td>
<td></td>
</tr>
<tr>
<td>damages of vehicle</td>
<td>[ ] serious [ ] slight</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant 3</th>
<th>name and address of driver/owner</th>
<th>vehicle type: [ ] govt. [ ] comp. [ ] private</th>
</tr>
</thead>
<tbody>
<tr>
<td>driving licence no.</td>
<td>[ ] valid [ ] non-v</td>
<td></td>
</tr>
<tr>
<td>insurance comp.</td>
<td>ins.no.</td>
<td></td>
</tr>
<tr>
<td>road licence no.</td>
<td>[ ] valid [ ] non-v</td>
<td></td>
</tr>
<tr>
<td>damages of vehicle</td>
<td>[ ] serious [ ] slight</td>
<td></td>
</tr>
<tr>
<td>details of vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precis of accident and remarks of the investigating officer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draw a sketch plan of the accident site - indicate directions and distance to referred 'known location'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>additional information on vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a notice of intended prosecution been served [ ] yes [ ] no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reporting officer</td>
<td>officer-in-charge Police Station</td>
<td></td>
</tr>
</tbody>
</table>
### Site

<table>
<thead>
<tr>
<th>Site</th>
<th>1</th>
<th>2</th>
<th>30-32</th>
<th>33</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>loss of control</td>
<td>pedestrian accident</td>
<td>changing of lanes</td>
<td>nose to tail</td>
<td>crossing driving directions</td>
<td>head-on collision</td>
<td>bicycle or handcart</td>
<td>other accidents</td>
</tr>
<tr>
<td></td>
<td>30-32</td>
<td>33</td>
<td>4</td>
<td>64</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Total Victims

<table>
<thead>
<tr>
<th>Type</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>day</td>
</tr>
<tr>
<td>2</td>
<td>night</td>
</tr>
<tr>
<td>30-32</td>
<td></td>
</tr>
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<td>33</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td></td>
</tr>
</tbody>
</table>

#### Type of Accidents

- **L** = lorry
- **T** = trailer
- **B** = bus
- **MA** = matatu
- **P** = pedestrian
- **PC** = pedal cycle
- **MC** = motor cycle

#### Accident Analysis and Proposals for Improvements

- forward → left turning →
- stopped → right turning →
- starting → changing lane →
- reversing ↔ loss of control ↔
<table>
<thead>
<tr>
<th>ACCIDENT TYPE</th>
<th>LOSS OF CONTROL</th>
<th>PEDESTRIAN ACCIDENT</th>
<th>CHANG. LANE (SIDEWIPE)</th>
<th>NOSE TO TAIL</th>
<th>CONVERGING DIRECTIONS</th>
<th>HEAD ON COLLISION</th>
<th>BICYCLE HANDCART</th>
<th>OTHER</th>
<th>TOTAL %</th>
<th>APPROXIMATE UNIT PRICES in US $ (unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2</td>
<td>30-32</td>
<td>33</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAVEMENT MARKINGS</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane markings</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.35 (m)</td>
</tr>
<tr>
<td>Edge lines &amp; centreline</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>0.80 (m)</td>
</tr>
<tr>
<td>Zebra crossings</td>
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<td>-5</td>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>1.40 (m²)</td>
</tr>
<tr>
<td>SIGNS AND SIGNALS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflectors at curves &amp; Junctions</td>
<td>40</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>3.40 (refl)</td>
</tr>
<tr>
<td>Improved guidance</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>5</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>5</td>
<td>15</td>
<td>170 (sign)</td>
</tr>
<tr>
<td>Give-way sign</td>
<td>10</td>
<td>5</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>130 (sign)</td>
</tr>
<tr>
<td>Stop sign</td>
<td>15</td>
<td>-20</td>
<td>55</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>30</td>
<td>30</td>
<td>30 000 (junction)</td>
</tr>
<tr>
<td>Fixed time signals</td>
<td>20</td>
<td>-10</td>
<td>60</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>36</td>
<td>35</td>
<td>35 000 (junction)</td>
</tr>
<tr>
<td>Traffic-actuated signals</td>
<td>20</td>
<td>-10</td>
<td>60</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>36</td>
<td>35</td>
<td>35 000 (junction)</td>
</tr>
<tr>
<td>Prohibited parking</td>
<td>20</td>
<td>10</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>280 (junction)</td>
</tr>
<tr>
<td>1-way traffic (street)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>30 000 (street)</td>
</tr>
<tr>
<td>Speed reduction 100-&gt;80</td>
<td>30</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>18</td>
<td>50</td>
<td>50 (km)</td>
</tr>
<tr>
<td>&quot; 80-&gt;60</td>
<td>20</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>12</td>
<td>50</td>
<td>50 (km)</td>
</tr>
<tr>
<td>MINOR CONSTRUCTIONS</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement of bus stops</td>
<td>30</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>4 300 (bay)</td>
<td></td>
</tr>
<tr>
<td>Rumble strips</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>50 (set of 4)</td>
<td></td>
</tr>
<tr>
<td>Speed bumps</td>
<td>20</td>
<td>60</td>
<td>-5</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>20</td>
<td>110 (one)</td>
<td></td>
</tr>
<tr>
<td>Raised zebra crossing</td>
<td>20</td>
<td>70</td>
<td>-5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>22</td>
<td>120 (one)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian guard rails or corresponding measures</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>20 (m)</td>
</tr>
<tr>
<td>Refuge on pedestrian cr. or corresponding measures</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>500 (one)</td>
</tr>
<tr>
<td>&quot; minor roads</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>30</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>70 (m of length)</td>
<td></td>
</tr>
<tr>
<td>Main roads widening at T-junction</td>
<td>-5</td>
<td>5</td>
<td>30</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td></td>
<td>15 (m³)</td>
<td></td>
</tr>
</tbody>
</table>

("." means increasing number of accidents)
## REDUCTION OF ACCIDENTS (%)

<table>
<thead>
<tr>
<th>ACCIDENT TYPE</th>
<th>LOSS OF CONTROL</th>
<th>PEDESTRIAN ACCIDENT</th>
<th>CHANGING LANE (SIDESWIPE)</th>
<th>NOSE TO TAIL</th>
<th>CONVERGING DIRECTIONS</th>
<th>HEAD ON COLLISION</th>
<th>BICYCLE HANDCART</th>
<th>OTHER</th>
<th>TOTAL %</th>
<th>APPROXIMATE UNIT PRICES in US $ (unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>30-32</td>
<td>4</td>
<td>5</td>
<td>66</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### COUNTERMEASURES

#### CONSTRUCTIVE MEASURES

- Sealing/constructing ped. walk way
- Channellization
- Footpath
- Cycle track
- Under/over pass for ped.
- Improve cross section
- Lightning
- Access control
- Overtaking/climbing lane

#### MAINTENANCE

- Pavement patching
- Maint. of signs
- " of road markings
- Clearing sight obscuring plants

#### INFORMATION & ENFORCEMENT

- Information
- Police enforcement
- Intensified police enf.

("." means increasing number of accidents)
SOME SAFETY ASPECTS IN ROAD PLANNING

Generally there are four main aspects in road planning which have a direct effect on road safety:

1. Road alignment
2. Road width
3. Sight distance
4. Road environment

The effect of these factors depends on their combined influence.

Road alignment is one of the factors which controls the speeds of road users. The more bends in the road the lower the speed; and the lower the speed the safer the road.

The accidents risk will rise if the road is generally straight, but there is a sharp bend with a small curve radius. In this case a road user feels comfortable travelling at a relatively high speed while the curve radius is large. When the sharp bend appears, it will be an unexpected hazard.

In Figure 4/1 we can see that a radius of less than 500m can increase accident risk while one of 200m or less can cause significantly higher risk.

Figure 4/1. Accident rate and curve radius
With curve radius 600m and bigger the risk is about 1.5 accidents/10^6 veh.km, with radius 400m about 2.0 accidents/10^6 veh.km and with a 100m radius 4.5 accidents/10^6 veh.km or over.

Figure 4/2 shows both the curve radius and the number of curves per kilometre. It is obvious that the more curves per kilometre the safer the road is. Even relatively small radius bends (e.g. 200m radius) are not dangerous, if the road is constantly full of curves, i.e. five or more curves per kilometre. On the other hand the road will be dangerous, if only one curve with a radius of less than 150m appears after a two kilometres straight stretch, which means a risk five times higher than average.

**Figure 4/2.** Accident rate by curve radius and the number of curves

![Graph showing accident rate by curve radius and the number of curves](image)

**Road width** has definitely an impact on accident risk. On the other hand it also affects the speeds: the wider the road the higher speeds tend to rise. As known
high speeds are connected with a large number of accidents. However, international studies have proved clearly that sufficiently wide rural roads have better safety than too narrow ones.

In Africa erosion caused by rains, running water and wind is quite substantial. If shoulders and ditch edges are not properly made, badly damaged road edges may appear quite soon after construction. This reduces the effective width of the road and makes drivers go closer to the middle of the road. Driving in the middle of the road will increase the number of accidents. Therefore it is important not only to have roads wide enough but also to have good shoulders and road edges, paved with durable materials as hot-mix asphalt concrete or cement concrete.

Sometimes bumps are used on shoulders to prevent vehicles from driving on them. This is not good because shoulders should:

- serve as an area where a damaged vehicle can be parked in case of a breakdown etc. Bumps can hinder pushing a damaged vehicle on to the shoulder.

- improve road safety for moving vehicles by allowing some extra space e.g. in case of emergency manoeuvres. However bumps lead to loss of control if a vehicle hits them at full speed.

- improve the safety of pedestrians and cyclists by enabling them to move aside from vehicles. The bumps make cycling impossible and walking uncomfortable. Subsequently, pedestrians and cyclists do not move on shoulder but prefer roadway.

Additionally the bumps cost money; it is much better to use the money to construct a shoulder of proper material without bumps and to paint the edgeline well.

Minimum shoulder width should be 0.25m on each side, the full effect on road safety will be achieved with 1.5m width but practically 1m per side is enough.

Recommended road widths by dimensioning speed and road class are in the table on next page.

Sight distance has - together with road width - an impact on road safety. Poor visibility alone may cause a collision between oncoming vehicles. However, more often narrow cross section and short sight distance will result to queueing. A slowly moving queue is one cause of hazardous overtakings. These may cause loss-of-control accidents, if the road is narrow, or head-on-collisions, if sight distance is limited.
Table 1. Recommended road widths. The shoulder width is (minimum 0.5m) not included.

<table>
<thead>
<tr>
<th>Speed ADT km/h</th>
<th>A International All</th>
<th>B National</th>
<th>C Primary</th>
<th>D &amp; E Secondary/Minor*</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;100 veh/d</td>
<td>7.5</td>
<td>7.25</td>
<td>7.25</td>
<td>7.00</td>
</tr>
<tr>
<td>90</td>
<td>7.5</td>
<td>7.25</td>
<td>7.25</td>
<td>7.00</td>
</tr>
<tr>
<td>80</td>
<td>7.0</td>
<td>7.00</td>
<td>7.00</td>
<td>6.50 6.25 6.25</td>
</tr>
<tr>
<td>70</td>
<td>7.0</td>
<td>6.75</td>
<td>6.75 6.50</td>
<td>6.00 6.00 6.00</td>
</tr>
<tr>
<td>60</td>
<td>6.50</td>
<td>6.50 6.50</td>
<td>6.00 5.75</td>
<td>5.75</td>
</tr>
<tr>
<td>50</td>
<td>6.00</td>
<td>5.75 5.50</td>
<td>5.50 5.50</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* If the length of the road is less than 250m, minimum width = 3.5m, if it is less than 600m, minimum width is 4.5m.

Figure 4/4. Accident rate by sight distance and road width (no junction accidents included).
Accident rates by sight distance are presented in Figures 4/4 and 4/5. Figure 4/5 includes all accidents, while Figure 4/4 excludes junction accidents. We can see that the accident rate is low while the sight distance is 400-500 m or over. This is quite natural, because 400 m responses the distance within which two oncoming vehicles still can stop, if their speeds are 90...110 km/h. The high accident rate, while the sight distance is less than 100(200)m, is due to the fact that within this range even 50(70) km/h is too fast speed to avoid an accident with an oncoming vehicle.

![Figure 4/5. Accident rate by sight distance (all accidents)](image)

Road environment plays a role in influencing the seriousness of accidents. International studies have pointed out that the area where vehicles land after an accident extends to some 9 m from the road side. The area of the heaviest impact extends up to 3 m from the road side. In the following table 2 the road side area is classified according to its effect on moving traffic.
Table 2. Roadside obstacles and their effect on traffic

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>of an obstacle to road side</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0...1m</td>
<td>High risk of collision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of capacity</td>
<td>0,5m = minimum space between road and sign edge etc.</td>
</tr>
<tr>
<td>1...1,8m</td>
<td>Remarkable risk of collision; impact on capacity</td>
<td>Poles etc. devices should be placed outside this area</td>
</tr>
<tr>
<td>1,9-3,0</td>
<td>Remarkable impact on the seriousness of accident damages</td>
<td>Special attention shall be paid on the smoothness of this area</td>
</tr>
<tr>
<td>3,0-9,0</td>
<td>Outer safety zone having an impact on damages along high speed roads</td>
<td>No sharp, hard obstacles nor constructions if possible</td>
</tr>
</tbody>
</table>

Devices which might contribute to increasing accident risk and also the seriousness of the damage are e.g.:

- road signs and informative signs
- lamp posts and traffic light signals poles
- culverts
- bridge supports
- rock cuttings and retaining walls

There are also some special features to be checked from the point of view of road safety in connection with alignment and road environment:

- guardrails, where they start and end
- cuttings and embankments in relation to road alignment
- road alignment, speeds and road safety measures

The correct planning of these matters can save tens of human lives. To make the idea more concrete there are 3 examples:
Example 1. Guardrail on a river bridge.

While constructing a new road the river bridge was afforded with guardrails. The designer never paid attention to the alignment before the bridge. Two serious accidents appeared shortly after the opening of the road: in both cases vehicle lost control at the bend, overturned and landed in the river.

The two mistakes in design were too sharp bend and too short guardrail. (Reflective tape etc. on the guard rail might have improved safety, because the accidents occurred in darkness or twilight.)

Example 2: Curvature and embankment/cutting relations

A new road was constructed through a mountaneous area. Several loss of control accidents with tens of fatalities have occurred since then.

To avoid the accidents both the vertical and horizontal alignment should have been different so that:

- no bend starts in the area of embankment
- proper transition curves make the bend smoother

These changes together would have made loss of control rare and ensured vehicles stayed in the cutting in the event of accident.
Example 3: Location of rumble strips and bumps on a sharp bend

Almost one serious accident every week occurred in this bend with radius $R=600m$ (no transition curve). It was established that the radius should have been 850m, preferably over 1000m. Because of the high cost of improving the curve cheaper measures were tried. To reduce the number of accidents speed limit signs (80km/h) with two sets of rumble strips were implemented.

Some time later a bump was also constructed. It was situated about 250m after the rumble strips. Several loss of control accidents appeared again. The main causes of the accidents were:

- firstly that the bump was too far from the strips
- secondly that because of going downhill and because of the next uphill section vehicles tried and were able to reach enough speeds to climb up the next section. The bump was unpainted and thus more or less invisible.

The bump - if it was necessary - should have been located close to rumble strips (about 50m after the second set). Now the drivers started accelerating after the last set of rumble strips and the bump was a nasty surprise when their speed was already high.

The lesson here is that road safety measures may be dangerous, if they do not base on real facts of driver psychology and the vehicle movement (normal acceleration is 0.6-1.5m/s² and deceleration 1.5-2.5 m/s²). Because accidents occur when speeds are high and circumstances unfavourable it is recommended to test the plan with speeds which are 20-30% higher than the design speed.
DESIGN DETAILS

1. DESIGN OF SPEED BUMPS, RAISED ZEBRA CROSSING AND RUMBLE STRIPS

These speed reducing accident countermeasures are artificially made elevations on the carriageway. The purpose is to control speeds by making it uncomfortable to drive over them at excessive speed.

When correctly used these measures are quite effective. The problems connected to them are normally due to poor design: e.g. the bumps may be too high or too short, or both. Because wrong form can even generate accidents, special attention shall be paid to the correct design.

When constructing any of these measures the drainage must be carefully studied. Otherwise, there is high risk of causing large pools during heavy rains.

Figure 5/1: Speed reducing countermeasure
1.1 **Speed Bumps**

Using speed bumps can help

1. eliminate excessive speeds in a road section e.g. in town centre or trading centre, when through traffic represents an accident risk.

2. force drivers to stop at junction approaches to observe the (main) road traffic properly.

The dimensions of speed bump shall vary as follows:

- **height** 5-8 cm, being maximum six in the former (1) case
- **length** 1.5-5m, being 3-5m in case (1) and 1.5-2.5m, when a nearly full stop is necessary or case (2).

The design chart is below in Figure 5/2.

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**Figure 5/2: Design of a speed bump**

When controlling traffic in a trading centre or similar area bumps should be placed so that there is a 50-75m interval between each of them.
There should also be good road signs and 1-2 sets of rumble strips (page 5/5) on both approaches. The arrangement is in Figure 5/3.

Figure 5/3: Controlling traffic flow in a trading centre by use of bumps.

Bumps can be used to give more emphasis to a stop sign at a junction approach. The height of a bump shall be in this case 6-8 cm and the length 1.5-2.5m. The arrangement is shown in Figure 5/4. In 4-leg junctions bumps can also be constructed on each of the approaches.

Bumps should always be painted white preferably with reflective paint. At both ends of a bump a 60 cm high white or yellow pole with reflectors in both driving directions should be erected.
1.2 Raised Zebra Crossing

Raised Zebra crossing can be used to replace a bump in locations where a considerable number of pedestrians/cyclists cross the carriageway. The design is shown in Figure 5/5.
When a zebra crossing is at a junction, the whole junction area can be raised. Normally this is a useful alternative on minor roads like collectors, residential streets etc. (Figure 5/6).

In central area, or anywhere kerb stones are used along the street, a raised zebra crossing should be constructed to the level of the pavement. The slopes should be respectively longer.

If the raised zebra crossing is separate e.g. from bumps, rumble strips should be used as a warning measure in both approaches. They shall be placed 80-120m before the zebra crossing. Also warning signs should also be used (Fig. 9/3).

1.3 Rumble Strips

Rumble strips are transversal strips across the road. They can be constructed either higher or cut deeper than the road surface. The purpose is to warn motorists of a hazard, dangerous road location or whichever require their special attention.

Rumble strips shall be considered as a temporary warning measure and removed when the actual hazard has been eliminated e.g. by reconstruction of the road.

Rumble strips can be used for example in the following ways:

- before a bump or a raised zebra crossing (or a set of them) in both driving directions.
- at an approach to a dangerous junction
- to give emphasis to a warning sign e.g. before a sharp bend or at a railway crossing.

Figure 5/6: Raised junction area
If rumble strips are for warning, there is no need for a sign to warn about them. It can be considered that the warning sign relating the actual hazard is enough; the rumble strips should be soon after the sign.
The following principles should be observed when using rumble strips:

- Rumble strips should be in groups of 3-5 stripes
- The thickness of raised strips should be 10-15mm. If strips are cut into asphalt the grooves should be 6-9mm deep.
- Width of the strips is 500mm or 0.5m.
- Length of the strips should be that of the road including shoulders.
- In town areas one set of rumble strips is normally enough, on high speed roads two or three sets can be used to allow enough operation time.
- The first (or only) set shall be placed 30-50m before the hazard (e.g. bump).

Some examples of the use of rumble strips are shown in Figure 5/7.

2. IMPROVEMENT OF A PEDESTRIAN CROSSING

Where improving safety at pedestrian crossing the following points should be noticed:

(1) To locate the crossing site to where the pedestrians naturally cross the road.

(2) To make the road to be crossed narrower and/or construct a good pedestrian way leading to the crossing site (Figures 5/9 and 5/13).

(3) To construct a median island to make it possible to cross the road in two stages.

(4) To illuminate and/or to equip the crossing site with reflectors.

(5) To reduce the possibilities to cross the road at other sites by installing pedestrian fences if necessary.

However, the restrictions like fences are always artificial methods and voluntary behaviour shall be prioritized, i.e. the crossing site shall be the most attractive alternative.

The more pedestrians use the crossing site the safer the crossing. This is why the number of crossing sites should be limited - and the crossings should be designed so that they really are used.

The median should be preferably 2m wide (minimum 1.6m). It should be marked with reflective signs. The kerb shall be painted yellow and 2-3 reflective studs or equivalents should be fixed at the end of it.
Pedestrian (zebra) crossing should be at least 2.5m wide and of the same width as the pavement or pedestrian way. In town centres the pedestrians' right-of-way can be emphasized by making the crossing 4-8m wide and also the material used can be different from that of the street pavement.

To improve the visibility of the crossing in darkness, reflective studs can be fixed on its both sides at one meter inter-vals.

Figure 5/8: Zebra crossing

Figure 5/9: Narrowings and refuge at a pedestrian crossing
3. JUNCTION DESIGN

The four factors affecting on junction safety are

- junction form
- use of islands
- sight distances
- bus stops near the junction

Additionally the geometry of both major and minor road and the visibility of junction, i.e. whether drivers notice the existence of junction or not, have a great impact on safety.

The shape and the size of a junction should be as simple and small as possible. Complicated junctions with large numbers of turning lanes and islands increase possibility of wrong manoeuvres and thus accident risk. Wide empty areas encourage drivers to take shortcuts and thus cause extra danger.

Sight distance depends on the junction form especially through the junction angle.

![Diagram showing relative accident risk with different junction angles](image)

**Figure 5/10:** Junction angle 80-90° is the safest

Left turn lane improves safety. If traffic volume is relatively small, instead of an additional lane road widening can be used. The widening should not be on minor road side but on the opposite side at T-junction.

**Figure 5/11:** Road widening at junction
Islands are used to separate traffic flows moving in different directions, to separate vehicles driving at different speeds, to force turning traffic to a certain direction or to form safe space for a vehicle to wait for e.g. a crossing moment.

Islands should be at least 7m$^2$ of area. Small islands cause maintenance problems. Too many islands make junctions unclear and cause wrong manouvers.

The median island is the best island type from the point of view of road safety. Triangular islands should not be used unless really necessary - preferably not at all.

The Median island should be well painted and provided with good road signs to prevent island accidents. The risk may be high especially during the dark hours. Reflective signs and paints are recommended.

**Figure 5/12:** Example of road signs in a junction

Bus stops at a junction should be placed after the minor road in the direction of ongoing traffic. Special attention should be paid to situating them correctly in relation to pedestrian paths.

**Figure 5/13:** Bus stops at a junction