## RS ENGINEERING TOOLKIT

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Road Safety Engineering

Procedure Note 1.

Identifying Hazardous Locations in Bangladesh - Site Selection Techniques
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APPENDIX A. IDENTIFICATION OF HAZARDOUS SITES
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1. INTRODUCTION

The level of success of a Road Safety Unit will depend largely on the ability of the team to use the accident database to accurately identify, prioritise and deal with sites with a history of ‘treatable’ accident problems. Identifying Hazardous Locations in Bangladesh - Site Selection Techniques is the first stage in this process. Figure 1. shows the relationship between site selection techniques and other road safety engineering practices.

There are several established and proven procedures for arriving at effective site selection practice. All systems depend on the availability of reliable data collected over a reasonable period of time, usually three full years. In Bangladesh there is a lack of widespread data, where we have data the problem of accident under reporting means that we only have part of the full picture.

Where data is building up, accident problems are beginning to emerge. This paper sets out an interim practice that uses the data that is available now.

This can be achieved by:

• reviewing accident plots on the network to find accident clusters
• examining the detail of the accidents in that cluster, if common accidents are found
• preparing a simple basic analysis

This analysis will then be sent to the Head of the Road Safety Unit who will then decide what further preliminary analysis is required or if that location should immediately be put on the Accident Blackspot programme for full investigation.

The database will quickly grow and it will be necessary to use more refined orthodox techniques. Appendix A reproduces ‘The Identification of Hazardous Sites’ written by Stein Lundebye and Youssef Lahrech, The World Bank. As the situation improves data builds up and local expertise develops, ‘The Identification of Hazardous Sites’ will become relevant and will become a valuable tool to use and build upon. We are grateful to Stein Lundebye and Youssef Lahrech who freely gave their permission to reproduce this work.

We are also grateful to Graham Elliott (Transport Research Laboratory, UK) who during a recent visit prepared a short paper, Section 3, that sets out additional techniques for developing MAAPfive data for these exercises. Graham Elliott has been responsible for developing the database in Bangladesh.

Note: This Procedure Note should not be used by persons without appropriate Road Safety Engineering training.
Figure 1. Identifying Hazardous Locations in Bangladesh - Site Selection Techniques in Road Safety Engineering
2. PRINCIPLES OF SITE SELECTION

2.1 Identifying accident problems

An ‘accident problem’, as defined in Road Safety Engineering terms, is a group of similar accident types found at a location, on a route or in a specified area.

If the accident history of two fairly similar junctions are being examined; 15 accidents occurred at both locations, and if we then look closely at the type of accidents and can find treatable problems at one of the sites and none at the other, we can direct our resources to the site with the problems.

For example if at the first site we find that accidents are spread, occurring on different arms of the junction and they involve different road users carrying out different manoeuvres, it is unlikely that effective measures can be found.

If at the second site six accidents involved a vehicle turning right, from the major road into the minor, and seven accidents involved a pedestrian crossing the major road it is very likely that countermeasures can be devised to treat the two identified accident problems.

2.2 Accident history

A three year period is normally required to determine a location’s accident history, five years in rural or lightly trafficked areas. In the majority of cases sufficient data is not available. That should not hold up the search for accident blackspot sites. Analysis based on a reduced time scale will be incomplete and compromised but it will throw up problems. These ‘compromised’ analyses will require additional confirmation and ratification, through site investigation techniques.

Conditions during the period of study should be unchanged. The assessment and analysis must always take major changes into account. If a major traffic management scheme has significantly altered traffic volumes and patterns in the second year, it is highly likely that the accident pattern will substantially alter.
2.3 Rising trends.

The high rate of traffic growth in Bangladesh will influence accident rates. If the number of accidents at a site are increasing (a rising trend), is the increase due to a worsening local problem or pro-rata with a general growth in traffic, or results of a local accident problem developing. There are several techniques (using control data) that will clarify the situation. These techniques are discussed later.

2.4 Common problems

Measures can often be devised at locations with a high incidence of accidents involving:

- non motorised vehicles
- buses
- trucks
- right turning vehicles
- cross road collisions
- loss of control
- vehicles skidding
- pedestrian accidents
- head on collisions
- vehicles leaving the carriageway
- speed related factors
- occurring during the hours of darkness

2.5 Objectives

1. The primary objective is to design the annual work programme to lead to the implementation of the maximum number of well-targeted measures in each year.

2. When discussing site selection techniques, reference is often made to ‘easy’ sites and ‘hard’ sites. In this context an ‘easy’ site is a location with a strong, clearly defined accident problem, for which (after further investigation) it should be relatively easy to find the correct measures. A ‘hard’ site is a location with problems requiring fuller investigations and possibly wide ranging treatment. ‘Hard’ sites are invariably the
more important locations, major junctions or interchanges and involve large numbers of accidents. If a scheme is developed it is likely that scheme will require negotiation and approval of several outside agencies and departments. This can be complicated, time consuming and may result in considerable effort being spent on a scheme that stalls or fails to get the approval of all the participants. The final programme should include a large proportion of ‘easy’ sites with a fewer number of the most promising ‘hard’ sites. By focusing most of our efforts on easy sites we will ensure that we will implement a large proportion of the schemes, but not neglect work on harder sites.

2.6 The site selection routine

Annual programme. The major site selection programme should commence as soon as the full year’s data becomes available. This should produce the basis for the years work. To complement this programme, supplementary scanning of accidents on the network should be carried out at three months, six months and twelve month intervals.

2.7 Regular reviewing of the accident network

Regular reviewing of the accident network is elementary but good practice. Basic but systematic reviewing of the network can identify potential accident blackspots quickly and easily. Probably one of the most cost-effective and productive methods of identifying blackspot sites in London developed from this practice. If an engineer had some free time he or she would scan over the latest accidents on the network. When a potential problem was located the engineer would retrieve the latest three years’ data and prepare a preliminary stick diagram. From the stick diagram it was quite easy to see if that site had a problem or not. If the site had a problem the scheme was put on programme for a full investigation. In many cases a scheme was designed and on programme for implementation a few weeks later. It is suggested that a similar practice operating here will yield similar results. This practice is set out in chapter 4.
3. THE SCOPE OF MAAPfive IN ACCIDENT BLACKSPOT INVESTIGATION

This section has been prepared by Graham Elliott, Transport Research Laboratory, UK. Graham Elliott has been responsible for establishing the MAAPfive system in Bangladesh and he has been instrumental in developing the system in many countries.

The site selection techniques using MAAPfive in Bangladesh can be divided into two distinctly different categories as follows:-

1. Highway Accident Blackspots
2. City Accident Blackspots

3.1 Highway accidents

The location of highway accidents are recorded with the following information on the police database:-

- Class of Road
- Route Number
- Kilometre Value
- 100m value

Thus an accident at km value 65.8 on the Dhaka - Mymensingh Road would be coded as follows:-

<table>
<thead>
<tr>
<th>Class of Road</th>
<th>Route Number</th>
<th>Kilometre Value</th>
<th>100m value</th>
</tr>
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<tbody>
<tr>
<td>= N</td>
<td>= 3</td>
<td>= 65</td>
<td>= 8</td>
</tr>
</tbody>
</table>

The Route Numbering system is consistent with the one currently in use in RHD. Maps of each zone have been provided to the police accident data units to ensure the correct route numbering system is used.
The km value assigned to each accident on a highway will, as much as possible, be derived directly from the value on the km post. Thus if the accident occurred 200m north of ‘KM Dhaka 56’ on Highway N3 then it will be coded as 56.2km on N3. On many roads this is not possible as there must be a single ‘zero point’ for each highway and in many cases the distance to this ‘zero point’ is not displayed on the km post. Further problems occur when km posts are missing and when they are not spaced at km intervals. To overcome these problems an ‘Inventory of Landmarks’ has been produced for each route indicating the km value to use for each major landmark on the road. The km values in these documents have been ‘tied’ to the km post values where appropriate so that each km of the road could be a slightly different actual length. In more extreme cases there will be an apparent missing section of road or even a duplicate section of road. The latter is usually the result of an inconsistency in km post values on either side of a district boundary.

The selection of sites for accident remedial treatment is a relatively simple task for highway accidents. MAAPfive produces simple histograms for any selected highway. The histogram interval can be set at anything from 100m to in excess of 100km. Each of the major highways in turn should be studied using histogram intervals of 10km initially and working down to 1km intervals in areas where there are many accidents. Alternatively there is a simple option to list the worst sites on the highway being analysed. These tools are available from the ‘Kilometre & Link/Node Analysis’ option of the ‘Location’ menu in MAAPfive.

In order not to miss a highway that has many accidents a list of ‘worst’ highways can be obtained. This is obtained from the ‘Worst accident list’ option of the ‘Find Records’ menu in MAAPfive. The fields ‘Road Class’ and ‘Route Number’ should be selected and a list will be obtained of all the highways in the country on which accidents have been assigned. This option can also be used to identify the worst accident sites on highways in the whole country. In this case the two fields selected above should be supplemented with the ‘Kilometre Value’ field. This will give a list of the worst km sections of road over the entire highway network of the country. Adding the ‘100 metre’ field would produce a list of the worst 100m sections of highway in the country.

### 3.2 City accidents
The location of accidents in a city or large urban area where there are good street maps available is recorded with the following information on the police database:-

- XY Map Code
- X Co-ordinate
- Y Co-ordinate

The use of a ‘XY Map Code’ field is necessary as local rather than a national grid system is being used. Each local grid system devised must be assigned a unique grid (XY Map Code) code so that accidents from one city cannot be plotted on a map of a different city.

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<th>CITY</th>
<th>XY Map Code</th>
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<td>Dhaka</td>
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<td>Other Cities in Dhaka Range</td>
<td>10,11,12 etc.</td>
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<td>Chittagong</td>
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<td>Other cities in Chittagong</td>
<td>3,4,5 etc.</td>
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<tr>
<td>Khulna</td>
<td>20</td>
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<tr>
<td>Other Cities in Khulna/Barisal Ranges</td>
<td>21,22,23 etc.</td>
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<td>Rajshahi</td>
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<td>Other Cities in Rajshahi Range</td>
<td>31,32,33 etc.</td>
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<td>Sylhet</td>
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<td>Other Cities in Sylhet Range</td>
<td>41,42,43 etc.</td>
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The selection of sites for accident remedial treatment is not as simple for city accidents as it is for highway accidents. MAAPfive plots the accidents on scanned maps of the city and this identifies the accident pattern very visually. Identifying sites for treatment is best done by looking at the accident plots on screen and making quick polygon analyses to see a summary of the data within the polygon. If the site is of interest then the data should be saved so that it can be analysed using the other options within MAAPfive.

A listing of the worst sites can be obtained using the worst ‘Worst accident list’ option of the ‘Find Records’ menu in MAAPfive. The fields ‘XY Map Code’, ‘X Co-ordinate’ and ‘Y Co-ordinate’ should be selected and a list will be obtained of the worst 10m by 10m grid cells within the city. This is of limited use as the grid size is small and because the
grid may cut through the centre of a blackspot and thus divide it into two or more cells. The analysis capabilities of MAAP for Windows overcomes these problems by allowing the user to specify a cell size and by allowing neighbouring cells to be considered in the analysis. Within MAAP there are two further options for creating a list of the worst accident sites based on grid co-ordinates. These are within the vector mapping option for which a blank vector map will need to be set up and within the text mapping option which allows a simple text based accident plot to be displayed at various scales. It should be re-stated, however, that there is no substitute for intelligent visual examination of accident plots.

3.3 Searching for selected types of accidents

Site selection for remedial measures is not simply about finding the sites with the most accidents. It is more about finding the sites where the maximum reduction in accidents can be obtained and sometimes this is not the very worst sites. It is useful to look at the accident pattern with a variety of conditions (filters) applied to the data search. The following categories of accidents are suggested as a start:

- Night time accidents
- Accidents involving a pedestrian
- Accidents involving a rickshaw
- Head-on collisions
- Rear-end collisions
- Accidents involving a right turning vehicle

One or more of these analyses may identify sites with high numbers of accidents and also a common feature within these accidents. It is the common features within the accidents at a blackspot that form the basis of any accident countermeasures.
4. REVIEWING OF MAAP ACCIDENT PLOTS TO PRODUCE A PRELIMINARY LIST OF BLACKSPOT LOCATIONS

It is not necessary for the person carrying out the review to be an engineer. The reviewer should be trained and be familiar with all MAAPfive applications.

There are two ways of screening the network effectively. The first is, to select all accidents occurring on the network, the second is, to select various accidents types. In both cases the procedure is asset out below. The Head of the Road Safety Unit will advise and set the requirements for each exercise.

4.1 Example 1.

4.1.1 Identifying and examining a cluster of accidents at Khilgaon Road, Dhaka

As stated previously the clusters of accidents are quite easy to identify. As soon as a cluster is found, in this case when looking at an accident plot at Khilgaon Road, Dhaka retrieve the accidents by drawing a polygon around the area of the map, see Figure 2.

![Figure 2. A cluster of accidents is found and the reviewer has specified the area by describing a Polygon around the cluster](image)
By following the instructions in the latest MAAP\textit{five} user manual produce an accident stick diagram that will include all accidents in the cluster, see Figure 3.

**Accident stick diagram Khilgaon Road, Dhaka**

Two year period ending 31 December 1997

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**Figure 3. MAAP\textit{five} accidents stick diagram**

4.1.2 Examining the stick diagram for accidents patterns

Examine the stick diagram carefully for common accident types, is there a pattern of common accident types?

Examine each accident classification, for example:

- collision type (nose-to-tail, right turning, opposite direction)
- road user type (pedestrian, rickshaw)
- vehicle type (bus, truck, baby-taxi)
- day of the week, hour of the day

In the case of the above stick diagram (Figure 3.) we can see that of 17 accidents 13 involved a truck, eight occurred during the hours of darkness and seven of the truck accidents resulted in nose-to-tail collisions. This indicates that there is an accident problem involving trucks at the site. If we look a little further we will see that only one of the total number of accidents involved a pedestrian.
By following the instructions in the latest MAAP\textsuperscript{\textit{five}} user manual produce an accident stick diagram that will include all accidents in the cluster, see Figure 3.

**Accident stick diagram Khilgaon Road, Dhaka**

Two year period ending 31 December 1997

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*Figure 3. MAAP\textsuperscript{\textit{five}} accidents stick diagram*

**4.1.2 Examining the stick diagram for accidents patterns**

Examine the stick diagram carefully for common accident types, is there a pattern of common accident types?

Examine each accident classification, for example:

- collision type (nose-to-tail, right turning, opposite direction)
- road user type (pedestrian, rickshaw)
- vehicle type (bus, truck, baby-taxi)
- day of the week, hour of the day

In the case of the above stick diagram (Figure 3.) we can see that of 17 accidents 13 involved a truck, eight occurred during the hours of darkness and seven of the truck accidents resulted in nose-to-tail collisions. This indicates that there is an accident problem involving trucks at the site. If we look a little further we will see that only one of the total number of accidents involved a pedestrian.
These problems need to be drawn to the attention of the head of the Road Safety Unit who will decide if a formal investigation is justified. To do this we need to prepare an accurate summary of the accidents. This summary should include details of the total number of accidents at the site and a break-down of the number of each of the major accident types. The reviewer should also add any point that may be useful.
### 4.1.3 Preparing the accident summary

It is recommended that the summaries are presented in a clear and consistent manner. The format shown in Figure 4. is recommended.

| LOCATION | .............. KHILGAON ROAD, DHAKA ...........................................
| THAN | .............. SABUJBAG .................................................................

**Accident summary**

In the 24 month period ending 31 December 1997 a total of 17 accidents occurred at the above location.

Of these accidents:

**Accident type**

- 13 (76%) involved a truck of which:
  - 8 (61%) occurred during hours of darkness
  - 7 (53%) resulted in nose-to-tail collisions
  - 1 (6%) involved a pedestrian

**Accident severity**

- 4 involved a fatality
- 8 involved grievous injury
- 3 involved simple injury

*The review should also add any further comments that he/she feels may help later assessments.*

Name of reviewer: .................................................................

Date sent to Road Safety Unit: .............................................

---

**Figure 4. Recommended format for summarising accident problems**

As soon as the reviewer is satisfied that all problems have been identified, the summary sheet should be sent to the Head of the Road Safety Unit.
4.2 Example 2.

4.2.1 Identifying and examining a cluster of accidents at Narayanganj Road, Dhaka

When scanning the Narayanganj Road, the reviewer identifies clusters of accidents (see Figure 5), and decides to call up the stick diagram of these accidents.

![Figure 5. The clusters of accidents on Narayanganj Road](image)

The MAAP\textsuperscript{five} stick diagram is then produced (see figures 6a and 6b).

4.2.2 The stick diagram

### Accidents at Narayanganj Road, Dhaka (sheet 1 of 2)

For the two year period ending 31 December 1997

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**Figure 6a.**
4.2 Example 2.

4.2.1 Identifying and examining a cluster of accidents at Narayanganj Road, Dhaka

When scanning the Narayanganj Road, the reviewer identifies clusters of accidents (see Figure 5), and decides to call up the stick diagram of these accidents.

![Figure 5. The clusters of accidents on Narayanganj Road](image)

The MAAP\textsuperscript{five} stick diagram is then produced (see figures 6a and 6b).

4.2.2 The stick diagram

**Accidents at Narayanganj Road, Dhaka (sheet 1 of 2)**

For the two year period ending 31 December 1997

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![Figure 6a.](image)
Accidents at Narayanganj Road, Dhaka (sheet 2 of 2)

For the two year period ending 31 December 1997

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Figure 6b.

The preliminary analysis can now be carried out and the reviewer finds that 21 accidents involved a truck, 10 involved a pedestrian and eight accidents involved a head-on-collision. A total of 17 accidents resulted a fatality and 11 accidents occurred during the hours of darkness.

The analysis has identified several potential accident problems and the reviewer decides to prepare a summary for submission to the head of the Road Safety Unit, see Figure 7.
4.2.3 The accident summary

LOCATION : ..................... NARAYANGANJ ROAD, DHAKA ......................
THANA : .......................... DEMRA ..................................................

Accident summary
In the 24 month period ending 31 December 1997 a total of 28 accidents occurred at the above location.

Of these accidents:
Accident type
21 (75%) involved a truck
11 (40%) occurred during the hours of darkness
10 (36%) involved a pedestrian
8 (28%) involved a head-on-collision

Accident severity
17 (61%) involved a fatality
9 involved grievous injury
1 involved simple injury

The review should also add any further comments that he/she feels may help later assessments.

Name of reviewer : ...............................................................................

Date sent to Road Safety Unit : ..............................................................

Figure 7. The summary sheet for the clusters of accidents on Narayanganj Road

The summary is now ready to submission to the head of the Road Safety Unit.
APPENDIX A

Identification of Hazardous Sites

Stein Lundebye and Youssef Lahrech
The World Bank
Stein Lundebye and Youssef Lahrech

Introduction

There are normally three stages involved in any hazardous road location improvement program: the identification, diagnosis, and classification stages. At the identification stage, an attempt is made to select a subset of road sections from the population of sections that constitute the network. This subset is then used as input to the subsequent stages. The end result is a ranked list of sections which are likely to yield the best return in terms of accidents prevented for a given sum spent on road safety improvements. The identification stage is introduced as a screen to reduce drastically the number of sections to be examined. It must be borne in mind that any identification system selects the sections which should be examined first and it does not necessarily select all the sections that merit examination.

The main objective of the road safety engineering work is to change the road environment in the most efficient manner (i.e. within a specified budget) such that the maximum benefit in terms of accident savings is gained. This chapter is concerned with finding out where problem locations exist and the preliminary investigation required to try to determine the nature of the safety problems.

The first analytical step in the development of an accident reduction programme is the identification of hazardous sites, routes and areas ("blackspots") which may then be subjected to a detailed investigation, with a view to diagnosis of the accident problem and identification of an appropriate remedial action.

A high accident location is usually defined as a location that experiences abnormal frequencies, rates, or the severity of accidents. However, such high accident history may not necessarily mean that the location is truly hazardous. A hazardous location would be one that presents a risk to the driver in terms of high probability of accident occurrence or high accident severity.

Surveys of practice in the USA (Zegeer, 1982) and the UK (Silcock and Smyth, 1984) reveal that the vast majority of roads and highways authorities rely upon accident-based indicators alone. It is likely that this situation will continue for some time, as data relating to accidents (particularly injury accidents) are routinely collected in many.
countries, and very few authorities (if any) have the resources to collect routinely information on traffic conflicts and such like.

Ordinarily, a two-stage process is used:

- firstly, the accident history of all locations is reviewed, to select a limited number of apparently dangerous locations for further examination
- secondly, the selected locations are examined in detail, in order to devise cost-effective remedial treatments

The objective of a hazardous site, route or area identification procedure is to identify both those that warrant detailed investigation, and those that do not. This chapter is concerned with the first stage only.

The identification process can be divided into three major steps which are described in the following sections:

- Step 1 - Identifying and prioritising sites
- Step 2 - Preliminary accident analysis
- Step 3 - Initial site visit

A.1 Accident data research

It is necessary to identify high accident sites in the network for which the road authority has responsibility. Ideally, a period of three to five years of accident data should be reviewed. This is because accidents, even at very hazardous locations, are relatively rare events having a considerable random element, particularly in the time at which they occur. Statisticians tend to agree, therefore, that as a general rule, three years is really the minimum period needed to smooth out any abnormally large random fluctuations, to produce a reliable ranking of hazardous sites, and eventually to make evaluations of the treatments (i.e. compare with a three year ‘after’ period).

However, if such a long period is not yet available on the computer database, rather than wait for this time to elapse, shorter periods can be investigated as long as caution is exercised over the conclusions made.
The factors affecting the choice of time period included the following:

- avoiding having environmental and other trends affecting results
- using annual accident count data, to avoid the effects of cyclical variation in accident occurrence
- computer storage and processing costs
- using a short period, in order to detect quickly any sudden changes in the accident rate (per unit time)
- using a longer period to improve statistical reliability (i.e. smoothing the effects of short term fluctuations in accident occurrence)

A.2 Ranking of high-risk locations

The first stage of the investigation process is to study the data in a logical manner in order to define and rank problem sites.

It is important to try to define a "reaction level", that is, the number of accidents at which the investigator takes some action. A reaction level is set against three aspects of the accident data:

- **the number of accidents**: for example all injury accidents, injury accidents involving skidding on wet roads, injury accidents involving pedestrians
- **the type of highway unit**: for example unit length of route, limits of a complex junction, all roads within a defined urban area
- **the time period**: it is normal to use full 12 month periods and consecutive multiples thereof, whether or not calendar years

A "reaction level" is therefore the number of accidents per highway unit occurring within a defined time scale and above which investigations should take place.

Reaction levels can be set to provide selections of single sites, groups of sites, routes and areas containing accident numbers capable of being studied and treated by safety engineering staff in, say, the first five years of a 10 year program.
As an example of a reaction level criterion for single sites could be a blacksite definition of 12 or more personal injury accidents at and within 100 m of a junction of two or more main roads or on a 300 m section of road during the past three calendar years.

Detailed examples of criteria adopted by a highway authority are set out in "Guidelines for Accident Reduction and Prevention in Highway Engineering" published by IHT (U.K.).

It is important to be able to identify accident problem sites as efficiently and precisely as possible. However, it must be borne in mind that the objective of any ranking programme must be to produce sites with "treatable" accident problems.

A number of criteria may be employed for identifying blackspots, four of the most common being:

- the accident frequency, that is the number of accidents (or accidents per km) in a given period exceeding some arbitrary threshold value. This criterion takes no account of exposure
- the rate of accidents (per veh-km or per veh) for a given period exceeding some arbitrary threshold value. This criterion does take account of exposure
- the frequency and rate of accidents both exceeding their respective arbitrary threshold values
- the accident rate exceeding a critical value derived from statistical analysis of accident rates for all sites (this is commonly termed the rate-quality method)

It is often argued that it is unwise to rely solely on the frequency or rate of accident criteria, as:

- the accident frequency criterion on its own will lead to site selection biased towards sites on high-volume roads and having a large number of accidents
- the accident rate criterion on its own will lead to site selection biased towards sites on low-volume roads and having relatively few accidents

Hence, the third criterion has gained much support, as it ensures that the high-risk (accidents per exposure) sites, where there are relatively many accidents that may be saved, will be investigated in detail.
The fourth criterion involves assuming that the accident rates for different sites are distributed according to some probability distribution, assuming a critical level of confidence (between 95% and 99.5%, say), and then finding the critical accident rate, such that only a proportion (0.5% to 5%, say) of sites will have a higher rate and thus be deemed blackspots.

There seems to be no good reason for not extending the procedure to consider accident numbers as well as accident rates, to overcome the bias problem associated with the use of only one or the other. The advantage of the statistical approach is that it reduces the amount of arbitrariness in setting threshold values.

One can stratify accident according to severity, in an effort to identify those sites having a high number and/or rate of serious accidents.

A.3 Single sites

The simplest way of ranking accident sites is to list them in descending order of accident total; the site at the top of the list having the highest number of accidents for a three to five year period. Most accident systems will produce lists of sites ranked in this way, for junctions, stretches of road, or grid referenced cells.

In order to identify "treatable" accident problem sites it will be necessary to carry out further analysis at individual sites from the list. A high accident number does not necessarily imply a treatable problem - it may simply be a function of the size and type of the junction and traffic flow.
Figure 1(a)

Figure 1. shows two sites with high accident totals. Both are large grade separated roundabouts. In 1(b) there is no obvious dominant accident pattern. This can be compared to 1(a) which has a very clear "treatable" problem, involving loss of control accidents occurring on a wet road surface during hours of darkness.

An accident total listing needs to be updated at regular intervals. It should indicate improving or worsening situations and point to the most effective use of resources.

This is the simplest ranking method and provides a very useful and powerful tool in the subsequent decision making process.
It is important to try to define a "reaction level", i.e. the number of accidents or points above which the investigator takes some action. The reaction level is set based on the following three variables:

- **Number of accidents**:
  - e.g. (a) all injury accidents
  - (b) severity points weighting
  - (c) all pedestrian injury accidents

- **Type of highway unit**:
  - e.g. (a) kilometre length
  - (b) within 50m of junction
  - (c) links or mid-block accidents
  - (d) all roads in a defined area

- **Time period**:
  - e.g. 12-month periods of consecutive months (not necessarily a calendar year) are the normal periods used
An example of a reaction level criterion could be a blacksite definition of:

nine or more injury accidents,
[or 15 points or more],
within 50m of junction,
[or on a 200m road section],
over the past three years

It is probably better to focus on injury accidents in setting a reaction level as these tend to be more reliably reported than damage-only ones.

A.4 Mass action sites

In order to rank potential sites for mass action treatment it is necessary to relate a selected type of accident feature or manoeuvre to individual sites so that the sites can be ranked according to the number of accidents occurring at each for the selected factor.

Examples would be to rank sites for the following: (i) bend accidents (to indicate the location of the bends with the worst record) (ii) right turn accidents (iii) overtaking accidents (iv) night time accidents (v) failure to give-way or stop accidents (iv) accidents involving skidding (vii) pedestrian accidents (viii) bicycle accidents.

A highway maintenance programme for resurfacing or surface dressing skid sites can be established around the rankings for wet-skid sites. Street lighting engineers can be informed, via a ranking system related to night time accidents, of those sites where further detailed analysis could lead to the installation of improvements in street lighting systems.

It is often difficult to rank mass action sites because a particular accident type normally only represents a sub-set of the data at any one site. Thus smaller the number are usually involved. However, the simplest approach is to try to assess the likely accident savings for each mass action plan and rank these, producing a list with the greatest potential for accident savings at the top of the list.

Ranking accidents by different classes of road user can produce results of great value in considering work priorities, especially of road safety staff.
For example, cycle accident locations can be identified and ranked and the information then used to determine the need for special cycle facilities, for example, cycle tracks. Child cyclist listings can indicate not only problem locations, but also where cycling training should be concentrated thus helping to ensure that road safety staff resources are used effectively.

Analysis of pedestrian problem sites could enable policies for the provision and phased implementation of pedestrian crossing facilities and guardrails to be determined. It would also indicate if age is a relevant factor, and help to establish where training of the young or elderly should be concentrated.

Other road users meriting this approach include motor-cyclists and commercial and heavy goods vehicle drivers.

A priority ranking system listing accidents or casualties against a number of characteristics such as time, location, number and age can provide valuable information to ensure that resources are directed to the situations most deserving of attention. Another method of locating accidents suitable for mass action treatment is by means of computer plots.

A.5 Route action sites

The simplest way of ranking sites is that lengths of road can be ranked in descending order by number of accidents, number of accidents per km and/or accidents per million vehicle kms.

The criterion for ranking of hazardous routes may be one of the following:

- the accident frequency exceeding some threshold value (this ignores variations in route lengths and traffic flows)
- the accident frequency per km exceeding some threshold value (this ignores variations in traffic flows)
- the accident rate (per veh-km) exceeding some arbitrary threshold value
Despite the limitations of using veh-km as a measure of exposure, the third criterion is widely used. In order to avoid the bias problem, the use of criteria two and three together is recommended.

Whereas in hazardous site identification there is a tendency to use short lengths of road, with hazardous road selection, the analysis of accident data will generally be based on relatively long lengths (from one to several km).

The comments about the choice of time period (previous sector) apply here as well, although the statistical reliability factor is not as critical; although accident counts for individual sites may be very variable, the accident counts for an aggregation of sites (e.g. a route) is likely to be less variable, meaning that a shorter period of analysis is required for equivalent precision, this is clear from the charts for estimating the confidence limits for the underlying true accident rate (UTAR); the greater the observed accident rate, the greater the precision for the same observation period, so that the same precision can be obtained with a shorter observation period.

In the analysis it is important to consider whether to treat junctions in the overall analysis for a length of road. The junctions may have already been identified through one of the methods referred to above, and double counting of accident sites should be avoided.

Information on traffic volume and site length may explain, to some extent, variations in accident frequency between sites. It is unwise, however, to use accident rate, for example, accidents per million vehicle kms, as the main ranking criterion, since the highest-ranked sites then tend to be those with low flows which happen to have had one or two accidents. However, the rate can be useful in conjunction with other criteria to rank sites for priority treatment.

The values obtained by this calculation can relate either to lengths of road between junctions or lengths including junctions. If calculations are made for different classifications of road, they can be compared with known national statistics.

When seeking to identify unusually hazardous sites, it is necessary to sub-divide roads into sections; with intersections, it is necessary to decide what length of each approach road should be included in the intersection. It is common practice to consider that the 20-
30m of adjoining approach road is part of the intersection. With the sub-division of roads into sectors, practice varies considerably.

The factors that should be taken into account when choosing section lengths include:

- roadway and traffic characteristics should be fairly uniform within a section
- the section length should be in keeping with the level of precision and degree of error in reporting accident locations
- the length of influence of a hazard may be considerable, with vehicles losing control at a hazardous feature colliding with an object some considerable distance downstream
- statistical reliability

With respect to the latter, it is clear that as the section length gets very small, then the probability of zero or one accident in the period must tend towards unity. As the section length gets very large, the effect of isolated hazardous features will be submerged and lost. Zegeer (1982) states that accident rates:

"become unstable and of questionable value for highway segments of short length (i.e. less than 0.3 mile) and/or with low traffic volumes (i.e. less than 500 veh per day), even when several years of accident and volume date are used."

Zegeer found that practice in the USA is very variable, with section lengths varying from 30m to about 500m for "spot" lengths, and from 0.5km to 2.5km for "section" lengths. He recommended using about 500m for "spot" lengths and 2.5km for "section lengths", both lengths being substantially greater than generally used in the USA.

The survey of UK practice (Silcock and Smyth, 1984) did not elicit much information about lengths of road used, but it seems that lengths as small as 30m are used.

A.6 Area-wide action

Traditional approaches to accident investigations work have only considered accidents at single sites or on lengths of road. A more recent concept is to investigate accidents across a wider area, particularly urban residential areas.
In an urban area in the UK, it would not be uncommon to find over 80 personal injury accidents per square km per year. If treatment is carried out over say 4 km sq. (2km x 2km), the potential for accident reduction can be high.

A.7 Area-wide identification

It is a relatively new area of activity, and there is some doubt about the criteria that ought to be employed for identifying hazardous areas. A number of criteria are possible which are as follows:

1. the accident frequency per square km per year (this does not take account of variations in the length of road and traffic flows)
2. the number of accidents per head of population (this also takes no account of road length and traffic flows)
3. the number of accidents per km of road (this takes no account of traffic flows)
4. the number of accidents per vehicle owned or available to the population in the area (this attempts to take account of traffic flows in a crude manner)

The areas are generally of the order of five square km or larger. While the comments on section length do not apply, those on the period of analysis generally do. Again, given the aggregation of accident data for many sites, a shorter time period may be used than for the identification of hazardous sites, and still have comparable statistical reliability.

To carry out an area-wide study, it is important to be able to identify the extent of the accident problem and the location of accidents within areas, and to be able to rank the areas potentially available for treatment. No one system can guarantee the production of a list of all the problem sites. Ranking areas for treatment is not a simple matter and an assessment of the potential accident savings for each action plan should be made. Those yielding the best returns in terms of accident savings related to the cost of implementation should be placed at the top of the list.

A.8 Example of an area-wide ranking process

It is important to locate and identify those areas where vulnerable road users are most at risk, both in terms of total numbers, and relative to population figures. Vulnerable road users can be defined as pedestrians, pedal cyclists and riders of powered two-wheelers.
Initially, a number of areas are ranked by total accident and casualty numbers. A second list concentrates on the worst of these areas, ranking them in relation to population figures. The areas listed concentrate on the local distributor network and access roads.

This list of areas for investigation could be derived by producing a series of country-wide overlay graph plots describing all accidents on local distributor and access roads over a three year period. These plots would be at 1:50,000 scale for rural areas, and at 1:20,000 per urban areas.

The plots are then overlaid on base plans for the country. Geographical areas are identified as precisely as possible by tracing round the boundaries of accident cluster areas. The boundaries are defined by individual roads, railway lines or other geographical features. The size of each area drawn should be a maximum of 5 square km.

A count can then be made from the plot of the total number of accidents within each area, and a list of the totals produced for further investigation.

An overlay plan of, say, the worst 10 areas in terms of total accidents or total casualties could then be produced. This could be overlaid onto a series of paper plots of some or all of the following vulnerable road user categories:

- all pedestrian casualties
- child pedestrians (under 16)
- elderly pedestrians (over 60)
- all pedal cycle casualties
- child pedal cyclists (under 16)
- powered two wheeler riders

The number of each type of vulnerable road user in each area is then determined. It is important to ensure that no significant clusters lie outside the areas already identified from the general accident plot.

The list can then be revised to include the number of casualties for each vulnerable road user category.
A more detailed analysis can then be undertaken that includes a comparison with population details. For this to be achieved, estimates are needed for each of the 10 areas in terms of total population under 16, and population over 60.

It is then possible to produce a number of alternative priority lists, including those generated by accident or casualty numbers, and those generated by casualty rates per head of population. A final priority listing for the areas should relate to priorities set out in the local authorities' Road Safety Plan.

Depending on the sophistication of the accident enquiry system, some of the above tasks can be computerised, particularly if digitised accident data is available for plotting on Ordnance Survey (OS) maps.

### A.9 Characteristics of ranking procedures

The preceding sections have outlined the use of ranking procedures to refine the identification of sites which are candidates for treatment. The purpose of ranking is to reduce an initial list of sites which might be considered, to a shorter list which contains (predominantly) "high risk" sites.

**Figure 2.** shows a flow chart illustrating the use of ranking procedures to identify a series of single sites with potential for treatment with accident remedial measures. The accident database can be used to generate a variety of types of enquiry, including formal blacksites and ad-hoc blacksite enquiries. These should be combined to provide a manageable list of sites with potential for treatment.

In a formal approach, sites are searched systematically and those with an accident total at or greater than some "reaction level" (e.g. 12 accidents in the last three years) are selected for in-depth study.

Informal procedures are not easily defined, but might entail reacting to some unusual circumstance, for example, a sudden, apparent, increase in accident frequency at a site, a series of fatal accidents, or requests for action from the community.
Both procedures are intended to distinguish sites with "real" intrinsic problems from the mass of sites available for possible study, and both suffer from the effect that random fluctuation can have in making "low risk" sites appear to have greater problems than "high risk" ones.

Some of the ranked lists will need to be updated at regular intervals as more accident data are added to the main accident data file. Similarly, as the national cost of accidents, traffic flows, populations, lengths of roads and other variables change, updating will be necessary.
Comparison of the updated information with previous information will show whether an accident site, length of road or class of road user is becoming "worse or better" in the league table. It is possible to computerise this element of the work so that data is assessed and ranked regularly - for example, every six months a new ranking list could be produced based upon the previous 36 months record. In this way changes can be monitored accurately, frequently and efficiently, and if necessary revised priorities can be established.

Information obtained from the preliminary rankings of sites and areas should be made readily available to management so that they can consider decisions on further accident investigation work leading to the formulation of engineering remedial measures; devising and guiding road safety education, training and publicity programs; and enforcement.

A.10 Conflict studies

While accidents themselves are the obvious measure of the safety of an intersection, it has long been recognised that their relative scarcity, in the sense of experimental data, mitigates against obtaining statistically significant relationships without considering many years of collision history. This becomes a drawback when attempting to re-evaluate the effects of improvements and countermeasures or when studying a relatively new intersection. What is required is a substitute for accidents which can be observed in sufficient quantity over a short period of time.

The role of conflict studies is best illustrated within the context of the total accident collection and analysis system.

A.11 Basic concepts

In general, for traffic studies a conflict can be described as an incident or situation involving one or more vehicles, which causes a disruption in the normal traffic flow or a change in the orderly pattern of driving behaviour under conditions intrinsic to the location at which it occurs.

Traffic conflicts can be grouped into a number of basic categories or types, such as left-turn conflicts, weaving conflicts, etc.
The user of the traffic conflicts technique is also confronted with the necessity of defining the degree of conflict necessary to result in an actual, recorded conflict. Users of the technique in various countries have adopted a range of qualitative definitions. The advantages to be gained from using broad definitions are ease of recording and repeatability whereas the main disadvantages appear to be the inefficiency of the statistics for prediction of accidents. On the other hand, the use of more restricted definitions is likely to result in improved correlation with accidents but the data is somewhat subjective and difficult to replicate.

A.12 Uses of the traffic conflicts technique in practice

Research studies have indicated a high potential for the use of traffic conflicts procedures in identifying and diagnosing hazardous road locations.

However, there are a number of problems associated with the use of the traffic conflicts technique which detract from its potential effectiveness. One such problem is lack of observer reliability and consistency and even where this is reduced to a minimum through experience and supervision there are certain to be differences in interpretation between different studies making comparisons extremely difficult.

Another difficulty lies with the nature of the data itself and particularly the accident statistics. Accidents at a single location may vary widely from year to year without any outwardly noticeable changes occurring in traffic flow or driver behaviour.

Despite these limitations, the process of observing and recording traffic events and vehicular manoeuvres can, at the very least, make evident problems and solutions which might otherwise remain undiscovered. Whilst the technique has been validated for vehicle/vehicle conflicts at intersections, the possibility of extending its use to other situations, such as overtaking pedestrian/vehicle conflicts is not out of the question.

A.13 Specific uses of the conflict technique

1. Identification of Hazardous Locations. In large samples, conflicts can be significantly related to accidents especially when several years of collision history are employed. If, for a particular country or jurisdiction, a correlation between accidents and conflicts at a sample of road locations is established, then at other locations where a
conflict count produces results outside the confidence limits of the relationship, a problem can be considered to exist.

The definition of "hazardous" or "non-hazardous" will be made by the agency involved and reflects the normal or accepted level of safety which may be partly a function of social or economic considerations. In any event, once a level of conflict occurrence has been established in relation to exposure factors to represent the demarcation point, all potentially hazardous locations can be identified without further need to await accident occurrence.

Ideally, one would want to identify only hazardous locations without including non-hazardous ones or omitting some which might be critical. This is, of course, impossible since no model is perfect. However, the process can be optimised by judicious selection of the confidence limits employed to ensure that whilst the chance of missing a critical location is low, the model still remains fairly selective. Costs for this kind of procedure may, however, prove prohibitive.

2. Priority ranking of Hazardous Locations. Once hazardous road locations have been identified, the periodic performance of a conflict count can ensure the maintenance of an up-to-date database which at any given time, can provide an indication of the relative priorities to be assigned for treatment.

Accident potential, as represented by conflict rate, can be combined with costs of various treatment levels to arrive at a simple cost-effectiveness model by which to rank critical locations.

A.14 Preliminary accident analysis

Refining the Ranking by Statistical Techniques

Before embarking on an in-depth investigation at any site, it is advisable to check that the site has higher numbers of accidents than might be expected, and that this difference is statistically significant. The following sections outline some simple statistical techniques which may be used.
Averages or "Norms"

It is important to know whether the level of accidents is higher than expected, for example, whether the number of skidding accidents at a site is worse than average.

If a particular route is under consideration, this can be divided up into equal lengths (e.g. kilometres) and the average number of accidents per section calculated. This is referred to as the arithmetic mean or norm.

To determine whether particular sections warrant further investigation, the standard deviation (measure of the variability in the data) is normally calculated. The coefficient of variation $C_v$ is a simple measure of how a set of data varies from its mean, with values of $C_v > 1$ regarded as very substantial deviation.

If $x_i =$ Number of accidents in route section i,

$n =$ Number of equal length sections in the route,

\[ \bar{X} = \frac{\sum X_i}{n} = \text{norm or mean} \]

\[ \sigma = \sqrt{\frac{\sum X^2 - (\sum X)^2}{n} / n} = \text{standard deviation} \]

\[ C_v = \frac{\sigma}{\bar{X}} = \text{Coeff. of variation} \]

Those sites that have more accidents than the mean plus one standard deviation should be the first to be singled out for investigation.
Example

Consider the example stretch of Federal Route 1 shown in Fig. 3.2 and take x as the frequency of injury accidents in three years.

<table>
<thead>
<tr>
<th>Section</th>
<th>Number of Accidents (X)</th>
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<tbody>
<tr>
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<td>13</td>
<td>4</td>
</tr>
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<td>12</td>
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<td>16</td>
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<td>19</td>
<td>12</td>
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<tr>
<td>20</td>
<td>0</td>
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<tr>
<td>21</td>
<td>16</td>
</tr>
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<td>22</td>
<td>2</td>
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<td>0</td>
</tr>
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<td>26</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ n = 27 \]

\[ \sum x = 168 \]

\[ \bar{x} = \frac{\sum (x / n)}{n} = 6.22 \]

\[ \sum x^2 = 2184 \]
\[
\sigma = \sqrt{\frac{2168 - 27(6.22)}{(27 - 1)}} = 6.62
\]

\[C_c = \frac{6.62}{6.22} = 1.06\]

Thus there is considerable variation between 1km sections along this road in their accident occurrence. Those sections with more than 12 accidents (i.e. 6.22 + 6.62) are certainly worthy of further investigation, i.e.:

<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>21</td>
</tr>
</tbody>
</table>

**A.15 Statistical tests**

“Norms” are frequently used to establish the significance of site parameters. Statistical tests can be carried out to establish the significance of the difference between the norm and a site value, and to define whether the difference is due to random fluctuations or real problem with the site. They are also used to examine the probability of certain events occurring. The statistical tests normally used in accident investigations are considered below:

**A.16 The Poisson Test**

This test (for randomly occurring events) is commonly used to determine whether a recent increase in accidents at a site was due to random fluctuation only (and will return to previous levels).

It is used to calculate the probability of a particular frequency of accidents occurring in a year when the long term average is known.

Statistical analysis procedures are based on the assumption that the data is governed by a random process. There is some evidence that accident counts are not always random. The randomness of accident counts can be assessed, by analysing the order in which
observations are obtained, using the "runs test of randomness". Such an analysis provides information not available from an analysis of the frequency of events.

The runs test of randomness is a standard non-parametric test, which enables one to assess the probability that a sequence of observations (accident counts, say) were produced by a random process. With some modifications, the test can be used to identify, in addition, the nature of non-randomness. That is, it can detect and distinguish between the following sources of non-randomness in annual accident counts:

- a secular trend
- a cyclic variation (an over-corrected process)
- a discontinuity

The test involves identifying runs above and below a varying specified level; establishing the 90% or 95% confidence limits for the number of runs (for each value of the specified level); rejecting the null hypothesis that the accident count sequence is random, if the observed number of runs is too high or too low (i.e. lies outside the confidence limits).

Example

Let us assume the injury accident figures for a site area are as follows:

- 1991 = 2 accidents
- 1992 = 0 accidents
- 1993 = 1 accident
- 1994 = 5 accidents

If this site is selected on the basis of the last year, it is better to confirm that some change has happened at the site such that the next year will also be high, and not that the apparent increase has occurred by chance.

Long term average = (2+0+1+5)/4 = 2

Using the Poisson Probability (Single factor values) tables (Appendix A), look for the high year value of 5 in the left hand column (k=5) and across to the column of (mean)=2.
The value here is 0.0361 which means that the probability of 5 accidents occurring where the long term average is 2, is 0.0361 or 3.61%.

However, the likelihood of five or more accidents occurring at the site should be quoted. To do this simply add the probabilities of k=5, k=6, k=7, k=8 etc.

That is :-

\[0.0361 + 0.0120 + 0.0034 + 0.0009 + 0.0002 = 0.0526\]

Thus the probability of five or more accidents occurring due to random fluctuation is 5.26%, i.e. about a one in 20 chance that this is random or a 94.74% (100-5.26) chance that this a real increase.

**A.17 Chi Squared Test**

This test is normally used for two purposes:

- to determine whether the number of accidents of a particular type is "significantly" higher than at similar sites

- to check whether there has been a "significant" change in the number of accidents at a site after treatment has been carried out

**Example**

A particular junction is suspected of having a poor skid resistant road surface, and has the following accident record:

"Skidding accidents" = 7

No skidding reported = 5

For all other similar junctions along this road the accident record over the same period was:
"Skidding accidents" = 37  
No skidding reported = 178

We need to test whether the skidding accidents are significantly different from what might be expected. The following (2x2) table should be set up:

<table>
<thead>
<tr>
<th></th>
<th>Site</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skidding</td>
<td>7</td>
<td>37</td>
<td>44</td>
</tr>
<tr>
<td>No skid</td>
<td>5</td>
<td>178</td>
<td>183</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>215</td>
<td>227</td>
</tr>
</tbody>
</table>

Using the Chi-Square formula:

$$\chi^2 = \frac{(|ad-bc| - \frac{n}{4})^2}{efgh}$$

$$\chi^2 = \frac{(7 \times 178 - 5 \times 37 - \frac{227}{2})^2}{12 \times 215 \times 44 \times 183}$$

$$= 9.81$$

In the Chi Squared Distribution Table (Appendix B), looking along the line with on degree of freedom (=1), the value just below the 9.81 calculated above is 6.64 which is the 0.01 "significance" level, i.e. 1%.

This means that the chance of getting seven skidding accidents at a site with a total of 12 by chance is only 1% (one in 100 chance). Thus it seems fairly certain that there is some reason why the skidding accidents are occurring at this site.
A.18 Interpretation of "Significance"

The significance or confidence levels of results from the above statistical tests can be interpreted with the following practical meanings:

It is generally agreed that only results significant at (or better than) the 5% level can be regarded as conclusive.

<table>
<thead>
<tr>
<th>Significance (Confidence) Level (%)</th>
<th>Subjectives Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1[99]</td>
<td>highly acceptable</td>
</tr>
<tr>
<td>5[95]</td>
<td>acceptable</td>
</tr>
<tr>
<td>10[90]</td>
<td>some indication</td>
</tr>
<tr>
<td>20[80]</td>
<td>weakly indicative</td>
</tr>
</tbody>
</table>

A.19 Preliminary visit

The site visit is a very important element of any accident investigation. The main purpose of the first site visit is to become familiar with the site and to ensure that available plans are up to date and detailed enough to identify specific features which may be contributing to accidents; for example, visibility sight lines, street furniture, buildings.

The investigator should identify the manoeuvres indicated in the accident reports and try to visualise the accidents, particularly those with common characteristics. It might be necessary to make visits at different times of the day, or in dark and/or wet conditions, in accordance with the factors revealed in the stick diagram.

It is often possible at this early stage to make a preliminary assessment of the likely causes of certain accident types.

The use of photographs taken at driver/pedestrian eye height or an overall view can be an invaluable aid in the office or at presentations to committees.
A.20 "Easy" and "Hard" sites

Following initial site visits to a group of sites it may now be possible to attempt to further rank sites even at this stage into two classifications. These are whether they will be easy or hard to treat. This can be done more accurately later when costs and benefits are estimated.

Easy sites are those where effective remedial measures can be readily identified and are of low-cost.

Hard sites are those which do not provide a clear indication of appropriate treatment or where this is likely to be very costly. In the former case, the site should be selected for further, more detailed investigation if it has high numbers of accidents. In the later case it may be necessary to include the site in a capital works programme for the area.

For operational purposes, the easy site should be tackled first as they should provide:

- good return on money spent
- an immediate improvement in the accident records (useful argument for allocation of funds for future years)
- an important psychological boost to staff to see successful results from implementation of schemes.
Reference for identification of hazardous sites chapter


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"Developing a Road Safety Master Plan and Road Traffic Accident Information System" (Appendix on Traffic Conflict Study), Ministry of Transport and Communications, Thailand.
### APPENDIX A

**Poisson Probabilities**  
(Single Factor Values)

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Road Safety Engineering: Procedure Note 1.

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Road Safety Engineering

Procedure Note 2.

Treating Accident Blackspots in Bangladesh
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**Procedure Note 2. Treating Accident Blackspots in Bangladesh**

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1. INTRODUCTION

Road traffic accidents are the result of a failing in the relationship among three elements, the human, the vehicle and the road.

Considerable international research has been carried out into the problem of road traffic accidents. To understand how road safety engineering has contributed to accident reduction it is necessary to set out some of the findings and commonly held views that have emerged from this work.

Safety specialists define the accident as ‘A rare, multi-factor, random occurring event, always preceded by a situation in which one or more persons have failed to cope with their environment.’

- **rare**, in that, many tens even hundreds of thousands of journeys may be safely made through the most hazardous location (accident blackspot) before the next accident occurs at that location
- **multi-factor**, each accident is the result of a unique chain of several events leading to the accident
- **random**, the next accident can occur at any point in time at any place
- **failed to cope**, the participant(s) were not able to avoid the incident

Road safety engineering can do little to prevent rare or unique events from occurring in the future. The practice achieves accident reduction where we discover locations on the highway, where road users are constantly failing to cope, in similar circumstances, in the same, environment, in other words, by treating an 'accident blackspot'.

This Procedure Note sets out the practice for treating accident blackspot sites. Accident blackspot site investigations, sometimes referred to as single site investigations, are the basis of Road Safety Engineering. The investigation of accidents occurring at a single location leads to an understanding of the cause of the accidents, and it is then possible to devise countermeasures that help future road users to cope.

Treating accident blackspots is one way of applying road safety engineering, and has now been practised for over 30 years. Other techniques, such as route studies, area-wide schemes and mass action plans have developed from this work. These techniques are all to be covered in separate, following Procedure Notes.

Figure 1. Accident Blackspot work in Road Safety Engineering, sets out the full range of practices and the relationship between those practices.

*Note: This Procedure Note should not be used by persons without appropriate Road Safety Engineering training.*
Figure 1. Treating Accident Blackspots in Bangladesh in Road Safety Engineering
2. COMMENCING THE INVESTIGATION

The majority of schemes will be generated by the Road Safety Units ‘Scheme Identification Programme’ supplemented by requests for an investigation coming into the Road Safety Unit from a number of external sources.

2.1 Administration

Each new investigation must be recorded in a central register as soon as it is received.

The register is a management tool and will help the Head of the Road Safety Unit to track the progress of each investigation.

It is suggested that the register contains the following details:

- scheme or investigation number
- date of request
- source of that request
- the site location and Thana
- are any highway schemes planned for this area
- the name of the engineer who will carry out the investigation
- date analysis completed
- date scheme designed
- date scheme agreed
- date scheme on programme - works order issued
- scheme implemented
- no feasible scheme

A master file will be opened for each investigation. The master file (bearing the investigation number) will contain a copy of all the administration papers and as the investigation proceeds, a record of all relevant developments (meetings notes, working papers etc.) that arise as a result of the investigation.
A working file should be opened at the same time. The working file will contain all of the working details relevant to the investigation, drawings, site photographs, calculations stick diagrams.

It is the working file which should be passed to the engineer who will carry out the investigation.
3. BUILDING UP THE ACCIDENT ANALYSIS

All stages of the investigation are important, but it should be kept in mind that a thorough and complete analysis that identifies the full extent of the problem(s) will probably lead to the implementation of measures that will achieve the best reduction in the numbers of accidents. A weak or compromised analysis will not.

If possible three years data should be used in urban areas and five years data in rural areas.

In many cases, accidents that have occurred on approaches to the location have been directly or indirectly attributed to events occurring at the location. When investigating hazardous locations it is important to extend the analysis to include accidents occurring within 100m of that location.

3.1 Retrieving the data

Refer to the latest MAAPfive user manual and retrieve the latest accident data for the location and the immediate vicinity.

![STICK DIAGRAM ANALYSIS](image)

Figure 2. MAAPfive accident printout
When the data is ready it will be possible to prepare the preliminary accident summary. A typical accident summary will state the total number of accidents that have occurred in the period, the major accident types (with percentages of the total) and any important features found in the analysis.

For example:

In the three years ending February 1998 a total of 32 accidents occurred at the junction of X Road and Y Avenue.

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<td>(34%)</td>
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<td>Right turning vehicle</td>
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<td>Cross road collisions</td>
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<td>(31%)</td>
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This information with a site location plan should then be entered on the Accident Stick Diagram Sheet, see Figure 3.

3.2 Preparing the chronological stick diagram

Accidents are usually complex events that involve many factors. Most of the factors are recorded in the data system. The stick diagram (Figure 2) reduces the data to present the primary details in a more visual, graphic way.
Each stick diagram page presents the details of ten accidents. By entering each of the basic items of information by day, date, time, light conditions, road surface, severity of injury and adding the accident conflict (a diagram of the collision) we can recreate each accident in a more visual, fairly easy to understand form. Four additional blank boxes are provided for you to add additional items of information that are noted occurring in many accidents, perhaps skidding, vehicle type or location details.

The details of 40 accidents can now be condensed to four A4 pages to provide an overview of the accident history.

To illustrate the conflict of each accident IDC have prepared a key of standard symbols for the stick diagram, see figure 4.
Figure 4. IDC Key to symbols for use with accident stick diagrams

- Moving vehicle indicating direction *
- Motor cycle/moped
- Autorickshaw Tempo/Mishuk
- Cycle Rickshaw
- Cart, either human or animal drawn
- Bicycle
- Pedestrian indicating direction and age
- Pedestrian in road not crossing and age
- Pedestrian getting on/off P.S.V. and age
- Bus passenger injured, with age of passenger
- Vehicle going ahead held up
- Vehicle turning
- Vehicle waiting to turn
- Vehicle stopping
- Vehicle skidding
- Vehicle overtaking
- Vehicle loss of control
- Vehicle changing lane
- Vehicle hit central barrier
- Vehicle hit kerb
- Vehicle hit street furniture
- Parked vehicle
- Vehicle which has disobeyed junction control indicated by asterisk

Note: Car unless specified, HT Heavy truck, MT Medium Truck, ST Small Truck, PSV Bus, MB Mini Bus (16-29 seats) MICRO Bus (12-15) seats.
3.3  **Showing the accident conflict on the stick diagram**

Each symbol represents a road user, the arrow indicates the direction of travel, if the arrow is terminated by a short line, that vehicle or road user was stationary at the time of the accident. Assuming that the top of the stick diagram is north, the right east etc., you can use the symbols to set out the event.

For example, if a vehicle was right turning, south to east, at the time of the accident, the symbol is shown starting at the bottom, turning to the right with the arrow pointing to the right.

![Vehicle turning right at the time of the accident.](image)

If that vehicle was stationary, held up and waiting to turn right, the diagram will be the same but the arrow will be substituted by a short vertical line.

![Vehicle waiting to turn right at the time of the accident.](image)

As the work progresses you are likely to see and note certain similarities. Perhaps, similar accident types, direction of travel, time of the day, day of the week. You should note these points. When the stick diagram is complete you should have a reasonable ‘feel’ for the accidents occurring at the site.

3.4  **Preparing the accident plot, Figure 5.**

Using a small scale plan or drawing, carefully plot the location of each accident and link the location to a balloon showing the accident conflict. As the accident plot builds up you will notice further similarities, in the accidents, again you should note any observations made.
As the work progresses certain pieces of information may not be clear or more detail may be required. The police accident reporting form includes fuller details, of the incident. Sketches and comments on the form often yield important clues and detail. If it is felt that additional information will help the investigation, the engineer should discuss the possibility of access to the forms with the Head of the Road Safety Unit who will, if necessary make arrangements with the local police for you to visit the local Thana police office to inspect the details.

Figure 5. Accident plot. The accident plot shows the major problem, 14 pedestrian accidents occurring in the junction. Ten of these accidents resulted in a fatality

By examining both the stick diagram and the accident plot, the dominant accident types should now be quite clear. There are several techniques for developing and teasing out finer points of the analysis. One method that is often effective is to colour code the accidents. Prepare additional photocopies of the accident plot and by referring to the stick diagram, colour code each accident type. For example:
• those occurring on a wet road surface
• those occurring during the hours of darkness
• those occurring on a weekday
• other examples are when the road is likely to be busy or accidents occurring on a weekend or a public holiday when the road will be less busy.

3.5 Quantifying accident problems

An analysis finds that nine accidents in a total of 20, involve pedestrian injury. How do we gauge the extent of this problem? A simple but effective technique is to compare the accident rate at the subject site with the accident rates found at similar (control) sites.

When using or preparing accident rates the important point to keep in mind is that you must always compare ‘like’ with like’.

If for example the above investigation is at a four armed traffic signal controlled junction, in an urban area, you need to obtain accident rates for similar junctions with similar exposure to accident risk i.e. other four armed traffic signal controlled junctions in urban areas.

Accident rates should be based on a three year average and it is advisable that they are updated frequently, preferably recalculated annually.

The following procedure produces reliable results.

Stage 1. Identify all similar sites, in this case four armed signal controlled junctions, in urban areas, with similar traffic / pedestrian flows. The sample shall include as many sites as possible but avoid including any location that may be affected by circumstances that may have altered accident rates for example, major traffic improvement schemes.

Note. If the exercise is being carried out in a city, where we can expect to find several similar sites we can look for ways to refine the rates. Traffic usually travels faster in outer areas, this affects accident rates and types. If this is likely to be the case split the data sets into two groups, the first for inner areas and the second for outer areas.
2. Extract the latest three year accident data for each site. In this case you will examine junction accidents but it is important to include accidents occurring on the approaches to the junction. Include all accidents occurring within 50m of the junction.

3. Prepare the data to show the total number of accidents occurring at each site in the following categories:

the total number of accidents at the site

the total number of accidents involving a

- vehicle turning right
- cross road collision
- nose to tail collision
- pedestrian
- non-motorised vehicle

the severity ratio, all accidents involving a fatality or serious injury (expressed as a percentage of total accidents)

total accidents occurring during hours of darkness

4. Produce a short report that sets out accident rates for each of the selected accident categories. The report should describe the methods used to arrive at the rates and provide a clear description of the parameters in the exercise, for example, have you used junction accidents only or included accidents occurring on the approaches to these junctions.

3.6 Using accident rates

It is now possible to compare accident rates found in the investigation with these rates. If the total number of accidents at the site is higher or lower than the average rate, or if we find that the rate of pedestrian accidents is higher or lower than the average rate, we can
state that in the analysis. In the above case we needed to know if nine pedestrian accidents is high or low. If the average pedestrian accident rate is three, the rate at the investigation site is three times higher. The pedestrian accident problem at this junction is three times greater than we would expect.

Accident rates are sometimes referred to as ‘expected levels’ of accidents. For example if a further site is discovered and that site meets the criteria for selection, you would expect the total number of accidents to be close to the average rates. Any substantial variation would indicate a specific problem.

### 3.7 Preparing the sorted stick diagram

By now you should have a good understanding of the accidents occurring at the location and it is possible to sort the accidents into groups of the similar, or dominant accident types. Re-number the accidents to show the major problems first, followed by secondary less common accident types and finally the rare or individual accidents. Re-draw the stick diagram in the sorted order.

When the sorted stick diagram is complete, redraw the accident plot and include the new (re-sorted) accident number so that they can be cross referenced with the revised stick diagram. See Figure 6, the sorted stick diagram.
The sorted stick diagram showing the ranked order of accidents.

Two or more heads are better than one. It is surprising how often an engineer can work on an analysis for several days and yet may miss the obvious. Always invite colleagues to look at your work, a second, fresh pair of eyes will often spot a pattern or grouping that you have consistently overlooked.

When you have reached this stage you should be ready to prepare a full written analysis. Your notes will help you to complete the analysis.

3.8 Completing the analysis

The analysis is likely to fall into one of three groups.

Clear problems have been identified

If clear, definable problems have been identified, write up a summary and an overview of the problems identified on the accident investigation sheet. The fuller, more complete analysis should be filed in the working file for future reference.

It is suggested that the accident summary is set out as follows:

*In the three year period ending February 1998 a total of 32 accidents occurred at the junction of X and Y junction. Of those accidents 19 involved a pedestrian, 16 crossing the main carriageway. Of the 16 main carriageway pedestrian accidents 11 occurred on the east arm, all occurred within 40m of the junction.*

*Of the remaining accidents, eight involved a vehicle turning right of which seven involved a vehicle turning south to east, in each case the right turning vehicle was in collision with a vehicle from the opposite direction. Seven of these accidents occurred outside of peak traffic conditions, when traffic is light.*

*Note. There is a serious problem of accident under reporting in Bangladesh. When quoting accident numbers, consider adding a footnote reported to the police*. 
Inconclusive or borderline analysis

Some investigations produce results that are inconclusive or borderline. There are problems but you know that there are far worse problems at other locations, and that your time would be more profitably spent working on those sites. Discuss this with the Head of the Road Safety Unit and if it is agreed, classify the investigation as ‘inconclusive analysis’. The master and working files should be stored away for possible future reference.

It is quite possible that these problems may suddenly worsen and to protect against this it is strongly recommended that accidents occurring at these sites are kept under review.

Arrange to review the accidents in 12 months time. The additional data gathered in this time will provide you with a fuller picture.

No identified problems found in the analysis

If the analysis has failed to identify specific accident problems stop the investigation. Report the result to the Head of the Road Safety Unit and if it is agreed that there is no or limited potential to achieve an accident reduction, close the file and record the details ‘no identified problems found in the analysis’ in the central register. The master and working files should be stored away for future reference.
4. **THE SITE VISIT**

4.1 **Personal safety**

Working on or even near to a public highway is always very dangerous. One moment of carelessness can result in an accident. By international standards road user behaviour in Bangladesh is poor. Every day we see examples of high speed, reckless driving and irresponsible behaviour. At present there are no standards for safe working on roads. Safety on site must always be paramount. You have to consider your personal safety, your colleague's safety and the safety of the general public.

If an on-site operation is considered to be unsafe by the senior officer on site, then that operation must not go ahead. The matter shall brought to the attention of the Head of the Road Safety Unit, who will make appropriate safe arrangements.

4.2 **Arriving at the site.**

Safety on site means thinking 'safety' the moment that you get to the site. Make sure that you park the vehicle away from conflict zones, a junction or busy area. Avoid leaving your vehicle in a position that inconveniences or may create a potentially dangerous situation, for example:

- Will your parked vehicle inconvenience pedestrians, perhaps forcing them to walk out into the carriageway?

- Will your stationary vehicle force slow moving vehicles to move out into a faster lane?

When available, reflective jackets must be worn at all times.

Certain tasks (taking difficult photographs, or dimensions) will require concentration. It is quite easy to become fully engrossed in these tasks but never pay less than 100% attention to oncoming traffic.

You should avoid working in the carriageway with your back towards oncoming traffic. If your duty requires you to photograph a junction approach, arrange for a colleague to watch oncoming traffic for you. Make sure that actual work and time spent on the carriageway is kept to a minimum. If it is possible avoid taking notes on the carriageway, go to the side of the road to write up notes.
Any unusual activity will distract a driver. When you are working in the carriageway avoid making sudden unpredictable movements. If you are trying to take a difficult photograph and you step back or to the side, this may cause a vehicle to swerve and lose control.

4.3 Team safety

If you have to work in the carriageway first discuss the implications for safety with your colleagues. Agree a safe procedure; arrange for one team member to watch oncoming traffic, instruct that all team members must obey an instruction from that observer.

4.4 Public safety

It is often the case in Bangladesh, that roadside work generates considerable local interest. If a crowd does start to gather, make sure that they are off the carriageway and not creating danger to themselves or others. When this has happened in the past the crowds have agreed to a friendly request to move on, or move off the carriageway.

4.5 Items usually required for the site visit

- reflective jackets
- working copies of the accident stick diagram and accident plots
- a camera for site photographs
- note book, survey pad for recording details
- a small scale plan will be useful for plotting the location of site details
- measuring tape
- stop watch for traffic signals

Some engineers prefer to carry out a preliminary site visit before starting the analysis. Others prefer not to visit the site until they have gained a clear understanding of the accident problems. There is no right or wrong time to make the first visit. If you choose to go to the site before you have carried out the analysis you will be more familiar with the local circumstances and features of the location. This will certainly help you with the analysis and accident plotting stages of the analysis.
4.6 The inventory

The first stage of the site visit will be to take details of the relevant features at the site. The numbers of lanes, details and location of the signs, the width of median strips, the traffic signal arrangements, the location of items that may have featured in accidents. Careful planning of site photographs will save a considerable amount of time and will be a useful reference point later.

4.7 The site investigation

4.7.1 Looking for clues or likely factors in the accidents

The timing of the site visit can be very important. If the analysis has identified a problem occurring during peak hours, at night time or at weekends, the site visit must be planned to take place at those times. If the accidents are occurring on a particular day of the week, perhaps there is a special event, for example a market is held on that day and this activity is a factor in those accidents. The only way to find out exactly what is going on is to visit the site on that day, as close to the time of the accidents as possible.

4.7.2 Keep the accident record in mind

If the accident record tells you that vehicles are not stopping, overshooting a junction. You must ask yourself, what does the road user see when approaching the junction?

- Is the junction conspicuous?
- Is there adequate warning?
- Are there adequate signs and markings?
- Are those warnings clear and distinct?

The objective of the site visit is to find reasons why the accident problems are occurring. If the analysis has been carried out properly this will not be as difficult as it seems. If we can find out why the accidents are happening there is a strong possibility that we can develop effective countermeasures.

For example, if an investigation has identified high numbers of accidents occurring at a ‘T’ junction, a minor road joining a major road. The identified problem is found to be
vehicles entering the major road - from the minor road coming into collision with through vehicles from the major road. These accidents are commonly called ‘cross road’ collisions, the problem is likely to be one of the following:

1. an overshoot problem
   drivers of minor road vehicles are failing to stop in time
2. a re-start problem
   drivers of minor road vehicles are stopping at the junction but are failing to safely enter the major road
3. a combination of both of the above

Examine the minor road approach to the junction, drive and walk the approach, what does the driver see?

- Is there sufficient warning of the junction?
- Is the junction conspicuous?
- Are there any misleading features?
- Are sight lines adequate?
- Are they clear of obstruction?

4.7.3 To look for clues that indicate that the drivers are overshooting the junction, (not seeing the junction in time)

1. In rural areas for example, is the major road the first junction after many miles of travel? Alternatively perhaps the driver is tired and not prepared for the junction.
2. Is the junction conspicuous? Can the junction be seen early? Does the junction blend into the background? Perhaps hidden by a bend? Does the eye run through the junction, tunnel vision? Looking through the junction and not seeing the junction detail.
3. Is it possible that at certain times of the year low sun reduces visibility of the junction?
4. Is there sufficient advance warning of the junction (warning, destination signs, road markings)? Are these markings in good condition? Can these signs be obscured by parked cars or stationary signs, or foliage in the summer months?
5. Are there skid marks on the road surface on the final approach to the junction? This will indicate recent, late vehicle braking.
6. Are there distractions on the final approach, for example advertising boards etc.?

7. Take up a position about 80m from the junction on the minor road. Watch traffic on the approach to the junction; If drivers are not aware of the junction you will see evidence of late breaking from vehicle brake lights.

4.7.4 To look for clues that indicate a restart problem, (the driver has stopped but has difficulty entering the major road)

Take up a position at or near the entrance to the major road. What does the driver see? Caution, if the accident data tells you that the vehicles involved in the accidents are buses or trucks the drivers eye line will be different.

The accident record will tell you if the vehicles are being hit by vehicles from the left or the right.

1. Is the approach speed of some vehicles too fast? If so, why?

2. Are the sight lines adequate? Is the driver able to see far enough down the road? Can you see all approaching vehicles? Is visibility impaired by street furniture - light columns, trees other objects? Perhaps street trade activities are obscuring the view?

3. Are there any parked vehicles? Perhaps a stationary bus is creating visibility problems?

4. Is the angle of the entrance of the minor road into the major road creating difficulties? If the angle is shallow at the entry point, this might mean that drivers have to glance over their shoulders to see traffic on the main road.

5. Right turning vehicles turning from a side road are very vulnerable. They have to cross one stream of traffic and then enter the second stream. If the major road is busy, there should be a safe protected area in the middle of the road, where the vehicles can cross one stream of traffic to wait in a safe area for a gap, before proceeding.

6. If there are long queue of vehicles waiting to enter the main road are drivers getting frustrated and ‘taking a chance’?

The investigation should also consider what the driver on the main carriageway sees? To do this we need to check by driving both approaches to the junction.

- Is the minor road conspicuous?
• Can the minor road and traffic in the minor road be seen?
• Are there any warning signs of the minor road junction? If so can these signs be seen at all times?

If the analysis tells you that the accidents are occurring in summer months and you have to visit the site in the winter when the trees and foliage are bare, consider what will the driver see when the trees are in full bloom. Will foliage mask traffic signs? If the accidents are occurring at night time will the sign be visible at night? Are the sign faces retroreflective?
5. ASSESSING ALL OF THE FACTORS AND PRODUCING THE SCHEME RECOMMENDATIONS

It is important that you always keep the objectives in mind. Each scheme has to meet many requirements. The scheme should:

- produce low cost measures to reduce the identified problems
- be implemented quickly
- be easy to implement
- be clear and easy for the road user to understand
- have low maintenance and running costs
- be acceptable to the community
- be easy to enforce - self-enforcing if possible
- not transfer the problems elsewhere
- not affect the accessibility of the emergency services
- not create unnecessary delays to traffic or the general public

To carry out the assessment you need to review all of the information and data relating to the site. If during the course of the investigation you have met and discussed the site with other officials, it is likely that they will have provided you with very useful background information and local knowledge. Local police officers (who may have attended the scene of the accidents) often provide a valuable insight into the cause of those accidents. This additional information provides further useful information which can be added to the assessment process.

The purpose of the assessment is to find logical reasons for the accident problems. A thorough and complete assessment will probably find those reasons. A compromised or short assessment will not.

Effective road safety engineering treats the cause, not the symptoms. If the problem involves vehicles leaving the carriageway at a bend, we could install a crash barrier. A crash barrier would certainly reduce the severity of future accidents at the site, but the problem would still exist. To remove the problem we need to look further.

Why are the drivers failing to cope at this bend?
To answer this question you need to consider the following:

- Is there sufficient advance warning of the bend?
- Is the speed of vehicles too fast for the bend?
- Is the proper line that the driver should take, clear to the driver in all circumstances (light / dark conditions, bad weather)?
- Are there features that distract or mislead drivers on this approach?
- Is the ‘super-elevation’ of the bend correct?
- Can the driver see far enough round the bend?
- Is there unexpected activity in the bend, pedestrian activity, vehicles moving out from a junction that is hidden to the driver?
- Has the road surface at the bend become worn and polished thus failing to provide adequate skid resistance?
- Does the carriageway at the bend drain efficiently? Ponding water creates many problems for drivers

On the assumption that the assessment finds clear reasons for the accidents it will now be relatively easy to specify the correct and most appropriate countermeasures.

We have said earlier that two heads are better than one. To widen the scope of the assessment it is recommended that you discuss each stage with your colleagues. Only when you are entirely satisfied with the conclusion, and the Head of the Road Safety Unit agrees with you, can we start to develop the countermeasures.

In many cases identifying countermeasures is fairly straightforward. If the problem is clearly defined the course of action may be quite clear.

A typical example:

Consider the situation where you have identified a cluster of pedestrian accidents. The accident rate is increasing and it has been established that the problem is largely due to the following factors:

- the road runs north/south
- there is a small but quickly growing township on the east side of the road
• people travelling to and from the city (on the west of the road), crossing the road are involved in the accidents

You have also learned that traffic volumes on the road are increasing and will continue to increase for the foreseeable future.

The solution is to provide safe pedestrian facilities. In this case you need to design the facilities to meet the immediate and medium term future needs.

5.1 Finding appropriate countermeasures to the problem

There is often a wide range of measures available for the engineer. Fig 7. TADS Remedial Measures Implementation Codes (May 1996) shows various measures available to engineers in London. In all, there are 97 items in ten categories. Selecting the correct measure(s) for each problem is a question of balancing the most appropriate measure and ensuring that the measure is suitable for that site’s circumstances. In many cases the final specifications will include a combination of several items.

There is always a risk that a keen engineer will hurry to a conclusion. An example of this occurred several years ago in London.

An engineer was working on an investigation on a long busy section of road and the investigation identified a very high number of accidents occurring during the hours of darkness. He assumed that the problem was due to poor street lighting and he arranged a street lighting improvement programme to be carried out. A year later the work was carried out. A year later the monitoring programme failed to show any reduction. Two years later the accident record of the site was investigated more thoroughly. The second engineer found that the reason few accidents were occurring during the day was the heavy volume of traffic was keeping speeds down. At night when the traffic was light, drivers were travelling faster and this was resulting in speed related accidents. If the engineer had looked closer at the original data he would have seen evidence of speed related accidents. This was an unfortunate mistake that you should always make every reasonable effort to avoid repeating in this country.
## Remedi Measure Implementation Codes (May 1996)*

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* Reproduced with the kind permission of the London Accident Analysis Unit.
You, the engineer should work progressively through the likely effect of each option and balance the likely effect against the impact that the measure will have.

For example

A problem of accidents involving vehicles turning right at a junction is identified. The analysis finds that all of these accidents involve vehicles turning south to east resulting in a collision with southbound vehicles from the opposite direction. The reason for these accidents is that drivers of the turning vehicles are either misjudging the speed or distance of oncoming vehicles.

If this case, if traffic signals are ruled out there are three basic options:

Option 1. Physically prevent future vehicles from carrying out that manoeuvre - by extending a central median for example.

This option removes the root of the problem and is an effective treatment. You would then have to consider two points:

- Do road users have suitable and reasonably convenient alternative routes?
- By preventing the manoeuvre, will diverted traffic lead to additional accident problems elsewhere on the network, in other words transferring the problem or accident migration. *There will be little risk of accident migration if the volume of diverted traffic is low and the alternative route does not have an accident history.*

Option 2. Consider prohibiting or banning that particular movement. If the ban is observed by all road users this can be an effective treatment. The considerations then would be the same as Option 1 but you now have to consider. Are road users going to obey the ban and continue to carry out this manoeuvre? Is the ban enforceable? Is it realistic to enforce it?

Option 3. Set out road markings and possibly traffic islands to provide drivers of turning and oncoming vehicles with a better alignment (path through the junction) to create better sight lines and intervisibility so that both road users can see each other.
The third option is the weakest. It is likely to achieve a reduction in the number of accidents but the basic problem of drivers failing to judge either the speed or distance of oncoming vehicles is still present.

5.2 Safety audit

When the proposals are complete and drawings and specifications have been prepared, a colleague who has not been involved in the development of the proposals should check the details of the scheme. The purpose of this independent check is to ensure that the final scheme does not include any elements that may increase accidents risks. This check ought to follow the latest safety audit practices, please refer to the Head of the Road Safety Unit.
6. ESTIMATING ACCIDENT REDUCTIONS

Estimating future numbers of road traffic accidents is always difficult and complex. Engineers often need to compare the relative values of various options and are often required to justify schemes. The following principles have now been used on a wide scale in Britain and they have been found to be reliable when applied over a large sample of sites.

The estimate of accident savings is calculated using the following basis and assumptions.

6.1 Estimating values

The first task is to estimate an accident reduction value for each of the implemented measures. This value (expressed in percentage terms) is normally taken from the average percentage reduction from ‘before and after’ monitoring programmes. If a particular measure consistently reduces a certain type of accident by (say) 50%, when we apply that measure at a site with a history of that type of accident, you can reasonably expect that measure to produce a 50% reduction of that type of accident.

Without the benefit of ‘before and after’ data we will have to rely on estimating these values. We can provide reasonable estimates by applying a common sense approach. To do this we need to consider the likely benefit of the measure and offset any likely disbenefit.

For example, in the previous section we considered three options to treat a right turning accident problem.

Option 1. Physically prohibiting the right turn.

If this measure is implemented, it will be highly effective in reducing the accidents. Vehicles will not be able to turn right at this junction in future and no accidents of that type will occur in future. Select a value of 100%. However, there is a small risk that the drivers, previously turning at this junction may be involved in accidents elsewhere on the local road network. Reduce the value from 100% to 95%.
Option 2. Prohibiting the right turn manoeuvre.

In practice it is unlikely that all drivers will comply with the prohibition of the right turning manoeuvre without physical prevention. If the local police are willing to focus enforcement at the site, the level of compliance may be high. There will still be the potential for accidents in the diverted accidents. It would still be reasonable to estimate an overall reduction of 50%.

Option 3.

Improve the alignment and site lines for drivers of right turning and oncoming vehicles. This will help drivers, but the basic problem of drivers misjudging the speed and distance of oncoming vehicles will continue. Apply a value of 25%.

Note: By using a three year basis for the investigation, the total number of accidents occurring at the site, over that period of time, has reduced the random element. If traffic volumes remain at approximately the same level and all other circumstances remain similar, the total number of road traffic accidents at that site will be at approximately the same level in three years time. In other words 15 accidents have occurred in the ‘before’ period and 15 accidents will occur in the ‘after’ three year period. *This can be considered optimistic in Bangladesh with 8% per annum traffic growth. Increased traffic invariably results in increased accidents.*

6.2 Applying values

To determine the effects of the implementation of a measure, on the total number of accidents occurring in a future three year period you apply the selected value to each of the accidents in the target group. The sum of these factors represents the three year accident reduction for that measure.

If that site has a specific accident problem and that problem has produced six accidents over a three years period, intervening by implementing a measure that is known to reduce that type of problem accidents by 50% would be likely to produce the following results:
**Figure 8. The effect of treating a small group of accidents**

<table>
<thead>
<tr>
<th></th>
<th>Target accidents</th>
<th>Other Accidents</th>
<th>Total accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before period</td>
<td>6</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>After period</td>
<td>3</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Change (Accident reduction)</td>
<td>-3</td>
<td>0</td>
<td>-3</td>
</tr>
</tbody>
</table>

Note: In this case, the measures will not affect the unrelated ‘other’ accidents and it can be assumed no change will occur in that group.

This example provides an accident saving of one accident per year.

### 6.3 Avoid double counting

It is important to remember that the measures can only reduce target accidents. If we are applying three separate measures at a site and each of those measures are known to achieve a 50% reduction of the target accidents, there is a risk that the engineer will forecast that each of those accidents will be reduced by an unrealistic 150%, thus double counting. To avoid double counting we apply the ‘benefit’ (reduction factor) in stages, as shown by the following example:

Example. Assume that you are considering implementing three measures at a site. The measures being considered have (in the past) achieved the following percentage reduction of target accidents.

- Measure A, 50%
- Measure B, 30%
- Measure C, 10%

**Stage 1.** Set out a table (see Figure 9 for a simplified calculation).

First column: Accidents occurring in the site’s accident history. In this case 8 accidents occurred in the ‘before’ period.

- First row, Accident No 1 (from the stick diagram).
- Second row Accident No 2 (from the stick diagram).
- Continue to assign all accidents from the accident stick diagram, the ‘accident history’.
Second column : Measure A. Reduces target accidents by 50% = reduction factor x 0.50.
Third column : Measure B. Reduces target accidents by 30% = reduction factor x 0.70.
Fourth column : Measure C. Reduces target accidents by 10% = reduction factor x 0.90.
Fifth column : The remaining value for each accident.

**Stage 2.** Assign the measures to the target accidents only.

Refer to the proposed measures.
Measure A, applies to Accident numbers (1, 3, 5 and 6), tick those boxes.
Measure B, applies to Accident numbers (4, 5, 6 and 7), tick those boxes.
Measure C, applies to Accident numbers (3, 6, 7 and 8), tick those boxes.

**Stage 3.** Completing the estimate.

Accident No 1 : Only one measure applies to Accident No 1 (1 x 0.50) = 0.50. Assign 0.50 to the Total remaining column.
Accident No 2 : No measures apply to this accident. Assign 1.00 to the total remaining column.
Accident No 3 : Measures A and C apply (1.0 x 0.50 x 0.90 = 0.45). Enter 0.45 to the remaining column. *This has avoided double counting by applying the reduction factor of the second measure to the lower (reduced) value only.*
Accident Number 6. (1.0 x 0.50 x 0.70 x 0.90) = 0.31.

The best method of avoiding double counting is to use the following method.
Figure 9. Avoiding double counting by assigning a reduction factor in stages

<table>
<thead>
<tr>
<th>Accident No</th>
<th>Measure A reduction factor (50%) x 0.50</th>
<th>Measure B reduction factor (30%) x 0.70</th>
<th>Measure C reduction factor (10%) x 0.90</th>
<th>Total value remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>√</td>
<td></td>
<td></td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>√</td>
<td></td>
<td>√</td>
<td>0.45</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>√</td>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td>5</td>
<td>√</td>
<td>√</td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>6</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>0.31</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>√</td>
<td>√</td>
<td>0.63</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>√</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>4.84</strong></td>
</tr>
</tbody>
</table>

Note: The measure applies to those accidents marked √.

When we have finished assigning the reduction factors to all of the accidents, the sum of column 5, in this case 4.84 is the number of ‘after’ implementation accidents. This figure shall be rounded up to five accidents.

The estimated accident saving will be (eight ‘before’ and five ‘after’) or a net saving of three accidents.
7. PRODUCING THE REPORT

The majority of accident blackspot schemes are straightforward and result in minor work proposals. To administer and process these schemes the engineer needs to prepare a short, routine paper that sets out a summary of the identified accident problems and how the measures will reduce those problems.

More complex, higher impact schemes will need more detail and supporting information. To obtain approvals and ensure that all interested agencies are informed it will be necessary to circulate these reports to a wider circle of readers. In many cases these readers will be busy people and it will be helpful to them if we set out the important information clearly.

Rather than producing two types of report it is recommended that report presentation is based on the layout shown in Figure 9. The front page contains a summary of the important details and the following pages provide all necessary supporting details and information.
Figure 9. The report front page

All the important information is shown on one page

By producing standard and consistent reports, both the regular and the occasional reader will become familiar with the reports and will be able to find the information that they need quickly, and this should help future efficiency.

7.1 To complete the report front page.

Complete the site location details. Enter, Thana, Reference, File number, Road Type and Date Issued sections.
Accident History. Enter the accident summary details.

Site Location Map. Paste a small scale plan of the area, with the site location circled.

7.2 Accident summary

Enter a brief description summary of the identified accident problems, site investigation findings, the reasons why those accidents are occurring, the proposed measures and how those measures will lead to a reduction in the numbers of those accidents in future.

7.3 Summary of proposals and estimated savings

In the appropriate columns, list each of the selected measures, enter the estimated annual accident reduction for each measure and once the average cost of a personal injury road traffic accident is known you can calculate the monetary value that the remedial measure will produce.

It is then possible to produce the estimated total accident reduction that the scheme is expected to produce, the monetary value that the scheme is expected to produce and if the estimated cost of the works is known we can calculate the first year rate of return.

All the important information is now on the front page.

7.4 Compiling the full report

The reader will probably require further information. This information should be set out in following chapters, for example:

Section 1. Accident analysis.

A full breakdown of the accidents occurring at the site. The breakdown will specify the identified problems with secondary details found during the analysis, rising trends and show comparative accident rates. Attach a copy of the stick diagram and the accident plot.
Section 2. The site investigation(s).

Describe the site, including the number of traffic lanes and the geometry of the junction. If applicable, include the layout of the traffic signals and road user behaviour, particularly if this may be contributing to the accidents. A scale site plan is useful.

Section 3. The assessment.

Discuss the details of the accident investigation and how this has led you to the findings - the reasons why the accidents are occurring. If more than one option was considered explain the reasons for the preferred scheme.

Section 4. The proposed measures

Provide full details of the proposals with scale drawings and estimates of cost.

Appendix. Include the sorted stick diagram and accident plot with any supplementary information that may be necessary.
SECOND ROAD REHABILITATION AND MAINTENANCE PROJECT

INSTITUTIONAL DEVELOPMENT COMPONENT

Road Safety Engineering

Procedure Note 3.

Route Studies in Bangladesh
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1. INTRODUCTION

Route studies in Bangladesh is the third in a series of Road Safety Engineering Procedure Notes. The full series of Procedure Notes provides a step by step programme of activities to carry out Road Safety Engineering in this country. Figure 1, shows the relationship between route study work and the other major activities.

Procedure Note 2 dealt with treating accident blackspots and safety engineering at hazardous locations. The reader should be familiar with Procedure Note 2 before moving onto this paper.

Widespread accident blackspot programmes commenced in the 1970’s. These programmes were very successful. Safety schemes were implemented quickly at low cost, with little inconvenience to the travelling public. Considerable accident reduction was achieved on a wide scale.

Encouraged by these results engineers began to look for wider applications for these techniques. One practice to emerge from this search is the analysis of accidents along sections of the highway or route studies. Route studies begin with an analysis of accidents occurring on a (typically four to 15 km long) section of road. The analysis is then used to identify the route’s accident problems so that accident countermeasures can be designed and implemented.

Engineers in many countries have been carrying out route studies for many years. In the majority of cases, schemes implemented using this approach have contributed to significant reductions in the number of accidents occurring along those routes.

In 1991 a major programme of route studies on London’s trunk road network began. This programme was designed to systematically cover the entire network. In the build-up to the start of this programme, current road study practice was reviewed, modified and extended.

The results following the implementation of recommendations coming out from this work were very encouraging. It was decided to publish details of the experience and the results achieved. A paper by Roger Legassick, London Accident Analysis Unit, London Research Centre, ‘The case for route studies in traffic accident analysis investigation’ was published in August 1995. The paper outlines methods used, accident problems
discovered, approaches taken to deal with those problems, and the results of ‘before and after’ accidents studies’ carried out into the implemented schemes.

The conclusions from this paper summarise the benefit of route studies as follows:

The design and implementation of remedial works based on the findings of single site accident analysis have consistently resulted in reductions in the number of road traffic accidents. However route study work allows the engineer to take a much wider perspective of the accident problems and to address them from three standpoints.

1. overall or route wide problems for which it has been found that wider-reaching, more effective measures can be identified and employed
2. localised specific problems which are more likely to be understood and thus more effectively treated within a route study
3. consistency and clarity of information to road users which can only be assessed and provided on a route basis and which improves the road users’ chances of coping safely

Note: The later point is one which only applies to route studies and not to single sites. Consistency on a route often requires a ‘tidy-up’ of signs, road markings and surfacing with the removal of old and superfluous signs. Route consistency work was pioneered by Hertfordshire County Council in 1968 when accidents on four major routes were treated, mainly by consistency measures. The ‘before and after’ study showed total accidents reducing from 1628 to 1286 - a highly significant reduction of 21%.

This Procedure Note is based on principles from that paper. The methodology has been slightly amended to suit local conditions and circumstances. By presenting details of these studies and the results of the ‘before and after’ investigations we are able to highlight several practical points that will be valuable to future route study practitioners in this country.

*Note: This Procedure Note should not be used by persons without appropriate Road Safety Engineering training.*
Figure 1. Route Studies in Bangladesh in Road Safety Engineering
2. BASIC ROUTE STUDY METHODOLOGY

The first task is to select a manageable section of road. If the section is too long, there is a risk that the study will become complicated and the work will lose direction. If the route is too short, the analysis may not identify route wide problems. Overseas experience suggests that five to 20 km sections are practical and manageable.

2.1 Carrying out the accident analysis

The following procedure (in italics) is the basic methodology referred to in ‘The case for route studies in traffic accident analysis investigation’.

1. extract all accidents occurring in the latest three year period
2. prepare chronological accident stick diagram showing individual accident conflict
3. re-sort accidents by common or dominant accident types, and prepare re-sorted stick diagram
4. plot all accidents (to scale) to show accident conflict
5. prepare site by site accident analysis. To quantify the extent of each problem the engineer will compare the rate of dominant groups of accidents occurring at each location with the expected rate. Note this is taken from ‘Levels of accident risk in Greater London’, (a publication prepared by London Accident Analysis Unit that identifies the average rate of common groups of accidents occurring by road type, and by area, of London)
6. prepare a detailed analysis of the all route accident history. Compare the all route accident rates with average rates for London
7. write up accident analysis for (a) individual locations and (b) the entire route
8. this should now identify the extent of the local and general accident problems
9. other investigations may include consultations with the local network manager, local police and traffic signal specialist all of whom are likely to provide a valuable insight that links local knowledge to the findings of the accident analysis
10. preliminary site visits, often more than one
11. a video recording of the entire route is made. This will normally be taken by driving the route in each of the lanes with the camera positioned at driver’s eye level

12. take photographs of the salient features along the route

13. obtain general traffic details, traffic counts, 85 percentile speed readings, signal details etc.

14. carry out traffic observations at problem points along the route

15. compile conclusions linking site survey findings with the problems discovered in the analysis history

It will now be possible to start drawing together a preliminary package of proposals for both the simpler (i.e. obvious) local accident pattern, (normally following the procedures developed for single site analysis) and consider options for the general accident problems.

Items 5 and 6 refer to quantifying the accident problems. You will need to compare accident rates occurring on the study route with average rates occurring on similar road(s), in Bangladesh.

Assuming that we have sufficient data, it will not be difficult to determine suitable accident rates for route study work. You will need route wide and site specific rates.

2.2 Producing - route wide accident rates

Assuming that you are about to start work on a route study on a National Road. You can select the control sample to be rates derived from either ‘all national roads’ or from a route that has similar characteristics, highway classification, traffic volumes, intersection design and road user usage. National Roads rates are likely to be bland, less specific than using a similar highway but the database will be stronger.

You need to obtain rates of accidents occurring for:

- the major junctions on the route
• the links between those major junctions
• the areas of the highway where higher than ‘average’ numbers of accidents are known to occur, for example bends, bridges and busy areas

2.3 Producing accident rates for major junctions

The procedure set out in Procedure Note 2 “Treating Accident Blackspots” is sufficient to determine a useful range of rates. When you are analysing the data you should look for common or reoccurring accidents, these reoccurring accident groups should be added to the list of categories.

2.4 Producing accident rates for links

The most common method used to identify accident rates on links is to find the total number of accidents occurring over a period, and express the rate as accidents per year per km.

• the frequency of 'all accidents' per km of carriageway
• the frequency of 'common accident’ types per km of carriageway
• severity ratio, the ratio of fatal and serious accidents in the total of all accidents

In Bangladesh the number of accidents involving the following groups are known to be high and you should include the following categories:

• pedestrian accidents
• a vehicle leaving the carriageway or highway
• a vehicle in collision with a roadside object
• a collision involving two vehicles from different directions
• accidents involving a bus
• accidents involving a heavy goods vehicle
• non-motorised vehicles
• head-on collision

2.5 Producing accident rates for other problem areas

It is quite clear that the incidence of accidents at bends, bridges and villages will be high and we will need to provide rates for these and other yet to be identified areas.

The basis for calculating these rates will largely be the same as the procedure described in Procedure Note 2. However it is important that you identify features within the groups so that like with like comparisons can be made. For example accident rates at bends are often related to the bend radius. To provide a rate for all bends on a route will not supply us with specific or useful data. The data will be more useful to the analysis if it is subdivided into divisions or groups, for example:

• bends up to 200m radius
• in the range 201m to 400m radius
• in the range 401m to 600m radius etc. etc.

It should now be possible to quantify all of the accident problems occurring along the route, and complete the study analysis.
3. TWO EXAMPLES OF ROUTE STUDY INVESTIGATIONS

The first example looks at a route study carried out in 1991. The route study investigates accidents occurring on this busy trunk road in west London.

This analysis identified two major route wide problems that eventually led to a comprehensive programme of remedial measures.

The following extract from the paper compares accident rates on the route with control accident rates (referred to as expected levels of accidents) to quantify the extent of the problem.

3.1 Case Study No 1. A4 Great West Road, London

We have found that a clearly defined analysis of the local and wider route problems has allowed the investigating engineer to focus on both sets of problems when carrying out site visits. This has led to a much wider range of treatment being specified.

The first example is a study undertaken in 1991 when we were invited to carry out an investigation into the numbers of accidents occurring along a 4.7km section of the A4 Great West Road trunk road, between Bath Road and Syon Lane. In the three year period ending February 1991 there was a total of 250 personal injury accidents along this section. These accidents included 96 accidents involving a vehicle turning right (generally from the A4). The right turn accidents account for 38% of total accidents, compared to the expected level of 18% for a similar route. In addition a total of 46 nose to tail (shunt type) accidents occurred on approaches to junctions. The overall severity of the accidents was higher than expected with seven fatalities and 56 accidents recorded as involving serious injury.

The second extract discusses how the problems were investigated and how the proposals were devised.

Addressing the major problem of the high numbers of right turning accidents
The major junctions along this route are controlled by automatic traffic signals. The signals run the right turns on an overlap stage (i.e. both main carriageway traffic flows run, the traffic from the opposite direction is halted and the right turn traffic receives a green signal). The high rate of right turning accidents was attributed to drivers who were not prepared to wait for the overlap stage manoeuvring through gaps in the oncoming traffic and coming to grief by misjudging the speed or distance of the oncoming vehicles.

In some cases this problem had been identified earlier during single site analysis. The natural effective solution to sites with this problem would be to hold the right turn traffic on a full red signal (preventing the gap jumping) and run the right turn as a separate stage when the opposite flow is halted. Where it has been possible to implement this measure our monitoring exercises (before / after studies) indicate an average 85% reduction of these accidents. The traffic signals along this length of the A4 are progressively linked, traffic flows in the morning and evening peak run close to saturation. In these circumstances controlling the right turns would have severe implications for capacity, likely to create unacceptable delays and queues, possibly resulting in the transfer of traffic, to unacceptable routes all of which could result in other accidents. The accident investigators recognised a temptation to look for minor uncontroversial treatments i.e. improving sight lines (realignment of the oncoming and right turning traffic) relocation of street furniture, and possibly adjusting signal timings. The outcome of these minor recommendations would be expected to help the situation and probably reduce the numbers of accidents but the underlying problem would remain.

Bearing in mind the magnitude of the overall problem we decided to look for a more effective treatment. After considering many options, the Highways Agency devised an arrangement of rationalising right turns for each direction along the route by prohibiting the right turn at alternate junctions and controlling the remaining right turns. The arrangement was tested by Traffic Control Systems Unit engineers and, following some minor refinements, the scheme was made permanent and gives evident safety benefits without increased capacity problems.

Addressing the secondary problem, i.e. the high number of accidents occurring on approaches to the junction
The problem of higher than expected numbers of accidents occurring on the approaches to junctions was addressed by increasing the extent of the junction warning features on these approaches. This was achieved by increasing the length of carriageway junction warning markings (to a distance of 150m from the junction), introducing new edge of carriageway and direction markings; and incorporating a new taller traffic signal post in the signal arrangement.

The final (third) stage addressing the local problems:

In this particular case the extent of the local problems was relatively small. Where groups or clusters of accidents occur (that are not treated by the above measures) it was relatively easy to recommend low cost but effective measures, e.g. Anti-skid surfacing at locations with a wet road surface accident history; central reserve gap closures where they were not being used safely; hatch marking to direct drivers away from or through areas of conflict; various minor junction and signal modifications to treat minor accident problems.

The second example looks at a route carried out in north London. Traffic management proposals were being considered on this section and it was decided to carry out the investigation so that safety measures could be incorporated into the final scheme.

3.2 Case Study No 2. The ‘Nags Head’ Study, London

In 1991 the London Accident Analysis Unit of the London Research Centre was requested to carry out an analysis of traffic accidents occurring on the A1 Holloway Road in the London Borough of Islington - The ‘Nags Head’ Study. The study concentrated on the section from Windsor Road in the north and continued to Loraine Road in the south. This exercise was carried out in conjunction with engineers from Traffic Control Systems Unit (TCSU), who examined the possibility of reintroducing right turns at strategic junctions.
The analysis identified a high rate of accidents. A total of 159 accidents occurred in the three year period ending March 1991. Based on the analysis of these accidents the following measures were recommended:

- reintroducing the right turn from Holloway Road into Camden Road
- reintroducing the right turn from Parkhurst Road to Holloway Road (south east)
- building a kerbed median strip with continuous pedestrian guard rail between the major junctions along the study route. It was anticipated that the median strip and guard rail would effectively prevent pedestrians crossing in these areas and focus that pedestrian traffic at the pedestrian crossing points at the junctions. To accommodate the additional pedestrians it was decided to improve the existing pedestrian facilities
- building out the kerb line at the major junctions along the route
  The kerb build outs were constructed to project from the existing kerb line, into the inside lane of the main carriageway effectively reducing the main carriageway from three lanes to two lanes wide. The inside lane along this route consisted of bus lay bys parking or loading areas. The build outs enabled the designer to bring forward the pedestrian crossing points so that pedestrians could stand at a better vantage point to see (and be seen) by approaching drivers. The build outs also allowed the traffic signals to be moved out and re-positioned on the build out, closer to the driver’s line of forward vision
- revisions to local direction signing
- minor local changes to ease local problems

3.3 Summary

Both studies show that by using a systematic procedure accident problems along routes can be clearly identified. When problems are identified it is then possible to develop road safety engineering solutions to deal with them. In both cases the recommendations put forward were implemented. The implementation of the measures led to significant accident reductions along the routes.
4. MONITORING ACCIDENTS ON ROUTE STUDIES

Monitoring the affect of implemented safety schemes is an essential component in road safety engineering.

All of the indications were that the A1 Nags Head scheme was successful. But, how successful? Did the number of target accidents go down? Did other types of accidents go up or down? Are new accident problems beginning to emerge?

To answer these questions, the London Accident Analysis Unit carried out a comprehensive ‘before and after’ implementation accident analysis as soon as 12 months ‘after’ accident data became available.

The following extract answers these questions and is a good example for designing procedures and presenting information for ‘before and after’ studies.

4.1 Background

A report prepared by the LAAU of work carried out by Traffic Control Systems Unit (TCSU) and the LAAU was published in October 1991. The report put forward a series of measures that were designed to reduce the high rate of personal injury accidents that were occurring on this section of Holloway Road.

The measures included:

- building a kerbed median strip with continuous guard rail along Holloway Road
- reintroducing a right turn from Holloway Road to Camden Road
- reintroducing a right turn from Parkhurst Road to Holloway Road southeast
- a revision of direction signing
- building out kerbs in Holloway Road
See Drawing No 94/RSC/2012/2

Construction work commenced in the early part of 1992 and elements of the scheme were implemented at different times throughout that year. Long sections of the median strip (with guard rail) were completed in the spring and the junction ‘build outs’ a little later. Work on the traffic signals was completed and commissioned in December 1992. Final lengths of guard rail were not installed until January 1993.

Whilst the scheme was not finally completed until January 1993, the implementation of important elements early in 1992 is likely to have had a direct bearing on accidents along this section of Holloway Road throughout that year. To avoid distortions of ‘before’ or ‘after’ accident data this analysis disregards all accidents along this section that occurred in the whole of 1992.

The study period. The assumption has been made that the first month of ‘after’ accidents is February 1993 and continues to include the twelfth month, i.e. in this case January 1994. To avoid the effect of seasonal variation it was decided that the first month of ‘before’ accidents should be February 1991 and then progress monthly to December 1991. The twelfth month reverts to January 1991.

Several events that are likely to have a bearing on traffic accidents occurred in Holloway Road during this period. This section of Holloway Road formed part of the Pilot Priority Route which was implemented in January 1991. Red Light Cameras were commissioned at Holloway Road / Camden Road (northbound in January 1993 and southbound January 1992), and at Holloway Road / Seven Sisters Road (northbound February 1992 and southbound March 1993).

4.2 Summary

The implemented measures have led to a statistically significant reduction in the total numbers of road traffic accidents occurring along the route. A total of 52 personal injury accidents occurred in the study ‘before’ period, i.e. the 12 months ending
December 1991, compared with 33 accidents in the ‘after’ period, i.e. the 12 months ending January 1994.

(Note: the ‘before’ study period accidents (52) are typical of annual numbers occurring on this route. The accidents in 1988, 1989 and 1990 were 44, 62 and 53 respectively, giving a monthly average of 4.4 accidents. A check of the London Accident Analysis Unit data base figures for the months February to June 1994 showed a further 11 accidents occurred during this period bringing the total ‘after’ accidents to 44 in 17 months, or an average of 2.6 per month.)

The largest single reduction is in the group powered two wheeled vehicles where 12 ‘before’ accidents occurred reducing to one in the ‘after’ period. Pedestrian accidents (one of the principle targets of the proposals) have reduced from 18 ‘before’ accidents to 11 ‘after’. Accidents involving a vehicle turning right have fallen from 11 to four. The only accident groups to produce an increase are those involving a bus or coach (resulting in injury to a passenger), from six to eight accidents; and accidents occurring on a wet road surface, from three to four accidents.

With the exception of the junction of Holloway Road and Tollington Road, where there has been a slight increase from seven to eight accidents, and the section of Holloway Road between Tufnell Park Road and Seven Sisters Road (one accident ‘before’ and one ‘after’) there have been reductions at all locations. The best accident reductions have occurred at the junction of Holloway Road and Seven Sisters Road, (17 to 11 accidents); the section of Holloway Road between Seven Sisters Road and Tollington Road (eight to two); and in the section from Windsor Road to Tufnell Park Road (six to one).

The 39% reduction in the number of pedestrian accidents is encouraging, particularly as the major reduction has been in Holloway Road. Here, accidents involving pedestrians crossing Holloway Road have fallen from 12 in the ‘before’ period to six in the ‘after’. The improvement in Holloway Road is further underlined by the fact that, despite the reduction of overall accidents on Holloway Road, accidents occurring on local side roads close to Holloway Road have risen from seven in the ‘before’ period to 11 in the ‘after’.
The introduction of red light cameras in this section of Holloway Road has contributed to a reduction of ‘disobeyed junction control’ accidents from an average of 4.6 per year to 3 per year in the ‘after’ period.

The study has examined accidents by time of day, day of week and month of year. This has produced some evidence that the number of southeast bound, weekday, morning accidents (when traffic on this direction of Holloway Road will normally be busy) has fallen. This suggests that, at busy times of the day, the combination of more regulated parking along the route with pedestrians using clearly defined crossing points is leading to less conflict, a more orderly interaction between the various road users and, consequently, fewer road traffic accidents.

Part of this analysis has included an investigation of the ‘before’ accidents to establish if any of the measures have introduced a new set of circumstances that may produce new accidents. There is no evidence in the first 12 month ‘after’ period accidents that a new problem (or a hitherto undetected problem) is emerging.

In financial terms, the first year reduction of 19 accidents represents a saving to the community of £760,760. This figure is calculated using a value of £40,040 for the average cost of an urban injury accident which is based on June 1993 prices and given in Highways Economics Note 1 (September 1994) - Road Accident Costs 1993. (The figure is based on the average cost of an accident on urban roads and includes an allowance for damage only accidents.)

Conclusion.

It appears that the recent changes carried out in Holloway Road, i.e. median strip with guard rail and kerb build outs, in combination with the pilot ‘red route’ scheme and red light cameras, , have produced a substantial reduction in road traffic accidents occurring on this section of Holloway Road.
Comparison of ‘before’ accidents with ‘after’ accidents.

Overall change in the numbers of accidents occurring on the study route

The total number of ‘before’ accidents has fallen from 52 to 33 in the ‘after’ period which represents a reduction of 37%. When the reduction of study route accidents is compared with control data the change found is as follows:

4.3 Change in numbers of accident on the study route

Table 1: Change in the numbers of accidents occurring on the study route

<table>
<thead>
<tr>
<th>Control data</th>
<th>Change relative to control</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.B Islington, all purpose trunk roads (less study area)</td>
<td>-39%</td>
<td>Better than 5%</td>
</tr>
<tr>
<td>Greater London all purpose trunk roads (less L.B Islington)</td>
<td>-34%</td>
<td>Better than 10%</td>
</tr>
<tr>
<td>Greater London all purpose trunk roads (less study area)</td>
<td>-34%</td>
<td>Better than 10%</td>
</tr>
</tbody>
</table>

Note. These figures suggest that a real change in the numbers of accidents has occurred.
4.4 ‘Before and after’ accident by location

Table 2: A1 Holloway Road - ‘Before and after’ accidents by location

<table>
<thead>
<tr>
<th>Location</th>
<th>Node / Link</th>
<th>‘Before’ accidents</th>
<th>‘After’ accidents</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windsor Road to Tufnell Park Road</td>
<td>139 - 150 (Part)</td>
<td>6</td>
<td>1</td>
<td>-5</td>
</tr>
<tr>
<td>Holloway Road j/w Tufnell Park Road</td>
<td>139</td>
<td>7</td>
<td>5</td>
<td>-2</td>
</tr>
<tr>
<td>Tufnell Park Road to Seven Sisters Road</td>
<td>138 - 139</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Holloway Road j/w Seven Sisters Road</td>
<td>138</td>
<td>17</td>
<td>11</td>
<td>-6</td>
</tr>
<tr>
<td>Seven Sisters Road to Tollington Road</td>
<td>132 - 138</td>
<td>8</td>
<td>2</td>
<td>-6</td>
</tr>
<tr>
<td>Holloway Road j/w Tollington Road</td>
<td>132</td>
<td>8</td>
<td>9</td>
<td>+1</td>
</tr>
<tr>
<td>Tollington Road to Loraine Road</td>
<td>119 - 132 (Part)</td>
<td>5</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td><strong>Total accidents</strong></td>
<td></td>
<td><strong>52</strong></td>
<td><strong>33</strong></td>
<td><strong>-19</strong></td>
</tr>
</tbody>
</table>

Accidents by location. (Table 2)

A total of six fewer ‘after’ accidents occurred at the junction of Holloway Road and Seven Sisters Road and in the link from Seven Sisters Road to Tollington Road. There were five fewer ‘after’ accidents in the section from Windsor Road to Tufnell Park Road. A slight increase (from eight to nine accidents) was recorded at the junction of Holloway Road and Tollington Road.
4.5 ‘Before and after’ accident by accident type

Table 3: A1 Holloway Road - ‘Before and after’ accidents by accident type

<table>
<thead>
<tr>
<th>Accident type</th>
<th>‘Before’ accidents</th>
<th>‘After’ accidents</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involving fatal or serious injury</td>
<td>5</td>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>Involving a pedestrian</td>
<td>18</td>
<td>11</td>
<td>-7</td>
</tr>
<tr>
<td>Occurring during the hours of dark</td>
<td>7</td>
<td>6</td>
<td>-1</td>
</tr>
<tr>
<td>On a wet road surface</td>
<td>3</td>
<td>4</td>
<td>+1</td>
</tr>
<tr>
<td>Single Vehicle (non pedestrian)</td>
<td>7</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>P.S.V. Passengers</td>
<td>6</td>
<td>8</td>
<td>+2</td>
</tr>
<tr>
<td>Involving a pedal cycle</td>
<td>7</td>
<td>5</td>
<td>-2</td>
</tr>
<tr>
<td>Involving a powered 2 wheel vehicle</td>
<td>12</td>
<td>1</td>
<td>-11</td>
</tr>
<tr>
<td>Involving a right turning vehicle</td>
<td>11</td>
<td>4</td>
<td>-7</td>
</tr>
</tbody>
</table>

4.6 Changes within the major accident groups

Accident type (Table 3)

There were 11 fewer accidents involving powered two wheel vehicles. Pedal cyclist accidents also reduced from seven in the ‘before’ period to five in the ‘after’. Accidents involving a pedestrian fell from 18 to 11 and accidents involving a right turning vehicle
fell from 11 to four. Accidents involving a passenger on board a Public Service Vehicle increased from six to eight.

Severity of accidents

Accidents involving a fatality or serious injury have fallen from five in the ‘before’ period to three in the ‘after’. In both periods the severity ratio of accidents in Holloway Road was less than 10%, about half of the expected rate of 19% for an Inner Borough Trunk Road. Source Table 2.2.1. Levels of accident risk (Issue 6).

Accidents involving pedestrians

Total pedestrian accidents have fallen by 39%, 18 to 11, which is in line with the overall accident reduction. A total of 12 pedestrians were hit whilst crossing Holloway Road in the ‘before’ period compared to six accidents involving a pedestrian crossing Holloway Road in the ‘after’ period.

Accidents occurring on a wet road surface

There has been a slight increase in the numbers of accidents occurring on a wet road surface. A total of three wet road surface accidents occurred in the ‘before’ period compared to four in the ‘after’ period. The four ‘after’ accidents occurred at different locations i.e. no accident pattern or cluster is developing.

Single vehicle non pedestrian accidents

The relatively high numbers of before and after SVNP accidents (seven ‘before’ and seven ‘after’) includes a large proportion of Public Service Vehicles. The numbers of Public Service Vehicles involved in accidents increased from six to eight accidents. Several of these accidents involved a passenger who was injured during a stopping or starting operation.
Accidents involving a pedal cycle

Accidents involving a pedal cyclist have fallen from seven in the ‘before’ period to five in the ‘after’ period. Concern was expressed during the construction of the Holloway Road kerb build outs that cyclists would be squeezed at these points. There is no evidence of this in the ‘after’ accidents. With the exception of two pedal cyclists who were balked by left turning vehicles (entering Seven Sisters Road) the ‘after’ period pedal cyclist accidents have occurred at different locations and appear to be the result of unrelated events.

Accidents involving powered two wheel vehicles

There has been a considerable reduction of the numbers of accidents involving powered two wheel vehicles, i.e. 12 ‘before’ period accidents compared to one in the ‘after’ period. In the ‘before’ period a total of five motor cyclists were either turning right or were hit by a vehicle that was turning right.

Accidents involving a U-turning vehicle

There were two ‘before’ period accidents involving U-turning vehicles. No accidents of this type occurred in the ‘after’ period.

The effect on the numbers of accidents following the installation of the kerbed median strip and pedestrian barrier in Holloway Road

Pedestrian Accidents. The total of nine ‘before’ period accidents involving pedestrians crossing Holloway Road includes two accidents occurring on a pedestrian crossing. The ‘after’ period accidents have fallen to four involving pedestrians crossing Holloway Road including one pedestrian accident occurring at a crossing.
The kerbed median strip and pedestrian barrier now channels pedestrians to the crossing points. There was concern that this additional crossing for pedestrian traffic would lead to additional numbers of ‘at crossing’ pedestrians accidents. There is no evidence that this has been the case.

Accidents involving a right turning vehicle. The kerbed median strip now physically prevents vehicular right turns into and out of Hercules Road and Bovay Place. There were four and two ‘before period’ right turning accidents respectively at these junctions compared to none in the ‘after’ period. It has not been possible to extend the analysis to confirm that re-routed traffic is not leading to additional accidents occurring elsewhere on the local network but a close examination of the ‘after’ period accidents has failed to indicate that re-routed traffic is resulting in other or additional accidents on the study area network.

Accidents involving a U-turning vehicle. There were two ‘before’ period accidents involving U-turning vehicles. No accidents of this type occurred in the ‘after’ period.

4.7 Accident occurring on other roads

Accidents occurring on other roads at major junctions

Both the ‘before and after’ accident data contain a number of accidents that occurred on roads joining Holloway Road, for example, a pedestrian crossing Seven Sisters Road, 15m north of Holloway Road being hit by a north east bound vehicle leaving Holloway Road. These ‘side road’ accidents, being within 20m of Holloway Road, are assigned to the nodes on the network and are included in the analysis. The improvements included very little change to the side roads, as they were principally designed to reduce the numbers of accidents occurring on Holloway Road.
Table 4 Accidents occurring on side roads at the junctions

<table>
<thead>
<tr>
<th>Location</th>
<th>‘before’ accidents</th>
<th>‘after’ accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tufnell Park Road</td>
<td>No accidents</td>
<td>1. Ped not at crossing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Ped not at crossing</td>
</tr>
<tr>
<td>Parkhurst Road</td>
<td>1. PSV stopping</td>
<td>1. PSV stopping</td>
</tr>
<tr>
<td></td>
<td>2. PSV stopping</td>
<td>2. PSV stopping</td>
</tr>
<tr>
<td></td>
<td>3. PSV Left turn</td>
<td>3. PSV Left turn</td>
</tr>
<tr>
<td></td>
<td>4. Left turn</td>
<td>4. Left turn</td>
</tr>
<tr>
<td>Seven Sisters Road</td>
<td>1. Ped not at crossing</td>
<td>1. PSV stopping</td>
</tr>
<tr>
<td></td>
<td>2. Ped not at crossing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Ped not at crossing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Driver of stationary vehicle opens door</td>
<td></td>
</tr>
<tr>
<td>Camden Road</td>
<td>1. Ped not at crossing</td>
<td>1. Ped not at crossing</td>
</tr>
<tr>
<td></td>
<td>2. Ped not at crossing</td>
<td>2. Ped not at crossing</td>
</tr>
<tr>
<td>Tollington Road</td>
<td>1. Ped not at crossing</td>
<td>1. Ped not at crossing</td>
</tr>
<tr>
<td></td>
<td>2. Left turn</td>
<td>2. Left turn</td>
</tr>
<tr>
<td>Loraine Road</td>
<td>No accidents</td>
<td>No accidents</td>
</tr>
<tr>
<td>Total accidents</td>
<td>7 accidents</td>
<td>11 accidents</td>
</tr>
</tbody>
</table>

4.8 Summary

The study examines and compares ‘before and after’ accidents by location and type. In many cases the procedure identifies clear improvements.

By setting out the findings in a logical step by step manner the reader can quickly find the important detail. It is suggested that the procedure used in this study is followed by the practitioners in this country.
SECOND ROAD REHABILITATION AND MAINTENANCE PROJECT

INSTITUTIONAL DEVELOPMENT COMPONENT

Road Safety Engineering

Procedure Note 4.

Mass Action Plans in Bangladesh
1. INTRODUCTION

2. GENERAL MASS ACTION PLANS
   2.1 Mass Action Plans
   2.2 The scope of Mass Action Plans
   2.3 The procedure for carrying out a basic Mass Action Plan
   2.4 The benefits of using Mass Action Plans
   2.5 Road Safety and Mass Action Plans

3. ROAD SAFETY ENGINEERING AND MASS ACTION PLANS
   3.1 An example of using a Mass Action Plan
   3.2 Preliminary site selection
   3.3 Checking the details of the accidents
   3.4 The site visit
   3.5 First year rate of return
   3.6 The final site selection

4. BUILDING ROAD SAFETY ENGINEERING MASS ACTION PLANS INTO THE ANNUAL PROGRAMME OF WORK
   4.1 Carrying out Annual Mass Action Plans
   4.2 Annual Mass Action Plans
1. INTRODUCTION

The Royal Society for the Prevention of Accidents (RoSPA, UK) defines Mass Action schemes as ‘The application of a remedy to locations with a common accident problem’.

The most tried and effective way of dealing with accident blackspots at single sites, on routes or in wider areas is to:

- identify all of the accident problems at that site, route or in that area
- investigate the circumstances of the accidents
- investigate the site conditions and then if possible
- design a package of proposals that will deal with all of those problems

A specific, data-led approach at a site that results in the specification of the remedial treatment coming from the analysis, will result in the measure(s) being directly targeted at the problem.

Mass Action Plans reverse from this approach. Road Safety Engineering, Mass Action Plans start by first having a measure that is known to reduce certain types of road traffic accidents. The database is then used to search for locations with a history of those accidents. The practice works towards implementing the measure at the most suitable sites or locations. The remedy is known and it is applied at locations with specific problems.

As the experience of a Road Safety Unit develops and grows, monitoring exercises will identify several low cost but effective measures and practices. Road Safety Engineers can take advantage of this by using Mass Action Plan techniques. The effective measures are then applied to a large number of problem locations quickly and efficiently.

In practice road safety engineering programmes are usually governed by cost. Safety engineers have to achieve maximum accident / casualty reduction often from a limited annual budget. Engineers have to spread the benefit of road safety engineering as wide as possible but they must keep cost in mind (we have to get best value for money). Mass Action Plans have proved to be the one of the ways of achieving this objective.

A well run, effective Road Safety Unit will adopt a balance of activities in the countermeasure programme. This programme will include Single Site Investigations, Route Studies, Area Wide and Mass Action Plans.

Figure 1 shows the relationship between Mass Action Plans and other practices in Road Safety Engineering.

Note: This Procedure Note should not be used by persons without appropriate Road Safety Engineering training.
Figure 1. Mass Action Plan in Bangladesh in Road Safety Engineering
2. GENERAL MASS ACTION PLANS

2.1 Mass Action Plans

Mass Action Plans are an efficient way to carry out improvements to the existing highway network. Low cost, low impact improvements, carried out by systematically implementing a measure on a Mass Action Programme basis, usually means that the work is better targeted and carried out more efficiently.

2.2 The scope of Mass Action Plans

A Mass Action Plan normally involves small scale improvements, but there is no reason why larger scale work cannot be carried out in this way. The programme might include work at individual locations or along sections of the highway. Most highway agencies use a variety of Mass Action plans to improve the road network.

A Mass Action Plan could be used to improve:

- traffic capacity - by implementing traffic engineering measures at junctions along a route
- the general roadside environment - by carrying out a landscaping programme of planting trees and shrubs along a route or in areas
- maintenance of the network - by improving street lighting, and implementing road surface programmes

2.3 The procedure for carrying out a basic Mass Action Plan

The procedure for carrying out a Mass Action Plan varies from project to project. However, the basic procedure usually implemented is shown in Figure 2 – ‘Procedure for carrying out a basic Mass Action Plan’.
2.4 The benefits of using Mass Action Plans

Rather than implementing a wide-scale programme of work on an ad hoc basis, using a Mass Action Plan approach introduces evaluation and planning at the site selection stage. Evaluation and planning takes time and effort, the cost of this time and effort is more than compensated for when we consider just two of the advantages or benefits:

- better targeted work, i.e. the measures are implemented where they are most required
- if this is achieved the programme will produce the best value for public money
2.5 **Road Safety and Mass Action Plans**

For many years Road Safety Units in many countries have been using Mass Action Plans to introduce safety measures quickly, efficiently and on a wide-scale basis. In many cases these programmes have resulted in substantial reductions in the number of road traffic accidents.
3. ROAD SAFETY ENGINEERING AND MASS ACTION PLANS

Road Safety Engineering Mass Action Plans start with a solution to an accident problem. By using the accident database to find locations with a history of the problem, we can begin investigating the possibility of applying the solution on a wide scale.

Figure 3. Carrying out a Road Safety Engineering Mass Action Plans
‘Special Studies in Bangladesh’, Procedure Note 9 and ‘Monitoring and Evaluating Implemented Schemes in Bangladesh’, Procedure Note 7 are designed to quantify the level of accident reduction that a safety measure has produced. Results from this work often lead to Mass Action Plans. To illustrate how these activities can be used in Road Safety Engineering programmes we use an example of a Mass Action Plan that is regularly carried out in Britain.

3.1 An example of using a Mass Action Plan

This example is based on the development of anti-skid road surfacing material in London.

A ‘simple-to-apply’ road surface dressing was developed. The purpose of the road dressing was to improve the skid resistance of the carriageway. The potential of this material to reduce accidents was enormous.

Following initial trials and tests the material proved to be effective. The results demonstrated that the material substantially reduced the stopping distance of a vehicle - particularly in wet weather conditions.

The material proved to be robust and even after being exposed to all weather conditions and substantial vehicle traffic, it showed little signs of wear and remained fixed on the carriageway.

The next stage of development was to implement the material at several sites. Sites with a history of wet accidents were selected and implementation was carried out. After a period of time the ‘before’ implementation accident rate was compared with the ‘after’ implementation accident rate. The results showed a substantial reduction in the rate of accidents in the following groups.

- accidents occurring on a wet road surface
- accidents involving a vehicle skidding
- accidents involving nose-to-tail collisions
The data was examined closely for signs of an increase in ‘other’ or ‘unrelated accidents’ – did the implementation of the material lead to, or introduce other accident types. The data was examined carefully but no evidence of this was found.

It was then decided to implement the measure on a wide scale.

The procedure ‘Figure 3. Carrying out a Road Safety Engineering Mass Action Plan’ described above is applicable in Bangladesh if similar circumstances arise.

### 3.2 Preliminary site selection

The first task is to identify all sites on the network with a high incidence of wet road surface accidents. To do this the engineer needs to go back to the accident database.

The sample should be based on three years accident data. If three years data is not ready the engineer should use the maximum period available.

One simple but very effective way of compiling a preliminary list is to use an accident plot. To do this the engineer has to ‘set the conditions’ for the search to retrieve only wet road surface accidents. The accident plot is then produced. If this is printed on transparent paper the engineer overlays the plot on a road plan of the same scale. This will show the groups and clusters of wet road surface accidents and the locations can then be identified.

A more systematic approach involves a closer examination of each site. This practice is more time consuming but much of this work can be carried out by a junior officer.

This involves preparing a simple breakdown of the accidents at each of the locations. In this case, the person carrying out this operation has to retrieve the accident details (total number of accidents and the wet road surface accidents) from the database, and then transfer the details to a summary sheet. See Figure 4. Preliminary listing (wet road accidents) summary sheet.
Figure 4. Preliminary listing (wet road accidents) summary sheet

WR = Wet road surface accidents

We should now have a complete list of all the problem sites on the network. We now have to make several checks to make sure that the treatment is appropriate, feasible and relevant for the site. The next stage is to check the details of the accidents.
3.3 Checking the details of the accidents

List the results year by year. Show the total number of accidents and wet road accidents. This will show if there is a rising trend.

*Note:* Traffic wears (polishes) the road surface over time, the skid resistance of the road surface lowers significantly when the road surface is wet. The point is, has the surface polished to the extent that, when it becomes wet the stopping distance of vehicles increases to a point where wet road surface accidents are increasing – resulting in the rising trend?

If no ‘wet’ accidents have occurred at the site in the last year this may indicate a local change perhaps the road has been resurfaced. In these circumstances the site would not be considered a high priority and should be dropped from the list.

The next stage is to take a closer look at the detail of the accidents. Stick diagrams (refer to ‘Treating Accident Blackspots in Bangladesh’, Procedure Note 2) were produced. This identified the location and direction of travel of the vehicles in the collisions. If the wet accidents are scattered over a large area, usually a large junction, that site would be dropped from the list of sites under consideration.

Every effort shall be made to avoid the possibility of implementing a measure with a short life span. A checking procedure should be constructed to establish if the site is likely to be altered, modified or improved in the foreseeable future.

3.4 The site visit

An engineer arranged to visit and inspect each of the remaining sites. The engineer was trained to identify flaws in the carriageway sub-base such as any signs of surface cracking or evidence of movement that might indicate structural damage. The engineer would then report back and a specialist inspection would be carried out to see if remedial work is required. The site would remain on the list until the results of the inspection were known.

Assuming that the site was suitable for treatment, the engineer would take dimensions of carriageway widths and areas not to be treated. It is possible to produce a specification of
the area to be treated. Most of the sites were junctions (the majority traffic signal controlled), pedestrian crossings or bends (all conflict points): generally the accidents had occurred on the approaches to these points. The length of the area to be treated depended on the speed of traffic using the road. Using a scale drawing the engineer is now able to prepare a diagram with dimensions for the contractor. The drawing specifies the net area (m²) to be treated.

3.5 First year rate of return

Assuming that the cost per m² is known and the cost of a personal injury accident is known it is now possible to calculate a crude estimate of the first year rate of return. This becomes very valuable in the ranking of the remaining sites.

To carry out the estimate you will need to refer back to the stick diagram to identify the number of target (wet road surface) accidents and estimate the accident reduction by using the rate reduction identified in the Special Study. For example:

Note 1: The average cost of a personal injury accident in Bangladesh is not yet known. To illustrate this example it is assumed that the average cost of a personal injury accident is 2,500 units and the cost of the anti-skid road surface material is 5,000 units.

If nine wet surface accidents occurred on the area of road to be treated and the expected accident reduction is 65%, it can be expected that the material will produce a net reduction of six accidents. If those figures are based on three year periods, it can be assumed that the material will produce a saving of two accidents in the first year.

If the total cost of the material is 5,000 units and the cost of a personal injury accident is 2,500 units in the case above (it is expected that two accidents will be saved in the first year), the estimated rate of return will be 100% in the first year.

Note 2: Anti-skid road surface material frequently achieves a first year rate of return in excess of 100%.
3.6 The final site selection

At this stage there should be enough information available to produce the final selection of sites to be treated and be confident that the list contains the sites where the material is most needed.

Note: There are several more refined techniques for ranking sites into priority. These techniques require a long and reliable accident history that is compared with accurate traffic data. For example, they are used to identify accident rates per million vehicle miles / kilometres. It seems most unlikely that this level of detail will be available in Bangladesh for sometime and for this reason these techniques have not been set out.
4. BUILDING ROAD SAFETY ENGINEERING MASS ACTION PLANS INTO THE ANNUAL PROGRAMME OF WORK

Mass Action Plans proved to be a highly effective part of the overall road safety programme. In the case of applying skid resistant surfacing materials, later studies proved that the material achieved accident reduction broadly in line with the estimated savings.

4.1 Carrying out Annual Mass Action Plans

There is a need to consider carrying out the Mass Action Plans on an annual basis. In the case of the anti-skid programmes, the road surface is constantly wearing, traffic patterns often change, random fluctuation within the annual accident rate are all factors that change priorities from year to year.

4.2 Annual Mass Action Plans

The annual routine that was adopted for the Anti-skid Mass Action Plan programme was to commence the site selection activities in April. At this time the accident data from the previous year becomes available. This means that the final list of selected sites is available in the late summer. By focusing the programme into one concerted run the contractors can plan for a batch of work to be carried out more effectively and thus offer a better price.

![Figure 5. The annual Mass Action Programme](image-url)
<table>
<thead>
<tr>
<th>Accident Type</th>
<th>Treatment-Measure</th>
<th>Effect</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross road accidents at traffic signal controlled junctions.</td>
<td>Extended inter-green period.</td>
<td>Significant reduction in the number of cross road accidents.</td>
<td>Very low cost, very high rate of return.</td>
</tr>
<tr>
<td>Right-turn accidents at traffic signals. The right-turning vehicle is in collision with a vehicle from the opposite direction.</td>
<td>Controlled right-turn. The right-turning traffic is held by a red signal – the opposing traffic is stopped and the red signal changes to green to allow the turning traffic to proceed.</td>
<td>Significant reduction in the number of right-turning accidents.</td>
<td>Medium cost, high rate of return. Careful consideration should be given when using this technique if pedestrian flows are high on the arms into which the right traffic is entering.</td>
</tr>
<tr>
<td>Wet road surface, skidding and nose-to-tail accidents.</td>
<td>Anti-skid road surface material.</td>
<td>Significant reduction in the number of target accidents.</td>
<td>Medium cost, high rate of return.</td>
</tr>
<tr>
<td>Loss of control at bends</td>
<td>Advance warning bend delineation</td>
<td>Significant reduction in the number of accidents</td>
<td>Low cost high rate of return</td>
</tr>
<tr>
<td>Accidents occurring during hours of darkness</td>
<td>Street lighting improvements</td>
<td>Small reduction in the number of accidents</td>
<td>Poor rate of return</td>
</tr>
<tr>
<td>Speed related accidents. High rate of fatal and serious accidents</td>
<td>Speed camera programme</td>
<td>Significant reduction in the number of fatal and speed related accidents</td>
<td>High rate of return</td>
</tr>
</tbody>
</table>

Figure 6. Measures often used in UK Mass Action Plans
<table>
<thead>
<tr>
<th>Measures</th>
<th>Effect</th>
<th>Likely result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conspicuous, standard traffic signs and road markings at bends</td>
<td>Early warning of the bend</td>
<td>Reduction in the number of accidents occurring at bends</td>
</tr>
<tr>
<td>Conspicuous standard marking and warning signs at speed breakers</td>
<td>Early warning of the speed breaker</td>
<td>Reduction in the number of accidents occurring at speed breakers</td>
</tr>
<tr>
<td>Removing trees from the inside radius of bends</td>
<td>Increase sight distance</td>
<td>Reduction in the number of accidents occurring at bends</td>
</tr>
<tr>
<td>Physical prevention of drivers using residential areas to shorten journeys</td>
<td>Reduction of avoidable conflicts in residential areas</td>
<td>Reduction of accidents in residential areas</td>
</tr>
<tr>
<td>Traffic clamping measures in residential areas</td>
<td>Reduction of vehicle speed in these areas</td>
<td>Reduction in the number of accidents occurring in residential areas</td>
</tr>
<tr>
<td>Relocate bus stopping points away from the main carriageway</td>
<td>Reduce vehicle and pedestrian conflicts in these areas</td>
<td>Reduction in the number of accidents occurring at or close to bus stops</td>
</tr>
<tr>
<td>At traffic signal controlled locations, with a history of pedestrian accidents. Introduction of separate pedestrian phase.</td>
<td>If the traffic signals are obeyed, enforced, a reduction of pedestrian / vehicle conflict</td>
<td>Reduction in the number of pedestrian accidents at signal controlled junctions</td>
</tr>
</tbody>
</table>

**Figure 7. Possible subjects for Mass Action Plans in Bangladesh**

Compiled by Arif Ahmed
GOVERNMENT OF THE PEOPLE’S REPUBLIC OF BANGLADESH
MINISTRY OF COMMUNICATIONS
ROADS AND RAILWAYS DIVISION

SECOND ROAD REHABILITATION AND MAINTENANCE PROJECT
INSTITUTIONAL DEVELOPMENT COMPONENT

Road Safety Engineering

Procedure Note 5.

Area Wide Road Safety Measures in Bangladesh
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11. REFERENCES
1. INTRODUCTION

The majority of a country’s road traffic accidents occur on the primary and secondary road networks. Area wide road safety engineering turns attention to residential areas where both the problem of accidents and the approach to accident reduction is quite different.

Accidents on the primary and secondary road networks often occur in groups and clusters. In many cases the analyses of these accidents leads to the identification of clearly defined common problems. These problems can then be dealt with by introducing road safety engineering measures. Accidents in residential areas are more likely to be scattered throughout the area. They often involve different accident types and consequently routine blackspot and route-wide practices are less likely to be effective.

International research and experience has shown that when we look at the details of accidents in residential areas, we find that the majority involve a vehicle traveling too fast for conditions. Area wide road safety engineering starts by addressing the matter of vehicle speed. Where safety engineers have applied devices on the roads to reduce vehicle speed (forcing the driver to travel at a lower speed) substantial reductions in the number of accidents have followed. There are a variety of low cost engineering techniques that reduce vehicle speed. The use of these techniques is the basis of the term ‘traffic calming’. In his book ‘A guide to Road Safety Engineering’ K W Ogden defines traffic calming as follows.

“Traffic calming is a term used to describe the introduction of physical devices aimed at enhancing amenity and safety, especially through speed reduction. It's prime application is within local residential precincts, but there are some situations where the balance of objectives for an arterial road may call for a degree of 'calming'. The safety benefits and the security benefits of traffic calming can be demonstrated. These benefits stem primarily from speed reductions, and these are achieved by development of an overall scheme rather than by specific devices at discrete locations. For this reason, it is vital that traffic calming schemes be developed and implemented on an integrated area-wide basis.”

When we look at residential roads in Bangladesh, we find that roads have evolved rather than be designed with safety in mind. There has been little, if any attempt to control or help road users and there are seldom any amenities for pedestrians or non-motorised vehicles. Junctions have inadequate sight lines, no right of way priority and there is little warning of dangerous conflict areas. This, plus the fact that motorised vehicles are clearly traveling too fast for these conditions, is resulting in a substantial number of avoidable accidents.

This paper sets out basic principles for applying traffic calming measures in residential areas. These principles can be applied now and refined and developed in the future to suit the special circumstances prevailing in Bangladesh.

See Figure 1 for the relationship between area wide treatment and other road safety engineering procedures.

Note: This Procedure Note should not be used by persons without appropriate Road Safety Engineering training.
Special Comment

The experience of traffic calming measures and area-wide treatment is now comprehensive. There is now a considerable amount of excellent technical literature and commentary available from many reliable sources. Much of this material has been derived from traffic calming experience in countries where there is high standards of road user behaviour, discipline and police enforcement. It is considered in many cases that this material is not yet relevant to present day Bangladesh.

The references included in this Procedure Note paper are now dated, but they are still reliable and relevant. They have been, and are still being used to refine the practice and consequently they are a good basis to start developing the practice here. The papers, referred to in the Reference Section are available in the Road Safety Centre of the Technical Library at Bangladesh Road Research Laboratory (BRRL). These are freely available to safety practitioners for research and development purposes.

We wish to express gratitude and appreciation to personnel working with the COWI-DRD-SMEC JV Road Safety Project, who freely contributed several technically valuable publications to this library.

IDC
February 1999
Figure 1. Area Wide Road Safety Measures in Bangladesh in Road Safety Engineering
2 REDUCING VEHICLE SPEED IS THE FIRST STEP TO ACHIEVING ACCIDENT REDUCTION IN RESIDENTIAL AREAS

Drivers are nearly always late, in a hurry. Drivers in residential areas in Bangladesh are no exception. All too often drivers are seen racing from one junction to another. They sound their horns, overtake recklessly, often forcing oncoming rickshaws to move over. They weave between pedestrians crossing the road. They drive far too fast for everyday conditions in residential areas. This leads to accidents and in many cases a resident of the area is seriously injured or even killed.

2.1 Impact speed is the most important factor in an accident

The simple facts are:

IF A CAR IS TRAVELING AT 20 MPH NINE OUT OF TEN PEOPLE SURVIVE IF HIT, BUT AT 40 MPH NINE OUT OF TEN ARE KILLED.

In the TRL / ODA publication ‘Traffic calming principles and applications’ (R Patel, I A Sayer and G Tiwari), December 1994, the authors illustrate this point by presenting the following table.

<table>
<thead>
<tr>
<th>IMPACT SPEED kph (mph)</th>
<th>DEATHS %</th>
<th>INJURED %</th>
<th>UNINJURED %</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 (40)</td>
<td>85</td>
<td>15</td>
<td>NIL</td>
</tr>
<tr>
<td>50 (31)</td>
<td>45</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>30 (18)</td>
<td>5</td>
<td>65</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 2. Pedestrian injuries at impact speeds

2.2 Shortest vehicle stopping distances

The shortest vehicle stopping distance at 30mph is nearly twice the distance of a vehicle traveling at 20mph.
Figure 3. Shortest vehicle stopping distances

*These shortest stopping distances are taken from the UK Highway Code and are based on a well maintained vehicle traveling on a dry, sound (high standard of skid resistance) road surface. If by chance it is raining and the road surface is wet, the shortest stopping distance increases considerably.

2.3 An example of a typical residential area accident

A child going to school is pre-occupied, possibly thinking about last night’s television programmes and walks carelessly out into the road. The child is hidden from oncoming drivers by parked vehicles, a tree, or perhaps people at a tea stall.

A driver of a car is approaching the point at which the child will cross the road. When the driver is 18m from that point he sees the child and he quickly applies the brakes.

If the approaching vehicle is traveling at 30 mph (48 kph) the shortest stopping distance will be 23m or 6 car lengths. The car will come to a halt 5m past the point at which the car crashed into the child.

If the approaching vehicle is traveling at 20mph (32 kph) the shortest stopping distance will be 12m or three car lengths. The driver is annoyed and scolds the child.*

2.4 Are we asking too much from the driver when we call for lower vehicle speeds?

Journeys in residential areas are short distance trips. A driver leaves, or returns home, to or from the major road network. If we assume that an average journey in a residential area is a distance of 300m and that it is possible to travel that far at a constant speed, the time to complete this journey will be:

- at 30 mph (48 kph) it will take the driver 21 seconds to complete the journey.
• at 20 mph (32kph) it will take the driver 31 seconds to complete the journey.

The countries that have reduced vehicle speeds in residential areas from 30 mph (48 kph) to 20 mph (32 kph) have invariably achieved a significant reduction in the number of road traffic accidents. In many cases accident rates have been halved. The cost to drivers and passengers is negligible.

2.5 How can we effectively reduce vehicle speed?

If we ask drivers to travel at a certain speed, the majority will not respond. Even the most responsible driver becomes distracted, preoccupied, or travels at a speed that he or she (wrongly) feels is safe.

We can set reasonable speed limits and provide clear signs to display those limits to drivers. In practice although this does have some effect, some but not many drivers respond.

We can enforce speed limits by assigning police to the area and punishing offenders, but we cannot enforce speed limits on all roads 24 hours a day, 365 days a year.

The reality is that a large proportion of drivers will choose to travel irrationally and too fast. To ensure that all drivers use roads in residential areas safely, we must construct roads so that they can only travel at a **calm,** reasonable speed.

**IF WE REDUCE VEHICLE SPEED IN RESIDENTIAL AREAS IN BANGLADESH WE WILL REDUCE ACCIDENTS. IF WE LOOK AT THE EXPERIENCE OF OTHER COUNTRIES WE WILL FIND THAT THEY HAVE DEVELOPED THE PRACTICE OF TRAFFIC CALMING FURTHER. THIS HAS LED TO A MORE COMPREHENSIVE, MORE EFFICIENT ACCIDENT REDUCTION PRACTICE.**
3. THE BACKGROUND AND DEVELOPMENT OF TRAFFIC CALMING AND AREA WIDE ROAD SAFETY ENGINEERING

Much of the early traffic calming work began in the Netherlands, Denmark, and Germany. Modern traffic calming practice owes much to this work. Over the past 25 years there has been considerable research and development into the practice. As a result many countries have now developed refined systems and procedures. Traffic calming measures are now extensively applied on a wide basis in residential areas. These schemes are achieving significant accident reductions.

It was not until the full scale of the problem of accidents in residential areas (in the United Kingdom) was realised that ‘area wide’ programmes were given the priority they deserved.

The realisation that 75% of all accidents in Britain occurred in towns and cities and that more than half occurred away from the major road network, principally on residential roads, resulted in a concerted effort to improve the situation.

This led to the production of The Institute of Highways ‘Guidelines for Urban Safety Management’, a comprehensive guide to developing a strategic, systematic and integrated approach to the problem. A major programme of traffic calming then began. The experience of constant monitoring and the evaluation of results led to improvements in design and practice. Feedback from the public was carefully taken into account.

More recently Urban Safety Management (USM) has been developed. USM considers safety in the whole urban area, involving all aspects of urban management. One programme to stem from this initiative is the SAFER CITY project in Gloucester. In this programme police, health, traffic management, planning development, environment, safety education and magistrates are working towards a strategy which aims to reduce accidents in the city by 30% in five years. This will involve measures being implemented in residential areas and on main routes.

Road safety practice evolves and develops at a faster rate when specialists work together. They learn about successes and failures. In this way they learn to build safer roads and to make existing roads safer in future.
A good example of international teamwork is the commencement in 1997 of the Developing Urban Management Safety (DUMAS) project, funded by the European Commission. This three-year project involves 10 partners from nine countries in Europe who are working together to develop the practice further.

If we can use the basic lessons learned from other countries and apply those lessons in a structured way, a programme of area-wide road safety work will make a considerable contribution towards reducing accidents in Bangladesh.
4. HOW THESE BENEFITS CAN BE APPLIED IN BANGLADESH?

There is currently little order on any roads in Bangladesh, particularly in the case of residential areas. There are no facilities for pedestrians and vehicles travel at excessively high speeds, weaving between slow moving rickshaws and pedestrians. There is no road hierarchy or give-way priority for vehicles at junctions. There is no order or rules and this has led to irrational and dangerous conflicts. What is needed to rectify the situation is a programme of Traffic Calming.

Traffic Calming is not new to Bangladesh. There are several examples in everyday use such as speed breakers used outside schools and colleges, and they are now beginning to be used in some residential areas. They are also used on bridges on National Roads. There is much to be gained by a wider, methodical application of these traffic calming measures.

By international standards speed breakers in Bangladesh are frequently open to strong criticism. We have received several reports that the installation of local speed breakers has actually contributed to accidents. It is not difficult to see why:

- there is seldom any advance warning of the speed breakers for drivers
- local speed breakers are not conspicuous, particularly at night
- the design of the profile varies from site to site, in many cases too high - too severe for the speed of traffic

However, they are successful in so far as they achieve the first objective - they reduce vehicle speed. Even in their present form they have probably prevented many accidents and saved many lives. The introduction of speed breakers in Bangladesh has been a very positive step forward and the next stage is to build on this initiative.

A recommended procedure to do this is set out in Figure 4 and the publications set out in Reference Section 11 provide a basis.
The basic procedure to develop a traffic calming scheme involves six basic stages. Monitoring and exchanging the results quickly leads to more refined and effective practice.

Stage 1: analysing and assessing road user habits and the accident history of the area.

Stage 2: taking into account future changes that will affect the area.

Stage 3: agreeing a coordinated area-wide (technical) approach to the problems found in the assessment and accident history.

Stage 4: developing a fully integrated proposal.

Stage 5: discussing and refining the proposal in line with other 'involved' agencies and the public.

Stage 6: implementing the 'agreed' measures.

monitoring and evaluating the results.

developing a national forum to bring together and take advantage of the lessons learned.

Figure 4. Developing area-wide schemes
5. APPRAISING THE EXISTING CIRCUMSTANCES

The first stage of area wide treatment is to review and identify the existing circumstances and the present road user travel patterns in the area. To do this the designer will need a fairly accurate scale plan of the area. That plan should show the property (frontage) of private and commercial properties. The plan should also show the pavement kerb lines, drives to properties and community services. For example, power sub-stations and drainage points should also be shown.

In order to carry out a survey of the road user usage in the area it is not necessary to carry out a full ‘origin and destination study’, but it is important to identify day to day traffic volumes, habits and patterns for each of the groups. The important points to identify are:

- areas of road user conflict
- areas where vehicles are frequently using excessive speed
- pedestrian routes, particularly those where children are exposed to risk, routes to school for example
- non-motorised vehicle commuter routes
- if the area is being used by traffic diverting from the local network, vehicles, particularly commuter traffic or commercial vehicles, taking a short cut through a residential area
- all areas where people congregate such as schools, mosques, play areas, shopping areas, community areas, cinemas

Frequent site visits at busy and off-peak times to observe road user behaviour will provide much useful information to supplement the investigation.

The accident history should be the basis of the appraisal. It is unfortunate that accident records are not yet available for residential areas. However, the local police thana office may be able to produce some details. Contact with representatives from local community groups may also produce useful information. However, it should be noted that the general public do not always produce reliable evidence.

As the appraisal nears completion, it will be necessary to find out what is likely to happen in the area in the short and medium term. What changes are planned for the area and its immediate vicinity? Is the residential area going to be extended? Are changes
likely to occur that will alter the day-to-day patterns of road users - a new cinema perhaps?

When all the information and details have been collected and analysed, the engineer should prepare an assessment report.

The assessment report should be a self-contained document and provide the reader with the following details.

- background - the background to the report
- a description of the area, the location, the community (site photographs would also be useful)
- a description of current road user behaviour
- if changes are planned, an estimate of future road user behaviour
- a description of road user conflict points
- a description of the accident record
- a summary of the above

THE ASSESSMENT SHOULD IDENTIFY ALL ‘SAFETY’ PROBLEMS. IF THESE ARE PRESENTED IN A METHODOICAL WAY IT SHOULD BE POSSIBLE TO START MAKING INITIAL RECOMMENDATIONS.
6. **SETTING THE OBJECTIVES FOR THE PRELIMINARY PLAN**

Having established the current and likely short term future road user behaviour patterns, it will then be necessary to decide the direction for producing the preliminary plan.

This is the task for senior officers, perhaps brought together to form a planning team. A meeting or series of meetings to discuss the identified problems in the assessment, and discuss the various options possible will probably result in deciding the best course of action.

Does the situation require a comprehensive approach or are low key measures likely to be more appropriate?

6.1 **Considering a basic, low cost approach**

If it is considered that speed reduction measures will achieve a good accident reduction, a series of speed breakers with raised platforms and signs throughout the area will achieve the objective. *Traffic Advisory leaflet 7/96 available in the BRRL Library provides a good example of how this can be applied in an area.*

6.2 **Considering a comprehensive approach**

The design team should consider that residential areas are for residents. The only vehicles traveling in these areas should be by residents for social and domestic purposes only. Commercial activity and businesses in these areas should be discouraged. Unless serving the community, (for example, delivery of goods, house moving) heavy commercial vehicle traffic is undesirable. This is the point that is emphasised in ‘Towards Safer Roads in Developing Countries’ page 34 and 35 TRL 1994.

“Residential areas need to be designed to increase pedestrian safety. Unnecessary usage by through traffic, particularly heavy vehicles, creates additional road safety hazards. Ideally the road user should be able to identify the street function by its appearance and layout. Threshold treatments at entry points to residential areas can be used to tell the driver he is entering a residential area. Conditions in residential areas should be such (because of road narrowing, culs-de-sac and loop-roads) that low vehicle speeds predominate, and priority should be given to pedestrians. Non-essential, inappropriate
and through traffic should be minimised in such areas. Overnight parking of commercial vehicles, especially those carrying hazardous loads, should be actively discouraged.”

In most cases residential areas in Bangladesh have been built using a grid-iron, (horizontal roads bisected by vertical roads) design. There is no road hierarchy, traffic on a minor roads does not give way to traffic on the major road. All turning movements at all junctions are permitted. By introducing and enforcing road hierarchy and restricting vehicle turning movements - even physically preventing entry at some points, with a policy of providing clearly defined, separate areas and paths of travel for pedestrians, non-motorised and motorised traffic, we will produce a much safer system.

6.3 Considering the improvement of the local environment

One of the major lessons learned from past traffic calming exercises is that by making an effort at the design stage, we can improve the visual appearance of measures so that they fit in with the local environment. This is appreciated by the local community and we can achieve additional safety benefits.

For example, a series of speed breakers implemented along a section of road will achieve a satisfactory result but if circumstances require wider treatment, we can go further. If there is a history of pedestrian accidents and we identify the natural pedestrian crossing points, we can build out the footpath to extend 2m or 3m from both kerbs to provide ‘pinch points’ to slow traffic at these points. This will force vehicles to slow down and we will have produced a facility for the pedestrians. The pedestrian can now stand at the edge of the pinch point and can see oncoming vehicles. Likewise drivers of oncoming vehicles, have to slow down and they can see the pedestrians. If the designer uses care and imagination, sensitively specifying materials, perhaps the planting of suitable trees and low growing foliage, the final result can be an attractive feature that fits into the local environment.

- the carriageway behind the kerb builds out is now in the ‘shadow’ of the build outs, after allowing for access to private properties and private driveways the remaining area can be marked and designated as a parking area
- drivers along this route will now know where to expect pedestrians and where to expect movement from parked vehicles
The cost of producing a more effective, attractive scheme will obviously be higher, but when we consider the additional benefits the additional cost is often easy to justify.

6.4 Discouraging ‘through’ traffic

As traffic volumes on the major road network increases, queues and delays on the major road network often encourage drivers to use residential areas to cut through and avoid those problems.

This traffic is using the area for convenience and the way to keep this traffic on the major road network is to make it difficult for drivers to enter and leave the area conveniently. By adopting a policy of road closures and one way streets, we can still provide local residents with reasonably convenient access routes, but make it difficult if not impossible for others to cross the area.

6.5 Summary

When all of the considerations have been made and the planning team are in agreement the team should produce outline guidelines for the designer (or design team). The guidelines should cover the following points:

- the level of intervention, should the scheme be low cost, low impact or more comprehensive? *It should be pointed out that many low cost schemes have achieved substantial accident reductions.*
- should the scheme require traffic management measures?
- should the scheme include a strong effort to improve or even enhance the area?
- identify the agencies who will later take part in the consultation stage
7. THE OPTIONS AVAILABLE TO THE DESIGN TEAM

As soon as the guidelines are received from the planning team the designer can start to build up the initial proposals. The designer should be entirely familiar with the problems identified in the assessment report and assuming that he / she has not played a part in the assessment, the designer should make several visits to the area to become familiar with the nature and characteristics of the neighbourhood.

7.1 Options available to the designers

The range of measures and devices for Traffic Calming that are now available to designers is comprehensive. In 1998 The Institution of Highways and Transportation published ‘Transport in the Urban Environment’. This lists the most frequently used measures. The list, Part III Traffic, Safety and Environmental Management, Section 20.8 Traffic Calming Measures (pages 275 - 278) is as follows:

- **Bar Markings**, although mainly used to draw attention to an approaching junction or roundabout on high speed roads, in the form of yellow transverse bar markings, are sometimes used prior to a change in speed-limit, possibly combined with, or part of, a ‘gateway’ feature. Yellow transverse bar-markings require special authorisation but other bar-markings generally fall within the powers provided under the Highways (Traffic Calming) Regulations (HMG, 1993) [Sb].

- **Build-outs** are a narrowing of the carriageway, constructed on one side of the road as an extension to verge or footway, and are often combined with sheltered parking or flat-topped crossing facilities.

- **Chicanes** consist of two or more build-outs on alternate sides of the road, but not opposite one another, and create horizontal deflections. Speed cushions may be used in conjunction with chicanes to make the chicane more effective, by precluding a ‘racing’ line.

- **Cycle Measures** are not specific traffic-calming measures but are features that should be provided to ensure the safety of cyclists, when negotiating particular traffic-calming measures, such as cycle-lanes or cycle tracks by-passing chicanes or pinch points.

- **Entry Treatment** consists of a change of surface, a ramp, a narrowing or some other features at a junction or change of road characteristic (see also gateways).

- **Environmental Road Closures** can be used as part of an area-wide scheme to reassign traffic.
**False Roundabouts** involve the creation of a small roundabout where there is no actual road junction and its purpose is to modify traffic speed. Legislation does not permit mini roundabouts, formed by road markings, to be used for this purpose.

**Footway Crossovers** are the continuation of an existing footway across the mouth of a side-road, with vehicles allowed to cross the footway but giving way to pedestrians.

**Footway Widening**, often as part of the redefinition of road space, is used to give more space to pedestrians or for planting. It may be part of a build-out and can be particularly effective at formal or informal pedestrian crossing points.

**Gateways** are combinations of natural or man-made features at the entry to, or exit from, areas where the rules or drivers’ expectations changes, such as at the introduction of speed-limits.

**Horizontal Deflections** occur at build-outs, chicanes and pinch points, often with priority signing.

**Islands** usually take the form of a longitudinal island, built in the carriageway, with or without facilities for pedestrians, to improve lane-discipline, restrict overtaking or lower vehicle speeds by reducing lane-width and separating cyclists from other vehicles.

**Junction Priority Changes** are used as part of an area scheme to interrupt long stretches of ‘through’ road. Care is needed in signing when introducing a change such as this.

**Junction Treatments** can incorporate a variety of measures as part of an overall scheme, including flat-topped road humps, narrowing and removal of excess areas of carriageway and the introduction of ramps, chicanes, horizontal deflections and tight curves.

**Mini-Roundabouts** are used at junctions on long straight roads to break up the road into shorter sections which slows traffic; also used at T or Y junctions to reduce the dominance of one particular flow.

**Narrowings** consist of short or long pinch points, often combined with priority signing.

**One-Way Streets** may be used as part of an area-wide scheme to break up a road into short sections and indirect routes. By creating detours, they can discourage ‘rat running’ but may encourage higher speeds because of the absence of opposing traffic. Contra-flow bus lanes or cycle routes may be incorporated.

**Over-run Area** is a part of the road which is textured or coloured, so that it appears to narrow the carriageway but can be used by large vehicles to complete turning manoeuvres; but attention needs to be paid to the needs of cyclists and pedestrians should be discouraged from waiting on these areas before crossing.
Parking involves redefining the road space to provide defined parking and to reduce the area of carriageway.

Pedestrian Refuges are used to aid pedestrians’ crossing movements, by allowing a carriageway to be crossed in two stages. They are also used to control overtaking and to improve lane-discipline.

Pinch Point consists of a pair of build-outs on opposite sides of a road to create a narrowing, thus helping to modify vehicle speeds and to reduce the risk to pedestrians when they cross the road (often combined with speed cushions and priority signing).

Planting can be used to change the perceived width of a road, to define a gateway and to improve the overall environment.

Raised Junctions consists of plateau or flat-topped road hump, built across the whole area of a junction.

Red Light Cameras are automatic cameras, which record red traffic violations - ‘red-running’.

Reallocation of Road Space entails the definition of road space to accommodate all users of the space in question, so as to reduce the dominance by motor vehicles.

Road Humps are used to reduce vehicle speed and, in the case of flat-topped humps, may provide a level surface for pedestrians to cross.

Road Markings are used to hatch out areas of carriageway, to define traffic lanes and to create the visual effect of narrowing of the carriageway.

Rumble Devices are part of a carriageway made of materials which create a noise or vibration as vehicles pass over. They are useful as an alerting device before a hazard but may not reduce speed. They may attract objections when sited close to houses.

Shared-Use Roads are short lengths of road, mostly in new estates, which can provide an attractive appearance in living areas. When used in shopping streets, it may be preferable to have a 25mm kerb upstand, except at crossing points, to assist pedestrians who are visually impaired.

Sheltered Parking consists of parking spaces protected by a build-out and can be in-line, angled or in echelon form.

Speed Cameras are automatic cameras, which record speed violations in excess of a pre-set threshold value.

Speed Cushions are a form of road hump, occupying only part of a traffic lane, which, generally can be spanned by buses and HGVs but not by cars and can be used in conjunction with chicanes.
Street Furniture, properly used, can help to redefine road space, create the visual effect of narrowing and contribute to gateways and other features.

Surface Treatments consist of change in the colour or texture of a carriageway, to denote where the character or use of the area changes (see also gateways).

‘Thumps’ are thermoplastic road humps not less than 900mm wide and 30mm to 40mm high.
8. THE STAGES IN DEVELOPING THE PRELIMINARY PLAN

If it has been agreed to adopt a comprehensive approach to the design, we need to build the plan in three stages.

**Stage 1** - Reducing conflict in the area, by using traffic management techniques. The problem of through traffic can also be dealt with at this stage.

**Stage 2** - Reducing vehicle speed in the area, by installing speed control devices on the road

**Stage 3** - Addressing the special needs of the area, dealing with accident blackspot sites and locations where road user conflicts are high.

**IT IS ESSENTIAL THAT THE OUTCOME OF ALL THREE STAGES ARE CONSISTENT AND COMPATIBLE.**

8.1 Reducing conflict in the area

The designer reviews the entire road network and considers introducing:

- road hierarchy - all junctions to have ‘right of way’
- a series of one way streets
- full, or part junction street closures

This operation provides the designer with the opportunity to remove considerable road user conflict. This is a task for a specialist and it might be necessary to co-opt a person with these skills into the design team.

8.2 Reducing speed in the area

The main thrust of the work will be reducing vehicle speed in the area. There are three elements to achieve a constant, wide-spread speed reduction. They are:

- at the entry points into the area, if we can reduce vehicle speed as the vehicle enters, it will then become easier to keep that vehicles’ speed at a lower level.
• at regular points along the road links within the area; and
• at junctions.

8.3 Addressing the special needs of the area

At this stage we should examine the accident history. If the accident history has identified accident problems, have those problems been addressed by the first two stages? Is it possible to provide facilities for vulnerable road users (pedestrians and non-motorised traffic)? Is it possible to provide facilities for vulnerable road users, perhaps designating special facilities along routes that children take to school as well as along principle non-motorised routes?
9. BASIC TRAFFIC CALMING APPLICATIONS

9.1 Entry treatment

Entry treatment uses devices to reduce the speed of the vehicle as the vehicle leaves the major road network to enter the residential area. Entry treatments include reducing the width of the road, raising the height of the road to form a ‘platform’, see Figure 5. The entrance to the area should also have clear signs to inform drivers that they are entering a Traffic Calmed area.

Figure 5. Entry treatment.

Reduce the speed of vehicles as they leave the major road to enter the residential area.
9.2 Link treatment

There are many options for reducing speed along links. These include:

- speed breakers (road humps, road bumps), see Figure 6
- pedestrian islands. A traffic island for pedestrians, located in the centre of the road. These effectively reduce the width of the road and make it easier for the pedestrian to cross - the pedestrian can now cross the road in two stages and if necessary shelter at the island, see Figure 7.
- reducing the width of the road by building out from both kerbs, often referred to as ‘pinch points’ or ‘build-outs’, see Figure 8. The design of these ‘build-outs’ vary considerably if the ‘build-outs’ are staggered they are referred to as ‘Chicanes’.

![Figure 6. Speed breaker, road hump](image-url)
Figure 7. Pedestrian island, refuge

Pedestrian islands used in sequence, along a section of road can be effective. They defer parking in the immediate vicinity and if they are located close to pedestrian ‘desire lines’ (natural pedestrian routes) they are well used.

Note: The indicator or marker post should be highly conspicuous, visible in all conditions. The post should be collapsible to minimise the possibility of injury if hit by an errant vehicle.
Figure 8. Pinch point, build out

There is a wide variety of designs and layouts for kerb ‘build-outs’. For the best results they should be used in sequence.


9.3 Junction treatment

Again there are many options for improving safety at junctions. These include:

- imposing ‘right-of-way’ priority, road hierarchy, see Figure 9.
- small roundabouts
- raised platforms, tables

Figure 9. Road hierarchy
Traffic from the minor road now gives way to traffic on the major road.
10. PUBLIC CONSULTATION

There are several instances where public authorities in Bangladesh have built effective and efficient links with local committees. In many respects public participation is stronger here than in many developed countries.

Public participation is an essential ingredient to the success of a scheme. It is likely that residents will be able to contribute much to each stage of the work. If local occupants can see that the outcome will be an asset, they realise that their participation will result in benefiting the entire community.

10.1 Consultation

Throughout the development of the plan the designer will need access to experienced highway engineering, highway maintenance, town planning and landscape architectural skills.

If the scheme includes traffic management changes, local emergency services (police, fire ambulance) representatives must be consulted. They need to be aware of proposed measures and be allowed to contribute to the design. Maintaining local emergency services during construction and following the completion of the scheme is absolutely essential.

Local traffic police will also be required to help and advise on enforcement and matters involving the smooth operating of traffic in the vicinity. This is likely to be a problem during both the construction period and when the scheme is complete.

If public service vehicles operate in the area they should be invited to contribute assistance.
11. REFERENCES


The following Traffic Advisory Leaflets are produced by THE DEPARTMENT OF THE ENVIRONMENT, TRANSPORT AND THE REGIONS, UK previously THE DEPARTMENT OF TRANSPORT

Traffic Advisory Leaflet 4/93 Pavement Parking
Traffic Advisory Leaflet 11/93 Rumble Devices
Traffic Advisory Leaflet 12/93 Overrun Areas
Traffic Advisory Leaflet 13/93 Gateways
Traffic Advisory Leaflet 1/94 VISP - A Summary
Traffic Advisory Leaflet 2/94 Entry Treatments
Traffic Advisory Leaflet 4/94 Speed Cushions
Traffic Advisory Leaflet 7/94 Thermo Plastic Road Humps ‘Thumps’
Traffic Advisory Leaflet 9/94 Horizontal Deflections
Traffic Advisory Leaflet 7/95 Traffic Islands for Speed Control
Traffic Advisory Leaflet 2/96 75mm High Road Hump
Traffic Advisory Leaflet 6/96 Traffic Calming : Traffic and Vehicle Noise
Traffic Advisory Leaflet 7/96 Highways (Road Humps) Regulations 1996
Traffic Advisory Leaflet 8/96 Road Humps and Grand Bourne Vibrations
Traffic Advisory Leaflet 10/96 Traffic Calming Bibliography
Traffic Advisory Leaflet 1/97 Cyclists at Road Narrowings
Traffic Advisory Leaflet 2/97 Traffic Calming on Major Roads, A49 Graven Arms Shropshire
Traffic Advisory Leaflet 6/97 Traffic Calming on Major Roads A47, Thorney Cambridge
Traffic Advisory Leaflet 12/97 Chicane Schemes
Traffic Advisory Leaflet 1/98 Speed Cushion Schemes
Traffic Advisory Leaflet 3/98 Traffic Calming Bibliography


SUMMARY

In many developed countries, the practice of using specialists to carry out safety audits of highway schemes during the design and construction stages has undoubtedly led to safer roads being produced. The adoption of Safety Audit Practice is one of the key activities identified by the National Road Safety Council and the introduction of the practice is specified in the National Strategic Road Safety Action Plan, launched last year.

The main aim of safety audit is to ensure that all new highway schemes operate as safely as practicable. This means that safety should be considered throughout the whole of the preparation and construction of any project. Specific aims are:

- to minimise the risk of accidents occurring on the scheme, and to minimise their severity
- to minimise the risk of accidents occurring on adjacent roads, i.e. to avoid creating accidents elsewhere on the network
- to recognise the importance of safety in highway design to meet the needs and perceptions of all types of road user; and to achieve a balance between needs where they may be in conflict
- to reduce the long term costs of a scheme, bearing in mind that unsafe designs may be expensive or even impossible to correct at a later stage
- to improve the awareness of safe design practices by all involved in the Planning, design, construction and maintenance of roads

The principles of safety audit are established through experience of effective accident remedial programmes, planned studies of the influence of design and traffic management on safety, and of the factors contributing to the occurrence of accidents. Figure 1. shows Road Safety Audit in relation to other road safety engineering practices.

The outcome of the audit is the identification of any potential problems, together with recommendations on how to rectify the problems.

For this practice to be successful in Bangladesh, the following principles need to be kept in mind:

- safety audit needs to be an integral part of highway planning, design, construction and maintenance
- the audit shall to be carried out by persons with Road Safety Engineering experience, working independently of the design team
- the audit report shall refer only to matters relating to road safety
- experience of the practice in Bangladesh shall be fed back, monitored, and the procedures adapted in the light of that experience. After a reasonable period, say two years, the revised version of this practice should be incorporated within highway legislation

The basic framework on which the following guidelines are based are as set out in the Road Safety Audit Manual (December 1996), Traffic Engineering and Safety Unit Design Branch, Department of Roads, Nepal. We fully acknowledge the contribution of that manual in the preparation of this work. Finally we also wish to express our gratitude to Dr. Md. Mazharul Hoque, Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka for his help and assistance.

Roger Legassick
February 1998 (Amended September 1998)
Figure 1. Manual for Road Safety Audit in Bangladesh in Road Safety Engineering
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1. EXPLANATION OF ROAD SAFETY AUDIT

1.1 What is road safety audit?

In simple terms safety audit is ‘a systematic method of checking the safety aspects of new roads in order to detect potential safety hazards before the road is open to traffic’. The principle behind it is that ‘prevention is better than cure’. Road user error is the major cause of road accidents, but defects in the road environment (poor alignment, inadequate signing, dangerous obstacles, etc.) are a contributory factor in many cases. Remedying these defects at the design stage is an economical and effective way of reducing road accidents. Road safety audits assess how the road will work once it is open to traffic, focuses on the safety of users - including pedestrians, cyclists, motorcyclists, truck and bus drivers, car drivers, and others. A Road Safety Audit Report identifies any road safety deficiencies and recommends ways in which these can be overcome. The report is submitted to the project director, who, after discussing the recommendations with the project manager, will decide what changes are to be made to the design.

1.2 Who does the auditing?

To be effective the audit needs to be carried out by a specialist (or team of specialists) empowered by standing procedure,\(^1\) who are independent of the design process. In this way the auditors will be taking a fresh look at the project without the distraction of having been involved in their design. The audit will be carried out by road safety engineers who, through practice will have gained experience in identifying potential hazards, see Figure 1.

Note: If the subject of the audit involves a complex - unusual structure or traffic signals the Head of the Road Safety Unit shall consider co-opting a specialist with relevant design and construction experience into the Audit Team. Safety Audit in many countries has benefited by including the experience of traffic police officers. It is recommended that Safety Audit in Bangladesh works towards including traffic police in Audit Teams as soon as possible.

\(^1\) In future Safety Audit Practice will be covered by Regulations.
1.3 What should be audited?

All road projects, even those involving no more than a new access onto a highway, can have safety implications, but in practice, and until staff and skill resources increase, it will be best to limit safety audit to the larger projects. Minor projects where safety clearly is an issue, such as alterations to busy junctions, should also be audited. Whilst the scope for safety audit is greatest with new roads and bridges, it is also appropriate for rehabilitation projects, as many of these involve significant changes to the road layout and geometry.

1.4 At what stages will projects be audited?

The earlier a project is audited the more scope there is to make improvements. In projects where there is a choice of route or standards, or there are known safety problems, the design team should discuss these matters with the Road Safety Unit at the earliest opportunity. The main audit is done after the detailed design is complete. Any changes to the design arising from the audit ought to be incorporated before the project goes out to tender. In some cases there will not be time for this, and any major changes or additions will have to be carried out by variation orders. A final audit should be made after completion of the works and prior to the opening of the road - this is for checking signing, road markings, and placement of road furniture. It is conventional to refer to audit stages as follows:

Stage 1 Audit feasibility
Stage 2 Audit draft design
Stage 3 Audit detailed design - the main audit
Stage 4 Audit pre-opening

1.5 Responsibilities

Safety audit is not a comprehensive check on the technical aspects of the project. It does not check if design standards have been followed. The audit will not check if structures such as bridges can safely take the loads that may be imposed on them. It is an assessment of the road safety aspects only. The highway design team remain responsible for all technical aspects and continue to report to the project manager for these matters.
Audit involves one set of professionals checking the work of other professionals, and this calls for much diplomacy and respect. Auditors must understand the background to design decisions and avoid commenting on any issue other than safety. Highway designers whose work is being audited should accept that the audit team may be able to improve on the safety aspect of the design to the benefit of everyone. The audit process brings specialist advice into the design process - it is not a test of the competence of the highway designers.

Highway designers must be given an opportunity to respond to the findings of the audit team, but the decision as to whether to adopt the recommendations rests with the Project Manager.

1.6 Costs and benefits

There is concern that this task increases the cost of the project, but this is rarely the case. Most changes involve minor issues for example signing, marking, and adjustments to the layout, these improvements cost little, if they are adopted in the early stages of the design process. And it has been suggested (from a limited British study) that one-third of future accidents at road improvements could be prevented by road safety audit. If the impact on costs is likely to be significant, the audit team will have to consider if the cost is justified by the likely savings in accidents and the matter may need to be referred to the Client.
2. PRINCIPLES FOR DESIGNING SAFER ROADS

2.1 Introduction

This section of the manual looks briefly at the basic safety principles. Safety audits are completed by assessing schemes with the help of detailed checklists. Points can still be overlooked unless the auditors have basic principles in mind. This section will also help scheme designers get a better understanding of how to produce safer road design.

The key principles are:

- **DESIGNING FOR ALL ROAD USERS**
- **PROVIDING EARLY, CLEAR AND CONSISTENT MESSAGES TO THE DRIVER**
- **ENCOURAGING APPROPRIATE SPEEDS AND BEHAVIOUR BY DESIGN**
- **REDUCING CONFLICTS**
- **MAKING ALLOWANCES FOR THE BAD OR IMPAIRED DRIVER**
- **CREATING A FORGIVING ROAD**

2.2 Designing for all road users

There has been a tendency in the past for scheme designers to focus on pavement engineering aspects of new and improved roads. It is quite common to find that when a highway passes through a town or village there is no change in design, when the road is opened to traffic, the higher speeds made possible by the improved road surface result in increased pedestrian accidents. But it is not just pedestrian needs that are forgotten - it is the needs of rickshaw drivers, bus drivers and their passengers, people who need to park their vehicles at the roadside, and people whose property fronts the roads and need access to it. They have all got a legitimate need to use the road and, if this is ignored, there will be problems and accidents. The speed limit needs to be frequently displayed, giving suitable early warning of all hazardous areas with appropriate reduced speed limits.
2.3 Providing a clear and consistent message to the driver

Good highway design will result in a driving task which is clear, simple and consistent. Safe designs are those which result in a road which can be easily read and understood by the driver and present him or her with no sudden surprises. This is a particularly important consideration when designing alignment - a sharp bend after a long straight section or just beyond a summit curve is sure to produce accidents - but it is also relevant to the design of junctions. Drivers can be warned of difficult or potentially confusing situations (and guided through them) with good signing and road markings. Provisions should be made for safe vehicle overtaking, pedestrian activity, non motorised vehicles, bus stopping points, segregated roadside activities.

2.4 Encouraging appropriate speeds and behaviour by design

In a way this is a refinement of 'providing a clear and consistent message to the driver'. We can influence traffic speed by altering the look of the road. If a high-speed road looks the same (same width, same shoulder treatment, etc.) as it passes through a village it is not surprising if drivers do not slow down. Where we want drivers to slow down we must give them clear visual clues, such as changing the shoulder treatment, providing a footway, and installing highly conspicuous signing and road markings.

2.5 Reducing conflicts

Conflicts, whether between vehicle streams, or vehicle types, or vehicles and pedestrians are always associated with accidents. In some cases conflict can be reduced or designed out - making the scheme safer by design; for example replacing a cross-road layout to a roundabout or staggered junction, by separating service areas from the main carriageway and by using guard-rail to channel pedestrians to safer crossing points.

2.6 Making allowances for the bad or impaired driver

A safe road is one which recognises the realities and limitations of human skills of the road user who will use that road. It must not place demands upon the driver which are beyond his or her ability to manage. To say that drivers are wholly to blame for their accidents is not helpful or constructive. Where possible we must produce roads that allow for a margin of error - a forgiving road.
2.7 Creating a forgiving road

A safe road is one which foresees a driver's mistakes or a failure of the vehicle. Many accidents involve the vehicle leaving the road, hitting a roadside object or running over an embankment. More needs to be done to reduce the severity of these loss of control accidents. This can be achieved by trying to maintain a roadside clear zone and putting more effort into protecting the motorist from those roadside hazards which cannot be removed.
3. CONDUCTING A ROAD SAFETY AUDIT

3.1 Introduction

This section of the manual contains a step-by-step guide to the practice of road safety audit. The process is illustrated in the flowchart, Figure 2.

Figure 2. The Steps in producing a Road Safety Audit

<table>
<thead>
<tr>
<th>The Step</th>
<th>Responsibility of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project referred to the Road Safety Unit for audit</td>
<td>Project Director, Project Manager</td>
</tr>
<tr>
<td>Project report and plans assigned to the Audit team</td>
<td>Head of Road Safety Unit</td>
</tr>
<tr>
<td>Study plans and inspect site</td>
<td>Head of Road Safety Unit</td>
</tr>
<tr>
<td>Hold commencement meeting with the designers</td>
<td>Head of Road Safety Unit</td>
</tr>
<tr>
<td>Undertake the audit</td>
<td>Audit team members</td>
</tr>
<tr>
<td>Write the audit report</td>
<td>Audit team members</td>
</tr>
<tr>
<td>Discuss and agree changes Project Manager</td>
<td>Project Manager and Head of Road Safety Unit</td>
</tr>
<tr>
<td>Hold completion meeting with Project Manager and designers Report on action to be taken is then sent to design team and to the Project Director</td>
<td>Project Manager and Head of Road Safety Unit</td>
</tr>
<tr>
<td>Follow up</td>
<td>Head of Road Safety Unit and Project Manager and Project implementation team</td>
</tr>
</tbody>
</table>

Audit practice will vary according to circumstances and in the case of minor projects some of the steps may be quite brief and informal, but the sequence of steps will remain broadly the same. It is important that the project manager takes an active interest, retains overall control, and makes the key decisions. The audit team should avoid direct contact with the design team.
3.2 Sending the project to the road safety unit for audit

In most cases projects will be referred to the Head of the Road Safety Unit by the project manager. It is worth repeating that the earlier a road is audited within the design and development process the better. The Head of the Road Safety Unit must keep himself informed about forthcoming road projects, and, if it seems that the need for a safety audit has been overlooked, the matter should be raised with the appropriate Project Manager.

3.3 Administration

Each new audit must be recorded in a central safety audit register as soon as the request is received. The register is a management tool and will help the Head of the Road Safety Unit to track the progress of each audit. It is strongly recommended that all documentation, and files relating to safety audit are stored separately in the Road Safety Unit.

It is suggested that the safety audit register contains the following details:

- the audit file number
- date of request
- source of that request
- the site location and Thana
- the name of the engineers who will carry out the audit

A master file will be opened for each audit. The master file (bearing the audit file number) will contain a copy of all the administration papers and documentation, and as the work proceeds, it will also contain a record of all relevant developments (meetings, notes, working papers, correspondence etc.) that arise during the course of the audit.

3.4 Obtaining the project reports and plans

The project manager must supply the Road Safety Unit with all necessary information for a thorough audit. This will include scheme reports, drawings and detailed items of
works and specifications. It may be necessary for the Road Safety Unit to seek extra information.

3.5 Studying the plans - inspecting the site

These two tasks take place about the same time. The auditors will familiarise themselves with the design details and if possible carry out a preliminary visit to the site and make an early assessment of the safety performance and accident potential of the scheme.

3.6 Holding a commencement meeting with the highway design team

The purpose of this meeting is to exchange information. It is an opportunity for the auditors to clarify issues of the works. There is merit in getting the designers' initial reaction to some of the amendments that are being considered. It will often be necessary to explain the purpose and workings of the audit process to the design team.

3.7 Undertaking the audit

Past experience indicates that the use of checklists or memory prompts are valuable aids to ensuring that nothing is forgotten or overlooked during the audit. A list of the types of issues and problems that can arise are presented in the Appendix A. These are considered to be 'generally appropriate' for carrying out audits in Bangladesh. In December 1997, the road safety engineering training class at RHD were requested to review the design details of an imaginary 20 kilometre section of highway. As a result, the class produced a list of topics. This list forms the basis of a wider checklist and is reproduced in Appendix A.

When familiarising and assessing the scheme (3.5 above) the audit team will review the checklists, disregard any items that are not relevant and add items that they consider to be appropriate to that particular scheme. The key principles for a good safety audit are:
• consider the needs of all road users (including pedestrians, especially children, non-motorised vehicles, cyclists, motor-cyclists, truck and bus drivers, as well as car drivers)
• be thorough and comprehensive
• be realistic and practical
• focus entirely on matters of road safety
• check compliance with relevant standards and guidelines (while remembering that compliance with standards does not guarantee that the road will be safe)
• use a team of at least two auditors - one to do the audit proper and the other to review it

It is recommended that the site be revisited at this stage. Inspecting the site during darkness as well as daylight is important, especially if it is either an urban scheme, or a Stage 4 audit. The inspection should include adjacent sections of road, because there will often be safety problems at the connection between the new and existing sections.

3.8 Writing the road safety audit report

The audit report sets out clearly what the problems are and makes recommendations on how they can be remedied. The recommendations on corrective action should give a clear indication of what needs to be done, but it will not normally be appropriate to provide a detailed design - that is the job of the highway designers. In some cases there may be no obvious solution to the problem, but the problem should still be identified in the report. The audit report does not give an overall assessment of the design, so there is no need to refer to the good points of the design. It is essential that the location of the problems be clearly identified and this can usually best be done by referring to the chainage. However, it may sometimes be necessary to provide diagrams, sketch plans, or annotated copies of the scheme drawings. Appendix B contains two examples of the presentation of the identified problems and the recommendations to overcome these problems that is used in Britain. It is strongly recommended that this method is adopted in Bangladesh.

Once the report is finalised it is submitted to the Project Manager and a copy is sent to the Project Director.
3.9 Agreeing the changes with the project director and the project manager

When the Project Manager has had time to read and assess the audit report, the auditors should arrange a meeting to consider the action to be taken. Decisions will be taken at this meeting about the changes (if any) that are to be made to the project. If the project is funded by an external donor it may be necessary to consult them, particularly if additional costs are likely.

3.10 Holding a completion meeting with the project manager and the designers

The purpose of this is to discuss the corrective action with the designers, make any necessary amendments, and agree how to follow these up. By the end of the meeting the Project Manager must have given the designers clear instructions, and a written copy will confirm this action. A copy will also be sent to the Project Manager for final approval.

3.11 Follow-up

To ensure that the recommendations are correctly implemented it is advisable that the audit team continue to provide advice and technical support to the designers and the implementation team.
4. SOME COMMON PROBLEMS

4.1 Introduction

This section sets out some of the more common safety problems that have been found in schemes that have been audited elsewhere.

4.2 Inappropriate use of standard designs

Standard designs for side slopes and side drains (which are often designed for worst case situations) are sometimes used in circumstances where they are not appropriate. This results in side drains which are far too deep and side slopes which are unnecessarily steep - both of which make the road more hazardous than it need be.

4.3 Schemes ignore roadside communities

Roadside communities generate substantial conflict. Activities involving pedestrians, buses, parked vehicles, roadside markets, non-motorised vehicles, need to be catered for.

4.4 Signing is inadequate

The general standard of traffic signs in Bangladesh is poor. This is believed to be one of the key elements in bad accident record. The standard for signs and road markings must be consistent. All schemes must specify retroreflective sign facings and thermoplastic road markings.
5. ROAD SAFETY AUDIT CHECKLISTS

5.1 Purpose and use of the checklists

There are many aspects to cover when carrying out a safety audit, the use of checklists can help the auditor to consider the basic issues. Eight sets of checklists have been devised which are appropriate to most highway schemes. They are detailed in the Appendix A and deal with:

1. planning
2. cross-section
3. alignment
4. roadside communities and facilities
5a. junctions - general
5b. junctions - additional checks for roundabouts
5c. junctions - additional checks for signal-controlled junctions
6. special road users
7. signs, markings and lighting
8. roadside hazards

These are to be used as a guide, to focus the audit towards typical matters that should be covered. Each scheme is different and will raise specific issues that may contain further safety implications. At the commencement of each audit, the audit team should review these lists and plan the work accordingly. If a route or a section of road is to be the subject of the audit it will be necessary to include other items. For example, will standards be consistent along the routes? In December 1997, the road safety engineering training class at RHD were requested to review the design details of an imaginary twenty km section of highway. As a result, the class produced a list of items. This list forms the basis of a wider checklist and may be useful for those about to carry out a safety audit on a route. This list is reproduced in Appendix B.

In the past there have been cases when audit teams have just ticked off items from checklist. This limits the potential of the audit. The audit team must always keep in mind that they are seeking to identify road safety deficiencies and in many cases these will be outside of the range of the checklist items.

When reviewing each of the points the audit team members should consider that the road user will have to cope with conditions at night and in adverse weather conditions.
As highway design teams become familiar with the checklists they will have a better understanding of the objectives of safety audit, and will be better able to anticipate and design out many problems.
6. PREPARATION OF THE SAFETY AUDIT REPORT

The findings of the Safety Audit shall be presented in an entirely self contained report. It is recommended that the report is compiled as follows.

6.1 Section 1. Background of the report

Specify the terms of reference for the report.

Set out the full circumstances leading to the production of the report. Has the scheme been the subject of earlier audit reports, if so have the recommendations been incorporated into the design?

List all documents and drawings on which the report is based.

List the name and designation of all officers contributing to the report.

If more than one member of the Road Safety Unit is assigned to carry out the audit, the most experienced person shall be nominated as Audit Team Leader, and the second person nominated as Team member.

Record all dates of significance. For example the dates of meetings, the dates of the audit survey.

6.2 Presentation of the audit findings

This is the most important section in the report.

The duty of the audit team is to focus only on matters relating to road safety. If during the course of working on the audit the audit team members discover an issue that may be helpful to the project design or management team, that matter shall be informally passed on, but kept outside of the audit procedure.
It is important to present the findings of the report in a clear and concise manner. Set out and number (sequentially) of each problem and recommendation. Each problem shall be identified by a clear description of the location and chainage. Two examples of clear presentation of identified problems and recommendations to overcome those problems are shown in Appendix C.

6.3 Completing the reports

The final draft reports shall be submitted to the Head of the Road Safety Unit for internal approval. When the Head of the Road Safety Unit is satisfied with the contents, the reports will be returned to the audit team. All audit team members will sign and date the original copy of the report, the copy reports can then be prepared and issued to the clients.
7. MONITORING SAFETY AUDIT

7.1 Objectives

Good Safety Audit practice evolves and develops as the knowledge and understanding of the road traffic accidents grows. The practice and procedures set out in this manual are elementary. Whilst every effort has been made to cover the most likely and common areas of present day design, construction deficiency, the author recognises that in its the present form it is not complete. This practice is workable and will identify many problems that can be treated. Through monitoring and evaluating, the practice can be modified and refined by local practitioners to become an effective tool in preventing future accidents in Bangladesh.

7.2 Internal circulation

When a Road Safety Audit report is produced an additional copy of that report should be circulated, for information, to all engineers in the Road Safety Unit.

7.3 Safety audit library

A library of published Road Safety Audits shall be maintained in each Road Safety Unit. Access to this library shall be made as wide as possible but at the discretion of the Head of the Road Safety Unit.

7.4 Developing the practice in Bangladesh

International practice of Road Safety Audit has developed quickly in recent years. Considerable improvements in audit standards have been achieved by practitioners meeting to review and discuss the latest experiences and Road Safety developments. This will work well in Bangladesh by first setting up informal links with other Road Safety Units and then arranging regular Road Safety Audit Forums to discuss ways of improving all areas of the service.
The main focus of these meetings shall be directed towards:

- procedures, problems encountered and ways to make the system more efficient
- refinement of the checklists in the light of experience in practice and new research becoming available
APPENDIX A

Road Safety Audit Checklist
### CHECKLIST 1 - PLANNING

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Is there a development plan or development strategy for the area and, if so, does the project conform to this?</td>
</tr>
<tr>
<td>1.2</td>
<td>Is the proposed design appropriate in relation to the forecast traffic volumes and traffic characteristics?</td>
</tr>
<tr>
<td>1.3</td>
<td>Does the route fit in with the physical constraints imposed by the topography?</td>
</tr>
<tr>
<td>1.4</td>
<td>Does the route serve major generators of traffic in a safe and adequate manner?</td>
</tr>
<tr>
<td>1.5</td>
<td>Is the frequency of junctions and their type appropriate for the function of the road and its design speed?</td>
</tr>
<tr>
<td>1.6</td>
<td>Does the project road fit in well with the existing road network? <em>(Check for potential problems at the connections - Will changes in traffic volumes cause problems?)</em></td>
</tr>
<tr>
<td>1.7</td>
<td>Does the project road relieve routes or sites with bad accident records? Does it have any harmful effects on safety on the surrounding road network?</td>
</tr>
</tbody>
</table>
**CHECKLIST 2 - CROSS-SECTION**

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Are the widths of the lanes, shoulders, medians (if any) in accordance with standards and adequate for the function of the road and the mix of traffic likely to use it?</td>
</tr>
<tr>
<td>2.2</td>
<td>Are there narrow sections (at bridges, culverts as well as other places) where there could be safety problems? If they are unavoidable, check whether they are designed as safely as possible.</td>
</tr>
<tr>
<td>2.3</td>
<td>Have the shoulders and side slopes been designed to a safe standard? (Check whether shoulders are constructed to a good standard, there is no drop at the carriageway/shoulder join, and that; side slopes are no steeper than 1.4)</td>
</tr>
<tr>
<td>2.4</td>
<td>Have the side drains be designed to a safe standard?</td>
</tr>
<tr>
<td>2.5</td>
<td>Is the connection between the project road and the existing road(s) designed consistently and safely?</td>
</tr>
</tbody>
</table>
### CHECKLIST 3 - ALIGNMENT

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Is the proposed design speed appropriate to the function of the road, the mix of traffic likely to use it, and the road environment? (Check whether different sections need different design speeds).</td>
</tr>
<tr>
<td>3.2</td>
<td>Do the horizontal and vertical alignments generally give sufficient forward visibility for the selected design speed? (Check for inadequate stopping sight distances).</td>
</tr>
<tr>
<td>3.3</td>
<td>Are there major inconsistencies in the alignment (such as a sharp bend following a straight downgrade section) and, if so and they are unavoidable, have adequate measures been taken to make drivers aware of them?</td>
</tr>
<tr>
<td>3.4</td>
<td>Do the horizontal and vertical alignments fit together comfortably? (Check for bad combinations, such as a sharp bend immediately after a summit curve, and a sag curve within a bend).</td>
</tr>
<tr>
<td>3.5</td>
<td>Does the alignment provide regular, safe overtaking opportunities? Does it avoid creating situations where overtaking is permitted but the forward visibility is unsafe for overtaking?</td>
</tr>
<tr>
<td>3.6</td>
<td>Does the design of bends adequately consider the following points, warning the approach transition curves, superelevation, carriageway widening, curve delineation?</td>
</tr>
<tr>
<td>3.7</td>
<td>Does the vertical alignment pose excessive demands on the power of heavy vehicles?</td>
</tr>
<tr>
<td>3.8</td>
<td>Is the transition between the project road and the existing road(s) handled safely?</td>
</tr>
</tbody>
</table>
### CHECKLIST 4 - ROADSIDE COMMUNITIES AND FACILITIES

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Does the cross-section, alignment and signing encourage drivers to adjust their speed on entering the town or village and maintain it at an appropriate level? <em>(Check that it will be quite clear to drivers that the road environment is changing and that they must slow down - consider traffic calming measures).</em></td>
</tr>
<tr>
<td>4.2</td>
<td>Is there adequate and safe provision for pedestrians to walk alongside the road and to cross it? <em>(Check for provision of footways and safe crossing places. In the busier places check whether pedestrian movements are controlled and channelled by guard-rail. Check whether side drains are pedestrian-friendly).</em></td>
</tr>
<tr>
<td>4.3</td>
<td>Is the design and provision of roadside parking and access to properties adequate, controlled and safe? <em>(Check provision at the popular bus and truck stopping places especially. Check that the opportunity has been taken to improve any problem sites).</em></td>
</tr>
<tr>
<td>4.4</td>
<td>Has the opportunity been taken to improve the traffic and parking situation in the towns and villages through which the road passes? <em>(Check for junction improvements, access control, provision of service lanes, parking areas and bus stops).</em></td>
</tr>
<tr>
<td>CHECKLIST 5A - JUNCTIONS - GENERAL</td>
<td></td>
</tr>
<tr>
<td>------------------------------------</td>
<td></td>
</tr>
<tr>
<td>5.1 Is the junction in a safe location? <em>(Check whether there are other junctions too close to it. Check whether approaching drivers will get a clear view of it. Check whether the site permits the junction to be of a proper layout and standard).</em></td>
<td></td>
</tr>
<tr>
<td>5.2 Is the type of junction (T-junction, staggered junction, signal-controlled junction, roundabout, etc.) suitable for the function of the two roads, the traffic volume, the traffic movements (pedestrian and vehicular), and the site constraints? Is it the safest alternative?</td>
<td></td>
</tr>
<tr>
<td>5.3 Is the layout of the junction adequate for all permitted vehicular movements and for all types of vehicle? <em>(Check using turning circle templates for buses and trucks).</em></td>
<td></td>
</tr>
<tr>
<td>5.4 Will the general type of the junction, its layout and the priority rules be recognised by approaching drivers in adequate time? Is the route through the junction as simple and clear as possible? Do the decisions that need to be made by drivers follow a simple, logical and clear sequence? <em>(Check for unusual or over-complicated layouts. Check that the signing and marking is correct and clear - if in doubt refer to the Traffic Signs Manual).</em></td>
<td></td>
</tr>
<tr>
<td>5.5 Does the layout encourage slow controlled speeds at and on the approach to STOP/GIVE WAY lines and other critical decision points? <em>(Check for Y and skew junctions which can be a problem. Also roundabouts with inadequate deflection).</em></td>
<td></td>
</tr>
<tr>
<td>5.6 Are the sight lines at and on the approach to STOP/GIVE WAY lines and other critical decision points adequate and unobstructed? <em>(Check for Y and skew junctions which can be a problem. Check signs, lighting columns, pedestrian guard-rail, etc.)</em></td>
<td></td>
</tr>
<tr>
<td>5.7 Is there adequate provision for channelling (and protecting where necessary) the different streams of traffic? <em>(Check the provision for right-turn lanes and storage areas, deceleration and acceleration lanes).</em></td>
<td></td>
</tr>
<tr>
<td>5.8 Is adequate provision made for pedestrians and non-motorised vehicles? <em>(Check whether it is convenient, easily-seen and understood, capable of being used safely (check intervisibility between pedestrians and vehicles) and large enough to meet demand).</em></td>
<td></td>
</tr>
<tr>
<td>5.9 Is the provision of night-time lighting adequate? <em>(Consider the need for drivers to recognise and understand the junction, and see pedestrians. Consider the needs of pedestrians who are negotiating the junction. Check that the layout of the lighting columns illuminates the junction effectively).</em></td>
<td></td>
</tr>
</tbody>
</table>
### CHECKLIST 5B - JUNCTIONS - ADDITIONAL CHECKS FOR ROUNDABOUTS

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.10</td>
<td>Is the geometry simple and easily understood? (Beware of roundabouts which are not circular, or which have awkward entry paths)</td>
</tr>
<tr>
<td>5.11</td>
<td>Are there too many entries for safe, efficient operation? Are they sufficiently separated from each other to avoid confusion?</td>
</tr>
<tr>
<td>5.12</td>
<td>Does the design deflect entering traffic sufficiently to ensure entry speeds are no greater than 50 km/h? (Check entry path curvature, centre island size and positioning).</td>
</tr>
<tr>
<td>5.13</td>
<td>Is the visibility for entering traffic adequate? (Note that if visibility is too good, it may encourage entry speeds which are too high).</td>
</tr>
<tr>
<td>5.14</td>
<td>Is the visibility for circulating traffic adequate? (Check that visibility across the centre island is not unduly obstructed by signs, landscaping or structures).</td>
</tr>
<tr>
<td>5.15</td>
<td>Has the centre island been designed to be forgiving to errant vehicles?</td>
</tr>
<tr>
<td>5.16</td>
<td>Has adequate provision been made for pedestrians to cross the arms of the junction? (Guardrail will usually be necessary to channel pedestrians to safe crossing points on the arms).</td>
</tr>
<tr>
<td>5.17</td>
<td>Have the needs of cyclists and other non-motorised vehicles been considered?</td>
</tr>
<tr>
<td>5.18</td>
<td>Does the signing make the priorities clear? (Entering traffic must give way to circulating traffic).</td>
</tr>
<tr>
<td>Checklist</td>
<td>Description</td>
</tr>
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<td>-----------</td>
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</tr>
<tr>
<td>5.19</td>
<td>Do the signal colours and signal sequence conform with National Standards?</td>
</tr>
<tr>
<td>5.20</td>
<td>Do the signals clearly indicate which movements are allowed at any one time?</td>
</tr>
<tr>
<td>5.21</td>
<td>Are the signal heads positioned so that drivers can see them easily, and in time to stop? (Check this for drivers at the stop line as well as those approaching at speed - it will usually be necessary to have secondary signals).</td>
</tr>
<tr>
<td>5.22</td>
<td>Are the signals for competing phases located so that they are visible only to the traffic for whom they are intended? (Check also that there is no risk that pedestrians may be misled by the traffic signals into thinking that it is safe for them to cross).</td>
</tr>
<tr>
<td>5.23</td>
<td>Are all right-turning movements protected (i.e. there are no conflicting movements) as far as possible?</td>
</tr>
<tr>
<td>5.24</td>
<td>Does the signing, marking and channelisation make it clear to drivers what path they should take through the junction?</td>
</tr>
<tr>
<td>5.25</td>
<td>Are pedestrian crossing places marked, and are pedestrians channelled to crossings? Are there pedestrian refuges?</td>
</tr>
<tr>
<td>5.26</td>
<td>Are the pedestrian crossings signal-controlled where appropriate? If so, is there a need for the crossing movements to be fully protected from conflicting traffic movements for example where there will be serious conflicts with turning traffic?</td>
</tr>
<tr>
<td>5.27</td>
<td>Are the pedestrian signals positioned so that pedestrians can see them?</td>
</tr>
<tr>
<td>5.28</td>
<td>Are signal inter-green periods adequate?</td>
</tr>
</tbody>
</table>
### CHECKLIST 6 - SPECIAL ROAD USERS

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Has there been a survey of non-motorised vehicle and pedestrian flows?</td>
</tr>
<tr>
<td>6.2</td>
<td>Will there be any major conflicts between motorised traffic and pedestrians and other road users?</td>
</tr>
<tr>
<td>6.3</td>
<td>Have pedestrians needs for crossing, and walking alongside the road been provided for? (Check particularly in towns and villages and at all junctions).</td>
</tr>
<tr>
<td>6.4</td>
<td>Have the needs of cyclists and other non-motorised vehicles been provided for? (Check the need and feasibility of cycle / cycle rickshaw lanes in towns).</td>
</tr>
<tr>
<td>6.5</td>
<td>Is the provision for pedestrians and non-motorised vehicles at bridges and narrow sections adequate in relation to pedestrian and vehicular traffic volumes and traffic speeds?</td>
</tr>
<tr>
<td>6.6</td>
<td>Is the provision of bus stopping places suitable? Is the location, design and signing adequate?</td>
</tr>
</tbody>
</table>
CHECKLIST 7 - SIGNS, MARKINGS AND LIGHTING

7.1 Is the provision for signing (regulatory, warning and informative signs and delineation) adequate and in accordance with National Standards?, Are retroreflective sign facings specified?

7.2 Are the sign sizes, placement and construction adequate, safe and in accordance with standards ?, Is the ‘x’ height (height of lettering) sufficient for the speed of oncoming traffic ?

7.3 Are the proposed road markings adequate and in accordance with standards ? Are thermoplastic materials specified ?

7.4 Is the delineation adequate, especially on sections with difficult alignments ? *(Check signs and road markings).*

7.5 Is there a need for the project road, or parts of it, to be lit at night ?

7.6 Is the proposed lighting scheme (if any) adequate ? Are there any hazardous dark areas ?

7.7 Has the siting of lighting columns been considered from a safety viewpoint ?

7.8 Are frangible or slip-base columns to be provided ?
### CHECKLIST 8 - ROADSIDE HAZARDS

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>Will bridge and culvert parapets, and other obstructions be close to moving traffic? If so, can they be relocated? If not, are they adequately signed and, where necessary, protected by a safety barrier?</td>
</tr>
<tr>
<td>8.2</td>
<td>Are bridge parapets designed to contain errant vehicles?</td>
</tr>
<tr>
<td>8.3</td>
<td>Are the ends of bridge parapets protected by a safety barrier? <em>(Check that any safety barrier is properly secured to the bridge structure and that the design of the barrier is safe).</em></td>
</tr>
<tr>
<td>8.4</td>
<td>Are bridge parapets, bridge railing, and pedestrian guard-rail safely designed? <em>(Check that horizontal elements are strongly supported and cannot come loose if hit by a vehicle).</em></td>
</tr>
<tr>
<td>8.5</td>
<td>Are there any poles or columns located close to moving traffic that could be located elsewhere?</td>
</tr>
<tr>
<td>8.6</td>
<td>Is a safety barrier provided where necessary and where traffic volumes and traffic speeds warrant it? <em>(Check for large drops (over 3 m) especially on the outside of sharp bends and on bridge approaches, as well as hazardous roadside objects that may need protecting).</em></td>
</tr>
<tr>
<td>8.7</td>
<td>Is the type, detailing, and placement of proposed safety barrier in accordance with safe practice?</td>
</tr>
<tr>
<td>8.8</td>
<td>Where a safety barrier is provided does it protect all roadside objects? <em>(Check that there are no signs, lighting columns, etc. in front of the barrier).</em></td>
</tr>
</tbody>
</table>
APPENDIX B

Safety Audit on Routes
PRELIMINARY CHECKLIST FOR ROUTES

In December 1997 Engineers attending the Road Safety Engineering class at RHD were requested to produce a list of topics to consider in reviewing the design standards of a theoretical 20 km section of highway. The object of the exercise was to introduce a higher standard of safety in the design, Safety Audit. The following list is the result of this exercise. It is expected that the list will be a useful basis for those about to undertake Safety Audit on Routes.

1  Consistency of the design

- all routes must be consistent, avoid any situation that may take the driver by surprise
- Are standards the same along the route?
- Are standards the same at the connection of the new road to the existing road network?

2  The design of bends

- **Radius**
  Is the radius appropriate for the speed of traffic?
- **Sight distance**
  Are sight distances appropriate?
- **Superelevation**
  Has superelevation been provided, if yes, is it adequate?
- **Speed of traffic**
  Is it necessary to consider a reduction of speed limit?
- **Widening of the bend**
  Are lane widths adequate?
- **Crash barrier**
  Will a crash barrier improve safety?
- **Vertical curve**
  Do vertical curves obstruct forward visibility?
- **Road markings**
  Are road markings adequate, edge of carriageway markings, hazard markings, etc?
• **Divider**
   If there is a high probability of a head on accident consider a divider.

• **Street lighting**
   Will street lighting improve safety?

• **Road surface.**
   Is it necessary to improve the skid resistance of the bend?

• **Drainage**
   Will the carriageway drain quickly/efficiently?

• **Advance signs**
   Do they clarify the message, considering day/nighttime conditions and future obstructions?

• **Junction activities**
   Does a minor road join the highway?
   Can this be avoided?
   Is the design safe?

• **Delineation of the bend**
   Will the curve of the bend be clear to drivers?

• **Transition curve**
   Has a transition curve been included?

• **Footways for pedestrians**
   Are facilities required?

• **Non-motorised vehicles**
   Are facilities required?

3 **The design of junctions**

• **Direction sign**
   Is the sign and the message clear? Is the location correct?

• **Sight distance**
   Check the sight distances of all manoeuvres

• **Advance junction warning**
   Is the sign clear and readable for the speed of the traffic?

• **Identify conflicts**
   Can the conflicts be reduced or removed?
• **Right turning accidents**
  Can these be avoided or made more safe?

• **Road surface on the approaches to the junction**
  Is it necessary to improve the skid resistance of the junction?

• **Road markings**
  Are road markings adequate, edge of carriageway hazardous etc.?

• **Street lighting**
  Will street lighting improve safety?

• **Pedestrians**
  Consider pedestrian movements - can these be made more safe?

• **Bus stops**
  Are these located safely, i.e.: off carriageway?

• **Parking**
  Will parking present problems?

• **Slow moving vehicles**
  Consider NMVs-can these be made more safe?

• **Road side activities**
  Will roadside activities create conflicts, hazards?

• **Drainage**
  Will the carriageway drain quickly/efficiently?

• **Unnecessary road connections-access points**
  Can secondary road connections be designed out or made safer?

4 **Narrow bridges and culverts**

• **Warning signs**
  Are they clear? Are they located suitably in advance of the hazard?

• **Speed reduction**
  Is it necessary to reduce the speed limit?

• **Increase conspicuity of bridge approach at night**
  Reflective materials, posts, studs etc..

• **Forward visibility**
  Are all sight lines adequate for the speed of traffic?

• **Barrier**
  Has a crash barrier been specified? Is the layout safe?
• **Pedestrian facilities**
  If pedestrians will use the area?
  Are the facilities safe?

• **NMV**
  If NMVs will use the area, consider if the facilities are safe.

5 **Bus-Stops**

• **Identify the locations for bus stops?**
  Are the bus-stops off the carriageway?
  Are the entrances, exits to the bus-stop areas safe?
  Are there “bus stop ahead” signs?
  Pedestrians, What facilities are there for pedestrians? Are they safe?

6 **Roadside activities**

Is it possible to segregate activities from both the highway and the immediate highway areas?

7 **Pedestrian facilities**

Pedestrian traffic along the carriageway
Across the carriageway

8 **Connection to the existing road network**

Avoid any sudden change of highway standards
Avoid a connection on a curve, at bridge approaches, level crossings etc..

• **Hierarchy**
  Have the hierarchy rules been applied?
  Avoid connections near densely populated areas
  Is it possible to avoid connection with existing junction?

• **Visibility**
  Check all sight lines.
• **Pedestrians**
  Are high pedestrian volumes expected?
  Have suitable facilities been included?

• **Accident history**
  Examine accident records on the existing road network. Does the proposal include measures to reduce the identified problems?

• **Signs**
  Is advance information and warning signs provided on the new road?
  Are they adequate?
  Do they include directions from / to the new road? Do they take into account the changes that the new scheme will introduce?

9  **Slow moving vehicles**

  What facilities are provided at the connection between the new and the existing road?
  Are they segregated on the new road?

10  **Street lighting**

  Review street lighting
  Connection to existing network
  At conflict points

11  **Signs and road markings**

  Are the signs consistent along the route?
  Does the specification of the materials include retroreflective sign facings, thermoplastic road markings?
  • **Sign locations**
    Check all sign locations.
  • **Readability**
    Is the height of the letter suitable for the speed of traffic?
    Are the signs likely to confuse road users?
• **Foliage**
  Is there any possibility of sign obstruction?

• **Street furniture**
  Is there any possibility of sign obstruction?

12 **Roadside objects**

trees adjacent to the roadside - develop safe policy
Are they close to the carriageway?

• **Lamp columns**
  Are they collapsible?

• **Crash barriers**
  Are they safe?

13 **Check sight distances**

  Horizontal and vertical curves
  Junctions
  Bus-Stops, lay-bys

14 **Drainage**

Will the carriageway drain (dry) efficiently?-Will the drainage system draw rain water away efficiently?

• Check crossfall
• Bends, superelevation
• SAG curves
• In areas where the carriageway is in cutting

15 **Speed limit policy along the route**

• stage reduction of speed limit if required
16 **Overtaking facilities along a route**

- Does the design provide areas for safe overtaking?

17 **Road users facilities, stopping rest areas etc.**

- only for the longer routes

18 **Emergency service facilities**

- Consider emergency facilities

19 **Policy for roadside deep ditches high embankment**

- Does the carriageway run parallel to high embankment, deep ditches?

20 **Cross-section**

- Lane widths

  Has a hard shoulder been provided?
APPENDIX C

Presentation of the Audit Findings
EXAMPLE A - A HIGHWAY IMPROVEMENT SCHEME

Bend at chainage 56+375 to 56+670

1. Problem.

1.1.1 The eastbound approach to the bend (approx. 400m radius) is potentially hazardous. It follows a long section of straight carriageway and it is likely to result in loss of control accidents, particularly at night. The situation is made worse by the fact that there is a 3m deep ditch running parallel to the north of the carriageway, to the outside of the bend.

1.2 Recommendation

1.2.1 Reduce the speed of traffic and increase drivers awareness of the bend. This can be achieved by displaying duplicate Advisory 40Kph speed signs, located on both sides of the carriageway, both signs mounted on a yellow backing board. The signs positioned x m from the bend tangent point.

1.2.2 Displaying duplicate ‘Bend Ahead’ signs, these to be located on both sides of the carriageway, both signs to be mounted on a yellow backing board. The signs positioned x m from the bend tangent point.

1.2.3 Widen edge of carriageway markings from 100mm to 150mm wide on final 100m approach to and throughout the bend.

1.2.4 Lay raised reflective carriageway studs on the final 100m approach to and throughout the bend.

1.2.5 Extend ‘No overtaking’ markings for a distance of 200m.

1. All Carriageway markings to be Thermoplastic or similar approved material.

2. All traffic sign facings to be fabricated from retroreflective materials.
EXAMPLE B - IMPROVEMENT SCHEME AT A JUNCTION.

6.1  Problem.

6.1.1. There is a significant volume of traffic turning right (south to east) on this high speed road. Drivers of vehicles will have to complete the right turn movement through gaps in oncoming southbound traffic. This will expose these drivers to the risk of error in either misjudging the speed or the distance of oncoming vehicles, resulting in serious high speed accidents.

6.2.  Recommendations.

6.2.1 Channelise right turning traffic on the approach to the junction and control the movement on a separate vehicle signal phase.

6.2.2 To display the lane distribution early on the approach to the junction, provide an Advance Direction Sign 200m from the junction. Reinforce the message by installing a Local Direction Sign 100m from the junction. Set out appropriate lane carriageway markings, with lane direction arrows.

6.2.3 High speed road red running. Provide vehicle actuated green stage extension on both main carriageway approaches. This can be achieved by installing vehicle detection equipment (in the carriageway) linked to the signal controller.

6.2.4 There will be heavy vehicle braking on both main carriageway approaches to the junction. It is advisable to include 70m of anti-skid road surfacing on these approaches.
Road Safety Engineering

Procedure Note 7.

Monitoring and Evaluating Implemented Schemes in Bangladesh
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5.3.3 Accidents involving vehicles changing type
5.3.4 Nose-to-tail shunt type accidents
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1. INTRODUCTION

Monitoring provides information of the performance of the implemented measures. How effective is that measure in reducing target accidents? Are there adverse effects? Is the measure likely to reduce one group of accidents but increase the risk of exposure to another? To be effective we must learn from implemented schemes. If a scheme is successful and we can establish all of the reasons we can use that information in future work. If a scheme fails and we can find out why we can avoid making the same mistake again. Figure 1 shows the relationship between monitoring and other Road Safety Engineering.

This paper sets out procedures for two levels of monitoring. The first is regular routine checks, how many accidents occurred at each site following implementation compared with the number of accidents occurring at the sites in the corresponding ‘before’ period. This enables engineers to track the progress of schemes and is a useful management tool. The second is in depth analysis, evaluating the ‘before and after’ accidents to identify more detail of the overall change brought about by the measures.

As the work of the Road Safety Units increases the number of safety schemes either to have been implemented or are nearing completion will grow rapidly. The important task of evaluating schemes will take up a valuable proportion of available investigation resources. The principle objectives of this paper, are to set out a procedure which not only promotes the efficient production of high quality technical reports but also minimises staff time used for accident investigations. Time spent monitoring and evaluating must not be compromised. The results provide engineers with clear data-led information to guide future work.

The most important activity in the monitoring programme is passing on results. Information from this source must be circulated freely and openly so that other practitioners can learn from the work and apply that experience in future.

Statistical evaluation is used to quantify results. The use of statistics in road traffic accidents is a complex issue so we have incorporated sections from a chapter from “Interim Guide on Identifying, Prioritising Hazardous Locations on Roads in Malaysia”, IKRAM, TRL January 1995 by Chris Baguley, TRL. This work sets out the full range of statistics in road traffic accidents analysis. The work is authoritative, clear and consistent and it is recommended that these principles are followed. We are grateful to Chris Baguley, TRL for permission to use this work.

Note: This Procedure Note should not be used by persons without appropriate Road Safety Engineering training.
Figure 1. Monitoring and Evaluating Implemented Schemes in Bangladesh in Road Safety Engineering
2. MONTHLY SCHEME MONITORING

As a Road Safety Unit becomes established the number of implemented schemes will quickly grow and it is important that a simple monitoring system is in place to track the effect of the work and control the programme.

Regular monitoring of implemented schemes gives the engineering team a running overview of the performance of each implemented scheme. Total ‘before’ implementation accidents are compared with total ‘after’. Each month the engineer can review each of the current schemes and see how each scheme is progressing. If the engineer needs to know more about the detail or type of accident he/she will have to retrieve the full information from the database. The system should also show the date that schemes pass all the stages leading to implementation, e.g. design agreed, works order issued, etc.. This will prevent investigations stalling and is a useful management tool.

One system that has proved to be very useful is Traffic Accident Diary System (TADS). TADS was developed by the Greater London Council, Road Safety Unit in the late 1970s. TADS has since been refined and developed many times, in 1995 the system was redesigned to suit modern needs and requirements. Versions are now being used by many London Boroughs and County Councils. See Figure 2 for a typical example of an early TADS monthly printout. A similar system using spreadsheets, updated monthly by administration staff will provide engineers and management here with valuable feedback.

2.1 Basic rules for monthly monitoring.

2.1.1 Period of monitoring

In most cases three years data is needed for accident analysis. The system tracks accidents from one month after completion of the scheme for a period of 36 months.

2.1.2 Construction period

Roadworks are likely to increase accident rates. The system is designed to disregard the scheme construction period or in the case of simple measures, the month of implementation.
First column: Borough (Thana) number and scheme number in that Thana. The units individual scheme number. Road classification. Information relating to the data base.

Second column: Date Investigated. Design agreed. Date works order issued. Implementation date. Not feasible (if it was not possible to design a scheme that scheme would be flagged and later the accidents are reviewed). Review date.

Third column: Implementation code. Each individual measure is assigned an individual code or reference number.

Fourth column: Location of the scheme and general notes in this case the scheme was the subject of an earlier investigation.

**Figure 2. Early Traffic Accident Diary System**

| BOARD/SCH | INVESTIG | IMPL | LOCATION | LEA BRIDGE RD/WESTERN RD/PETERBOR | J | F | M | A | M | J | J | A | S | O | N | D |
|-----------|----------|------|----------|-----------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13/051    | 8303     | IMPL | 8          | 8306                              | J | F | M | A | M | J | J | A | S | O | N | D |
| LAAU SCH 2226 | DESN AGD 8305 | CODE | OUGH RD | 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| LINK 0077/0087 | DESN PGM 06A | NOTES | SEE ALSO SS1030/023 | 86 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| ROAD TYPE P | W/O ISSD 8306 | | | 85 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| RESTRICTED LOC. IMPLEM | 8403 | BEF/AFT | 35 MONTHS - BEFORE 20 AFTER 7 | 84 | 0 | 0 | 0* | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| ORIENTATION E | NOT FEAS | | | 83 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| REFS 3838/3848 | REVIEW | | | 82 | 1 | 0 | 3 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 3 |
| * MONTH OF SCHEME IMPLEMENTATION | 81 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
2.1.3 Seasonal variation

Accident rates fluctuate throughout the year. Bad weather and longer daily hours of darkness in winter months are usually associated with higher accident rates. To avoid seasonal variation, the system selects the first month following completion of the measures and compares accidents occurring in that month with the number of accidents occurring in the corresponding month of the previous year. This principle is followed through the 36 months, see Figure 3.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>TOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>A.32</td>
<td>A.33</td>
<td>A.34</td>
<td>A.35</td>
<td>A.36</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1992</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>B.36</td>
<td>B.25</td>
<td>B.26</td>
<td>B.27</td>
<td>B.28</td>
<td>B.29</td>
<td>B.30</td>
</tr>
</tbody>
</table>

Before period in italics. If the month of implementation is May 1995 the first ‘after’ month will be June 95 (A1), will be compared with June 1994 (B1). The second month (A1 + A2 is compared with B1 + B2), month three A1 + A2 + A3 is compared with B1 + B2 + B3. This procedure is followed until 36 month ‘before’ and 36 months ‘after’ data is reached.

Figure 3. Avoiding seasonal variation

2.3 Preparing a basic monitoring system

Using these principles it should be possible to devise a basic system using spreadsheets to present this information. Each month the engineers provide administration staff with progress information. The administration staff assign the progress details and the latest accident numbers to the spreadsheet. When this is complete, a listing of all sites is prepared and issued to the Head of the section and each of the engineers.
3. ‘BEFORE AND AFTER’ STUDIES, EVALUATING SAFETY ENGINEERING SCHEMES

We need to quantify the accident change occurring as a result of implemented measures of important schemes. If a scheme is particularly successful in reducing target accident we must not stop there perhaps a further detailed analysis of ‘after’ accidents will identify secondary treatable problems. If we can quantify the reasons and the extent of the reductions we can apply the same measures at other sites with similar problems.

There are two methods of developing this information. The first comes under the heading of Special Studies (see figure 1.1). If anti-skid road surface dressing is applied at 15 locations, what has been the collective result at those sites? How effective has the measure been in reducing target accidents? Have the measures had any adverse affect? The methodology to carry out special studies will be covered in a subsequent Procedure Note.

The second method is an in-depth ‘before and after’ analysis of single schemes. It is not necessary to evaluate all schemes. If for example a less important scheme is showing an overall reduction and the number of target accidents are down, the investigator should check to make sure that there is not a treatable problem within the ‘after’ accidents.

A full study requires three years ‘before’ and three years ‘after’ data. Accident recording is still in its infancy in Bangladesh and in many cases it will be difficult to obtain three years ‘before’ data. In these cases worthwhile results will be achieved from one year’s ‘before’ data, compared with the first, second, and third years ‘after’ data. If using shorter ‘before’ periods avoid seasonal variation by comparing complete years ‘before’ data with complete years ‘after’ data.

3.1 Procedure for carrying out ‘before and after’ accident analysis of road safety schemes

Normally these evaluation reports will be produced when ‘after implementation’ accident data for 12 month and 36 month periods are available, it might be advisable to prepare a report at 24 months for certain schemes.
From time to time this procedure may need adjustment to enable a study to reflect more accurately a particular scheme’s effectiveness.

3.1.1 Background

Write a short introduction. Describe location, e.g. junction type (roundabout, traffic signal controlled etc.); date of original accident study report; dates of implementation of the measures; and a brief summary of the original study conclusions.

3.1.2 The original accident analysis

Describe the principle problems needing attention, as identified in the original analysis, and give details of accident totals, dominant accident patterns, clusters and trends.

3.1.3 The implemented measures

From the file documentation, describe the implemented measures (and, when appropriate include drawings agreed by the various departments, organisations, contributing to the scheme) and the dates of start and finish of works. Note: if multiple measures have been carried out, completion of the final item will be the scheme finish date. The month of completion will be disregarded i.e. the first month of the ‘after’ period will be the first full calendar month following completion. If the implemented scheme varies from the recommendations of the accident study, describe all variations and the reasons for them.

3.1.4 ‘Before’ period accidents

Identify the ‘before’ period. The ‘before’ period will be the 36 months immediately prior to the month in which work on site commenced. The construction period will be excluded. If it is not possible to obtain the actual date that work commenced, the original study period analysis can be used. From this analysis, average accident rates for the ‘before’ period will be calculated.
3.1.5 ‘After’ period accidents

Note: accident data will not include the latest month of accidents within the MAAPfive database as this must be considered to be provisional.

Prepare chronological stick diagrams for the ‘after’ period, whether 12, 24 or 36 consecutive months, and write up a full analysis based on this data. If it helps to illustrate the analysis, prepare a sorted stick diagram and produce an accident plot.

3.1.6 Data presentation (change of accident type)

Table 1 Figure 4, page No. 30 presents a typical example of the accident problems by type of accident identified in the ‘before’ period (and as analysed in the original report if available). In cases where 12 months ‘after’ data is being analysed, Table 1 will compare this with the 36 months ‘before’ and translate the data to monthly accident rates and the average annual change. Select accident groups to include the most common accidents occurring at the site.

3.1.7 Statistical tests

Initially, carry out a simple ‘k test’ using the number of accidents from the 36 month ‘before’ period to compare with the ‘after’ period. This requires that data from periods of equal length are used. For the full 36 month ‘after’ period, compare the actual accidents in the ‘after’ period with the 36 month ‘before’ period. For a 12 month ‘after’ comparison, factor these accidents up to an equivalent 36 month figure, to estimate the accident level at the end of 36 months, should they continue at the same level.

If this indicates that the difference between ‘before and after’ data is significant at better than 10% at the end of 12 or 36 months, then a full Chi² test using appropriate control
data should be carried out on the total accidents. The full \( \chi^2 \) test will not be carried out if the ‘k test’ produces indications of differences below these significance levels.

### 3.1.8 Data comparisons

Write up a full comparison of the changes of accident numbers, type or groups, noting particularly:

- Are target accidents up or down?
- What has been the effect on unrelated accidents?
- Are any new accident problems evident?
- Is there a group or cluster of accidents that may respond to further analysis and possible measures?
- How do the accident changes compare with the original estimate of accident savings?

### 3.1.9 Conclusions

What has been the overall impact of the scheme in terms of change to accident casualty data?

### 3.1.10 Recommendations

A recommended course of action will be given for each problem identified within the ‘after’ period. Prior to publication, a draft of the report findings, conclusions and recommendations will be discussed with the Head of the Road Safety Engineering Unit to achieve agreement on a final version.

It is recommended that the final report will also include a copy of the original report (with drawings) as an Appendix.
4. USING CONTROL DATA AND STATISTICS

4.1 Control data

In most of the above monitoring measures (and particularly accident changes) it is necessary to take into account other factors not affected by the treatment which might also influence that measure. Examples are: a change in speed limit on roads which include the site; National Road Safety campaigns; traffic management schemes which might affect volume of traffic.

These changes may be compensated for by comparing the same 'before and after' periods with accidents (or other measurements) at "control" sites which are untreated. Control data can be either by matched pairs or area controls.

A matched pair control site should be similar to the treated site in general characteristics and also geographically fairly close to it (but not close enough to be affected by any traffic diversion). This is so that the control will be subject to the same local variations which might affect safety (e.g. weather, traffic flows, enforcement campaigns).

Although the matched pair is the best statistical method to use, in practice it is very difficult to find other sites with the same problems which are left untreated purely to carry out statistical tests. Area controls which comprise a number of sites are, therefore, much more frequently used.

When choosing control sites:

- they should be as similar as possible to treated sites
- they should not be affected by the treatment
- there should be more than 10 times the number of accidents at the control sites

For example, if the traffic signals at a site are modified then a control group of sites might be all other signalised sites in the town. But if there were only two other signalised junctions and these had lower flows and much fewer accidents as did other uncontrolled junctions, then it would be better to use all signalised junctions in the area.
4.2 Evaluation

4.2.1 The effect on accidents

This step of the procedure focuses on evaluation of whether the treatment has been successful in achieving its objective of reducing the number of accidents. This therefore requires comparison of the number of accidents in the target group ‘before’ the treatment with the number ‘after’ treatment (with the assumption of a similar ‘before’ pattern if nothing were done), and to study whether any other accident type has increased.

This Guide does not attempt to delve deeply into the different statistical techniques, but to suggest practical and simple ways in which schemes can be evaluated. The following sections generally refer to "a site" but the same techniques can be used for mass, route and area-wide action as long as appropriate control groups are chosen.

The main problem when using accident data for evaluation (even assuming high recording accuracy) is to distinguish between a change due to the treatment and that due to other sources. Some of the other factors that need to be considered are discussed below:-

4.2.2 Changes in the environment

This feature was mentioned in the last section of Step 9 whereby a change in the environment of driving habits can affect the accidents occurring at the study site. For example, a change in the national speed limit for the class of road at the site, or closure of a nearby junction to the site producing a marked change in traffic patterns.

This feature can be taken into account by the use of control site data but for this to be valid it is important that these other sites experience exactly the same changes as the site under evaluation.

4.2.3 Random fluctuation

The rare and random nature of road accidents can lead to quite large fluctuations in frequencies occurring at a site from year to year, even though there has been no change in the underlying accident rate. This extra variability makes the effect of the treatment more
difficult to detect; but a test of statistical significance can be used to determine whether the observed change in accident frequency is likely to have occurred by chance or not.

### 4.2.4 Regression to the mean

This effect complicates evaluations at high accident or blackspot sites in that accidents at these sites tend to reduce even when no treatment is applied. Even if a 32 year total is considered at the worst accident sites in an area, it is likely that the accident frequencies were at the high end of the naturally occurring random fluctuations, and subsequent years will yield lower numbers. This is known as *regression to the mean*. 

As an example consider Table 7.1 which gives the actual numbers of recorded accidents involving personal injury for 122 nodes in the town of Seremban over a two-year period. For sites with 5 or more accidents in year 1 there were overall fewer accidents in the following year. Conversely, sites with 4 or less accidents have more accidents in year 2. If an accident countermeasure had been installed at the worst 9 sites at the end of year 1 then a highly significant reduction of 37% might be claimed after year 2, even though the measure had been completely ineffective (this same result would be obtained by doing nothing). An even higher false result would be obtained if the other 113 sites were used as a control group.

<table>
<thead>
<tr>
<th>No. of injury accidents per site in 1991</th>
<th>No. of sites</th>
<th>Total accidents in 1991</th>
<th>Total accs. at same sites in 1992</th>
<th>Change in accidents (uncontrolled)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-10</td>
<td>1</td>
<td>10</td>
<td>6</td>
<td>-40%</td>
</tr>
<tr>
<td>7-8</td>
<td>2</td>
<td>15</td>
<td>10</td>
<td>-33%</td>
</tr>
<tr>
<td>5-6</td>
<td>6</td>
<td>32</td>
<td>20</td>
<td>-38%</td>
</tr>
<tr>
<td>3-4</td>
<td>17</td>
<td>61</td>
<td>68</td>
<td>+12%</td>
</tr>
<tr>
<td>0-2</td>
<td>96</td>
<td>76</td>
<td>119</td>
<td>+57%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>122</strong></td>
<td><strong>194</strong></td>
<td><strong>223</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 7.1

*Injury accidents at 122 nodes in Seremban*

Possibly the most straightforward way of allowing for both the regression-to-mean effect and changes in the environment would be to use control sites chosen in exactly the same way as the treated sites, and identified as having similar problems, but LEFT untreated. In practice, it is both difficult to find matched control sites and, if investigated, to justify *not* treating them.
There has been much debate among statisticians over many years on this subject and the best way to deal with it (see refs. 2,3,4,5).

The effect does, however, tend to be diminished if longer periods of time are selected. For example, Abbess et al.\(^3\), in a study in two counties of the UK calculated that regression-to-mean had the following effects at high accident sites (i.e. more than 8 injury accidents per year), on average, on their accident rate:

<table>
<thead>
<tr>
<th>Period of accident data</th>
<th>Regression-to-mean change in annual accident rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td>15 to 26%</td>
</tr>
<tr>
<td>2 years</td>
<td>7 to 15%</td>
</tr>
<tr>
<td>3 years</td>
<td>5 to 11%</td>
</tr>
</tbody>
</table>

Due to the uncertainty and complexity of allowing for this effect reliably at any site it is suggested, therefore, that where the highest accident sites are chosen for treatment, then the above order of allowance should be made when calculating any estimate of the actual reduction in accidents the countermeasures have produced.

4.2.5 Accident migration

There is still some controversy over whether or not this effect exists but it has been reported by several researchers\(^6,7,8\). It is simply that an increase in accidents tends to be observed at sites adjoining a successfully treated site giving an apparent transfer or 'migration' of accidents.

It can be detected by comparing the accident frequencies in the surrounding area before and after implementation of treatments at sites in the area with a suitable control. It is unclear precisely why this effect occurs but is suspected that drivers are 'compensating' for the improved safety at treated sites by being less cautious elsewhere.

Again, there are no established techniques yet available to estimate this effect for a particular site. The first reported occurrence of this feature\(^6\) found an overall increase in
surrounding areas of about 9% and a later study\textsuperscript{8} of a larger number of sites estimated 0.2 accidents/site/year.

4.2.6 Risk compensation

This is an even more controversial effect, though related to the previous section. The philosophy of "risk compensation" or "risk homeostasis theory" suggests that road users will change their risk-taking behaviour to compensate for any improvements in road safety. That is, road users tend to maintain a fixed level of accepted risk, so will take more risks when given greater accident protection, for example, if provided with seat belts or anti-lock brakes.

Whilst again the extent of this effect is extremely difficult to monitor, the engineer should be aware of the possibility of risk compensation when introducing countermeasures. For example, a scheme giving pedestrians more apparent priority using speed tables or raised pedestrian crossings (which give the impression of extensions to the footway) may lead the pedestrian into taking much less care in crossing the road.

For further reading on this subject see references\textsuperscript{9,10}.

4.2.7 ‘Before and after’ periods

There are a number of points to be taken into account when choosing periods to compare ‘before and after’ the treatment was applied :-

- ‘before and after’ periods at the treated site should be identical to that at the control site
- the period during which work was carried out should be omitted from the study. If this period was not recorded precisely, a longer period containing it should be omitted
- the ‘before’ period should be long enough to provide a good statistical estimate of the true accident rate (so as to remove as far as possible random fluctuations). It should not, however, include periods where the site had different characteristics. Three years is widely regarded as a reasonable period to use.
- The same applies to the ‘after’ period which ideally should also be three years. However, results are often required much sooner than this. A one year ‘after’ period
can initially be used if there is no reason why this should bias the result (as long as the same period is used at the control sites). However, sensitivity is lost and the estimate of the countermeasure's success should be updated later when more data becomes available.

4.2.8 Standard tests on accident changes

In evaluating a treatment the answers to the following questions will usually be required:

- Has the treatment been effective?
- If so, how effective has it been?

It is assumed that the user of this Guide will need to interpret accident data practically without necessarily understanding the underlying statistical theory. For this purpose it is sufficient to assume that the ‘before and after’ accidents are drawn from a normal or Gaussian distribution.

This means that we can use the “Chi-square test” to answer the first question above, i.e. whether the changes at the site were statistically significant. However, let us first consider the size of that change by using the “k test”.

4.2.9 The k test

It is possible that although accident levels reduced at a treated site in an 'after' period, the general level of accidents is also reducing; the "real" reduction at the site due to the treatment thus being less than the actual numbers observed (i.e. overestimating effectiveness). Conversely, if the general level of accidents is increasing an underestimate of the treatment would be obtained. The “k test” can be used to show how the accident numbers at a site change relative to control data.

For a given site or group of similarly treated sites, let:

\[ a = \text{before accidents at site} \]
\[ b = \text{after accidents at site} \]
\[ c = \text{before accidents at control} \]
\( d = \) after accidents at control

then \( k = \frac{b/a}{d/c} \)

or, if any of the frequencies are zero then \( \frac{1}{2} \) should be added to each, i.e. :

\[
k = \frac{(b + \frac{1}{2}).(c + \frac{1}{2})}{(a + \frac{1}{2}).(d + \frac{1}{2})}
\]

If \( k < 1 \) then there has been a decrease in accidents relative to the control;

if \( k = 1 \) then there has been no change relative to the control; and

if \( k > 1 \) then there has been an increase relative to the control.

The percentage change at the site is given by :

\[(k-1) \times 100\%
\]

Example :

Let us assume that Table 7.2 gives the annual injury accident totals for a priority T-junction in a semi-urban area which had Stop signs on the minor road originally, but where a roundabout was installed three years ago. The control data used are accidents on all other priority junctions in the District over exactly the same 6-year period.

\[
k = \frac{6/20}{418/388} = 0.278
\]

Therefore, as \( k < 1 \) there has been a decrease in accidents relative to the controls of :

\[(k-1) \times 100\% = 72.2\%
\]
### Table 7:10.3.2

Injury accidents totals in three year period at a treated site and controls

<table>
<thead>
<tr>
<th></th>
<th>Site</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before</strong></td>
<td>20((a))</td>
<td>418((c))</td>
<td>438((g))</td>
</tr>
<tr>
<td><strong>After</strong></td>
<td>6((b))</td>
<td>388((d))</td>
<td>394((h))</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>26((e))</td>
<td>806((f))</td>
<td>832((n))</td>
</tr>
</tbody>
</table>

#### 4.2.10 The Chi-Squared test

It is important to answer whether the above change in accidents was indeed produced by the treatment or whether this occurred by chance. This test thus determines whether the changes are statistically significant.

With reference to the above table, chi-squared is calculated by the formula:

\[
\chi^2 = \frac{\left(\frac{|ad - bc| - \frac{n}{2}}{efgh}\right)^2 \cdot n}{e-f-g-h}
\]

**Example:**

Using the data in Table 7.2,

\[
\chi^2 = \frac{\left(\frac{|20 \cdot 388 - 6 \cdot 418|}{26 \cdot 806 \cdot 438 \cdot 394}\right)^2 \cdot 832}{832} = 26.832
\]

\[
\chi^2 = 5.38
\]
Now looking at the chi-squared distribution table (Appendix D) and the first line (one degree of freedom, \(\nu=1\)), the value for chi-square of 5.38 lies between 3.84 and 5.41. This corresponds to a value of significance level (on the column header line) between 0.05 and 0.02, which is normally quoted as greater than the lower level, i.e. better than the 5% level if significance.

This means that there is only a 5% likelihood (or 1 in 20 chance) that the change in accidents is due to random fluctuation. Another way of stating this is that there is a 95% (100%-5%) confidence that a real change in accidents has occurred at the junction.

The 5% level or better is widely accepted as the level in which the remedial action has certainly worked, though the 10% level can be regarded as an indication of an effect.

### 4.2.11 Group of sites with same treatment

For a number of sites, \(N\), which have had the same treatment, the overall effect is a rather more complex calculation, i.e. by solving the following equation for \(k\) over all the sites, i.e. \(i = 1\) to \(N\). The other symbols are as in previous equations.

\[
\sum_{1}^{N} \frac{a_i + b_i}{1 + k \left( \frac{d_i}{c_i} \right)} = \sum a_i
\]

For testing, the natural logarithm of a variable such as \(k\) is usually found to have a more symmetrical distribution (amenable to standard statistical treatments), and the standard error, \(\sigma\), of \(\log e k\) can be approximated to the following:

\[
\sigma(\log e k) = \sqrt{\frac{1 + (2 / \sum (a_i + b_i))}{\sum (a_i + b_i) d_i / c_i}} \cdot \frac{d_i / c_i}{(1 + d_i / c_i)^2}
\]

The following ratio should then be calculated using \(\log e\) of the value of \(k\) calculated above and its standard error from the previous equation:
\[
\frac{\log_e k}{\sigma (\log_e k)}
\]

and if this value is outside the range ± 1.96 (Student's t), then the change is statistically significant at least at the 5 percent level.

Now to test whether the changes at the treated sites are in fact producing the same effect on accident rates, calculate the following chi-squared value:

\[
\chi^2 = \sum \frac{(b_i - ka_i d_i)^2}{k(a_i + b_i) d_i c_i}
\]

If this is significant with N-1 degrees of freedom [refer to the (N-1)th row in the table of Appendix D, where N is the number of treated sites], then unfortunately, the changes at the sites are not producing the same effect. If non-significant, then it is likely that they are producing the same effect.
References


5. **AN EXAMPLE OF A THREE YEAR ‘BEFORE AND AFTER’ STUDY**

In the summer of 1993 a safety scheme was implemented at Euston Road / Grays Inn Road (King’s Cross) in central London.

Monthly monitoring showed that the ‘after’ accident rate fell noticeably. The accidents were periodically reviewed and the number of target accidents (pedestrians) were lower. As soon as three years ‘after’ data became available a standard three year ‘before’ and three ‘after’ accidents study which carried out. That report uses techniques described in this procedure note, is set out (in italics) as follows:

5.1 **Background**

*In November 1990 the London Accident Analysis Unit (LAAU) produced a report on accidents at the traffic signal controlled junction of A501 Euston Road and Gray’s Inn Road (Kings Cross). The finding of the investigation was to recommend a package of remedial measures to reduce the number of accidents involving pedestrians at this location.*

*This report monitors the change in the number of personal injury road accidents occurring at this location in the 36 months following the scheme implementation.*

5.1.1 **The original accident analysis**

*In the 36 month period ending June 1990 there was a total of 45 personal injury accidents that occurred at this location. These included 37 accidents that occurred in the junction and eight on the final 30 metres of the Euston Road approach to the junction. The principal problem identified was accidents involving pedestrians, of which there were 26. Of these, five resulted in serious injury. Fourteen accidents involved vehicles (west to north) in collision with pedestrians crossing on the west side in either A501 Euston Road or York Way.*

5.1.2 **The implemented measures**

*The measures, completed in June 1993 include:*
• new median strip with guard rail in A501 Euston Road
• closure of median strip gap adjacent to Birkenhead Street
• erect high intervisibility guard rail at the corners of Birkenhead Street and Crestfield Street
• realignment of A501 Euston Road entrance to York Way to include enlargement of pedestrian island in York Way

5.1.3 Maintenance

Improvements to existing anti-skid road surfacing on the Gray’s Inn Road approach to the junction.

5.2 ‘Before’ period accidents

The ‘before’ period used in this study is the 36 months ending May 1993. The whole month of June is the ‘construction period’ which has subsequently been excluded from this study.

In the 36 month period ending May 1993 there was a total of 56 personal injury accidents that occurred at this location. These include seven accidents that occurred on the adjacent link from Pancras Road to Gray’s Inn Road. The accidents are described as follows:

5.2.1 Pedestrian accidents

A total of 35 accidents involved pedestrians. Of these, 16 involved pedestrians hit by eastbound vehicles. These include nine on the west arm approach (one occurred on the crossing) and seven on the east arm exit (two occurred on the crossing). Five accidents involved pedestrians in collision with northbound vehicles in York Way (all occurred off the crossing). Two accidents involved pedestrians hit by vehicles turning left (west to north), both of which occurred off the crossing. One accident involved a pedestrian standing in the carriageway (northeast corner) hit by a vehicle turning left (north to west). Three pedestrian accidents occurred in Gray’s Inn Road (westbound approach) of which all three occurred off the crossing. Two accidents occurred at the junction of Birkenhead Street (both occurred off the crossing). Six pedestrian accidents occurred at
the junction of Crestfield Street (all occurred off the crossing). Of these three occurred on the approach and three on the exit.

5.2.2 Injury to bus/coach passengers

There were two accidents that resulted in injury to bus/coach passengers. Both involved eastbound vehicles and both resulted in serious injury. One occurred on the immediate approach to the junction at York Way and one occurred east of the junction with Pancras Road.

5.2.3 Accidents involving vehicles changing lane

Six accidents involved vehicles changing lane. Of these, two occurred in Gray’s Inn Road, two involved westbound vehicles (at the junction of Birkenhead Street and leaving the junction at Crestfield Road) and two involved eastbound vehicles, one on the exit from the junction at Pancras Road and one on the exit from A501 Pentonville Road (east arm).

5.2.4 Nose-to-tail type accidents

Four accidents were nose-to-tail shunt type. They occurred at different areas of the junction.

Other type of accidents:

Two accidents involved vehicles overtaking, of which one occurred on the eastbound approach and one in Gray’s Inn Road. Two accidents resulted in side swipe impact (one eastbound and one westbound). Two accidents involved vehicles turning right. They occurred at different areas of the junction. Three accidents involved injury to a bus/coach passenger (two involved eastbound vehicles and occurred during the hours of darkness).

One accident involved a vehicle making a ‘U’ turn (eastbound approach). One accident was a cross road collision.
5.2.5 **Dark accidents**

There were 20 accidents that occurred during hours of darkness. Of these, 13 involved pedestrians. These included nine in collision with eastbound vehicles (three on approach and six on exit), two involving pedestrians in collision with northbound vehicles in York Way and one accident involving a pedestrian hit by a vehicle turning left (west to north). Four accidents that occurred during hours of darkness involved westbound vehicles, and three involved vehicles changing lane, (two in Gray’s Inn Road and one at the junction of Birkenhaed Street). One accident occurred at Crestfield Street.

Three accidents that occurred during hours of darkness involved eastbound vehicles, of which two occurred on the exit from Pancras Road and one within 50m of York Way.

5.2.6 **Accidents that occurred on a wet road surface**

There were 10 accidents that occurred on a wet road surface. Nine involved pedestrians, of which seven involved eastbound vehicles (three occurred on the approach, three occurred on the exit and one occurred on the northeast corner of the junction). Two accidents involved northbound vehicles. The remaining accident involved a vehicle changing lane on the westbound approach in Gray’s Inn Road.

5.2.7 **Serious accidents**

There were seven accidents that resulted in serious injury. Five involved pedestrians. Of these, three occurred at the junction of Crestfield Street and involved westbound vehicles. Two accidents involved vehicles in Pentonville Road. Two involved injury to bus/coach passengers of eastbound vehicles.

5.3 ‘After’ period accidents

In the 36 month period ending June 1996 there was a total of 31 personal injury accidents that occurred at this location. These include five accidents that occurred on the adjacent link from Pancras Road to Gray’s Inn Road. The accidents are described as follows:
5.3.1 Pedestrian accidents

A total of 12 accidents involved pedestrians. Of these, five involved pedestrians hit by eastbound vehicles. These include three on the west arm approach (one occurred on the crossing), one in the middle of the junction at York Way and one on the east arm exit. Three accidents involved pedestrians in collision with northbound vehicles in York Way (all three occurred off the crossing). Four accidents involved westbound vehicles. These include two in Gray’s Inn Road (one occurred on and one off the crossing) and two at the junction of Crestfield Road (one on approach and one on exit).

5.3.2 Injury to bus/coach passengers

There were six accidents that resulted in injury to bus/coach passengers. Of these, five involved eastbound vehicles and occurred on the immediate approach to the junction at York Way (one resulted in serious injury). The remaining accident occurred in the middle of the junction and involved the vehicle northbound.

5.3.3 Accidents involving vehicles changing lane

Two accidents involved vehicles changing lane. Both involved westbound vehicles.

5.3.4 Nose-to-tail shunt type accidents

Five accidents were nose-to-tail type, of which three involved eastbound vehicles, two occurred on the approach and one in the middle of the junction at York Way. Two, involved westbound vehicles and occurred on the Gray's Inn Road approach.

Other types of accidents :

Two accidents involved vehicles overtaking. These occurred at different locations, and one resulted in fatality and involved eastbound vehicles. Four accidents were different types and occurred at different locations.
5.3.5  Dark accidents

There were 11 accidents that occurred during hours of darkness. Of these, six involved pedestrians, including three in collision with eastbound vehicles (all three on the approach), two in collision with a westbound vehicle at Crestfield Road. The remaining five accidents that occurred during hours of darkness comprised four on the eastbound lane and one westbound in Gray's Inn Road.

5.3.6  Accidents that occurred on a wet road surface

There were six accidents that occurred on a wet road surface. Four involved eastbound vehicles of which one accident resulted in a fatality. One accident involved a northbound vehicle in York Way. The remaining accident involved a vehicle changing lane in Gray's Inn Road.

5.3.7  Serious and fatal accidents

There were seven accidents that resulted in serious injury and one accident that resulted in a fatality. Of these, the accident that resulted in a fatality and one that resulted in injury both occurred on the immediate approach to the junction with York Way. Three accidents that resulted in serious injury involved pedestrians. Of these two involved eastbound vehicles and one involved a westbound vehicle in Gray's Inn Road. Three accidents involved westbound vehicles, of which two occurred in Gray's Inn Road.
5.4 Data comparisons

Table 1: Change in 'before and after' monthly rates for various accident types

<table>
<thead>
<tr>
<th>Accident type</th>
<th>'Before' accidents</th>
<th>'After' accidents</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pedestrians</td>
<td>35</td>
<td>12</td>
<td>-23 (66%)</td>
</tr>
<tr>
<td>Pedestrians on crossings</td>
<td>4</td>
<td>3</td>
<td>-1 (25%)</td>
</tr>
<tr>
<td>Injury to bus/coach passenger</td>
<td>3</td>
<td>6</td>
<td>+3 (50%)</td>
</tr>
<tr>
<td>Involving vehicles changing lane</td>
<td>6</td>
<td>2</td>
<td>-4 (67%)</td>
</tr>
<tr>
<td>Nose-to-tail shunt type</td>
<td>4</td>
<td>5</td>
<td>+1 (25%)</td>
</tr>
<tr>
<td>Involving total or serious injury</td>
<td>7</td>
<td>8</td>
<td>+1 (14%)</td>
</tr>
<tr>
<td>Occurring during hours of dark</td>
<td>20</td>
<td>11</td>
<td>-9 (45%)</td>
</tr>
<tr>
<td>Occurring on a wet road surface</td>
<td>10</td>
<td>6</td>
<td>-4 (40%)</td>
</tr>
<tr>
<td>Total accidents</td>
<td>56</td>
<td>31</td>
<td>-25 (45%)</td>
</tr>
</tbody>
</table>

Total accidents at the junction of the A501 Euston Road and York Way decreased from 56 to 31, a reduction of 25 accidents (45%). The original scheme targeted accidents involving pedestrians. Accidents involving pedestrians have decreased from 35 in the ‘before’ period to 12 ‘after’, a reduction of 23 accidents (66%).

Other accident types also show an overall reduction; accidents occurring during the hours of darkness have fallen from 20 accidents in the ‘before’ period to 11 ‘after’ (45%), accidents occurring on a wet road surface have fallen from 10 accidents in the ‘before’ period to six ‘after’ (40%).

The following accident types have shown an increase: Accidents involving a fatality or serious injury have risen from seven accidents in the ‘before’ period to eight ‘after’ (14%). Nose-to-tail shunt type accidents have risen from four in the period ‘before’ to five ‘after’; and accidents that resulted in injury to bus/coach passenger have risen from three in the period ‘before’ to six ‘after’.

The original scheme anticipated an annual saving of four accidents per year. The implemented measures have led to a saving of 8.3 accidents per year.
5.5 **Statistical tests**

The reduction in the total ‘before and after’ accidents was statistically tested using the ‘$k$ test’. The result showed the reduction was statistically significant. Chi$^2$ tests were completed for various accident types and the results are shown in Table 2 (below). The control data used in these Chi$^2$ tests was inner London trunk road accidents for the various accident types.

<table>
<thead>
<tr>
<th>Category</th>
<th>% Change</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents</td>
<td>-39.9</td>
<td>Better than 5% level</td>
</tr>
<tr>
<td>Total pedestrians</td>
<td>-133.9</td>
<td>Better than 5% level</td>
</tr>
<tr>
<td>Pedestrians on crossing</td>
<td>11.1</td>
<td>Not significant</td>
</tr>
<tr>
<td>Change of lane</td>
<td>-64.84</td>
<td>Not significant</td>
</tr>
<tr>
<td>Dark</td>
<td>40.3</td>
<td>Not significant</td>
</tr>
<tr>
<td>Wet</td>
<td>32.4</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

5.6 **Conclusion**

The implemented measures have been successful in reducing pedestrian accidents and total accidents at the junction of the A501 Euston Road and York Way.

5.7 **Summary**

The report identifies accident change within the major accident groups. Each accident group has been evaluated and we can see the change brought about by the scheme. In the majority of cases ‘after’ accidents are lower than ‘before’ implementation. In some cases, the ‘after’ accident rate has increased. It was not thought that this increase was related to the implemented measures and no further action was necessary.

The report is presented in a fairly easy to follow way, thus making it easier for the reader to follow and understand.
6. PRODUCING THE REPORT

6.1 Front page (see Figure 5)

Title block in the Road Safety Units house style and showing the Road Safety Units logo.

6.2 Second page (see Figure 6)

Scheme title and study synopsis, giving a brief summary of:

- the measures implemented
- the change in numbers of accidents
- a description of ‘before’ and ‘after’ accidents
- the findings and recommendations made

6.3 Third page

List the contents of the report.
**Table 1: Airport Road - Biswa Road**

<table>
<thead>
<tr>
<th>Accident type</th>
<th>‘Before’ accidents</th>
<th>‘Before’ monthly rate</th>
<th>‘After’ accidents</th>
<th>‘After’ monthly rate</th>
<th>Average annual change ±</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total accidents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving fatal or serious injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving a pedestrian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occurring during hours of dark</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occurring on a wet road surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving a non-motorised vehicle (non pedestrian)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving bus or coach passengers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving an Auto-Rickshaw, Mishuk, Tempo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving a powered 2 wheeler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving a right turning vehicle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4. Table 1 showing accident change**
Airport Road / Biswa Road

‘Before and after’ accident analysis

Prepared by
Road Safety Unit
Roads and Highways Department
Sarak Bhaban, Dhaka.

by
(Name of Author)
Contents

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</tr>
<tr>
<td>2</td>
<td>Summary of main accident problems</td>
</tr>
<tr>
<td>3</td>
<td>Major accident types</td>
</tr>
</tbody>
</table>

Figure 6. Report contents page
6.4 Circulating the report

In the large majority of cases these reports will contain very useful information. This information will be valuable to other road safety units and researchers. A widespread exchange of evaluation papers must be encouraged. When it is achieved the development of Road Safety Engineering will benefit significantly.

6.5 Internal circulation

- to be agreed
- one copy to be circulated to all Unit engineers, before filing in published ‘Before / After’ reports file
- master copy to be filed in original scheme file
Road Safety Engineering

Procedure Note 8.

Accident Studies in Bangladesh
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1. INTRODUCTION

If we look back at most successful safety programmes we invariably find that those programmes have been based on the findings of analysis of accident data and research. By establishing the extent and depth of accident problems we can target resources, influence policy and benefit from better direction.

Whilst accident studies and research is a specialised field, a Road Safety Unit directing time and resources towards a series of relatively simple reports on relevant topics will make more progress when they have access to these data-led reports.

There are many safety issues and problems now facing highway and traffic engineers in Bangladesh. What constitutes good (safe) highway design? What constitutes poor (unsafe) practice? In some cases international research is available, but this is not always relevant to Bangladesh. By analysing local data we can identify the extent of many problems, then work constructively towards a solution - the alternative is to rely on opinion and guesswork.

In addition to monitoring and evaluating single sites (Procedure Note 7) there are two further types of study that are frequently carried out. A routine Accident Study investigates accident types and the frequency relative to various highway conditions. For example, if we investigate one accident group, perhaps ‘vehicles leaving the carriageway’ and we find that this type of accident occurs more frequently on certain types of road, we can then advise designers to avoid those circumstances in future or we can set about designing measures to reduce that problem. If we investigate pedestrian accidents occurring at pedestrian crossings in a city and we find out which of the crossing types are performing well, i.e. have low pedestrian accident rates, and which are performing less well, higher accident rates, we can apply this information in future.

The second type of study, Special Studies is different. A Special Study measures and quantifies the extent of accident change following implementation of similar highway engineering measures at groups of sites. When we have established the level of performance of that measure in a larger group of sites we are far more confident in the results. Special Studies is the subject of Procedure Note 9.

Figure 1 shows the relationship between Accident Studies in Bangladesh and other road safety engineering practices.

*Note: This Procedure Note should not be used by persons without appropriate Road Safety training.*
Figure 1. Accident Studies in Bangladesh in Road Safety Engineering
2. FIRST PRINCIPLES

2.1 Always compare ‘like with like’

As we have said before we must always compare ‘like with like’. If we are evaluating differing accident rates, for example, accident rates at two types of pedestrian crossing, we must only compare rates for similar circumstances, these sites must have similar traffic vehicle volumes, road classification and mix of traffic. It is very unlikely to find absolutely identical sites, but variations must be kept to a reasonable minimum.

Sample size and study period duration

The larger the number of sites in the study sample and the longer the study period the more reliable (robust) will be the results. If possible three years data should be used. Three years data reduces the effect of the random nature of accidents. We can avoid the effects of rising or falling accident trends by using identical three years data. In reality we seldom have access to ‘pure’ data. The study period for individual sites should always be free of any change that may have altered road user behaviour at the sites. If there has been changes that have altered road user behaviour, it is likely that this will affect accident rates and that site should not be included in the sample.

If we have a good base of sites with three full years accident data and we find other suitable sites, but they only have one or two years data, the study will benefit by including these additional sites. In these cases, two things are important. They are:

- avoid seasonal variation, do not use part year’s data always use a full (complete) year’s data
- to compare accident rates between the sites it will be necessary to reduce summary data to one year average accident rates
2.2 Skill requirements to carry out an accident study

It is not essential that the person is a trained traffic engineer. Day to day contact with safety engineers will be sufficient to provide the researcher with specialised knowledge that may be required. The major requirements are, that the person:

- has a background in research, a good understanding of statistics
- has a good understanding of accident causation
- is capable of accurate figure work
- has a good understanding of all MAAPfive accident data-base application
- has an understanding of Excel tabulation procedures
- has good report writing skills

With practice a person’s ability to produce practical, reliable and useful reports will come quickly and these will have a major impact on the direction of the Road Safety Unit.

Avoid making judgment, expressing opinion and guesswork. The report should only contain the facts as found in the investigation.
3. **BASIC PRACTICE**

The procedure for carrying out each study will be different and will require a different approach. Careful planning of each stage of the work is essential. If we can anticipate the problems, difficulties and snags, we can take steps to avoid problems.

A routine accident study follows the stages as shown in Figure 2, Producing an accident study.

3.1 **Direction of the study**

The object of the exercise is to identify and quantify accident problems. This is seldom as easy as it sounds. The researcher will need help and assistance to keep the work moving in the right direction. It will be easy for the researcher to get side tracked or bogged down. It is strongly recommended that weekly working party meetings are set up. These meetings held at the beginning of the week need not be time consuming, perhaps half an hour will be sufficient to cover the following points:

- progress made
- difficulties, problems encountered
- the next week’s plan
- direction of the report

It is suggested that the Head of the Road Safety Unit attends the meeting with one other person. Ideally the third person should have first hand experience of the study subject.

3.2 **Preparation work**

As soon as the subject for the work is agreed the researcher should set out a proposed plan of action. This plan of action should identify the steps to be taken, gather all information necessary to start the analysis. When the plan is agreed with the Head of the Road Safety Unit, the work can commence.
3.3 Data collection

In the majority of cases the study will need to break down the sample sites into similar groups. The best way to do this is to visit each site and prepare a simple technical inventory. If the sample size is large it might be better to engage a small team of technicians to carry out the work.

As soon as the inventory is prepared, the site accident data can be retrieved from the accident database.

The study is likely to require other information, for installation dates and traffic flows example. This information should be gathered as required through the usual channels.

3.4 Coding the data

Spreadsheets have made analysis work much easier. By coding the site information and screening the accident details we will later be able to produce several variations and permutations of the data.

3.5 Assigning the data to the spreadsheets and running the first tabulations

As soon as the accident and site data is coded, the data can be assigned to the spreadsheets and a tabulation of all sites can be prepared.

This will produce the following summaries:

- a total of all accidents occurring at each site and all sites in the study
- individual totals of selected common types for each site and the total for all sites

3.6 Breaking down and analysing the data

This stage is the most important, the researcher will now have a good understanding of the accidents and will be able to suggest lines for developing the data. To ensure that the work is relevant and well directed, the researcher will need assistance and close supervision throughout.
The summary of all accidents in the study will contain many different classifications of the subject, this will not be meaningful except as a point of reference at a later stage.

The next stage is to identify groups of similar classification sites, transferring the accident data to spreadsheets to produce accident rates for comparison between other similar groups.

For example:

- does the rate of pedestrian accidents increase on roads with a higher speed limit?
- does the rate of pedestrian accidents increase as the width of pedestrian crossings increase?
- are pedestrian accident rates higher at sites without a pedestrian refuge (centre island) when compared to a site with a pedestrian refuge?
- is the rate of accidents higher on a road with sealed hard shoulders than at sites with unsealed shoulders? If so what type of accidents are occurring? Does that rate increase or decrease with the carriageway width?

In some cases it might be necessary to develop and confirm points that may be coming out of the data. To do this the researcher may have to go back to the accident data, reclassify data and re-run the tabulations.
Figure 2. Producing an accident study
4. DEVELOPING THE BASE FOR AN ACCIDENT STUDY TO IDENTIFY ACCIDENT RATES AT PEDESTRIAN CROSSINGS IN CITIES

The Action on Road Safety section of the National Road Safety Strategic Action Plan targets the problem of pedestrian accidents in major cities. To do this the plan sets out a four stage operation:

- review pedestrian facilities in major cities
- identify proposals for improvement of pedestrian facilities
- obtain approval
- obtain funding and implement

How do we start to review pedestrian facilities? How do we find out exactly what constitutes a safe or unsafe pedestrian crossing? The following procedure will provide us with the information.

4.1 Preparing the inventory

If we can break down the crossings into groups of similar crossings, examine the number and type of accidents occurring at sites in similar groups, the results will tell us which crossings are safer and which are less safe. This information will enable us to proceed to Stage 2.

The first stage is to identify the location of each formal crossing in the city. When this is done we need to produce a fairly detailed inventory of the crossings. This inventory of crossings will be a useful working tool in many following exercises.

It is recommended that a simple pro-forma is produced. The pro-forma shall include a complete list of the most common pedestrian crossing features.

It is probably best that this task is carried out by a team of technicians. It will be necessary to obtain commitment, consistency and accuracy from the team. It will be necessary to fully brief and equip the survey team. In advance of that meeting prepare a survey manual.
At that meeting stress the importance of the work and the important part that they, the survey team will play in producing an accurate study. Go through the survey manual and make sure that each member of the team has a clear understanding of the work involved.
<table>
<thead>
<tr>
<th>PEDESTRIAN CROSSING INVENTORY SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Adjacent side roads (within 100m)</td>
</tr>
<tr>
<td>Crossing type</td>
</tr>
<tr>
<td>If signal controlled what type?</td>
</tr>
<tr>
<td>Road classification</td>
</tr>
<tr>
<td>Road usage</td>
</tr>
<tr>
<td>Parking</td>
</tr>
<tr>
<td>Roadside frontage</td>
</tr>
<tr>
<td>Speed limit of road</td>
</tr>
<tr>
<td>Width of crossing</td>
</tr>
<tr>
<td>Width of Carriageway</td>
</tr>
<tr>
<td>Width of central refuge</td>
</tr>
<tr>
<td>Type of central refuge</td>
</tr>
<tr>
<td>Street lighting</td>
</tr>
<tr>
<td>If applicable, is street lighting provided on the central refuge?</td>
</tr>
<tr>
<td>Is pedestrian guard rail provided ?</td>
</tr>
<tr>
<td>If yes what type?</td>
</tr>
<tr>
<td>Length?</td>
</tr>
<tr>
<td>On crossing exits length</td>
</tr>
<tr>
<td>On central refuge</td>
</tr>
<tr>
<td>Road surface</td>
</tr>
<tr>
<td>Advance warning of the crossing</td>
</tr>
<tr>
<td>Average daily traffic flow</td>
</tr>
<tr>
<td>Average pedestrian flow</td>
</tr>
<tr>
<td>Date of implementation</td>
</tr>
<tr>
<td>Date of survey</td>
</tr>
<tr>
<td>Names of survey team</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Figure 3. The inventory sheet**
4.2 Survey manual

Produce diagrams of the measurements required.

Produce sketches of the guardrail types (with names or description codes), any special definitions, discuss mast arm signals, anti-skid road surfacing and any other item that may not be clear to the team.

Produce a series of photographs with detailed explanations of special features etc.

Produce the standard inventory field sheet. Go through the sheet with the survey team section by section and make sure that they are familiar with the expressions needed. A sketch layout of the site will be useful. Request that the technicians use the reverse side of the sheet for this purpose.

Each team will consist of three persons. One person to supervise and sign the completed survey sheet, the second to hold the tape measure and the third person to watch for on-coming traffic when the individuals are working in the carriageway.

Equipment: In addition to measuring equipment, pens and prepared field sheets, the survey staff will need to wear reflective jackets.

If any site is judged to be particularly dangerous (Airport Road, for example) it will be necessary to arrange for the busier road surveys to be carried out at quiet times (Friday mornings) when traffic is light. It might be advisable to obtain the assistance of the police to control traffic whilst the team are working on the carriageway.

It will be helpful to arrange to take a photograph of each of the crossing approaches. Stipulate that these photographs should be taken 20m and 50m downstream from the crossing.

4.3 Safety on Site

Working on, or adjacent to the carriageway is dangerous, and it is important to stress safety on site.

Reflective jackets will be worn at all times.
Warn that if, in the opinion of the survey team leader, any person disregards a safety procedure or instruction from the leader, that person will be dismissed from site and a written report will be submitted to the Head of the Road Safety Unit.

Discuss the importance of individual site safety.

Discuss the importance of colleagues’ site safety.

Discuss the importance of public site safety.

4.4 Safe Storage of the Survey Field Sheets

As the completed field sheets are returned it is important to have a procedure to check the accuracy of data and protect against loss of the work. It is recommended that:

- the master sheets are photocopied, the master copy filed in a central register, the photocopy now becomes the working copy
- a supervisor should check the returned field sheets. Is all the data there? Are dimensions clear? Have any obvious errors crept in? If there is any doubt that accuracy is being compromised, carry out random site checks

It is now possible to design and prepare a simple pedestrian crossing spreadsheet that will contain the location and all of the important features of the crossings.

4.5 Extracting and screening the accident data

Using standard MAAPfive procedures occurring within 200m of the pedestrian crossings. When the accident data is ready, it will be necessary to examine the details of each accident and select only those accidents that have occurred close to the crossing - those accidents related to activities at the crossing.

Assuming that the pedestrian crossing is on a main road we will not usually be interested in any accident occurring in side roads. If a side road accident involves two vehicles colliding that accident is clearly unrelated to the pedestrian crossing, and its inclusion in
the study will reduce the value of the findings. However if an accident involves a vehicle turning from the side road into the main road it is quite possible that this accident may have been related to activities at the crossing.

We need to include all main carriageway accidents occurring at the crossing and all accidents occurring within 60m of the crossing. To do this accurately it might be necessary to examine the police FIR report sheets.

*Note: If it becomes obvious that an accident has been wrongly assigned to a location please reject that accident from the study data and inform the person in charge of the accident data-base. That person will take steps to assign the accidents to the correct location.*

When we have finished screening all of the accidents at all of the sites, we are ready to commence coding the accidents for analysis.

### 4.6 Coding the accident data

If we look closer at the detail of the accidents and group the accidents into various common types, the analysis will provide us with a much clearer picture of what is happening at each of the sites.

Assuming that the researcher is familiar with all of the MAAPfive codes we can obtain a lot of information directly from the data-base. For example Section 63, describes the location of the pedestrian accidents:

- on a pedestrian crossing
- within 50m of a pedestrian crossing
- central island/divider
- road centre
- footpath
- road side
- bus stop

This information should be treated as being indicative, not absolute, as errors in the system may have occurred.
We need to know where the accidents are occurring. For example: Are the pedestrian accidents occurring at the crossing? What type of vehicle accidents are occurring at the sites? What type of vehicles are involved in these accidents? What are the conditions when the accidents occurred? If we identify and code the accidents accordingly we will be in a position to answer many of these questions.

A recommended coding that will be suitable for a pedestrian study is set out as follows:

Location of pedestrian accidents

- pedestrian accident at the crossing (Pxg)
- on crossing approach (Pap)
- on crossing exit (Pex)

Accident type

- involving a single vehicle (Svl)
- involving nose-to-tail collision (Ntl)
- involving a vehicle changing direction (turning) (Trn)
- involving a vehicle skidding (Skd)

Vehicle type

- involving a truck (Trk)
- involving a bus (Bus)
- involving a car (Pcr)
- involving a three wheel motorised vehicle (Thr)
- involving a non-motorised vehicle (Nmv)

Accident conditions

- occurring on a wet road surface (Wet)
- occurring during hours of darkness (Drk)
We are now in a position to code each accident and prepare a summary of all accidents occurring at each site. When we have compiled summaries for all of the sites in the study, we can start to produce overall summaries. It is suggested that spreadsheets are used for this task.

4.7 Preparing the spreadsheet

First prepare a spreadsheet for all sites in the study, see Figure 4, Spreadsheet : All sites in the study. As soon as the spreadsheets are completed we will be able to work out average rates for all sites in the study. This will not tell us very much and we will need to start identifying common groups of crossings.

Figure 4. Spreadsheet : All sites in the study
This will enable us to work out average accident rates for all accidents in the study and we can now begin to see the extent of the various accident problems. To develop the data further we need to prepare additional spreadsheets. We have to compare groups of similar sites (‘like with like’) and to see where that data takes us. Some obvious comparisons should be:

1. all sites on 30 mile per hour roads without a central pedestrian island with the same road width
2. all sites on 40 mile per hour roads without a central pedestrian island with the same road width
3. all sites on 50 mile per hour roads without a central pedestrian island with the same road width
4. all sites on 30 mile per hour roads with a central pedestrian island with the same road width
5. all sites on 40 mile per hour roads with a central pedestrian island with the same road width
6. all sites on 50 mile per hour roads with a central pedestrian island with the same road width

We will now be able to see if the increasing speed limit increases accident rates at these sites.

Examine Figure 4. carefully, look at the sites with higher accident rates. Do those sites have anything in common?
5. PREPARING THE BACKGROUND FOR AN ACCIDENT STUDY

Preparing to carry out an accident study was covered in the IDC Road Safety Engineering Training Programme. The example used in the class workshops was based on developing a study to produce accident rates for the different types of shoulder treatment on national roads in Bangladesh.

Several international studies have produced evidence that sealed shoulders are much safer than unsealed. We learn from international research that a sealed shoulder allows the driver more room to recover from an incident, perhaps avoiding an on-coming vehicle, so there are fewer incidents of vehicles straying off the carriageway. The sealed shoulder avoids the problem of a ‘lip’ or a ‘drop’ forming at the edge of the pavement. The sealed shoulder also removes the problem of the driver of a vehicle leaving the pavement area having to deal with loose gravel or earth which can turn to mud in the rainy season.

There is one area of concern. The sealing of shoulders invariably leads to an increase of vehicle speed. Driver behaviour in Bangladesh is extremely poor. We need research that will tell us if sealed shoulders provide a safety premium over unsealed shoulders. We also need to establish if there is a ‘speed related’ problem at sites where the shoulder has been sealed.

The first stage is to prepare a short introduction. This introduction will tell readers about the background of the subject. It should be remembered that not all readers will be technically familiar with highway terms and expressions. In this case, the researcher should prepare a brief summary that explains the purpose and typical construction of road shoulder.

5.1 What is the purpose of the road shoulder

The class identified the following points:

- stabilises the road, protects the structural area against erosion
- provides a margin of safety for drivers of vehicles (to take evasive action if necessary)
- allows slow moving vehicles to ‘move over’ to allow faster vehicles to pass
allows pedestrians to walk ‘off carriageway’
allows out of order vehicles to move off the carriageway for repairs
accommodates road side furniture (road signs etc.)

5.2 Typical shoulder construction

The class identified the following forms of construction:

Edging between the shoulder and main carriageway

• brick on edge

Shoulder construction

• stone chips and sand
• brick chips and sand
• khoa consolidation with seal coat
• brick flat soling and herring bone bond
• sandy soil

Embankment

• selected earth

Embankment treatment

• turfing
• cement concrete block
• palisading
• brick filled, wire mattress

The researcher can now prepare the introduction and background to the report.
5.3 **What highway classifications (highway groups) should we consider?**

The class was asked what information should the inventory include:

- carriageway widths (lanes)
- main carriageway surface (blacktop)
- road / highway classifications
- embankment category
  - elevated
  - ground level
  - in cutting
- traffic volume (ADT)
- urban or rural setting
  - industrial
  - commercial
  - residential
- shoulders
  - type (prepare a schedule of codes)
- local terrain, environment
  - hill
  - flat
  - normal
- speed limit of carriageway
- access to main carriageway
- geometry (bend, straight alignment)
- road side activities
- road side furniture

This is a comprehensive list and it might be difficult to economically obtain all of this information. Before preparing the final list, the method of obtaining the detail should be discussed and agreed with the Head of the Road Safety Unit.
5.4 Grouping ‘like with like’ sites

The class was asked what groups of similar sites and site conditions should be drawn together to produce ‘like with like’ accident rates. The following categories were identified as being the most important:

- width of the carriageway
- sealed or unsealed shoulder
- width of the shoulder
- pavement surface
- bend or straight highway alignment
- access / junction per kilometer

5.5 What accident types should we consider?

The class identified the following accident types:

- head on accident
- nose to tail accident
- over turning accident
- pedestrian accident
- hit the road side furniture
- skidding accident

5.6 Conclusions

The workshop exercises have started to build up a useful study specification. In some cases the specification may be too demanding. It is recommended that the following course of action be taken.

Carry out a pilot study.
Select four routes. These routes should contain both sealed and unsealed shoulders. The routes should be 10 to 30 km long.

- carry out inventory
- code the routes as previously described
- code and assign accidents occurring on those routes to spreadsheets
- tabulate accidents and prepare analysis of results

This exercise will help the team to refine the practice and may lead to a more practical specification. The analysis will probably produce some very useful data. It should be remembered that we need to focus on the difference between sealed and unsealed shoulders. Total accident rates per kilometre will be a first indicator of any differences and we need then to look closely at the different accident types occurring between the groups. For example: Is the rate of single vehicle accidents per kilometre higher on highways with unsealed shoulders?
6. PREPARING FOR A PROGRAMME OF ACCIDENT STUDIES

6.1 Designing the programme

The programme should be as wide ranging as possible. The Head of the Road Safety Unit is responsible for managing the overall programme and supervising resources to achieve the best results. The Head of the Road Safety Unit will be in contact with several other organisations involved in Road Safety and will be aware of the various research and study programmes. Every effort should be made to avoid duplication of effort and to ensure co-ordination between the work of the different organisations.

6.2 Administration

As soon as it is agreed to carry out an Accident Study the person responsible for that study shall record the details in the central register.

The register is a management tool and will help the Head of the Road Safety Unit to track the progress of each study.

It is suggested that the register contains the following details:

- study number
- date the work started
- name of the researcher, person responsible for the study
- title of the study
- completion date

A master file will be opened for each study. The master file (bearing the study number) will contain a copy of all the administration papers and as the investigation proceeds, a record of all relevant developments (meetings notes, working papers etc.) that arise as a result of the work.
A working file should be opened at the same time. The working file will contain all of the working details relevant to the investigation, drawings site photographs, calculations and stick diagrams.

It is the working file which should be passed to the researcher who will carry out the investigation.

6.3 Report writing

The report should be as short as possible, in other words keep it simple.

All reports should be presented in the Road Safety Unit’s house style.

The following format is recommended:

Section 1 : Introduction. Discuss the objectives of the report.

Section 2 : Background. Any background information that will help the reader to understand the purpose of the study.

Section 3 : Methodology. Discuss the method(s) used to prepare the report, analyse the data and arrive at the findings.

Section 4 : The findings. Set out the final tabulations and describe how each of the findings were arrived at.

Section 5 : Conclusions. Set out each of the conclusions arrived at during the preparation of the report and if applicable set out the recommended course of action.

Section 6 : Appendix. The Appendix should contain any item that the reader may need.
6.4 Circulating the final report

When the final report is complete and the Head of the Road Safety Unit has agreed any final amendments, one copy of the report should be circulated to each member of the Road Safety Unit. This copy should be filed away in the Road Safety Unit library for future reference.

In house circulation, one copy should be submitted to each division within the organisation with a covering letter explaining the major points found in the work:

- one copy of the report should be sent to the National Road Safety Council
- one copy should be sent to each of the Heads of other Road Safety Units
- one copy should be sent to the officer responsible for road safety in each of the Zone offices
- one copy to a nominated officer at Bangladesh Road Transport Authority
- one copy sent to the Bangladesh Road Research Laboratory, and passed on for filing to the Road Safety Centre Library

*Note: It is hoped by making the work freely available, we will benefit from research and analyses being carried out in other Road Safety Units.*
SECOND ROAD REHABILITATION AND MAINTENANCE PROJECT

INSTITUTIONAL DEVELOPMENT COMPONENT

Road Safety Engineering

Procedure Note 9.

Special Studies in Bangladesh
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5. EXAMPLES OF HOW SPECIAL STUDIES HAVE IMPROVED ROAD SAFETY ENGINEERING

   5.1 Road surface treatment
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APPENDIX A.

THE EFFECT OF MEASURES DESIGNED TO REDUCE RIGHT-TURNING ACCIDENTS AT SIGNAL CONTROLLED JUNCTIONS

A good example of a well constructed study that was used by engineers at the decision making stage. We are grateful to the London Accident Analysis Unit (LAAU) of the London Research Centre (LRC) for permission to reproduce this report.
1. INTRODUCTION

In previous papers we have stressed the importance of monitoring and evaluating implemented road safety engineering schemes. The results of this work provide the basis for improving practices in the road safety unit and contribute much towards producing safer highway design in other areas of highway and traffic engineering.

The reader should be familiar with practices laid out in Procedure Note 7. Monitoring and Evaluating Implemented Schemes in Bangladesh. In evaluation of single schemes we compare ‘before’ accident rates with ‘after’ accident rates to determine the effects of the measures.

The reader should also be familiar with Procedure Note 8 Accident Studies in Bangladesh. This details the practice of breaking down and analysing accident data from several similar sites to identify and then quantify the level of common accident types occurring at those locations.

Special Studies is the practice of carrying out ‘before and after’ accident analysis at groups of sites, where similar road safety engineering measures have been implemented. When we break down this data into accident rates for each of the major accident types, the comparison identifies the aggregated change in those accident groups and the effect of the measures. Although the practice is not scientific, we work from a broader base and the level of confidence in the results is much stronger.

When we consider using a particular measure at a site in the future and we have the benefit of knowing how the measure has performed at several other locations, we are better able to forecast the likely performance. The findings from Special Studies will also be valuable to others, particularly design teams, who can use the information to produce schemes that will avoid past problems. Safety Audit teams also need access to the work so that they can identify potential problems and specify an appropriate course of action.

Special studies are reasonably easy to produce. A keen person with a good understanding of statistics, working with engineers in the road safety unit will soon be able to produce a series of studies that will enable the engineers to make more efficient and often more cost effective decisions.

Figure 1 shows the relationship between Special Studies in Bangladesh and other road safety engineering practices.

*Note: This Procedure Note should not be used by persons without appropriate Road Safety training.*
Figure 1. Special Studies in Bangladesh in Road Safety Engineering
2. SPECIAL STUDIES

By evaluating the performance of the measure implemented at a number of similar locations we have the opportunity to identify the level of accident change, and thus establish the effect of that measure. To do this we aggregate the total number of accidents occurring in the ‘before’ period and compare that with the total number of accidents occurring in the ‘after’ period, see Figure 2.

![Figure 2. ‘Before’ and ‘after’ implementation accident comparison](image)

Special Studies have three major objectives that need to be identified:

- the level of change in the total number of accidents occurring at the site,
- the target accidents - *the identified accident problem*, and
- unrelated accidents - *those accidents not in the target group*
3. **PRODUCING A SPECIAL STUDY**

3.1 *What subjects should be considered?*

Any widely implemented program of work that has been carried out in the interest of road safety should be considered for inclusion in the programme.

For example, in Bangladesh there have been several programmes of work implementing central barriers on faster roads.

Central barriers prevent overtaking and as a result of implementation they have prevented many head on collisions, resulting in many saved lives. A Special Study into this programme would be very productive. We will then learn if the implementation has produced an overall reduction in accidents and casualties. We could also find out how the different accident types have changed. Has the barrier led to different accident types occurring on these routes. For example, if there are several gaps in the barriers, the gaps are for vehicles to turn - how many accidents are occurring at these gaps? It is likely that when we know exactly what is happening we can improve the successful areas of the scheme and correct the unsuccessful.

3.2 *Skill requirements to carry out a special study*

It is not essential that the person is a trained traffic engineer. Day to day contact with safety engineers will be sufficient to provide the researcher with all the specialised knowledge that may be required. The major requirements are, that the person:

- is familiar with evaluating implemented schemes Procedure Note 7
- has carried out Accident Studies, familiar with Procedure Note 8
- has a background in research, a good understanding of statistics
- has a good understanding of accident causation
- is capable of accurate figure work
- has a good understanding of all MAAP/ive accident data-base applications
- has an understanding of Excel tabulation procedures
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- has an understanding of Excel tabulation procedures
- has good report writing skills
With practice a person’s ability to produce practical, reliable and useful reports will come quickly and the work will have a major influence on the direction of the Road Safety Unit.

It is important that the person carrying out the Special Study should avoid making judgments, expressing personal opinions and guessing. The report should only contain the facts as found in the investigation.

3.3 Basic practice

It is not possible to set out a step by step procedure that covers every eventuality. Most investigations require a separate, individual approach. Careful planning of each stage of the work is essential. If we can anticipate problems, difficulties and snags, we are more likely to make better progress. It is also likely that as the data is developed, opportunities will emerge which will result in a change direction and produce better results.

A routine study generally follows the stages as shown in Figure 3. Producing a special study.

3.4 Direction of the study

The object of this particular exercise is to identify the level of change in accident rates at groups of sites where similar measures have been carried out. The researcher will need help and assistance to keep the work moving in the right direction. It will be easy for the researcher to get side tracked or bogged down. It is strongly recommended that weekly working party meetings are set up. These meetings held at the beginning of the week, need not be time consuming, perhaps half an hour will be sufficient to cover the following points:

- progress made
- difficulties, problems encountered
- the next week’s plan
- direction of the report

It is suggested that the Head of the Road Safety Unit attends the meeting with one other person. Ideally the third person should have first hand experience of the study subject.
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Figure 3. Producing a special study
3.5 Preparation work

As soon as the subject for the study is agreed, the researcher should set out a proposed plan of action. This plan of action should identify the steps to be taken and all the information necessary to start the analysis, should be gathered. When the plan is agreed with the Head of the Road Safety Unit, the work can commence.

3.6 Data collection

Implementation dates are important to the accuracy of the report.

We need to know the month in which the work was finished, i.e.: the start of the ‘after period’. Note that it is quite common for the early months of a scheme to produce high numbers of accidents. This ‘high’ accident rate then settles down as the road user becomes more familiar with conditions.

The second detail that we need is the month in which the work commenced at the site. Accident rates increase during periods of road works and the implementation period must be ignored if we are to get a clear picture of what has happened in the ‘before and after’ periods.

To obtain these dates the researcher needs to contact the implementation agency as soon as possible. Obtaining replies can be difficult and if delays are creating a problem the matter should be taken up with the Head of the Road Safety Unit who should deal with the matter. The researcher should plan to carry out other tasks during this period but should closely monitor the progress of the replies and details coming back.

As soon as the implementation period for each location is identified we can select the ‘before’ and ‘after’ periods and submit the request for the accident data.

3.7 Selecting the study ‘before’ and ‘after’ periods

The ‘before’ and ‘after’ periods should be as long as possible. Three years ‘before’ compared with three years ‘after’ is ideal but may not be possible in the foreseeable future.

To avoid seasonal variations the researcher should use units of complete one year’s data.
3.5 **Preparation work**

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3.7 **Selecting the study ‘before’ and ‘after’ periods**

The ‘before’ and ‘after’ periods should be as long as possible. Three years ‘before’ compared with three years ‘after’ is ideal but may not be possible in the foreseeable future.

To avoid seasonal variations the researcher should use units of complete one year’s data.
3.5 Preparation work

As soon as the subject for the study is agreed, the researcher should set out a proposed plan of action. This plan of action should identify the steps to be taken and all the information necessary to start the analysis, should be gathered. When the plan is agreed with the Head of the Road Safety Unit, the work can commence.

3.6 Data collection

Implementation dates are important to the accuracy of the report.

We need to know the month in which the work was finished, i.e.: the start of the ‘after period’. Note that it is quite common for the early months of a scheme to produce high numbers of accidents. This ‘high’ accident rate then settles down as the road user becomes more familiar with conditions.

The second detail that we need is the month in which the work commenced at the site. Accident rates increase during periods of road works and the implementation period must be ignored if we are to get a clear picture of what has happened in the ‘before and after’ periods.

To obtain these dates the researcher needs to contact the implementation agency as soon as possible. Obtaining replies can be difficult and if delays are creating a problem the matter should be taken up with the Head of the Road Safety Unit who should deal with the matter. The researcher should plan to carry out other tasks during this period but should closely monitor the progress of the replies and details coming back.

As soon as the implementation period for each location is identified we can select the ‘before’ and ‘after’ periods and submit the request for the accident data.

3.7 Selecting the study ‘before’ and ‘after’ periods

The ‘before’ and ‘after’ periods should be as long as possible. Three years ‘before’ compared with three years ‘after’ is ideal but may not be possible in the foreseeable future.

To avoid seasonal variations the researcher should use units of complete one year’s data.
‘Before’ and ‘after’ accident data can be affected by a National trend in the number of accidents. For example, if accidents are increasing (or decreasing) by a consistent 5% per annum, accidents in the ‘before’ periods will be influenced by these trends. Procedure Note 7, Section 4.1 discusses the use of controls to compensate for these trends.

If implementation of the work has been carried out over a short period of time and we have access to reasonable controls, see Figure 4, it will not be difficult to select the ‘before’ and ‘after’ periods.

In the majority of cases implementation of the work will have been carried out over a relatively long period of time. If we use the periods immediately ‘before’ and immediately ‘after’ implementation we find that the ‘before’ and ‘after’ periods will overlap, Figure 5.
Figure 5. ‘Before’ and ‘after’ periods overlap

It is not possible to use controls

When this is the case we can aggregate the results and compare the ‘before’ and ‘after’ change but we cannot use controls.

Using controls increases the validity of any findings and we should make every effort to find a way use them. One possibility is, to extend the implementation period as shown in Figure 6.

Figure 6. ‘Before’ and ‘after’ periods overlap

By extending the implementation period the researcher can now use controls.

3.8 Carrying out the site inventory

Refer to Procedure Note 8 ‘Accident Studies in Bangladesh’, Section 4.1.

The details required will depend entirely on the subject of the study. If the subject is central barriers on National Roads in Bangladesh it will be important to identify:
Figure 5. ‘Before’ and ‘after’ periods overlap

It is not possible to use controls

When this is the case we can aggregate the results and compare the ‘before’ and ‘after’ change but we cannot use controls.

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Figure 6. ‘Before’ and ‘after’ periods overlap

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Refer to Procedure Note 8 ‘Accident Studies in Bangladesh’, Section 4.1.

The details required will depend entirely on the subject of the study. If the subject is central barriers on National Roads in Bangladesh it will be important to identify:
• the type of barrier installed on the route
• the location of gaps in the barriers
• the conditions and features along the route as set out in Procedure Note 8.

The best way to obtain this information is to travel in both directions and carry out a video recording of the route.
3.9 Coding the data

Spreadsheets have made analysis work much easier. By coding the site information and screening the accident details we will later be able to produce several variations and permutations of the data.

As soon as the MAAPfive accident sheets are received the researcher will sort into two groups all ‘before’ and all ‘after’ accident data, the two sets of data must be kept separate. The data should be marked as follows:

Site A - Name of site : Name of study : ‘BEFORE’ Period Accidents

Site B - Name of Site : Name of study : ‘AFTER’ Period Accidents

At this stage we need to anticipate the areas of change in accident type. If the study subject is relatively straight forward, for example, treatment at bends, the target accident group is quite obvious. If this programme led to the implementation of retro-reflective chevron boards, advance retro-reflective ‘bend ahead’ warning signs, thermoplastic hazard and edge of carriageway markings, we would expect to see a reduction in the number of single vehicle loss of control accidents and accidents occurring during the hours of darkness. We should select and code those accidents. Other subjects such as a study investigating the performance of central barriers will be more difficult. The researcher will identify the obvious group ‘head-on collisions’ but other groups will be more difficult. It is recommended that ‘before’ and ‘after’ data is reviewed to see if any changes stand out. The reviewer should then discuss and agree on the final selection of accident groups with the Head of the Road Safety Unit.

The numbers and severity of casualties in both the ‘before’ and ‘after’ periods should also be identified. It is conceivable that a number of accidents are reduced by a measure, but the nature of the accidents in the ‘after’ period have changed.

3.10 Assigning the data to the spreadsheets and running the first tabulations

As soon as the accident and site data is coded, the data can be assigned to the spreadsheets and tabulations can be prepared. If the study contains locations with high numbers of accidents and casualties, the researcher should consider using a separate
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As soon as the accident and site data is coded, the data can be assigned to the spreadsheets and tabulations can be prepared. If the study contains locations with high numbers of accidents and casualties, the researcher should consider using a separate
spreadsheet for each location and then transferring the totals to the Summary Sheets. See Figure 7. for an example of a typical summary spreadsheet.

This will produce the following summaries:

- a total of all accidents occurring at each site and all sites in the study
- individual totals of selected common types for each site and the total for all sites
- the total number of casualties in the groups, fatal, serious and simple injury

### 3.11 Developing the comparisons

The use of accident rates is often used to present data. For example, accidents per kilometer of highway for subjects dealing with route-wide treatment. If the amount of time in the ‘before’ period differs from the amount of time in the ‘after’ period, the researcher can use the accident rate per month to provide a like-with-like comparison.

By comparing the totals in the ‘before’ tabulation with the ‘after’ tabulation, the researcher will have now established the overall accident and casualty changes.

But what has been the effect of the measures on roads with a higher speed limit? Are the measures more effective in rural or urban areas? This and further detail can be extracted from the data by selecting and ‘before’ and ‘after’ data from similar groups of sites and preparing further spreadsheets. For example, by selecting from the inventory all sites in each of the various speed limit groups, say 50 mph and 30 mph, and assigning that data to separate spreadsheets, then a simple comparison can be made. If the inventory identifies urban and rural areas a similar comparison can be made.

As soon as the researcher and the Head of the Road Safety Unit are satisfied that the important points have been covered, the report can be compiled.
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As soon as the researcher and the Head of the Road Safety Unit are satisfied that the important points have been covered, the report can be compiled.
Figure 7. Summary spreadsheet

The totals of all site ‘before’ implementation accident data

*Note*: The designer of this summary sheet has anticipated the most relevant accidents. These are set out in a logical sequence, the degree of accident casualty, fatal grievous and simple injury. This is followed by the location of pedestrian accidents, vehicle involved in the accident and conditions prevailing at the time of the accident. The abbreviations used are as follows:

- Pedestrian at crossing (Pxg)
- Pedestrian on approach to crossing (Pap)
- Pedestrian exit from crossing (Pex)
- Single vehicle (Svl)
- Nose-to-tail (Ntl)
- Turning movement (Tm)
- Skidding (Skd)
- Truck (Trk)
- Private car (Pcr)
- Three wheel vehicle (Thr)
- Non-motorised vehicle (Nmv)
- Wet road surface (Wet)
- Darkness (Drk)

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<th>Site No.</th>
<th>Casualty</th>
<th>Total Accidents</th>
<th>Pxg</th>
<th>Pap</th>
<th>Pex</th>
<th>Svl</th>
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The totals of all site ‘before’ implementation accident data.
4. PREPARING THE REPORT

As stated in Procedure Note 8 (section 6.3), the report should be as short as possible, in other words keep it simple.

The following format is recommended:

Section 1: Introduction. Discuss the objectives of the report.

Section 2: Background. Any background information that will help the reader to understand the purpose of the study.

Section 3: Methodology. Discuss the method(s) used to prepare the report, analyse the data and deduce the findings.

Section 4: The findings. Set out the final tabulations and describe how each of the findings were deduced.

Section 5: Conclusions. Set out each of the conclusions arrived at during the preparation of the report and if applicable set out the recommended course of action.

Section 6: Appendix. The Appendix should contain any item that the reader may need.

The presentation of the report should follow the guidelines as set out in Procedure Note 7 (Section 6). If the reports are consistent, they will be easier for the occasional reader to follow.

4.1 Circulating the final report

When the final report is complete and the Head of the Road Safety Unit has agreed any final amendments, one copy of the report should be circulated to each member of the Road Safety Unit. This copy should be filed away in the Road Safety Unit library for future reference.

In house circulation, one copy should be submitted to each division within the organisation with a covering letter explaining the major points found in the work.
• one copy of the report should be sent to the National Road Safety Council
• one copy should be sent to each of the Heads of other Road Safety Units
• one copy should be sent to the officer responsible for road safety in each of the Zone offices
• one copy to a nominated officer at Bangladesh Road Transport Authority
• one copy sent to the Bangladesh Road Research Laboratory, and passed on for filing to the Road Safety Centre Library

Note: It is hoped by making the work freely available, we will benefit from research and analyses being carried out in other Road Safety Units.
Study into the effect on road accidents following implementation of road safety engineering measures carried out at bends on National Roads.

Prepared by
Road Safety Unit
Roads and Highways Department
Sarak Bhaban, Dhaka.

by
(Name of Author)

Figure 8. Recommended report front cover
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*Figure 9. Recommended contents page*
5. **EXAMPLES OF HOW SPECIAL STUDIES HAVE IMPROVED ROAD SAFETY ENGINEERING**

Special Studies have contributed much towards the understanding of the accident performance of new highway engineering methods and techniques. They allow the engineer to draw data-led conclusions. Two of many examples where they have assisted engineers in London are as follows:

5.1 **Road surface treatment**

One of the primary objectives of pavement design is to produce a road surface with a high level of skid resistance. Skid resistance of the pavement surface reduces considerably in wet conditions, particularly if this follows a long period of dry weather. Wet weather and skidding accidents are a problem in all countries. In many cases accident investigations find that wet and skidding accidents occur in groups and clusters. Site investigations frequently link the problem to polished or pavement wearing of a surface. The cost of resurfacing the area is likely to be prohibitive and difficult to justify.

In the early 1970s’ an anti-skid road surfacing material was developed and became available to engineers in Britain. The product consisting of fine chippings set into a resin base was easy to apply sprayed onto the existing road surface.

Tests showed that the material substantially improved the skid resistance of the carriageway. By improving the skid resistance, the vehicle stopping distance is reduced, and controllability of the vehicle is improved, particularly when the road is wet. The safety benefit was clear.

Several locations were treated with the material on a trial basis. The material proved to be practical with no obvious problems or inconvenience to the public. The first special studies indicated a substantial reduction in the number of accidents occurring on a wet road surface and accidents involving a vehicle skidding. This encouraged decision makers and it was decided to extend the programme. The second batch of sites were treated.

As soon as there was sufficient ‘after’ accident data, special study work confirmed the earlier findings. Accidents occurring on a wet road surface, those involving a vehicle
skidding, and accidents involving two vehicles, travelling in the same direction (nose-to-tail collisions) all reduced substantially following the implementation of the anti-skid material to the road surface. The investigations looked closely for evidence of an increase in ‘other’ accident types. *Did application of the material create an accident problem?*
There was no evidence in the data to support this.

Further more detailed studies examined the performance of anti-skid material at:

- traffic signal controlled junctions
- roundabouts
- bends
- uncontrolled pedestrian crossings; and
- signal controlled pedestrian crossings

A comprehensive picture then emerged, for example it was then possible to find:

- the optimum length of anti-skid material to lay onto the approach road to a junction, a pedestrian crossing or a bend
- if the efficiency of the material fell away over time, does traffic wear the material down to a stage when it is no longer effective?
- does the material produce the same results on 30mph, 40mph and 50mph roads?

The studies consistently showed that the material reduced the number of wet road surface accidents by over 60%. This helped engineers to forecast accident savings at sites with a problem of wet road accidents. The Road Safety Unit had an annual financial budget, which was low and could not be exceeded. The cost of a personal injury accident, the amount of anti-skid material required, and the cost per m² were all known. This enabled the engineers to prepare specifications, carry out simple cost benefit calculations and select the sites that would produce the best value for money.

The Special Study reports were circulated to traffic engineering design teams and this information was used to improve the road surface specification at new traffic signal installations, controlled and uncontrolled crossings.
5.2 Traffic signal specifications and signal timings

Traffic signal design in London is another area that has benefited from the use of special studies. Traffic signals are installed to manage high volumes of conflicting traffic. However cross-road accidents have always been a feature of accidents at signal controlled junctions. Cross-road accidents occur for one of two reasons. Either the driver does not see the red signal in time to stop, or the signal changes to red and a driver on the final approach, decides to take a chance and run the red signal resulting in a collision with a vehicle moving out from the side road.

High Intensity signals were introduced in London in the early 1970s’. High Intensity signals incorporate a bright lens in the signal head. The traffic signal aspect is now brighter and more conspicuous to drivers of oncoming vehicles. The implementation of these signals led to a notable reduction in the number of cross-road accidents, but the number of cross-road accidents remained at an unacceptably high level. It was considered that the major problem was drivers taking a chance by running the early stage of the red signal, amber gambling or red light running.

Publicity campaigns alerting drivers to the problem made little impression. Cross-road accidents continued and it was decided that the next stage would be to extend the inter-green period at problem locations. Note the inter-green period is the amount of time taken from the closing down of the green signal to traffic on one approach, to the start of the green signal to traffic of the second arm. The inter-green period is designed to allow traffic to clear the junction between signal stages. At that time traffic signals would usually be set with 3 or 4 seconds clearance or inter-green. By extending the inter-green period by two seconds, the errant driver would have extra time to clear the junction before the side road traffic commences.

Researchers then identified and listed the sites with the highest number of cross-road accidents.

They looked closer at the detail, time of day, and day of the week of the accident. It was realised that at some sites the accidents predominated in the evening, early mornings or at weekends (when the roads are less busy): At other sites the problem was more general.
This made it possible to improve the specification to the Signals Unit engineers. A 24 hour extended inter-green period was specified at sites where the problem was general, and the inter-green period was extended at nighttime or at weekends at sites where the problem existed at those times, thus avoiding the possibility of congestion problems at those sites.

It is relatively easy to change signal timings. The signal engineer either carries out the adjustment at the site by changing the mechanism in the control box unit or alters the signal plans. The implementation of the programme was carried out quickly and at very little cost. Accidents at the implemented sites were closely monitored, and it was soon clear that the measure was producing a distinct reduction in the rate of target accidents. As more ‘after’ implementation period data became available, it became possible to show that the reduction was significant and that there was no adverse affect in other accident groups.

This proposal was slightly controversial in that several of the proposed junctions were running at capacity and that the two seconds per cycle lost running time would increase queue lengths and add to traffic delays.

The programme commenced and the sites where the inter-green period was extended were closely monitored for accident rates. Special studies were soon able to demonstrate that the programme was successful, the number of cross-road accidents in the target group fell and no obvious accident problems were discovered in the ‘after’ period accidents.

For an example of a well constructed Special Study refer to Appendix A. THE EFFECT OF MEASURES DESIGNED TO REDUCE RIGHT-TURNING ACCIDENTS AT SIGNAL CONTROLLED JUNCTIONS
APPENDIX A

THE EFFECT OF MEASURES DESIGNED TO REDUCE RIGHT-TURNING ACCIDENTS AT SIGNAL CONTROLLED JUNCTIONS

A good example of a well constructed study that was used by many engineers at the decision making stage. The report enabled road safety engineers and designers to select the most suitable option for each particular problem.

We are grateful to John Devenport at the London Research Centre (LRC), London Accident Analysis Unit (LAAU), Environment and Transport Studies, 81 Black Prince Road, London SE1 7SZ for permission to reproduce this report.
THE EFFECT OF MEASURES DESIGNED TO REDUCE RIGHT-TURNING ACCIDENTS AT SIGNAL CONTROLLED JUNCTIONS

This study contains an analysis of the before and after accident records of twenty-eight signal controlled junctions (ATS sites) in the Greater London area each of which has been treated with one of four remedial measures designed to reduce right-turning accidents.

These measures were the early cut-off of one of two opposing traffic flows, the holding on a red signal of a right-turning flow which benefits from an early cut-off, the conversion of a two-phase junction to a split-phase method of control, and the repositioning of the central detector loop at sites with an early cut-off closer to the centre of the junction in order to ensure that the right-turn phase is called on each occasion.

The results of the study indicate that the application of one of these measures is likely to result in a fall in right-turning accidents on the arm(s) benefiting from the remedial measure of between 18% and 90%, and a significant fall in all right-turning accidents of between 33% and 73%. Pedestrian accidents, however, may be adversely effected.

Report by A. G. Simmonds
L.A.A.U. / H18F
March 1987
Report ATWP 84
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Appendix A : Examples of Phasing, etc., Studies in this Report.
Appendix B : Peak-Hour Traffic Flows (Vehicles per Hour)

Note : In the interests of brevity Tables 1.1 to 4.9 (Accident Totals and Rates for each site) and Appendices C to G (Location of Sites, etc.) have been included in a separate appendix to this report which may be obtained from the London Accident Analysis Unit, Telephone 01-633-8591 or 01-633-6850.
1. **AIM**

The aim of this study is to investigate the before and after accident records of ATS sites where a measure to reduce right-turning accidents has been introduced on road safety grounds.

Four remedial measures have been considered :-

i) Early Cut-Off (ECO), mostly two-phase, four-arm junctions.

ii) Right-Turn Held on Red (RTHR), added to a junction with an early cut-off, all but one at three arm junctions.

iii) Two-Phase to Split-Phase, all at four-arm junctions.

iv) Repositioned Central Detector Loop (RCDL), at sites with an early cut-off.

Diagrammatic examples of the above changes in phasing may be found in Appendix A and some examples of peak-hour traffic flows before the implementation of the above measures in Appendix B.

2. **SITE SELECTION**

This report deals with 28 sites in Greater London. By 1 April, 1986, the then GLC Road Safety Unit had arranged the implementation of over 2,000 accident remedial schemes in the Greater London area, over 500 of which involved work on traffic signals (ATS). Of those 500 nearly 80 involved either changing the phasing or moving a central detector loop but, for a variety of reasons usually concerned with the implementation of other schemes at the same site, no more than 28 were suitable for inclusion in this study.

A history of each of the sites inevitably indicated that a variety of other measures had been carried out in conjunction with those being studied or during the before and after periods under consideration. In order, therefore, to maximise the available data the sites were divided into two categories. The first was purist in its selection and included, apart from the measure being studied, only those measures which, it was thought, would either not have a major effect on accidents and/or might well be carried out as part of a general site improvement, i.e., high-intensity signals. The second, or ‘impure’, category included such measures as port-to-port turns, banned turns or the provision of a pedestrian facility.
Despite the method of selection the number of sites in each remedial group remained low, the actual numbers available for analysis being as follows :-

i) Two-Phase to ECO, 5 pure, 1 impure.
ii) ECO to RTHR, 9 pure, 1 impure.
iii) Two-Phase to Split-Phase, 5 pure, 3 impure.
iv) Repositioned Central Detector Loop, 4 pure.

For the purposes of this report the ‘pure’ sites were analysed separately and then all the sites in each remedial group, ‘pure’ and ‘impure’, together.

There were insufficient Two-Phase to RTHR or ECO to Split-Phase sites to warrant analysis.

Appendices C to G give details of the sites selected.

3. ACCIDENT DATA

Before and after accident data were obtained for each site. The amount of data available varied depending on the date, or dates, when the particular measure was applied, the date when any further measure was implemented at the same site, and a study ‘closing date’ of November 1985.

Accidents in each remedial group were sub-divided into nine categories and analysed accordingly. The categories of accident analysed were ‘all’, pedestrian, non-pedestrian, right-turning, right-turning with the overlap or split-phase, powered two-wheeler, pedal cycle, peak and off-peak.

4. RESULTS

A summary of before and after accident totals, monthly rates and the percentage change for each of the four remedial groups in the study is to be found in Summary Tables 11.1 - 11.4. Separate data for each of the 28 individual sites can be found in Tables 1.1 to 4.9 in the appendix to the main report, which is available on request.
It should be noted that the percentage changes in each table allow for control trends and are not straightforward changes in before and after accident rates. The analysis does not include any estimate of the effects of regression to mean.

5. ACCIDENT ANALYSIS

The method of statistical analysis used in this report is presented in section 9 below.

5.1 Accident rates

The average ‘all accident’ rates for signal controlled junctions on London’s Trunk, Principal (using pre-abolition traffic authority definitions) and all roads between 1983 and 1985 were 7.14, 4.83 and 4.83 accidents per site per annum respectively. The before ‘all accident’ rates for the four remedial groups were all above average (see Table A). As one would expect, given the selection of sites and the proportion of right-turning flows as indicated in Appendix B, they were particularly high for right-turning accidents (London average of 1.25 accidents per site per annum (ASA) at signal controlled junctions).

The amount of pedestrian activity varies between the sites, but the before average pedestrian accident rate is not much in excess of the London-wide average of 1.44 ASA at signal controlled junctions. It is worth noting that three of the four RCDL sites are on trunk roads. Of the 28 sites, in fact, 5 are on trunk, 21 on principal and 2 on non-principal roads (using pre-abolition traffic authority definitions).

5.2 All accidents

Table A shows that all four measures were effective in reducing total accidents at ‘pure’ sites by between 19% and 41%, although the change effected by the RTHR was not statistically significant. These reductions in total accidents came about primarily as a result of the obviously high proportion of right-turning accidents and the effectiveness of the measures in reducing them.
Table A: Summary of results (pure sites)

ASA = Accidents per Site per Annum during before period
NS = Not significant at the 10% level or better

Note: In the right-turning category ‘overlap’ includes split-phase.

5.3 Non-pedestrian accidents

All remedial groups showed falls in non-pedestrian accidents in excess of 31%, but the improvement effected by the ECO was not statistically significant.

5.4 Pedestrian accidents

Table A shows that, with the exception of the two-phase to split-phase group, pedestrians were adversely effected by the introduction of these measures. In the case of the RTHR group there was a significant increase of 58%, and there were non-significant increases of 12% and 7% recorded in the ECO and BCDL groups respectively. The exception to these increases, a fall of 9%, was recorded in the two-phase to split-phase group.

Given these results a more detailed analysis of pedestrian accidents was carried out on all ten sites in the RTHR group, i.e., the nine ‘pure’ sites plus the one ‘impure’ site.

Table B shows the location of pedestrian accidents at RTHR sites using the notation given to each traffic lane of a four-arm junction in order to facilitate the easy analysis of accidents.

Figure 1 shows the same in diagrammatic form.
In the case of three-arm junctions, which constitute 9 of the 10 RTHR sites, lanes BO and BI are omitted.

<table>
<thead>
<tr>
<th>Lane(s)</th>
<th>Accidents</th>
<th>Change (%)</th>
<th>T Value</th>
<th>Sig.</th>
<th>Chi-Squared Value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before 4</td>
<td>After 2</td>
<td>-41.04</td>
<td>0.63</td>
<td>NS</td>
<td>1.39</td>
</tr>
<tr>
<td>AO(2)</td>
<td>8</td>
<td>16</td>
<td>+135.85</td>
<td>1.98</td>
<td>5%</td>
<td>7.88</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BO(3)</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BI(3)</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>21</td>
<td>+253.78</td>
<td>2.50</td>
<td>2%</td>
<td>2.89</td>
</tr>
<tr>
<td>CI(4)</td>
<td>16</td>
<td>15</td>
<td>+10.56</td>
<td>0.01</td>
<td>NS</td>
<td>2.43</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5</td>
<td>-1.73</td>
<td>0.14</td>
<td>NS</td>
<td>2.54</td>
</tr>
<tr>
<td>DO</td>
<td>13</td>
<td>10</td>
<td>-9.29</td>
<td>0.34</td>
<td>NS</td>
<td>11.96</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td>69</td>
<td>+50.68</td>
<td>1.84</td>
<td>10%</td>
<td>5.96</td>
</tr>
</tbody>
</table>

Table B. Location of pedestrian accidents at early cut-off to right-turn held on red sites (all sites)(1)

(1) = All three-arm with one exception  
(2) = Approach with right-turn held on red (RTHR)  
(3) = One site only (‘impure’)  
(4) = Approach with early cut-off  
NS = Not significant at the 10% level or better
Figure 1. Location of pedestrian accidents at RTHR sites

AI = Approach with RTHR
CI = Approach with ECO
I = Flow into the junction
O = Flow out of the junction
(i) = One impure site only. No accidents before or after.

When pedestrian accidents at RTHR sites are analysed by location it can be seen that pedestrians in the AI lane, i.e., the one on which the RTHR operates and the one which benefits from the ECO, were adversely effected to a significant degree by the introduction of the RTHR (see Table B).

Pedestrians were also significantly disadvantaged in the CO lane, the one directly opposite the AI lane and the one into which straight-ahead AI traffic directly flows.

If the accidents in the AI and CO lanes are added together, i.e., 15 before and 37 after, after allowing for controls, the result is an increase of 190.89%, significant at the 0.1% level or better.
If the pedestrian’s direction of travel is considered there appears to have been a very large and significant increase in accidents in lane AI involving pedestrians crossing to the other side of the road (AI to AO), i.e., across the approach with the RTHR first (+332.40%, significant at the 2% level or better.)

There also appears to have been a large and significant increase in accidents in lane CO involving pedestrians crossing to the other side of the road (CO to CI) (+371.71%, significant at the 5% level or better).

If the accidents involving the above two pedestrian movements (AI to AO in lane AI and CO to CI in lane CO) are added together there was an increase of 352.05%, significant at the 0.1% level or better.

The above results, however, should be treated with some degree of caution as it is sometimes very difficult to establish the exact location and direction of travel of an injured pedestrian from the accident data. When using pre-1982 accident data, for instance, it is often unclear as to which arm of the junction the accident occurred on. For example, using the notation for a three-arm junction shown in Figure 1 and assuming north is at the top of the page, if a vehicle is coded as travelling north to south on a road with the same name throughout and a pedestrian is coded as crossing from East to West it is unclear whether to assign the accident to AI or CO. In addition, whereas the reported direction of travel of a vehicle may be considered as being reliable the same cannot always be said for that of a pedestrian.

Caution is also required in interpreting significance levels when substantial numbers of sub-groups have been tested. In such cases it becomes much more probable that a result which is due to random fluctuation will be encountered. It is important, therefore, that a greater degree of significance is demanded for a given level of confidence in the sub-groups of pedestrian accidents discussed above.

Nevertheless, despite these cautionary comments, the apparent increases are of sufficient magnitude to be a cause for concern.

5.5 Right-turning accidents

Right-turning accidents fell significantly by between one-third (at RCDL sites) and 73% (at two-phase to split-phase sites).
The number of right-turning accidents occurring on the approaches with the advantage of the overlap/split-phase fell by between 18% and 90%, significantly at RTHR and two-phase to split-phase sites. In the case of the ECO group, however, the non-significant reduction of 18% was only half that for right-turning accidents generally instead of being superior as in the other three groups.

Table C shows right-turning accidents in each remedial group broken down by right-turning movement using the notation shown in Table B and Figure 1 above.

Apart from those on the AI arm, which is the right-turn with the overlap or split-phase (AI+CI in the latter case), the only other significant change occurred on the BI arm in the two-phase to split-phase group where right-turning accidents fell by 79%, significant at the 10% level. There is no obvious explanation for this fall.

<table>
<thead>
<tr>
<th>Remedial Measure</th>
<th>Right-Turning Movement</th>
<th>AI (1)</th>
<th>CI (2)</th>
<th>BI</th>
<th>DI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-Phase to ECO</td>
<td>Before/After (1)</td>
<td>+34</td>
<td>24</td>
<td>7</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Change (%) / Sig (%)</td>
<td>-18</td>
<td>NS</td>
<td>-50</td>
<td>NS</td>
<td>-79</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECO to RTHR</td>
<td>Before/After (3)</td>
<td>115</td>
<td>21</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Change (%) / Sig (%)</td>
<td>-79</td>
<td>0.1</td>
<td></td>
<td></td>
<td>+26</td>
</tr>
<tr>
<td>Two-Phase to Split-Phase</td>
<td>Before/After (4)</td>
<td>59</td>
<td>5</td>
<td>11</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Change (%) / Sig (%)</td>
<td>-90</td>
<td>0.1</td>
<td>-47</td>
<td>NS</td>
<td>+3</td>
</tr>
<tr>
<td>Repositioned Central Detector Loop (5)</td>
<td>Before/After</td>
<td>59</td>
<td>35</td>
<td>9</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Change (%) / Sig (%)</td>
<td>-36</td>
<td>NS</td>
<td>-28</td>
<td>NS</td>
<td>-7</td>
</tr>
</tbody>
</table>

Table C : Right-turning accidents by remedial measure and right-turning movement (pure sites)

(1) Approach which benefits from the ECO and has the RTHR. One of the two split-phase lanes.
(2) Approach with the ECO. The second split-phase lane.
(3) All of the sites in this group are 3-arm only. Consequently there are only two right-turns possible, AI and DI.
(4) AI and CI combined.
(5) There are no ‘impure’ sites in this group.
5.6 Peak and off-peak accidents

Significant reductions were achieved in off-peak accidents in the RTHR, two-phase to split-phase and RCDL remedial groups. There was a non-significant increase of 8% in peak accidents in the RTHR group. At the RCDL sites there was a non-significant fall of 34% in accidents during the peak, but a significant one of 22% during the off-peak period. At ECO sites the improvement was greater during the peak period when this facility is most likely to be called.

5.7 Powered two-wheeler and pedal cycle accidents

No conclusions can be drawn as to the effect of the measures on accidents involving powered-two wheelers or pedal cycles. The lack of significance in these results may be due to the small amount of data, particularly for cyclists which are involved in only about 8% of the accidents.

5.8 Pure and impure sites

With the solitary exception of the right-turning category in the two-phase to ECO group the addition, where possible, of the ‘impure’ sites to the analysis, had no substantial effect in terms of significance levels. However, in three cases the addition of these sites resulted in an increased level of significance (see Summary Tables 11.1 to 11.3 below).

6. DESIGN MODIFICATIONS

At two of the sites design modifications were carried out in an attempt to further reduce total accidents, and in the case of the AAA site to reduce pedestrian accidents which had increased as a result of the initial scheme.

6.1 AAA South Side / BBB (ECO to RTHR Site 3)

The RTHR facility was introduced at this site in March 1976 (1). Monitoring the results of this first scheme revealed that, along with a significant fall of 49% in the total number
of accidents, including a significant 100% fall in right-turning accidents, there was a worrying 42% increase in pedestrian accidents. As a result of further analysis of the accidents the junction was redesigned in July 1983 so that the right-turning traffic held by the red phase was channelised into two lanes and segregated from the two straight-ahead lanes by a refuge (2). None of the other analysed ECO to RTHR sites had similar channelisation. Table D shows the effect of these measures at this site.

<table>
<thead>
<tr>
<th>Accident Category</th>
<th>Before 1</th>
<th>After 1</th>
<th>Before 2</th>
<th>After 2</th>
<th>Before 1</th>
<th>After 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acc</td>
<td>Cha (%)</td>
<td>Acc</td>
<td>Cha (%)</td>
<td>Acc</td>
<td>Cha (%)</td>
</tr>
<tr>
<td>All</td>
<td>37</td>
<td>-49</td>
<td>26</td>
<td>-25</td>
<td>37</td>
<td>-47</td>
</tr>
<tr>
<td>Ped'n</td>
<td>8</td>
<td>+42</td>
<td>NS</td>
<td>NS</td>
<td>8</td>
<td>-26</td>
</tr>
<tr>
<td>Non-Ped.</td>
<td>29</td>
<td>-74</td>
<td>15</td>
<td>-10</td>
<td>29</td>
<td>-53</td>
</tr>
<tr>
<td>R. Turn'g</td>
<td>23</td>
<td>-100</td>
<td>3</td>
<td>+93</td>
<td>23</td>
<td>-75</td>
</tr>
<tr>
<td>RT + O/L</td>
<td>22</td>
<td>-100</td>
<td>2</td>
<td>+16</td>
<td>22</td>
<td>-89</td>
</tr>
<tr>
<td>P'd-Two</td>
<td>10</td>
<td>-92</td>
<td>5</td>
<td>-4</td>
<td>10</td>
<td>-59</td>
</tr>
<tr>
<td>P. Cycle</td>
<td>0</td>
<td>(+)</td>
<td>NS</td>
<td>+280</td>
<td>0</td>
<td>(+)</td>
</tr>
<tr>
<td>Peak</td>
<td>7</td>
<td>+4</td>
<td>NS</td>
<td>+45</td>
<td>7</td>
<td>+41</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>30</td>
<td>-57</td>
<td>19</td>
<td>-57</td>
<td>30</td>
<td>-67</td>
</tr>
</tbody>
</table>

Table D: Summary of results at AAA South Side / BBB

Note: The after 2 period was of 28 months only. All other ‘before’ and ‘after’ periods were of 36 months

NS = Not significant at the 10% level or better
(+) = Infinite increase

The second scheme resulted in a further non-significant fall of 25% in total accidents and a 48% reduction in pedestrian accidents.

Overall, the introduction of the above measures at this site resulted in a fall of 47% in total accidents, significant at the 5% level, a 75% significant reduction in right-turning accidents and a 26% reduction in pedestrian accidents.

Whilst both schemes were effective in reducing total accidents the first resulted in an increase in pedestrian accidents, but the second, whilst still retaining most of the benefits achieved by the first, reduced both pedestrian and non-pedestrian accidents.
6.2 CCC / DDD (Two-Phase to Split-Phase Site 5)

This junction was converted from a two-phase to a split-phase method of control, in favour of north and southbound traffic, in July 1980 (1). Three years later, in July 1983, a split-phase method of control was also introduced on DDD in favour of east and westbound traffic (2). Table E shows the effect of both of these measures at this site.

<table>
<thead>
<tr>
<th>Accident Category</th>
<th>Before 1</th>
<th>After 1</th>
<th>Before 2</th>
<th>After 2</th>
<th>Before 1</th>
<th>After 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acc</td>
<td>Cha (%)</td>
<td>Acc</td>
<td>Cha (%)</td>
<td>Acc</td>
<td>Cha (%)</td>
</tr>
<tr>
<td>All</td>
<td>21</td>
<td>18</td>
<td>18</td>
<td>6</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>Ped'n</td>
<td>3</td>
<td>0</td>
<td>-100</td>
<td>NS</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Non-Ped</td>
<td>18</td>
<td>18</td>
<td>+17</td>
<td>NS</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>RT + S/P</td>
<td>13</td>
<td>5</td>
<td>-48</td>
<td>NS</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>RT Turn'g</td>
<td>7</td>
<td>0</td>
<td>-100</td>
<td>10%</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>P'd-Two</td>
<td>5</td>
<td>6</td>
<td>+49</td>
<td>NS</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>P. Cycle</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Peak</td>
<td>1</td>
<td>3</td>
<td>+238</td>
<td>NS</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>20</td>
<td>15</td>
<td>+2</td>
<td>NS</td>
<td>15</td>
<td>3</td>
</tr>
</tbody>
</table>

Table E. Summary of results at CCC / DDD

Note: The before 1 period was of 36 months, the after 1 before 2 period 35 months and the after 2 period 28 months.

NS = Not significant at the 10% level or better
(+ ) = Infinite increase

The table shows that, with the exception of the right-turning with split-phase category, which showed a fall from 7 accidents to 0 significant at the 10% level, the introduction of the north and southbound split-phase at CCC had no significant effect on accidents.

The addition of the split-phase on DDD, which gave the junction a four-phase method of control, however, resulted in significant falls in all, non-pedestrian and off-peak accidents. Apart from right-turning accidents, which fell from 5 to 1 (5 to 0 with the split-phase), there were falls in cross-road type accidents (from 6 to 1) and shunt or similar accidents (from 4 to 1). Overall, i.e., before 1 after 2, there were significant falls in all, non-pedestrian, right-turning and off-peak accidents.

It should be noted that the right-turning with split-phase category applies only to north or southbound traffic in the Before 1 – After 1 situation and only to east or westbound traffic in the Before 2 – After 2 situation. The solitary right-turning accident in the After
2 situation involved a northbound vehicle turning east. No separate analysis of this category was carried out for the Before 1 – After 2 situation as, by then, all right-turning traffic had the advantage of the split-phase.

6.3 Discussion

The simple problem for pedestrians with an early cut-off signalling system is that, although there are periods in the signal’s cycle when a particular phase is running, one of the movements which pedestrians, and to a lesser extent drivers / riders, might expect to be associated with that phase has, in fact, been stopped. Typically, traffic may be continuing to flow north-south whereas the south-north traffic has been stopped. In these circumstances pedestrians may see the stopped traffic, but fail to realise that the other half of the road is occupied by moving, and often fast moving, traffic.

This problem is made less clear and more dangerous for pedestrians by the conversion of ECO sites to RTHR, where one turning flow is stopped, but where there is continuing straight-ahead traffic from the same approach.

Analysis of the AAA site indicates that while there are clearly problems for pedestrians when converting ECO sites to RTHR these may be reduced by careful consideration of the existing pedestrian movements and accidents, particularly those involving the arm which benefits from the ECO. Further study will be needed to establish how effective the provision of measures which remove some of the ambiguity that pedestrians face at such locations are in reducing the number of pedestrian accidents. These measures include the provision of a pedestrian phase, repositioning secondary signals, the provision of pedestrian refuges and additional signs for pedestrians.

However effective such amendments to the design might be, engineers will need to pay particular attention to pedestrians when considering the conversion of an ECO to a RTHR.
7. SUMMARY

(i) Primarily as a result of the high proportion of right-turning accidents and the effectiveness of the measures in reducing these accidents, the four measures studied were effective in reducing total accidents by between 19% and 41% at ‘pure’ sites. With the exception of the RTHR facility all of these reductions were significant.

(ii) Right-turning accidents were significantly reduced by all four measures by between one-third and 73%. The approaches which benefitted from the overlap or split-phase experienced reductions of between 18% and 90%, but in the case of the ECO group the reduction was only half that for all right-turning accidents.

(iii) Statistically significant reductions were achieved in off-peak accidents in three remedial groups, but at two-phase to ECO sites the greater improvement was achieved during the peak period, when the facility is more likely to be called.

(iv) Pedestrian accidents would appear to have been adversely effected by the introduction of all but the split-phase, the most worrying result being the statistically significant 58% increase at sites changed from ECO to RTHR.

(v) Pedestrians crossing both the lane which benefitted from the RTHR (AI) and the lane into which the AI traffic directly flows (CO) were adversely effected to a significant degree by the introduction of the RTHR, in particular if they were crossing to the other side of the road, i.e., across lanes AI or CO first.

(vi) Improved vehicle channelisation and the provision of a pedestrian refuge between the right-turning and straight-ahead lanes over and above the original conversion from an ECO to a RTHR at AAA South Side / BBB resulted in a further reduction in total accidents and a 48% reduction in pedestrian accidents. Overall, the implementation of the two schemes achieved a significant reduction of 47% in total accidents and a 26% decrease in pedestrian accidents.

(vii) The introduction of a second split-phase facility at the CCC / DDD site, which gave the junction a four-phase method of control, resulted in significant falls in all, non-pedestrian, right-turning and off-peak accidents.

8. CONCLUSIONS

The results of this study indicate that the application of any of the four measures considered in this report is likely to result in a, possibly significant, fall in right-turning accidents on the arms receiving the benefit of the remedial measure of between 18% and 90%, with total right-turning accidents falling significantly by between 33% and 73%.
The other category of accident most likely to be reduced by one of these measures is off-peak accidents.

With the exception of the split-phase, however, pedestrians may be adversely affected by the introduction of these measures. In the case of the RTHR a significant increase in pedestrian accidents of nearly 60% was observed, with particular problems for pedestrians crossing the approach with the RTHR and the lane directly opposite.

Further work is needed to establish how the increase in pedestrian accidents associated with the introduction of a RTHR is related to levels of pedestrian activity and if it can be reduced, or reversed, by changes in design.

9. STATISTICAL ANALYSIS

There is some difficulty in attempting to combine accident data from several different test sites when the before and after periods are not the same in each case. The method of analysis used in this report is based on a method devised by J.C. Tanner (1) which provides a means of combining accident data from several sites. This method, however, has some residual difficulties which have not yet been fully resolved.

Two parameters were used to test the accident data:

T tested the overall effect of measures implemented at the test sites. The T test used is more normally distributed than the student’s t test and is a double sided test with a 5% significance level of 1.96 unrestricted by degrees of freedom.

Chi$^2$ tested the variation of individual site group trends against the overall trend (*). A significant value of Chi squared indicates that the effect of the measures at individual groups of sites varied significantly from the overall trend. (* For the purpose of statistically testing the data against overall control trends, sites in each borough were aggregated and compared to the relevant accident trends in the respective borough.)

For the purpose of this study, the control figures used were the appropriate type of accident in the borough concerned.
Significance levels of 10% or better quoted in this report. Results with significance levels of 10%, however, should only be considered as indicative, greater significance levels, i.e., 5% or better, normally being required to indicate positive change. In some cases the low level of significance, or the back of it, may be due to the small amount of data considered. Additional sites, or longer time periods, could result in greater significance being achieved.

Caution is also required in interpreting significance levels when substantial numbers of sub-groups have been tested. In such cases it becomes much more probable that a result which is due to random fluctuation will be encountered. It is important, therefore, that a greater degree of significance is demanded for a given level of confidence when large numbers of data sub-sets are involved.

10. REFERENCES

1. Problem in the Combination of Accident Frequencies’ by J.C. Tanner, Biometrika, Volume 45, Parts 3 and 4, pages 331-342.
11. SUMMARY TABLES

11.1 Two-Phase to ECO

11.1.1 Sites 1-5 (pure sites)

<table>
<thead>
<tr>
<th>Accident Category</th>
<th>Table</th>
<th>Accidents In Study</th>
<th>Accident Rate Per Month</th>
<th>% Change</th>
<th>T</th>
<th>Chi-Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td>Value</td>
</tr>
<tr>
<td>All</td>
<td>1.1</td>
<td>122</td>
<td>73</td>
<td>0.68</td>
<td>0.48</td>
<td>-24.24</td>
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<tr>
<td>Pedestrian</td>
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<td>28</td>
<td>21</td>
<td>0.16</td>
<td>0.14</td>
<td>+11.74</td>
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<tr>
<td>Non-Pedestrian</td>
<td>1.3</td>
<td>94</td>
<td>52</td>
<td>0.52</td>
<td>0.34</td>
<td>-33.57</td>
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<td>Right-Turning</td>
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<td>33</td>
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<td>0.22</td>
<td>-36.49</td>
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<td>R/T with Overlap</td>
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<td>24</td>
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<td>0.16</td>
<td>-18.49</td>
</tr>
<tr>
<td>Powered-Two Pedal Cycle</td>
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<td>11</td>
<td>0.08</td>
<td>0.07</td>
<td>+12.95</td>
</tr>
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NS = Not Significant

11.1.2 Sites 1-6 (all sites)

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NS = Not Significant
11.2  ECO to RTHR

11.2.1  Sites 1-9 (pure sites)

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NS = Not Significant

11.2.2  Sites 1-10 (all sites)

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NS = Not Significant
11.3 Two-Phase to Split-Phase

11.3.1 Sites 1-5 (pure sites)

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NS = Not Significant

11.3.2 Sites 1-8 (all sites)

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<th>T</th>
<th>Chi-Squared</th>
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NS = Not Significant
11.4 Repositioned central detector loop

11.4.1 Sites 1-4 (pure sites) (1)

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<th>Sig.</th>
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</table>

(1) There are no ‘impure’ sites in this remedial group.
NS = Not Significant
Appendix A: Examples of phasing etc., studied in this report

2 Phase to Early Cut-Off

Before

After

20
Early cut-off to right-turn held on red (all the sites except one are 3 arm)

Before

After
2 Phase to Split-Phase

Before

After

Repositioned Central Detector Loop

Loop
Appendix B : Peak-Hour Traffic Flows (Vehicles Per Hour)

<table>
<thead>
<tr>
<th>Remedial Measure / Borough</th>
<th>Site No.</th>
<th>Site Location (Main Rd)</th>
<th>Peak (AM) or (PM)</th>
<th>Total Flow On Arm With Facility</th>
<th>Right-Turn Flow On Arm With Facility</th>
<th>% Right-Turn</th>
<th>Straight-Ahead Flow On Opposite Arm</th>
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<td>EEE</td>
<td>AM</td>
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<td>PM</td>
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<td>23.6</td>
<td>1,242</td>
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<tr>
<td></td>
<td>XXX</td>
<td>PPP</td>
<td>AM</td>
<td>2,062</td>
<td>142</td>
<td>6.9</td>
<td>1,094</td>
</tr>
<tr>
<td></td>
<td>XXX</td>
<td>PPP</td>
<td>PM</td>
<td>1,560</td>
<td>202</td>
<td>12.9</td>
<td>1,596</td>
</tr>
<tr>
<td>Repositioned Central Detector Loop</td>
<td>Richmond-Upon-Thames</td>
<td>Twickenham Road</td>
<td>AM</td>
<td>1,190</td>
<td>554</td>
<td>46.6</td>
<td>520</td>
</tr>
<tr>
<td></td>
<td>Richmond-Upon-Thames</td>
<td>Twickenham Road</td>
<td>PM</td>
<td>814</td>
<td>281</td>
<td>34.5</td>
<td>684</td>
</tr>
</tbody>
</table>

Note: Peak = the highest hourly flow during the period in question. In some cases the data presented is the only data available for that particular site.

NRT = No Right Turn
T-JUNCTION - TYPE A (COMPOUND CURVE)
Recommended for all junctions used frequently by buses and long vehicles

COMPOUND CURVE RATIOS
R1 : R2 : R3 = 2.5 : 1 : 5.5 = 30m : 12m : 66m

VISIBILITY STANDARDS
SHOULDER

T-JUNCTION - TYPE B (CIRCULAR CURVE)
Recommended for minor junctions not used frequently by buses. Corner radius may be reduced to 8m for lightly- trafficked roads and private accesses joining a road with a carriageway width ≥ 7m. May be further reduced to 6m if only used by car/utility vehicle.

X is normally 9m but may be reduced to 4.5m for lightly- trafficked simple junctions.

MAJOR ROAD DESIGN SPEED  Y DISTANCE
50 km/h  70
60 km/h  90
70 km/h  120
80 km/h  150

Providing more space than this may make the junction less safe as it will encourage high approach speeds

NOTES:
1. Crossroads are dangerous and must not be used. Staggered T-junctions are much safer.
2. The simple T-junctions shown on this sheet are suitable for most minor junctions on single carriageway roads.
3. The paved area should be kept to a minimum, consistent with the design advice. Large expanses of pavement without markings and channelising islands are confusing and encourage unsafe speeds.
4. The minor road should meet the major road at an angle of 90°. In difficult circumstances angles of between 80° and 100° are permissible.
5. The junction should be on level ground. The minor road approach should be level for a distance of at least 15m from the edge of the minor road.
6. In urban areas the limits of the paved area should be formed by continuous barrier kerbs (see Design Advice Note 14). Footways and pedestrian guardrail (see Design Advice Note 10) should be provided in order to keep pedestrians off the carriageway and channel them to safe crossing points. Guardrail also helps discourage rickshaws from stopping in the junction and keeps the carriageway clear of people selling things.
7. In rural areas mountable or semi-mountable kerbs will help define the edge of the paved area and discourage over-running.

All dimensions are in metres unless otherwise specified
T-JUNCTION - TYPE C (MINOR ROAD CHANNELISING ISLAND)

Provision of a channelising island in the minor road approach will improve safety by:
(1) Making the junction more visible to drivers approaching on the minor road;
(2) Guiding drivers of turning vehicles into taking the safest path through the junction;
(3) Enabling pedestrians to cross the minor road in two stages.

The Type C design is recommended for junctions where these problems arise, or where the minor road flow exceeds 500 motor vehicles 2-way AADT.

NOTES:
1. The corners between the major road and the minor road are in the form of a compound curve - for details see Design Advice Note 1.
2. The shoulders may be omitted where there is little NMV traffic.
3. The channelising island and the road edges should be kerbed - using barrier kerbs in urban areas and semi-mountable kerbs in rural areas where speeds are higher.
4. The channelising island may be lengthened in order to further discourage drivers from passing the island on the wrong side.

All dimensions are in metres unless otherwise specified.

ROAD MARKINGS AT A TYPE C T-JUNCTION

- F2 GIVE WAY LINE
- F7 WARNING LINE
- F8 TRAFFIC ISLAND
- F9 EDGE LINE
- F10 EXTENDED TRANSVERSE LINE
- F14 GIVE WAY MARKING
- A33 KEEP LEFT SIGN

Refer to Traffic Signs Manual for details

The warning effect of the F8 traffic island marking can be reinforced by laying rumble strips between and parallel to the diagonal lines.

Tapers for development of central islands

Central islands should normally be developed symmetrically about the centreline at the tapers shown below:

<table>
<thead>
<tr>
<th>DESIGN SPEED</th>
<th>TAPER RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-70</td>
<td>1 : 20</td>
</tr>
<tr>
<td>&gt;70</td>
<td>1 : 25</td>
</tr>
</tbody>
</table>

Not to scale
T-JUNCTION TYPE D (SINGLE LANE DUALLING)

Provision of a physical island in the major road together with a right-turning lane benefits traffic flow and safety in the following ways:

1. Vehicles waiting to turn right into the minor road do not obstruct the through traffic
2. Vehicles waiting to turn right into the minor road are protected from being hit by through traffic
3. Vehicles turning right into the major road can do so in two stages and are protected between stages
4. Provision of only a single lane in each direction on the major road discourages unsafe overtaking within the junction.

The Type D design is recommended for junctions where the minor road flow exceeds 500 motor vehicles 2-way AADT and there are right-turning accidents, or where vehicles waiting on the major road to turn right obstruct the through traffic and are a hazard. This is an expensive design and a roundabout may sometimes be a cheaper and safer alternative.

NOTES:

1. The corners between the major road and the minor road are in the form of a compound curve - for details see Design Advice Note 1.
2. The shoulders may be omitted where there is little NMV traffic.
3. The traffic islands and the road edges should be kerbed - using barrier kerbs in urban areas and semi-mountable kerbs in rural areas where speeds are higher.
4. The channelising island may be lengthened in order to further discourage drivers from passing the island on the wrong side.

All dimensions are in metres unless otherwise specified.
Roundabouts are a safe, effective form of junction and are suitable for most situations. Their safety benefits result primarily from the control they exercise on approach speeds. Moreover, conflict points are few, they are well-spaced, and there is little speed difference between the conflicting vehicles.

Traffic entering the roundabout has to give way to traffic from the right that is already on the roundabout. Observance of this rule is essential if the roundabout is to work efficiently.

Type A roundabouts are not suitable where there are high volumes of NMVs (see Type B).

1. This Type A design includes 2m wide shoulders / NMV lanes which continue through the roundabout. The shoulders may be omitted where there is little NMV traffic. The design is not suitable for high flows of NMVs, and in these situations the Type B design is preferred.

2. Generally the centre island of the roundabout should be circular, with its centre at the point of intersection of the central lines of the entry roads. If the central lines cannot be made to meet each other at the same point, the centre should be placed between the different points of intersection.

3. The layout must deflect entering vehicles sharply to the left in order to control speeds to a safe level. This can be achieved by having a large centre island and single lane entries that point directly towards the island. Entry deflection is vital for safety.

4. There should generally be no more than four entry roads and there must be good separation between them. A high flow entry should have a large angle between it and the next entry.

5. The outer circle diameter should generally be 40-60m. Below 40m it becomes difficult to provide sufficient entry deflection. If the diameter is increased above 60m the roundabout becomes big enough to allow vehicles to reach unsafe speeds in the circulatory carriageway.

6. The width of the circulatory carriageway should normally be 7m plus any NMV lane. NMV lanes should not be less than 2m wide.

7. The design of the entry and exit lanes should be based on the swept turning paths of buses or similar vehicles. Use of turning circle templates is recommended.

8. The entries should generally have a single lane for MVs plus an NMV lane where NMV flows warrant it. The corner radii should be 10-15m. Larger radii will permit unsafe entry speeds.

9. There should normally be a channelising island in each entry road in order to separate entry and exit traffic. The island also provides a refuge for pedestrians and helps to warn drivers that they are approaching a junction.

10. The exit will be a single lane and will generally need to be wider than the entry lane in order to accommodate the swept turning path of a bus. The corner radii at the exit should be about 10-15m. Larger radii will permit unsafe exit speeds.

11. In urban areas the limits of the paved area must be formed by continuous barrier kerbs. The kerbs around the centre island should be at least 200mm high in order to make the island more visible, and discourage pedestrians from crossing to it. Footways and pedestrian guardrails will almost always be necessary. Pedestrian crossings will normally be required across the entry roads.

12. In rural areas kerbs must be always be used to define the edge of the paved area and prevent vehicles from over-running the edge. Where approach speeds are high and there are few pedestrians the use of semi-mountable kerbs is recommended in order to reduce the risk of vehicle damage.

13. Refer to Design Advice Note 7 for details of visibility requirements and signing at roundabouts.

All dimensions are in metres unless otherwise specified.
Visibility Requirements

Forward visibility - Drivers approaching the roundabout must have a clear view of the Give Way line from:

<table>
<thead>
<tr>
<th>Speed</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 km/h</td>
<td>60</td>
</tr>
<tr>
<td>60 km/h</td>
<td>80</td>
</tr>
<tr>
<td>70 km/h</td>
<td>100</td>
</tr>
<tr>
<td>80 km/h</td>
<td>120</td>
</tr>
</tbody>
</table>

Visibility at entry - Drivers must be able to see a 40m length of the circulatory carriageway (ahead and to the right) from a point 15m back from the Give Way line.

Circulatory Visibility - Drivers must be able to see a 40m length of the circulatory carriageway ahead of them.

Providing more visibility than this is undesirable as it will encourage unsafe speeds.

Note: The warning effect of the F8 traffic island marking can be reinforced by laying rumble strips between and parallel to the diagonal lines. It is recommended that all markings be made of thermoplastic for maximum durability.

SIGN REFERENCES

<table>
<thead>
<tr>
<th>A2</th>
<th>GIVE WAY SIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A32</td>
<td>TURN LEFT SIGN</td>
</tr>
<tr>
<td>A33</td>
<td>KEEP LEFT SIGN</td>
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<tr>
<td>B13</td>
<td>SHARP CHANGE OF DIRECTION CHEVRON</td>
</tr>
<tr>
<td>C2</td>
<td>PEDESTRIAN CROSSING SIGN</td>
</tr>
<tr>
<td>C28</td>
<td>ADVANCE DIRECTION SIGN</td>
</tr>
<tr>
<td>C32</td>
<td>DIRECTION SIGN</td>
</tr>
</tbody>
</table>

Refer to Traffic Signs Manual for details of location

All dimensions in metres unless otherwise specified.
ROUNDABOUT - TYPE B

This type of roundabout is designed for junctions with high volumes of NMVs. A separate network of NMV paths is provided, so that conflicts between MVs and NMVs can be minimised. It can be assumed that the NMV path around the roundabout will carry two-way traffic as this will enable the NMV drivers to travel the least distance. The NMV paths may also be used by pedestrians, in which case it may be necessary to widen them. Care must be taken to prevent motor vehicles from using the NMV paths. Pedestrian guardrail will be necessary around the perimeter of the circulatory carriageway and on the approaches to it - this will help keep pedestrians off the carriageway and discourage vehicles from stopping to let down or pick up passengers.

Refer to Design Advice Note 6 for general advice on design of roundabouts, and Design Advice Note 7 for details of signing, marking and visibility requirements.

All dimensions are in metres unless otherwise specified.
Objective
Guardrail should be an effective barrier to pedestrian movement. It should be strong, and easily maintained.
It should be friendly to pedestrians, and not to be a hazard to vehicles when hit.
It should not interfere with visibility and should look acceptable.

Application
Pedestrian guardrail can be useful in the following situations:
a) Hazardous location on straight stretches
Where the road is congested and vehicles move at a fast pace, guardrail should be provided on both sides of the carriageway so as to channelise the pedestrians to planned crossing locations.
b) At junctions
Pedestrian guardrail should be provided to prevent people from crossing the road within the junction and to guide them to the nearest pedestrian crossing. Guardrail also helps discourage rickshaws and buses from stopping in the junction and keeps the carriageway clear of people selling things.
c) Schools
Provision of guardrail near schools where children would otherwise run straight into the road is essential.
d) Bus stops, railway stations, etc.
Provision of guardrail along footways with suitable access at bus stops, railway stations and other areas of heavy pedestrian activity such as cinema houses, stadiums, etc. is recommended for improving pedestrian safety in such areas.
e) Overpass, Subway, etc.
Guardrail may be necessary at these locations in order to compel the pedestrians to use the facilities provided for them.
f) Central reserves
Where there is a central reserve or a median, guardrail can be erected within it to deter the pedestrians from attempting a crossing.

Basic Design
The guardrail shown here has been designed so that drivers can see through it, so it is particularly suitable for use with pedestrian crossings and outside schools.
Pedestrian guardrail is normally 1m high and perhaps 1.5 m in difficult places, where pedestrians are reluctant to go a longer distance. They should be of heavy duty where there is a risk that pedestrians will try to break them. In exceptionally hostile situations brick or RCC walls may have to be used.
Guardrail should be set back (normally 300 mm) from the traffic face of kerb to give adequate clearance for passing vehicles.
Sections of special length, apart from 2 m long, should be used where there is a need for such sections to accommodate trees or telephone or electric poles.

Colour
Dark Green

All dimensions are in millimetres unless otherwise specified
Introduction
Gates are a traditional way of marking the entrance to a special place. When used on the highway they help to warn drivers that they are entering a town, village, or residential area and should slow down.

Design Features
This Advice Note shows a typical design but other designs are permissible. They will usually include vertical elements close to the edge of the road in order to give drivers the impression that the road is narrowing. It is also possible for the gate to span the carriageway, like the temporary bamboo structures that are erected to advertise special events. If the gate is to be effective it must be visually prominent. The design shown here combines large reflective signs with kerbed islands, delineator posts, and rumble strips (see below) on the carriageway. The visual impact can be increased by planting soft trees and shrubs, but make sure that they will not obscure the signs or drip water onto them.

Rumble strips are low ridges across the carriageway. Drivers hear a noise and feel a slight bump when they drive over them, and this should make them more alert. They can be used on their own as well as with gates. Rumble strips must be laid across all traffic lanes so that drivers cannot drive around them but stop them short of the carriageway edge to allow for drainage. Each strip can be up to 15mm high provided that no vertical face exceeds 6mm in height. They are normally made of thermoplastic (as shown on the drawing on this page) or bituminous premix material. They need to be regularly rebuilt in order to maintain their profile. Concrete rumble strips are more expensive but are much more durable.

Rumble strips are an uncomfortable obstacle to rickshaws, so where the road is well-used by rickshaws it is recommended that a by-pass be provided as shown on the drawings.

Use and Location
Gates are unlikely to reduce speeds when used on their own. They are most effective when they are the first element in a series of speed-reducing measures, such as road humps, roundabouts, and checkpoints.

Gates must be sited where they can be seen from a distance. Check that the gate is visible over at least the stopping sight distance for the traffic speed at the site. Try to put the gate where it will reinforce other visual clues to the way the road character is changing. In rural areas for example put the gate about 50-100m ahead of the first buildings in the village. Vehicles crossing rumble strips do create noise so check that this will not be a problem.
When to use humps
Road humps are the most effective way of controlling vehicle speeds. Excessive speed is a major factor in many road accidents. Road humps are particularly suitable for use on residential or other minor roads where speeds are 50km/h or less but need to be reduced further in order to prevent accidents. Road humps on high-speed roads are a hazard and should only be used with extreme caution, and if there is no other alternative. Road humps must only be used with other elements that help control speeds and ensure that road users expect to encounter humps. Warning signs are not enough - they should be supplemented by features such as gates (see Design Advice Note 11) roadside planting, and other visual effects. A series of humps should be provided - not a single hump. It is important that noise and other problems be considered as well as the implications of traffic diverting onto other roads. There are two types of humps: circular humps and flat-topped humps. This Design Advice Note gives details of circular humps.

Dimensions and spacing
The hump must have a circular profile and be 100mm high at its highest point. If it rises higher than this it may cause damage to vehicles. The length of the hump (chord length) and the spacing between humps is determined by the desired speed - see table below. Note that 15% of vehicles will travel at speeds at least 20% higher than the average speed.

<table>
<thead>
<tr>
<th>Average speed</th>
<th>Hump length</th>
<th>Radius</th>
<th>Distance between humps</th>
<th>Chord length</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>3.0m</td>
<td>11m</td>
<td>25m</td>
<td>1.5m</td>
</tr>
<tr>
<td>30 km/h</td>
<td>4.0m</td>
<td>20m</td>
<td>75m</td>
<td>1.0m</td>
</tr>
<tr>
<td>40 km/h</td>
<td>6.5m</td>
<td>53m</td>
<td>150m</td>
<td>0.6m</td>
</tr>
<tr>
<td>50 km/h</td>
<td>9.5m</td>
<td>113m</td>
<td>250m</td>
<td>0.25m</td>
</tr>
</tbody>
</table>

Features
The hump is bounded by kerbed shoulder islands fitted with delineator posts as shown on the drawings. These help to make the hump more visible and prevent motor vehicles from driving off the carriageway to avoid the hump. A widened shoulder is provided so that rickshaws, cyclists and pedestrians can by-pass the hump. Where the road is kerbed or on a slope the hump must be sharply tapered at the sides to form a narrow drainage channel between the hump and the kerbed shoulder island.

Signs and markings
Sign B31 (road hump warning sign) must be used in advance of the first hump in the series. A supplementary plate will be needed displaying an appropriate legend, e.g., “3 HUMPS AHEAD” or “HUMPS FOR 200m”. As a reminder the sign should be repeated at the first hump. The F17 checkerboard marking should appear on the hump itself and this should preferably be made using thermoplastic for maximum durability. Refer to the Traffic Signs Manual for further details of signing and marking.

Construction details
It is essential that the hump be constructed to exactly the correct profile. The required precision is best achieved by using a template. Alternatively the profile can be checked by measuring the deviation from a string stretched parallel to the road surface at a height of 100mm.

The hump will normally be constructed using premix bituminous carpeting of a grade which will maintain the shape of the hump and resist rutting over the expected life of the pavement.

The hump should be built up using successive layers of carpeting. Each layer should be no more than 50mm thick and should be sufficiently compacted before adding the next layer. The profile of the hump should be checked with the template before adding more layers. In order to key in the hump to the adjoining pavement a 500mm wide by 50mm deep trench shall be excavated across the full width of the existing pavement at the limit of the hump. The bituminous carpeting should extend to the outer limit of the trench. A run-on fillet should be provided to smooth the transition from pavement to hump - see the drawing headed “Key Way”.

Geometric design of circular hump (for 50 km/h desired speed)
Radius = 113m  Chord length = 9.5m

Geometric design of circular hump (for 40 km/h desired speed)
Radius = 53m  Chord length = 6.5m

Geometric design of circular hump (for 30 km/h desired speed)
Radius = 20m  Chord length = 4.9m

Geometric design of circular hump (for 20 km/h desired speed)
Radius = 11m  Chord length = 3.0m

All dimensions in metres unless otherwise specified
Introduction
Bus bays enable buses to stand off the main carriageway while passengers board and alight. This reduces the risk of overtaking accidents and avoids delays to the other traffic. Unfortunately bus drivers are often unwilling to use them, either because they do not want following buses to overtake them or the bays are inconvenient to use.

Location
This is of critical importance. Surveys should be carried out to determine where the buses stop. The survey period should span several days as well as different time periods during the day. Local people should be consulted, but their information may not always be reliable. Moreover, their views on where buses should stop must be treated with caution because they have no control over the bus drivers. The bus drivers will generally stop where it is most convenient for their passengers, regardless of the hazard that this causes to other road users.

A compromise has to be found between safety and convenience. The safest arrangement for bus bays is that shown in Diagram A (left). Bus bays on opposite sides of the road are staggered so that the buses pass each other before stopping. The bus bays are located beyond (i.e. past) any junction or pedestrian crossing. This ensures that conflicts and obstructions to visibility are kept to a minimum. The preferred stopping point for passengers and bus drivers is indicated in Diagram B, and the further the bus bay is away from this point the less it will be used. Bus bays that are before a junction are more likely to be used than those that are after a junction. The best location must be determined on a site by site basis. Diagram C shows a compromise solution that may be appropriate at some sites.

Design features
It is essential that bus bays be convenient to use, both for bus drivers and bus passengers. The entry and exit tapers (see Plan of Bus Bay) are essential for safe and smooth manoeuvring. Providing a platform and shelter will help encourage passengers to wait in the correct place off the bus standing area. Shade trees will also be beneficial. Many passengers will transfer to or from rickshaws so it makes sense to provide rickshaw access to the back of the platform, as well as somewhere for the rickshaws to park.

Construction
The pavement within the bus bay must be strong and durable. When loaded buses start off their wheels impose considerable force on the pavement. Buses may also spill diesel and oil when stopped. Consequently concrete construction is preferred to bituminous surfacing. Good maintenance is important because bus drivers will not use bus bays if the pavement is in poor condition.

All dimensions are in metres unless otherwise specified.
**KERBS**

**Introduction**

Kerbs define the edge of traffic islands and carriageway and help retain their structure. They assist drainage of the carriageway and they protect adjacent areas from encroachment by vehicles. They are also useful in highlighting the edge of the road because they reflect vehicle headlights.

**Types of Kerb**

The main types of kerb and their application are shown below. Typical dimensions are given, but these can be varied to suit particular circumstances.

- **Barrier**
  - This type of kerb is required to provide protection to footways, pedestrian guardrail, traffic signs, signals etc. It should not normally be used on high-speed roads.

- **Semi Mountable**
  - This type of kerb can be used in rural situations where high speeds would make barrier kerbs risky. These kerbs will help to prevent over-running, but they should not be used where there are footways adjacent to the edge of the carriageway.

- **Mountable**
  - Offers very little resistance to errant vehicles. This type of kerb is used to define traffic islands and road edges in situations where there is a high risk of the kerb being hit by vehicles.

- **Kerb with integral drain**
  - This is a durable and effective way of providing drainage, and reduces the risk of water penetration into the edge of the pavement. All types of kerbs can have integral drains.

**Construction**

Kerbs should be pre-cast using concrete class 30. Refer to RHD Standard Specifications for Road and Bridge Works.

Dropped kerb at pedestrian crossing

**TRAFFIC ISLANDS**

**Introduction**

Traffic islands are a key element in the design of safe, efficient junctions. They can be used to:
- separate conflicting traffic streams
- control the path of vehicles
- provide segregated lanes for some vehicle types or some traffic movements
- reduce unnecessary areas of carriageway, thus helping to limit vehicle paths
- warn drivers that they are approaching a junction
- provide shelter to vehicles that are waiting to make a manoeuvre
- slow vehicles down by deflecting them from a straight ahead path
- assist pedestrians to cross the road
- locate traffic signs and signals where they will be less at risk of being hit

**Design requirements**

1. Traffic islands must help drivers to recognise and follow a safe path through the junction. This calls for care in location, alignment, sizing and construction details.
2. They must be of sufficient size to be easily seen, especially at night. Islands should normally have an area of at least 4.5m² in urban areas and 7m² in rural areas. Note that too many small islands can be confusing.
3. The island shape should be determined taking into consideration the wheel tracks of turning vehicles, the radii of left and right turns, island nose radii, etc.
4. Islands will normally be bordered by raised kerbs. The kerbs can be painted in alternate black and white stripes to make the islands more visible.
5. Islands used as pedestrian refuges should normally have barrier kerbs and be 1.5m wide (1m absolute minimum). Dropped kerbs (see below left) should be provided at the crossing points.
6. Islands will normally be provided with reflective traffic signs (typically A33 Keep Left). Ensure that there is at least 300mm clearance between the edge of the sign and the traffic face of the kerb.
7. Island noses which face oncoming traffic should normally have a radius of at least 0.75m. Other noses can have radii of 0.3m - 0.6m. On high-speed roads island noses facing oncoming traffic should be offset from the vehicle path in order to reduce the risk of collisions (see below).
8. Appropriate carriageway markings (typically F8 Traffic island) should be used to guide drivers safely past the island.

**Cross Section**

- 30 Premix Asphat or Paving Slab
- 50 Base course
- In-situ concrete Class 7
- 12 dia bar @ 250 c/c (100 long)

**Nose Offsets**

- a) islands in the minor road arm of priority junctions
  - 1.5m
  - /R0.75m
- b) channelising islands on high-speed roads
  - 0.5 m
  - /R0.75m
  - Not to scale

**Tapers for development of central islands**

Central islands should normally be developed symmetrically about the centreline at the tapers shown below.

<table>
<thead>
<tr>
<th>DESIGN SPEED</th>
<th>TAPER RATIO</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1 : 20</td>
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<tr>
<td>&gt;70</td>
<td>1 : 25</td>
</tr>
</tbody>
</table>

**Road Safety Division**

**Design Advice Note 14**

**Kerbs and Traffic Islands**

All dimensions are in millimetres unless otherwise specified
Introduction
Safety barrier (also called guardrail or safety fence) is provided in order to physically prevent vehicles from running off the carriageway into a more hazardous area. Ideally, the barrier will safely contain the vehicle without massive deceleration and will redirect along the line of the barrier in such a way that the driver can bring it back under control. Well-designed safety barriers can be very effective in reducing the severity of run-off-road accidents. They also help define the edge of the road, which can be a useful secondary benefit. Flexible steel beam safety barrier described here is the most widely used type, but it is expensive and technically demanding. Other options to be considered include rigid RCC barriers, walls made of cheap materials like brick and brick-filled gabions, and even dense planting of soft trees and shrubs.

Criteria for provision of safety barrier
Safety barriers are a hazard in itself and it should only be used where there is a clear need to protect vehicles from a serious hazard. There are basically three such situations:
1. Preventing vehicles from falling down a steep slope - this applies where there is a drop of 3m or more at or near the edge of the road and the slope is steeper than 5(horizontal) to 1(vertical);
2. Protecting vehicles from hitting a roadside object, such as the end of a bridge parapet;
3. Preventing out-of-control vehicles from crossing the median on a dual carriageway.

However, it is not economic to install safety barrier in all these situations. Other factors to be taken into account include:
1. whether there have been run-off-road accidents at the site - in the case of an existing road;
2. whether the site is on a sharp bend - defined as where the safe speed to negotiate the bend differs from the approach speed (80th percentile speed) by more than 15km/h;
3. whether it is a busy road - defined as a road with an AADT of >1,000;
4. whether the approach speed (80th percentile speed) is greater than 65km/h. If two or more of these considerations apply there is probably a good case for installing safety barrier. A bad record of casualty accidents involving run-off-road vehicles (3 or more a year) will in itself be sufficient justification for safety barrier.

Design advice (these are just the basic principles - get expert advice when doing the detailed design)

Beam type - Two basic types of steel beam barrier are described here (see top right):
1. Untensioned corrugated beam (UCB) and open box beam (OBB). OBB is the best choice for high-speed roads and for protecting vehicles from hitting roadside objects. Both types are designed to flex on impact so as to absorb energy.
2. Containment capability - Single beam safety barrier is designed to contain cars. Buses and trucks may roll over it. Safety barrier which will reliably contain heavier vehicles has to have two beams, and should be of the Double Rail Open Box Beam type - see top right.

Post spacing and post type - The posts are critical to the proper performance of the barrier. They must provide firm support to the beam but be capable of being pushed back or bent back when a vehicle hits the beam. If the posts are made too strong the beam will be unable to flex and absorb energy. See above right for recommended post spacings. Steel posts provide the best performance. Except on terminal sections they will normally be driven into the ground - a pressure plate welded to the post head will increase the resistance to being pushed over. In poor ground conditions either use longer posts with larger pressure plates, or use concrete foundations.

Beam height - Normally the centre of the beam should be at a height of 610mm above carriageway level. If it is higher than this small vehicles may run under it. If it is much lower then vehicles may roll over it.

Installation length - Steel beam barrier needs to be at least 30m long in order to perform properly - if it is much shorter than this it will have no strength. The barrier should extend about 15m past the roadside object it is protecting. On sharp bends the barrier should continue a short distance beyond the bend because this is the most likely place where vehicles will run off the road.

Terminal sections - There is no entirely safe way of terminating steel beam barrier but it should always be flared away from the carriageway edge and ramped down - see opposite. The final section needs to be strongly anchored into the ground. Safety barrier and bridge parapets - Where barrier is used to prevent vehicles from hitting the end of a rigid bridge parapet it is essential that the barrier and parapet strongly connect to each other. The barrier must line up with the traffic face of the parapet. It should get stiffer as it gets closer to the parapet connection, and this can be achieved by reducing the post spacing and setting the last few posts in concrete foundations.

Manufacture, installation and maintenance
It is best to purchase from a specialist manufacturer as this will help ensure that all the components (beams, posts, fittings, etc.) are of proper quality and will work together correctly. Everything must be well galvanised in order to protect against corrosion. All manufacturers will provide corrugated beam sections, but open box beam may only be available from British suppliers. Dimensions may vary between manufacturers. It is essential to follow the manufacturer's instructions, as correct installation is critical to performance. Failure to do this could result in a safety barrier which is ineffective or even hazardous. Steel beam safety barrier should not need much maintenance other than repair of accident damage. When barrier is provided as part of road projects it is important to give the local RHD field division a small supply of beams, posts and fittings, together with some training in how to repair the barrier.

All dimensions are in millimetres unless otherwise specified.

Design Advice Note 15

Steel Beam Safety Barrier

The People's Republic of Bangladesh
Ministry of Communications
Road Safety Division

SCALE: 1:200

DWG NO: DAN-15

DATE: MARCH 2000

DESIGNED BY: IDC3

APPROVED BY: (RRMP3)
# Speed Survey Analysis

**Survey point**  
Dhaka-Mymensingh road, north of Joydevpur junction - COWI site MY1 - at entrance to Quasem Rotor & Spinning Mills Ltd - ch. 2+650

**Survey dates:**  
Tuesday 29/2/00 10.45 to 12.15  
Monday 13/3/00 14.00 - 15.20

A=towards Dhaka  
B=towards Mymensingh

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# Speed Survey Analysis

**Survey point:**  
**Survey dates:**  
**Survey direction:** A - towards ????? B - towards ?????

<table>
<thead>
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<th>Both directions - all vehs</th>
<th>Direction A - all vehs</th>
<th>Direction B - all vehs</th>
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</thead>
<tbody>
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<tr>
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<tr>
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<th>Medium truck</th>
<th>Small truck</th>
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**Survey day & time**  
FIRST SPEED :-
### Direction B - all vehs

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<th>Mini bus</th>
<th>Micro bus</th>
<th>Pick-up</th>
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<tr>
<td></td>
<td>Car</td>
<td>Baby taxi</td>
<td>Tempo</td>
<td>Motorcycle</td>
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<td>0</td>
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<td>0</td>
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<td>B</td>
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<td>0</td>
<td>0</td>
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</tbody>
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<table>
<thead>
<tr>
<th>A &amp; B</th>
<th>#DIV/0!</th>
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<td>#DIV/0!</td>
</tr>
</tbody>
</table>

| A     | 0    | 0    | 0    | 0    |
| B     | 0    | 0    | 0    | 0    |
### Poisson Test

Used to determine whether the recent increase in the number of accidents is likely to persist or whether increase was due to random fluctuation.

#### Input figures in yellow cells

<table>
<thead>
<tr>
<th>Year</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Average/year</strong></td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

#### So what is the probability of getting **exactly** 5 accidents in year 4, when the long term average is 2, purely due to random fluctuation?

Using poisson probability (single factor values):

- **k = no. of accidents in problem year** = 5
- **x = no. of events/yr** = 4

<table>
<thead>
<tr>
<th>Poisson Probability</th>
<th>0.036089409</th>
</tr>
</thead>
</table>

The probability of 5 accidents occurring, purely due to random fluctuation, at a site where the long term average is 2 is 0.0361 or 3.6%.

**96.4 %** chance that a real increase in accidents has occurred.

#### Input figures in yellow cells

<table>
<thead>
<tr>
<th>Year</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Average/year</strong></td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

#### How likely is it that **5 or more** accidents will occur at the site, purely due to random fluctuation

We need to add the probabilities for k=5, k=6, k=7 etc etc.

Using poisson probability (cumulative values):

- **k = no. of accidents in problem year** = 5
- **x = no. of events/yr** = 4

<table>
<thead>
<tr>
<th>Poisson Probability</th>
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<tr>
<td><strong>K+1</strong></td>
<td>0.0120298</td>
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<tr>
<td><strong>K+2</strong></td>
<td>0.00343709</td>
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<tr>
<td><strong>K+3</strong></td>
<td>0.00085927</td>
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<td><strong>K+4</strong></td>
<td>0.00019095</td>
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<td><strong>K+5</strong></td>
<td>3.819E-05</td>
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<td><strong>Total</strong></td>
<td>0.05264471</td>
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</tbody>
</table>

**94.7 %** chance that a real increase in accidents has occurred.

#### Significance Levels

<table>
<thead>
<tr>
<th>Significance</th>
<th>Confidence</th>
<th>Subjective</th>
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</thead>
<tbody>
<tr>
<td>Level</td>
<td>Level</td>
<td>Interpretation</td>
</tr>
<tr>
<td>1%</td>
<td>99%</td>
<td>Highly Acceptable</td>
</tr>
<tr>
<td>5%</td>
<td>95%</td>
<td>Acceptable</td>
</tr>
<tr>
<td>10%</td>
<td>90%</td>
<td>Fair</td>
</tr>
<tr>
<td>20%</td>
<td>80%</td>
<td>Indicative</td>
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</tbody>
</table>

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