SECTION 1: Introduction

1.1 Introduction

This manual provides guidance to identify and improve road traffic crash (RTC) sites. It has been written primarily as a training aide / reference manual for road engineers and other stakeholders involved in designing and maintaining roads. It should be of interest to anyone concerned with the safety of our roads, including PWD engineers, traffic policemen, and highway engineering consultants.

The manual provides practical guidance on setting up a RTC reduction programme. This is defined as: a systematic process for identifying locations with an unusually high incidence of RTCs, analysing the contributory factors, and then designing and implementing engineering countermeasures.

It has been a tradition in road safety to analyse road safety data for understanding why crashes occur, which factors influence risks, and what determines crash severity, and based on this understanding, to arrive at reliable conclusions on how to prevent them most effectively and efficiently. We call this a data-driven approach. In this approach, we derive priorities by using crash data, background data, exposure data, and data of safety performance indicators.

Most countries have accepted “Vision Zero”, a road safety principle that has been promoted by Sweden since 1997. The “Vision Zero” policy targets to achieve zero deaths on road sometime in future. Vision Zero accepts, as a basic starting point, that human beings make conscious and subconscious mistakes. That is why accidents occur, and the safety work must in the first instance be directed at those factors which can prevent accidents leading to death and serious injury. Accidents in themselves can be accepted, but not their serious consequences.

The Safe Systems Approach (SSA) is based on “Vision Zero” policy. The three key principles of SSA are:

- Principle 1 Recognition of human frailty
- Principle 2 Acceptance of human error
- Principle 3 Creation of a forgiving environment and appropriate crash energy management.

These principles make it clear that the system designers have ultimate responsibility for the design, upkeep and use of the road transport system, and are thus responsible for the safety level of the entire system. We have ample evidence to suggest that road designs - lane width, shoulder presence, number of lanes, median design - influence driving behaviour (operating speeds, lane changes etc.), therefore, one could expect that roads themselves play an important role in road safety, and improved geometry design and infrastructure could in turn help to improve road safety.
Some countries have had RTC site programmes for many years, and they have proved to be a highly cost-effective way to reduce RTCs. Road infrastructure improvements (e.g., road upgrading and pavement texture) and roundabout design are found to be beneficial for safety. Speed control through traffic calming measures have proved to be very beneficial.

This is only a provisional guide to the subject, not a comprehensive reference work. It is hoped that with more experience it will be possible to improve the effectiveness and suitability of the practices and procedures outlined in this manual.

1.2 Overview of the technical Process

The task is to identify where accidents are happening and investigate them to determine the factors involved so that appropriate and effective remedial measures can be applied. Taking actual accidents as the starting point is of fundamental importance, because it is not possible to reliably identify and analyse hazardous locations from the look of the road alone. The available RTC data from traffic police provide a reasonable starting point.

Road accidents happen in many forms and in many locations. It is neither feasible nor useful to analyse each individual crash in detail. The key is to try and identify locations where an above-average number of RTCs are occurring, as these are potentially worthwhile sites for investigation and treatment. Road safety specialists recognise four main approaches to the task of treating roads with bad RTC records:

• Single site: treatment of individual sites (e.g. junctions, bends, or short (300-500m) lengths of road) at which accidents are clustered (these sites are sometimes called "accident clusters" or "accident blackspots")
• Route action: safety treatments applied to the whole length of a road which has a bad overall accident record
• Mass action: application of standard treatments to locations having common accident features (e.g. provision of central refuges at pedestrian crossings on wide roads)
• Area action: safety treatments applied throughout an area (often a section of town) which has a bad overall accident record (e.g. traffic management and traffic calming measures undertaken throughout a housing area).

The process of eliminating or improving accident black spots in a road network is composed of several activities, as illustrated in the following figure:
**Identification of blackspots** is the procedure to locate those spots in the road network that are particularly dangerous, that is, the black spots.

**Diagnosis** is the process to study what are the problems, the accident contributing factors and the deficiencies for each of the identified black spots.

**Finding countermeasures** implies a methodical analysis to design suitable countermeasures for each black spot, based on actual problems and deficiencies.

**Estimating effects** is the process to estimate the safety effects (and if necessary, also other effects) and costs of suitable countermeasures.

**Prioritizing** implies finding the best action plan (or investment program), according to some defined criteria, and based on estimated effects and costs as well as budget restrictions.

**Implementation** is the actual realization of the prioritized measures included in the action plan (or investment program).

**Follow-up and evaluation** is the last and very important step, which aim is to assess the actual results (effects and costs).
SECTION 2: Definition & Technical Process

2.1 Introduction
The term operational definition refers to the basis and methodology applied to identify accident black spots (Elvik 2008a). In the same literature, different definitions and methodology used to identify accident black spots have been discussed which shall be probed based on following dimensions:
1. Do they refer to a specific type of roadway segment/location or not?
2. Do they identify black spots using SLW or consider reference?
3. Do they consider the recorded accidents or an estimate of the expected accidents?
4. Is normal safety level considered or not?
5. Is the accident severity considered or not?
6. The length of the identification period used.

Table 2.1 below summarises the definitions of accident black spots in terms of six characteristics mentioned above.

Table 2.1: Operational Definitions across different countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Reference to Population of sites</th>
<th>Sliding Window applied</th>
<th>Reference to normal safety level</th>
<th>Recorded or expected number of accidents</th>
<th>Accident severity considered</th>
<th>Length of identification period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>No</td>
<td>Yes, 250m</td>
<td>Yes, by means of critical values for accident rate</td>
<td>Recorded, minimum critical value 3</td>
<td>No</td>
<td>3 years</td>
</tr>
<tr>
<td>Denmark</td>
<td>Yes, detailed categorization of roadway elements</td>
<td>Yes, variable length</td>
<td>Yes, by means of accident prediction models</td>
<td>Recorded, based on statistical test - minimum 4 accidents</td>
<td>No</td>
<td>5 years</td>
</tr>
<tr>
<td>Flanders</td>
<td>No</td>
<td>Yes, 100m</td>
<td>No</td>
<td>Recorded, weighted by severity</td>
<td>Yes, by means of weights</td>
<td>3 years</td>
</tr>
<tr>
<td>Germany</td>
<td>No</td>
<td>No, accident maps inspected</td>
<td>No</td>
<td>Recorded, minimum value 3 or 5</td>
<td>Yes, by critical values</td>
<td>1 year (all accidents) or 3 years (injury accidents)</td>
</tr>
<tr>
<td>Hungary</td>
<td>No</td>
<td>Yes, 100m or 1000m</td>
<td>No</td>
<td>Recorded, minimum 4 accidents</td>
<td>No</td>
<td>3 years</td>
</tr>
<tr>
<td>Norway</td>
<td>No</td>
<td>Yes, 100m or 1000m</td>
<td>Yes, by means of normal accident rates for roadway elements</td>
<td>Recorded higher than normal by statistical test, minimum values 4</td>
<td>Yes, by estimating accidents costs and potential savings</td>
<td>5 years</td>
</tr>
</tbody>
</table>
Blackspots are, in most countries, not identified by sampling accidents in reference to a location or type of site. In most countries, blackspots are identified by applying a sliding window to the locations of accidents and fixing the position of the window at points where it contains the (local) maximum number of accidents.

An accident black spot is generally taken to be a site that has an abnormally high number of accidents. The definitions suggest that black spots cannot be meaningfully identified without some reference to the normal level of safety. Some of the currently employed definitions of black spots in European countries make an explicit reference to the normal level of safety, but – surprisingly – not all definitions make such a reference.

Blackspots are in all countries identified in terms of the recorded number of accidents. The only exception from this is the black spot definition developed by LNEC in Portugal, which relies on the Empirical Bayes method. In some countries, tests are performed to determine if the recorded number of accidents is significantly higher than the normal number expected for similar sites. Presumably, sites that do not pass this test are deleted from the list of blackspots and not treated as abnormal.

Some definitions of black spots consider accident severity, other definitions do not. If accident severity is considered, there is no standard way of doing so. Three different approaches can be identified. One approach is to set a more stringent critical value for the number of serious injury accident accidents than for all injury accidents when identifying blackspots. A second approach is applying weights to accidents at different levels of severity. A third approach is to estimate the costs of accidents. These costs vary according to injury severity; hence, costs will be higher at sites that have a high proportion of fatal or serious injury accidents.

(Comparison Different Black Spot Identification Methods Maen Ghadia *, Árpád Török)

The length of the period used to identify blackspots varies from 1 year to 5 years. A period of 3 years is used frequently. Research by Cheng and Washington (2005) shows that the gain in the accuracy of blackspot identification obtained by using a longer period of 3 years is marginal and declines rapidly as the length of the period if increased. There is little point in using a longer period than 5 years.

First, Elvik (2008b) claims that the length of the period used to identify black spots varies from 1 year
Section 2: Definition & Technical Process

to 5 years, a period of 3 years is used frequently [19]. Next, research by Cheng and Washington (2005) shows that the gain in the accuracy of black spot identification obtained by using a longer period of three years is marginal and declines rapidly as the length of the period is increased. There is little point in using a longer period than 5 years [20]. Additionally, LTNZ (2004) stressed out that a 3-year crash period could be used in heavily trafficked networks or areas where road changes are recent or ongoing [21]. A three-to-five-year period is preferred because:

- It is long enough to provide a sufficient number of crashes for meaningful results;
- It is short enough to limit the number of traffic and environmental changes that may bias results;
- It helps remove statistical fluctuation and reduce the impact of the regression-to-the-mean effect;
- It provides a consistent base for before and after comparisons.

Given the lack of standardisation and the many dimensions that characterise definitions of road accident black spots, one of course needs criteria specifying what constitutes a “good” definition of a road accident black spot. Such criteria have evolved over the past 20 years, following pioneering work by Hauer and Persaud (1984) who pointed out difficulties in reliably identifying blackspots by using the recorded number of accidents as the only criterion. Overgaard Madsen (2005) discusses in detail criteria for identifying blackspots. He proposes that an adequate definition of a blackspot should satisfy following criteria:

1. It should control for random fluctuations in the number of accidents.
2. It should account for as many of the factors that are known to influence road safety as possible.
3. It should identify sites at which fatal and serious injury accidents are overrepresented.
4. It should identify sites at which local risk factors related to road design and traffic control make a substantial contribution to accidents.

The first and second of these criteria suggests that the identification of a black spot should rely on the expected number of accidents, not the recorded number. In practice, this would appear to be difficult, since the expected number of accidents cannot be observed, but must be estimated. However, a method has now been developed that permits the expected number of accidents to be estimated for a single location; the Empirical Bayes method.

The third criterion implies that the identification of blackspots should either rely on fatal or serious accidents or assign a greater weight to these accidents than to slight injury accidents or property-damage-only accidents. This criterion is relevant to the extent that road safety policy seeks to prevent the most serious accidents.

Weighting principle
The question to be raised is what accidents with different severity should be included in the identification and how should they be weighted to get increased focus on severity. In a literature review the following six weighting principles where identified (Deacon et al. 1975, Baerwald et al. 1976, Taylor and Thompson 1977, Ogden 1996, Ragnøy et al. 2002, Hauer et al. 2002, European Commission 2003, German Road and Transportation Research Association 2003, Overgaard Madsen 2005, Sørensen 2006):
1. Same weight for all accidents
2. Only the most severe accidents included
3. Weighting by number of vehicles
4. Weighting by accident type
5. Weighting by injured road users
6. Combination

**Same weight for all accidents** In the method of identification that we have used which is also the first principle given above, no weighting is done. All registered accidents are thus an integral part of the identification, and severity is not taken into consideration.

Table 2-2 Black spot definitions followed in various Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Reference to population of sites</th>
<th>Sliding Window applied</th>
<th>Reference to normal level of safety</th>
<th>Recorded or expected number of accidents</th>
<th>Accident Severity Considered</th>
<th>Length of accident period</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIARC</td>
<td>Yes</td>
<td>No, map based clustering approach</td>
<td>Yes by means of critical values for road sections and junctions</td>
<td>Recorded based on threshold value of 5 crashes per year or 3 pedestrian injuries per year</td>
<td>Yes selection is recommended based on accident severity</td>
<td>3-5 years</td>
</tr>
<tr>
<td>South Africa</td>
<td>Yes</td>
<td>Area or Region wise window (30-50m radius) applied in absence of data Precise location using maps or GPS in presence of data</td>
<td>Yes by means of crash density (number of accidents divided by length of road)</td>
<td>Recorded based on indices if data is available</td>
<td>Yes</td>
<td>3 -5 years</td>
</tr>
<tr>
<td>Turkey</td>
<td>Yes</td>
<td>No, fixed section of 1 km length</td>
<td>Yes by means of critical values of frequency, severity and rate</td>
<td>Recorded, indices exceeding the critical values</td>
<td>Yes</td>
<td>3 years</td>
</tr>
<tr>
<td>HSM 2010</td>
<td>Yes</td>
<td>No, aggregation based on base conditions</td>
<td>Yes by means of accident prediction models called Safety Performance Functions</td>
<td>Recorded based on weighed observed and predicted values using Empirical Bayes Method</td>
<td>Yes in some cases</td>
<td>3 years</td>
</tr>
<tr>
<td>UK</td>
<td>Yes</td>
<td>No</td>
<td>Yes based on authorities own average accident rates</td>
<td>Recorded, based on STATS 19 database</td>
<td>No</td>
<td>3 years</td>
</tr>
</tbody>
</table>
2.2 Redefining Black Spots for India

The current definitions as proposed by MoRTH and Ministry of Rural roads lay emphasis on accident frequencies. Keeping in context the world practice of defining black spots based not only on accident frequency but also accident rate and severity index we need to relook at the definition of black spots for our country.

In wake of the global studies the following definition can be adopted for Indian Context ‘a black spot is the segment of road of length 500m or an intersection with an influence of 100m wherein either the accident rate or severity index exceeds the critical value for similar homogeneous segments/intersections and accident type over a period of three years’.

2.3 Black Spot Management process:

The black spot management process includes several steps as highlighted in Figure 2-1

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**Fig 2-1 Black Spot Management Flow Chart**
2.3 Technical Process for treating a black spot

The technical process used for treating blackspot is given in Figure 2.2.

Figure 2.2: Standard Process
SECTION 3: Crash Data Collection & Identification of Blackspot

3.1 Crash Data Collection

The use of data has underpinned the development of successful programmes and strategies in countries which have managed to reduce their road safety problems. An understanding of the magnitude of the economic, medical and social impacts has generally been the motivation for many countries to start investing significantly in road safety programmes. Reliable information on crashes helps guide counter-strategies and ensures treatments are as targeted and effective as possible.

Almost all the States in India need to improve the quality and availability of crash data before some of the approaches described in this manual can be used. For this reason, the following sections outline the importance of data and ways in which data can be improved.

3.1.1 Importance of Data

Crash data are essential for:

- Assessing and communicating the scale of the road crash problem, and making the case for increased investment in road safety
- Identifying the most important road safety issues that need to be tackled as a priority
- Making a business case for road safety engineering treatments at a location, route or area
- Targeting treatments at the ‘real’ issues
- Monitoring road safety performance
- Evaluating the impact of individual measures, whole schemes and strategies
- Determining what works, and what does not work

A variety of sources of crash data are used to support the development and monitoring of road safety programmes internationally. The poor quality and availability of the range of crash and injury data in many States in India remains a major impediment to obtaining significant and measured improvements in road safety levels.

3.1.2 Sources of Data

There are a wide range of data types and sources that can be used to develop and monitor road safety improvement strategies but police crash data are by far the most important source used specifically for blackspot analyses. Other data are considered to be complementary and can ‘fine tune’ interventions.

3.1.3 Crash Data

Police crash report information is the main source of data used for road safety engineering analyses. It should be noted that increasingly concessionaires/PPPs are being made responsible for safety on the routes they operate and may also be required to collect similar crash data.

In all the States in India, police collect information on crashes that occur across the road network (see Figure xx); this is generally a statutory requirement when injury crashes occur. Data collection by the police is undertaken in a wide range of ways from State to State. It is important to understand that it is not done primarily to collect information which can be used by road safety stakeholders to develop countermeasure schemes and policies. It is chiefly collected for legal purposes, the information is...
used in court cases as evidence where persons are fined or charged in relation to crashes. The information may also be required as part of the insurance claim procedure to allocate blame.

In its simplest form, police crash data will include a narrative description about the crash. This means that there is no clear structure to the reporting of the crash details and it is down to the individual officer what information they record (what is considered important) and how much information is provided. This means that detailed or comparative analyses cannot be easily undertaken.

In some States countries the police collect information on crashes on a structured pro-forma questionnaire (see Figure xx). This has significant advantages since it helps the officer to collect a wider range of consistent details which are useful for road safety purposes.

The information received in the police department may be in written form or oral description. Head constable in the police station records details of all crime cases in the main register or Register No. 4. Register No.4 has pre-defined 21 columns in which the necessary details related to crime are entered to keep the records of each crime. Some police stations maintain all data records in the register as well as in computer. Preliminary investigations may find no occurrence of criminal offence. In such cases no further action is taken by the police. However, if there is evidence of cognizable offence then FIR is registered U/S 154. The format of each FIR is standard and same for all kinds of crime/accidents which are generally registered. Many police stations have started recording this in a computerized database. All the information related to the crime/accident including fatalities is reported to circle office (CO) with a FIR copy to get update and action required on the investigation. A copy of FIR is also sent to District Head Quarter. A formal communication through phone call or message is send to SSP office where all information related to accident and fatalities are entered and recorded in Daily Dairy/Register by police officials present in the SSP office.

Information recorded in FIR

<table>
<thead>
<tr>
<th>S.No.</th>
<th>ITEM</th>
<th>Details recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Description</td>
<td>Date, day, time, name of the police station</td>
</tr>
<tr>
<td>2</td>
<td>Victim</td>
<td>Name, gender, action at the time of crash,</td>
</tr>
<tr>
<td>3</td>
<td>Road user at fault(accused)</td>
<td>Name, gender, action at the time of crash</td>
</tr>
<tr>
<td>4</td>
<td>Witness statements</td>
<td>Description of the incident including description of the location with few landmarks</td>
</tr>
<tr>
<td>5</td>
<td>IPC No.</td>
<td>IPC no. under which the case is registered</td>
</tr>
<tr>
<td>6</td>
<td>Injury details</td>
<td>Fatal/non fatal/hospitalization</td>
</tr>
</tbody>
</table>
Section 3: Crash Data Collection Identification of Blackspot

Comment on IRC crash data format here >>>

Based on these various inputs and further discussions within the H-1 committee, the sub group designed and formulated revised A-1 and A-4 forms. The new form is mainly designed to record various facts related to an accident covering the general identification details, road features where accident occurred along with important details related to vehicle, victims and property damage involved in a particular accident, while at the same time keeping the data entry / recording process simple and less time consuming. Additionally, the A-1 form has been designed to be 'Optical Character Readable (OCR)' which can further reduce the time taken for manually entering the data into a computerized system. Similarly A-4 form has been designed to obtain analysis tables important from macro perspective. The form A-4 is totally based on the information collected/reported in form A-1.

Put the figure of IRC data collection format here >>

<table>
<thead>
<tr>
<th>Crash related</th>
<th>Road related</th>
<th>Vehicule related</th>
<th>Person related</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Crash identifier-FIR number</td>
<td>• Area/Location</td>
<td>• Vehicle number</td>
<td>• Occupant’s vehicle number</td>
</tr>
<tr>
<td>• Crash data</td>
<td>• Road name</td>
<td>• Vehicle type</td>
<td>Date of birth</td>
</tr>
<tr>
<td>• Crash time and date</td>
<td>• Road number</td>
<td>• Registration plate number</td>
<td>Sex</td>
</tr>
<tr>
<td>• Crash municipality/place</td>
<td>• Number of lanes</td>
<td>• Disposition after accident</td>
<td>Injury severity</td>
</tr>
<tr>
<td>• Crash location</td>
<td>• Ongoing road works</td>
<td></td>
<td>Safety equipment</td>
</tr>
<tr>
<td>• Crash type</td>
<td>• Type of roadway</td>
<td></td>
<td>Impacted by which vehicle</td>
</tr>
<tr>
<td>• Crash grade(type) by severity on a 1-4 scale</td>
<td>• Physical divider(yes/no)</td>
<td></td>
<td>Alcohol presence (yes/no/unknown)</td>
</tr>
<tr>
<td>• Weather conditions</td>
<td>• Actual accident spot</td>
<td></td>
<td>Driving licence number</td>
</tr>
<tr>
<td>• Number of vehicles involved</td>
<td>• Road surface (paved/unpaved)</td>
<td></td>
<td>Use of Requisite safety device</td>
</tr>
<tr>
<td>• Hit and Run (yes/no)</td>
<td>• GPS Location</td>
<td>• Mechanical failure(yes/no).</td>
<td>Age</td>
</tr>
<tr>
<td>• Number of people who need/not need hospitalization.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The EU’s Safety Net initiative (with CARE) has reviewed crash data collection in Europe with the aim of setting out best report practice for pro-forma content. The project identified 73 variables for the CADaS (Common Accident Data Set) with 471 values (Figure 3.1). These were selected to be comprehensive, concise and useful for crash data analyses. This can be a useful source of guidance on what variables and fields should appear in a crash report pro-forma.

<table>
<thead>
<tr>
<th>Crash related</th>
<th>Road related</th>
<th>Vehicle related</th>
<th>Person related</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Crash identifier</td>
<td>• Type of roadway</td>
<td>• Vehicle number</td>
<td>• Person ID</td>
</tr>
<tr>
<td>unique reference number assigned</td>
<td>• Road functional class</td>
<td>• Vehicle type</td>
<td>• Occupant’s vehicle number</td>
</tr>
<tr>
<td>to the crash usually</td>
<td>• Speed limit</td>
<td>• Vehicle make</td>
<td>• Pedestrian’s vehicle number</td>
</tr>
<tr>
<td>by police</td>
<td>• Road surface conditions</td>
<td>• Vehicle model</td>
<td>• linked vehicle number</td>
</tr>
<tr>
<td>• Crash data</td>
<td>• Intersection</td>
<td>• Vehicle model year</td>
<td>• Date of birth</td>
</tr>
<tr>
<td>• Crash time</td>
<td>• Traffic control at intersection</td>
<td>• Engine size</td>
<td>• Sex</td>
</tr>
<tr>
<td>• Crash municipality/place</td>
<td>• Road curve</td>
<td>• Vehicle special function</td>
<td>• Type of road user</td>
</tr>
<tr>
<td>• Crash location</td>
<td>• Road segment grade</td>
<td>• Vehicle manœuvre (what the vehicle</td>
<td>• Seating position</td>
</tr>
<tr>
<td>• Crash type</td>
<td></td>
<td>was doing at the time of the crash)</td>
<td>• Injury severity</td>
</tr>
<tr>
<td>• Weather conditions</td>
<td></td>
<td></td>
<td>• Safety equipment</td>
</tr>
<tr>
<td>• Light conditions</td>
<td></td>
<td></td>
<td>• Pedestrian manœuvre</td>
</tr>
<tr>
<td>• Crash severity</td>
<td></td>
<td></td>
<td>• Alcohol use suspected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Alcohol test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Drug use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Driving licence issue date</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Age</td>
</tr>
</tbody>
</table>

**Figure 3.1: Common Accident Data Set (CADaS)**

Crash data are much easier to analyse and use if the information is entered into a database system (see Figure 9), more information on this is provided in Section xxx.

Insert a picture of crash database here >>

For every set of general details about a crash, it is possible for there to be several records for vehicles and casualties (because there can be more than one vehicle and more than one casualty involved in a crash). This lends itself particularly well to storage in relational type database systems. Note that damage-only crashes will not have a casualty record.
Crash data are frequently and ideally collected at the actual crash scene. This means that there is an opportunity for the collection of accurate crash location information. This is essential to allow spatial analysis of crashes and targeted road safety engineering (and enforcement) treatments at unsafe locations. The crash locations can be plotted on maps and clusters, which are locations with higher crash occurrence, will become apparent as the crash numbers build-up over time (see Figure xx).

Add a figure of crash data spatial analysis here…>>>  

Masshad ,Iran (Spatial analysis of crash data)

Police crash data are broadly categorized into different severities based on the level of the worst injured casualty. Crashes are generally categorized as being:

- **Damage only - no one is injured**, but there is damage to vehicles or property.
- **Slight** - at the worst there is bruising, bleeding and only minor medical assistance is required to treat any casualties.
• Serious - at least one person was hospitalized overnight, or there were life threatening injuries sustained.
• Fatal - at least one person died as a result of the crash. Ideally the medical progress of seriously injured persons is followed for up to 30 days, however, in many countries only deaths at the scene are considered.

(WHY DAMAGE ONLY DATA IS IMPORTANT AND WHY WE CAN’T USE IT NOW- DATA QUALITY):

• Damage only data:
  - Crucial for BS id.
  - Risk of biased id.
  - Can get rid of false positives and negatives identified through random recorded fluctuations.
  (Sorensen 2007)

Most countries define a fatality as those occurring at the scene or within 30 days of the crash happening. This is international best practice and should be adopted.

The severities are important since crash and casualty severities are useful in quantifying the economic impact of road crashes. Safe System working also aims to reduce the most serious crashes as a priority; the severity of the range of crashes at a particular location is one of the factors which can be used to prioritise sites for treatment in line with this focus. Related to this, crash severities are also important for developing and applying economic appraisal methods.

3.1.4 Health System Data (Hospitals/ Ambulance Service)

Data on deaths and injuries resulting from road crashes may also be available from medical databases. It is good practice for hospitals to collect a range of information on patients, chiefly for budgeting and resource planning purposes. Ideally information is collected on all patients who receive treatment at health facilities and it is also recommended that the broad cause of any injuries is recorded. Involvement in road crashes is generally one of the major cause of unintentional injuries which require treatment in most States. In India, road traffic injuries account for xx% of the fatalities resulting from unintentional injuries.

It should be noted that hospitals will generally only hold data on seriously injured road victims, since minor injuries will more likely be treated at home or at smaller local health facilities which are less likely to be recorded.

Medical data will be much more accurate for the assessment of injury severity, though it is very unlikely that any significant information on the crash circumstances, vehicles involved or detailed location information will be collected.

Medical data may not directly assist an engineer to identify hazardous locations; however, it can assist road safety personnel to assess under-reporting rates and the realistic distribution of injury severities (proportions of fatal/serious/slight) even though hospitals record the severity of trauma injury on a different basis to the simpler categorization used for road casualties.
The ambulance system may also collect data on those persons collected from the scene of crashes and it is likely that some information on the incident location may be collected.

All traffic crashes are recorded as a Medico Legal case in hospitals. Most hospitals do not use any standardized formats. The Ministry of Health has recently established a National Injury Surveillance Centre in Delhi, which is expected to play a bigger role in data collection from health care institutions. With the initiative of NISC, National Injury Surveillance, Trauma Registry and Capacity Building Center has been established recognizing the dire need for a data management system which generates authentic information on the mortality related data of the road traffic injury victims. It also tells about the crash related information (Injury Surveillance) as well as the information on pre hospital care given to the trauma victims.

This has been introduced in few hospitals around Delhi. However, due to lack of training, inadequate supervision the data base is not very useful. Existing data is of poor quality, non-representative and difficult to access, and includes a limited number of relevant variables.

### 3.1.5 Other Useful Data Types & Sources

Although the main type of data used in road safety engineering is crash report information, there is a range of other data that can be used to help engineers. These may be available in datasets from pre-existing surveys; in some cases collection of such data may be commissioned specifically as part of the site investigation process.

These data include:

- **Flow and related data:**
  - Vehicles per day
  - Traffic mix
  - Pedestrian crossing/road use
- **Road condition information:**
  - Friction
  - Rutting
  - Potholes
  - Micro/macro texture
  - Condition information
- **Speed data**
3.5 Identification of Blackspots

3.5.1 Simple Parametric Methods

The concept of parametric models incorporates largely two differing school of thought in the process of black spot identification. The first is based on the concept of ‘accident rates, frequency and severity’ and the second concept is the derivation of ‘Safety Performance Functions’. The accident rate concept involves lesser data resources and is computationally less intensive than the concept of Safety Performance Function.

Safety Performance Functions (SPFs) through regression analysis, are developed to be used to predict the number of accidents on a roadway segment. SPFs utilise roadway features such as volume of traffic plying on the stretch, speed information, geometric features along with observed accidents (AASHTO, 2010). The generalised linear regression analysis is performed, of which negative binomial model being the most common one.

Safety Performance Functions can be developed for different segmentation approach, levels of accident severity. Further, range of inputs like traffic volumes, speeds, lane configuration, etc. can be used for SPF development (Cafiso et al. 2010; Hauer and Bamfo 1997; Hu and Donnell 2010) (Transportation Research Board (TRB), 2014). These input variables have a vital impact on the prediction power of the SPF and thus good quality and quantity of such data is necessary to generate high-quality SPF models. The availability of such detailed data, however, is limited most of the times and thus is important to find alternative means to collect such data.
The following paragraphs shall highlight the derivation of accident rates using a simplistic relationship amongst accidents.

### 3.5.1.2 Accident Rates

The grouping of accidents merely on the basis of frequency alone undermines the role of traffic volume in accident analysis. Example 1 highlights the importance of traffic volume in black spot identification.

#### Example 1

Consider two mid-blocks with the following crash record for 3 years and traffic volume details for accidents of the type head-on-collisions.

**Table 3.1: Crash record and traffic volume for head-on-collision accidents per year for a road segment of 0.5 km**

<table>
<thead>
<tr>
<th>Mid-block number of each 0.5 km</th>
<th>Fatal</th>
<th>Serious</th>
<th>Minor</th>
<th>ADT (vehicle/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>20,000</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>8,000</td>
</tr>
</tbody>
</table>

As per the black spot identification using merely the frequencies both mid-blocks 1 and 2 have similar crash record and hence are equally prioritized as black spots. However accounting for AADT (equation 1) the following accident rates are computed for midblock based on frequency.

\[
A_r = \frac{A_i \times 10^6}{365 \times \text{AADT}_i \times L_i \times T} \left( \frac{\text{Accident}}{10^6 \text{Vehicle Km}} \right) 
\]

**Equation 1**

Wherein

- \(A_r\) - Accident rate
- \(A\) - Number/ frequency of Accidents for segment \(i\)
- ADT - Average Daily Traffic for segment \(i\)
- AADT – Annual Average Daily Traffic - Average daily traffic multiplied by 365 days for segment \(i\)
- \(L\) - The length of the investigated road section \(i\) in Km
- \(T\) - The number of years

**Table 3.2: Accident Rates**

<table>
<thead>
<tr>
<th>Mid – block number</th>
<th>Accident Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.66</td>
</tr>
<tr>
<td>2</td>
<td>11.64</td>
</tr>
<tr>
<td>Average (std deviation)</td>
<td>8.15 (4.94)</td>
</tr>
</tbody>
</table>

From example 1 it is seen that an inclusion of traffic volume resulted in mid-block no 2 becoming the higher prioritized black spot. The example 1 is hence able to highlight the importance of traffic.
volume on identification of a black spot. The equation 1 utilized for assessing the accident rate assumes that accidents and traffic volume are governed by relationship. Hence an increase in traffic volume may result in an increase on number of accidents. This relationship may not be entirely true if there are other variables in dominance affecting the accident occurrence. Therefore though the black spot identification process should include traffic volume, it should also evaluate the relationship between various factors with system as a whole.

3.5.1.2 Relative Accident Severity Index:

Another common practice adopted by agencies is the use of accident severity as a measure to identify the black spots. According to National Highway Authority of India (NHAI), hazardous locations are to be evaluated based on Accidents Severity index (ASI). Hazardous spots with Accidents Severity Index (ASI) more than Threshold value (Average Severity + 1.5*Standard Deviation) will be treated as Black spots. For estimation of ASI, the weight age to fatal accident will be assigned a value of 7 and grievous injury accident a value of 3, based on NHAI's criteria.

The threshold value computation formula as per NHAI for first order, second order, third order, fourth and fifth order priority black spots are given in Table 3.3.

Table 3.3: Threshold value of priority black spots

<table>
<thead>
<tr>
<th>Priority</th>
<th>Threshold value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First order black spots</td>
<td>Average Severity + 1.5*Standard Deviation</td>
</tr>
<tr>
<td>Second order black spots</td>
<td>Average Severity + Standard Deviation</td>
</tr>
<tr>
<td>Third order black spots</td>
<td>Average Severity + 0.5*Standard Deviation</td>
</tr>
<tr>
<td>Fourth order black spots</td>
<td>Average Severity</td>
</tr>
<tr>
<td>Fifth order black spots</td>
<td>Below Average Severity</td>
</tr>
</tbody>
</table>

The relative accident severity index is computed as given in equation 2.

\[ \zeta_i = \frac{S_i}{A_i} \quad \text{Equation 2} \]

\[ \zeta_{ave} = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} A_i} \quad \text{Equation 3} \]

Wherein

\( \zeta_{ave} \) - Average relative accident severity index
\( S_i \) = fatal injury * 7 + grievous injury * 3 + minor injury * 1 for road segment \( i \)
\( A_i \) number of accidents in section/segment \( i \) for certain number of years
\( n \) - total number of homogeneous sections for a particular accident type

Using equation 2 in example 1 would result in midblock 1 and 2 being on the same rank of prioritised black spot.

Table 3.4: Accident Severity index
3.5.1.3 Accident Severity Rate

In order to provide higher weight age to fatal accidents especially in low volume roads accident severity rate could be introduced. The accident severity rate shall compute the severity index using $S_i = \text{fatal injury} \times 7 + \text{grevious injury} \times 3 + \text{minor injury} \times 1$. Once the index is computed the rate is calculated as given in equation 3

$$Q_r = \frac{S_i \times 10^6}{365 \times \text{ADT} \times L \times T}$$ \hspace{1cm} \text{Equation 4}

Wherein

- $Q_r$ - Accident rate
- $S_i$ - Accident Severity Index for section $i$
- ADT - Average Daily Traffic
- AADT – Annual Average Daily Traffic - Average daily traffic multiplied by 365 days
- L - The length of the investigated road section in Km
- T - The number of years

Using equation 3 on example 1 the accident severity rate are as computed in table 3.5

<table>
<thead>
<tr>
<th>Mid – block number</th>
<th>Accident Severity Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.79</td>
</tr>
<tr>
<td>2</td>
<td>34.47</td>
</tr>
<tr>
<td>Average (std deviation)</td>
<td>24.13 (14.6)</td>
</tr>
</tbody>
</table>

The above example amply asserts the simplicity of deriving accident rates; relative accident severity index and accident severity rate but also underlines the cautionary statement of the implications of assuming a linear relationship between accident rates and traffic volume as well as the arbitrary nature of weighing the accident severities. These methods are widely used around the world for assessing the black spots and have proven to be beneficial given their computational simplicity.

Tables 3.2 and 3.4 shows the process of identifying the black spots using the accident rates, relative accident severity index as well as accident severity rate. In order to prioritize these black spots two different techniques can be adopted, namely

1. Identifying the threshold values for frequency as well severity based accident rates, indices - similar to table 3.3.
2. Defining the critical values for each accident type within a homogenous section

3.5.2 Prioritizing accident black spots
3.5.2.1 Method 1

The process of prioritization can be kept simplistic with defined thresholds similar to table 3.3. For the first order black spots the values should exceed the summation average values within the homogenous section of same accident type and 1.5 times their standard deviation. This criterion is not satisfied by any of the tables. Hence the second order ranking of black spots is looked into which again was found to be a non-satisfying criterion. The third order ranking of black spots led to prioritization of tables 3.2, 3.4 and table 3.5 as shown in Table 3.6.

Table 3.5 Ranking of sites based on threshold values

<table>
<thead>
<tr>
<th>Mid-block number</th>
<th>Rank for values in table 3.2</th>
<th>Rank for values in table 3.4</th>
<th>Rank for values in table 3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

3.5.2.2 Method 2

The second option for ranking of sites for black spot treatment is based on identifying the spots/segments within the homogenous sections of same accident type that exceed a critical value of accident rate defined for the same. The computation of the critical value assumes that the accident rate for a particular type of accident within a homogenous section follows a normal distribution when the average accident rate is greater than 20. However it is well known that accidents are random and hence are Poisson events. A continuity correction is therefore applied to convert the discrete values of accident rates to continuous distributions. Since a spot/segment is classified as a black spot if their accident rate exceeds or is equal to the critical value; the critical value takes the form as given in equation 5, 6 and 7:

\[ A_c = \hat{\lambda} + k_\alpha \sqrt{\frac{\lambda}{m_j}} - \frac{0.5}{m_j} \]  
\[ Q_c = \omega + k_\alpha \sqrt{\frac{\omega}{m_j}} - \frac{0.5}{m_j} \]

Wherein

- \( \hat{\lambda} = \sum_{i=1}^{n} \frac{A_i}{m_i} \)
- \( \omega = \sum_{i=1}^{n} \frac{S_i}{m_i} \)

is the average accident rate for sections belonging to same population for a total of n sections.

- \( m_j \) is the continuity correction assuming normal distribution
- \( k_\alpha \) is a constant chosen for the significance test.
- \( A_i \) is the accident rates on section \( i \) during a certain time period.
- \( m_j \) - Number of vehicle kilometers in millions on section \( i \) during a certain time period.

The critical value of accident severity rate is computed as follows:

\[ Q_c = \omega + k_\alpha \sqrt{\frac{\omega}{m_j}} - \frac{0.5}{m_j} \]  
\[ \omega = \sum_{i=1}^{n} \frac{S_i}{m_i} \]
is the average accident severity rate for sections belonging to same population for a total of \( n \) sections.

\[-0.5 \frac{m_j}{m_j} \] is the continuity correction assuming normal distribution

\( k_\alpha \) is a constant chosen for the significance test.

\( S_i \) is the accident severity index on section \( i \) during a certain time period.

\( m_j \) - Number of vehicle kilometers in millions on section \( j \) during a certain time period.

The critical value of relative accident severity index is computed as follows:

\[
N_c = \zeta_{ave} + k_\alpha \sqrt{\hat{\sigma}^2} - 0.5
\]

\[\zeta_{ave} = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} A_i} \]

And the variance \( \hat{\sigma}^2 \) is measured with

\[
\hat{\sigma}^2 = \frac{1}{n-1} \sum_{i=1}^{n} (\zeta_i - \zeta_{ave})^2
\]

Table 3.6 shows the result of applications of equation 5, table 3.7 shows the application of equation 6 and table 3.8 shows the application of equation 7

Table 3.6 : Identification of Accident Black spot applying the critical value concept of Accident rate \( A_c \)

<table>
<thead>
<tr>
<th>Mid-block number of each 0.5 km</th>
<th>Fatal</th>
<th>Serious</th>
<th>Minor</th>
<th>ADT (vehicle/day)</th>
<th>Average accident rate ( \hat{\lambda} )</th>
<th>Critical value of accident rate ( A_c ) assuming ( k_\alpha = 1.282 )</th>
<th>Accident Rate, ( A_r )</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>20,000</td>
<td>6.65</td>
<td>7.81</td>
<td>4.66</td>
<td>Not a black Spot</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>8,000</td>
<td>8.42</td>
<td>11.64</td>
<td>Is a black spot</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.7 Identification of Accident Black spot applying the critical value concept of Accident Severity rate \( Q_c \)

<table>
<thead>
<tr>
<th>Mid-block number of each 0.5 km</th>
<th>Fatal</th>
<th>Serious</th>
<th>Minor</th>
<th>ADT (vehicle/day)</th>
<th>Average accident Severity rate ( \omega )</th>
<th>Critical value of accident severity rate ( Q_c ) assuming ( Q_c )</th>
<th>Accident Severity Rate, ( Q_r )</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>20,000</td>
<td>6.65</td>
<td>7.81</td>
<td>4.66</td>
<td>Not a black Spot</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>8,000</td>
<td>8.42</td>
<td>11.64</td>
<td>Is a black spot</td>
<td></td>
</tr>
</tbody>
</table>
Identification of Blackspot

Table 3.8 Identification of Accident Blackspot applying the critical value concept of Relative Accident Severity rate $N_c$

<table>
<thead>
<tr>
<th>Mid-block number of each 0.5 km</th>
<th>Fatal</th>
<th>Serious</th>
<th>Minor</th>
<th>ADT (vehicle/day)</th>
<th>Average relative accident Severity index $\zeta_{ave}$</th>
<th>Critical value of relative accident severity rate $N_c$ assuming $k_\alpha = 1.282$</th>
<th>Accident Severity Rate, $Q_r$</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>20,000</td>
<td>19.7</td>
<td>21.74</td>
<td>13.79</td>
<td>Not a black spot</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>14</td>
<td>25</td>
<td>8,000</td>
<td>22.86</td>
<td>34.47</td>
<td>Is a black spot</td>
<td></td>
</tr>
</tbody>
</table>

3.5.2.3 Complex Parametric Models

The parametric models are data intensive and the output relies solely on the quality of data. The parametric methods began as early as 1980’s wherein the initial assumption was that accident being a discrete occurrence it follows Poisson distribution (Jovanis, P.P and Chang H.L., 1986; Jones, B et.al., 1991; Miaou S.P and Lum H.,1993; Miaou S.P.,1994). Section 3.1 dealt with accident black spot assuming Poisson distribution.

Since Poisson was of single parameter form they were extended to Negative Binomial distribution, Poisson–Lognormal distribution, Poisson-Weibull Distribution and to account for excessive zeros the zero inflated Poisson as well as the Zero inflated Negative Binomial models were introduced. These models form the basis of defining the Safety Performance Functions (SPFs) and can be of fixed or random parameters (Shankar et.al., 1995; Anastasopoulos P.C. and Mannering F.L., 2009; El-Basyouny, K. and Sayed T.A., 2009; Ukkusuri, S. et.al.,2011; Mitra, S and Washington. S.,2012). The parametric models suffer from the drawback of estimating the coefficients of prediction variables globally using a given data set which may have an adverse effect on the model output in event of presence of outliers (Thakali, L.,et.al., 2016). However these models are highly popular for their ease in interpretation of results. Since accident data collected from field consists of various short falls, the choice of modeling approach falls within the discretion of the modeler. The following figure
Section 3: Crash Data Collection Identification of Blackspot

illustrates the data and methodological issues that Lord and Mannering 2010 foresee in accident analysis and the models that can be used to tackle the shortcomings.

Figure 3-2: Figure derived from Lord and Mannering 2010: Methods to be adopted for various characteristics of Accident data
SECTION 4: Blackspot Analysis

Blackspot analysis and investigation is a technique used by road authorities that have access to crash data with precise geo-locations. Recording of crash locations is covered in detail in Section 3. Where the precise locations of crashes are recorded, this allows spatial analyses to identify locations where excessive numbers of crashes are occurring.

If detailed and accurate crash data with precise locations are not available, then alternative techniques such as ‘Area wide treatments’ or ‘Corridor analysis and treatments’ can be followed. If sufficient resources are available, it is beneficial to undertake those analyses alongside blackspot analysis since these methods will identify slightly different road safety issues.

Some common misconceptions about blackspot analysis are:

- Locations with the most crashes will always be the highest priority for countermeasure treatment
- Locations with higher crash occurrence always result from an underlying safety problem

Care must be taken to ensure that the analysis has not just detected a ‘random statistical fluctuation’ Interpretation of the results of a blackspot analysis requires caution, since the analyses may just identify locations with high traffic flow or particularly busy intersections.

Once high risk sites have been located through blackspot analysis they need to be followed up with further interrogation of the crash data to identify any patterns in the types of crashes occurring and a site investigation undertaken by an experienced road safety engineer. The site visit is essential to determine where the road infrastructure itself has contributed to the occurrence of a concentration of crashes. It is also necessary to determine whether or not the crash problem is likely to be rectified through the implementation of economically viable engineering treatments.

The definition of a blackspot varies depending on the context and who is using the word.

To the road safety professional:

“A blackspot is a location where more crashes have been identified as occurring than would be expected given the road circumstances and conditions”

This can be further developed as being:

“A location where an identifiable and treatable underlying problem has been identified that is contributing to the crash occurrence”

To a member of the public or a politician, a blackspot may be

“Any location that crashes frequently happen and possibly a single location where one serious or fatal crash has happened”

4.1 Equipment and Resources Requirement

Equipment

For the desk-based analyses, crash data systems any suitable crash data management system may be required to make it easier to undertake the analyses. Crash data analysis software can make network screening and analysis of patterns significantly more straightforward; GIS or crash data analysis software may be necessary for spatial analyses.

For the site visits, similar equipment is necessary as for Road Safety Audit/RS Assessment. This includes: Video camera(s), GPS, tape measures, maps, digital cameras, spirit levels, notepads, a
vehicle and personal protective equipment (hard hats, high visibility clothing, etc.). It may not always be possible to inspect the site safely without temporary traffic management such as warning signs/cones. It may be appropriate to temporarily close the road in the case of high speed busy corridors such as expressways and some of the national highways.

**Resources**

Data analyses can be undertaken by professionals with an engineering, mathematics or statistics background. Though they would have the pre-requisite skills to undertake such analyses in a systematic manner, formal training in undertaking blackspot analysis is recommended.

Once the initial analyses have been carried out, the site visits and assessment of potential remedial measures should be undertaken by experienced road safety engineers with similar qualifications to those described for Road Safety Audit. In particular they need to have undertaken basic training in collision investigation or road safety engineering.

In addition to the involvement of engineering specialists and other technical personnel, there is usually a management process to review the schemes and to sign-off on the individual schemes for implementation. This may well be a committee-led process.

4.2 When to undertake Blackspot Analysis

Blackspot analysis is typically undertaken every year after all crash records have been closed for the previous year. The current international recommendation is that (fatal) crash reports are closed within 30 days of their occurrence, i.e., if a severely hurt person dies of their injuries within 30 days, the crash records should be amended, however if they die after 30 days the record is not amended to reflect this change. Crash data sets for a year are however seldom closed by February of the following year because different States may fail to return the information in a timely manner.

Undertaking blackspot analyses every year is advised since a severe localised problem can emerge very quickly. It is also useful to monitor blackspots on a regular basis to detect any changes in crash occurrence across the network.

4.3 Methodology

Blackspot analysis is undertaken in 7 steps, as described in the sections that follow and shown in Figure xxx.
Step 1: Investigate Background Data

As a preliminary step, the data for the whole country, state, network or jurisdiction should be investigated and analyzed to gain a broad understanding of the data and general trends.

The main types of information required are:

- General trends in crash data across the available years of data
- Typical number of casualties per crash severities (separately for high speed rural and urban roads, if possible)
- Average number of crashes per year for:
  - Different types of road (NH, SH, Single carriageway, dual carriageway, OTHER ROADS etc.)
  - Different types of junctions/ intersections

Add more information here….

Step 2: Screen Network for Blackspots

Consideration of whether a site constitutes a blackspot is often based on very simple rules and definitions. A site is usually considered as being a blackspot if there are greater than ‘x’ crashes in a section or at a site of less than ‘y’ length in ‘z’ years within a distance of ‘a’ metres. These definitions need to be determined locally in every State since patterns in crash reporting and occurrence vary so greatly.

In order to achieve a robust result, three years of crash data need to be used as a minimum. Under some circumstances (i.e. where there is significant under-reporting in States) it may be necessary to use up to five years of data. Reference should be also made to the blackspot definition guidelines issued by the MoRTH from time to time.

The number of years of data used is a trade-off between using the most recent crashes (which are more likely to be relevant to the network state as it is currently) and obtaining enough crashes per typical cluster identified so that random fluctuations are reduced. Cluster sites should ideally have enough crashes so there is a better chance to identify patterns in the characteristics of the crashes occurring. Ideally sites identified should have greater than 10 - 15 crashes if possible (this is a very basic rule of thumb).

Low volume rural roads may require longer periods of data to be used since crashes will be rare on these. For example, in New Zealand up to 10 years of crash data are used to screen these types of road. However it becomes questionable if crashes from the earlier years are relevant to the road network at the time of analysis.

The main methods used to identify blackspots are based on spatial analyses of the locations where crashes occur. The methods used all aim to identify road sections which have higher crashes occurring on them compared to other road sections. The methods that can be used differ according to the quality and type of location information available for crashes, and the nature of the network being screened (different approaches may be needed for a dense urban network when compared with a rural network).

The methods and modules available in dedicated crash data system packages or GIS software vary. The following sections outline some of the more common methods used.
Crash Density (Nearest Neighbour Method)

This method effectively finds discrete areas of higher crash densities. In this method crash database or GIS software search a fixed radius from each individual crash and if there is another crash which falls within the radii they are clustered together (see Figure xxx). The program continues to cluster crashes until no more are within range. This system is simple to understand and produces a series of cluster sites with defined, but variable, lengths along roads or at junctions.

Figure xxx: Nearest neighbour clustering

This method can be undertaken in GIS packages such as MapInfo and ArcView and is also implemented in a Crash Data Software.

Figure xxx: Cluster Analysis module in a Crash Data System
**Fixed Radius (Crashes with most neighbours)**

A variant of the crash density nearest neighbour method is a similar technique in which circles with fixed radii are drawn around every crash and the software counts the number of other crashes that occur within the fixed distance of the circles. This method effectively fixes the size of section that will be identified. This is relatively inflexible method and the process means that some longer sections may not be identified and similarly some very treatable shorter sections may be missed.

This method can be done in GIS packages such as MapInfo and ArcView.

**Heat Maps**

The heat map method produces an overlay over the road network which shows up areas of higher crash densities with ‘hotter’ or brighter colours. Superficially the results are similar to the crash density method; however this method requires some additional user interpretation to decide which sites are the worst and what their extents or lengths are.

This method is commonly available in a range of GIS packages.

**Corridor Analysis or Fixed Length Methods**

The first question to be asked is if the road sections should have constant or variable length, because this has essential implications for how the road system should be divided.

Constant length means that all the sections have the same length, for example five kilometres. This means that the sections are probably not homogeneous with regard to different relevant traffic and road design characteristics.

Variable length means that the road sections have different lengths but similar characteristics, for example between one and five kilometres. This offers the opportunity to ensure more or less homogeneous sections.

Division can be done of several road characteristics such as:

- Road category, type, status or function
- Cross section including number of lanes, lane width, shoulder and the presence of bicycle lanes and side strips
- Possibility for oncoming traffic
- Speed limit
- Number and design of intersections and access roads
- Alignment including hills and bends
- Roadside buildings
- Traffic including AADT and type
- Road category or road authority
- Traffic
- Design
- The length of the section in the town
- Number of buildings or houses in the town
- Changing of road design including speed limit
- Road sign with town and the character of the sign
The reason that constant length is suggested in the old references is that accident, traffic and road design data back then did not have the quality that made use of variable length possible. The problem in using variable length is that short road sections tend to be more often identified than long sections. This can be explained by the fact that short sections in comparison with long sections usually have more traffic and road related “disturbances” through for example intersections and access roads, what can result in more traffic conflicts. In addition, the problem is that there is a risk that local accidents peaks on long sections not will be identified because they will drown in the average for the whole section, while local maybe random accidents peaks on short sections will result in an identification of the section.

**Recommendation**

Despite the objections to divide the road system in road sections with variable length, this division is recommended. The reason is that it is necessary to have more or less homogeneous sections to make a model based identification of hazardous road sections.

But in our case, the lack of data quality forces us to use the older method as we have done in AAF/Km.

**Step 3: Prioritise blackspots for further investigation**

It is unlikely to be possible to investigate all backspots in detail; therefore it is necessary to prioritise further review and treatment. Road authorities may wish to focus their efforts on strategic/important roads that have higher traffic flows or those locations that have a greater number of higher severity crashes.

Embedded in the Safe Systems approach is a clear focus on reducing the most severe crashes; those which result in fatalities and serious injuries. Economically it is also more efficient to tackle these more serious crashes as a priority since they also inflict significantly greater financial losses on the economies of countries in addition to the pain and grief resulting.

Blackspot sites will have different numbers of crashes, with different severity profiles. These differences in site characteristics can be used to sort them into prioritised lists for investigation and analyses. To help focus actions and resources on the locations which have more fatalities or KSI (Killed and Serious Injury) crashes a severity-linked weighting scheme can be used give an initial rank to the identified cluster sites.

If no severity weighting is used, sites are ranked simply by listing them in order of the number of crashes which occur at them. What this means is that a site with 20 crashes which are all slight in severity would rank higher than a site with 10 crashes of which 5 are fatal and 5 serious.

For this reason a method of severity linked weightings is useful to produce the initial site priority order. If the same two sites were re-ranked with a severity weighting applied of 10 for a fatal crash, 5 for a serious crash and 1 for a slight crash, the first site will ‘score’ 20 (20 slight crashes times a weight of 1) and the second site would ‘score’ 75 (5 fatal crashes times the weighting of 10, and 5 serious crashes times the weighting of 5).
There is merit in using severity weightings when initially screening and ranking crash locations. If the sites are identified on the basis on the count of all crashes irrespective of severity first, some very severe sites with fewer crashes may be missed from the initial site listing.

Many international roads authorities/ organisations do try to ensure that the most severe sites are tackled as a priority; however some countries still treat all (injury) crashes with the same level of priority. It has become clearer that certain crash types correlate strongly to higher severity outcomes; this is another reason for taking severities into account.

Three main methods are generally used to take severity into account, these are:

1. Engineering expertise and judgement applied [Bias towards treating the more severe sites applied in an ad-hoc manner]
2. Weighting according to crash costs for different severities [Fatal=100, Serious=10, Slight=1, multiplied by the number of crashes of a given severity at a site to give a score]
3. Weighting in line with international practice [Fatal = 10, Serious = 5, Slight = 2, Damage Only = 1, multiplied by the number of crashes of a given severity at a site to give a score]

There is no clear right and wrong practice for using any of these methods, however an approach which favours more severe crashes but which does not weight as heavily as a system based on crash costings is recommended.

The pros and cons of these methods are listed in Table xxx.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering judgement</td>
<td>Simple, no fixed definitions</td>
<td>Lacks objectivity</td>
</tr>
<tr>
<td></td>
<td>Flexible</td>
<td>Lacks repeatability</td>
</tr>
<tr>
<td></td>
<td>Fine for more manageable programmes with low numbers of sites</td>
<td>Difficult for less experienced staff</td>
</tr>
<tr>
<td>Weighting according to crash costs for different severities</td>
<td>Easy to explain why ratio chosen</td>
<td>May focus treatment on sites with just one fatality</td>
</tr>
<tr>
<td></td>
<td>Reflects costs because of crashes at sites</td>
<td>Multiplies errors of random nature of crash occurrence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ideally need accurate costings to be available</td>
</tr>
<tr>
<td>Weighting in line with international practice</td>
<td>Can obtain balance between treating locations with different severities</td>
<td>Appears difficult to set the weight levels for different severities</td>
</tr>
<tr>
<td></td>
<td>Removes chance of wasting money treating false positive sites with single random fatal crashes</td>
<td>May need different ratios for high speed and low speed roads - complexity</td>
</tr>
<tr>
<td>No Weightings</td>
<td>Easy to rank sites based on crash numbers/ frequency irrespective of severities</td>
<td>Wastes resources on locations with many low severity crashes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generally discouraged internationally</td>
</tr>
</tbody>
</table>
In the table below we can see the different weighing schemes and severity categories used by different countries:

<table>
<thead>
<tr>
<th>NSM based on injured road users road users.</th>
<th>Killed</th>
<th>Very seriously injured</th>
<th>Seriously injured</th>
<th>Slightly injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanders (Geurts 2006)</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Norway (Ragnay et al. 2002)</td>
<td>33.2</td>
<td>22.7</td>
<td>7.6</td>
<td>1</td>
</tr>
<tr>
<td>Portugal (European Commission 2003)</td>
<td>100</td>
<td>10</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ringkøbing County, Dk (Sørensen 2003)</td>
<td>33</td>
<td>15</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.6. Severity categories and weights in reviewed identification methods in BSM and NSM based on accidents. Denmark and Germany use different weights for different roads and the average weights are shown.

Step 4: Analyse Crash Types and Patterns

The crash characteristics from identified blackspots should be investigated to identify patterns in the occurrences of the crashes. Identified patterns and commonalities should provide clues which help to
diagnose the underlying problem at the site and also will inform the development of a treatment plan targeted at solving the underlying issue.

For example:

1. If there is a high proportion of crashes in the cluster involved pedestrians, it could be due to a lack of appropriate infrastructure (footpaths or safe crossings) provisions for pedestrians
2. If there are large number of rear end collisions, it could be due to a light phasing issue, a surface friction problem, or a general speed related problem
3. If there are large number of head-on collisions, it could be due lack of overtaking opportunities encouraging dangerous overtaking
4. If there is a high proportion of turning/or emerging vehicle crashes it could that there is a lack of adequate visibility, or excessive speed

There are a number of key information types that can help diagnose the most common issues at a range of sites. So a summary report which shows a range of the key information on a single report is extremely useful. The typical information included is as follows:

- Crash types (with time trends)
- Crash numbers by severity (with time trends)
- Casualty numbers by severity
- Wet/dry break down of crashes
- Light/dark breakdown of crashes
- Severity indication (proportion of KSI crashes)

Ideally these data should be displayed efficiently and in a standard format so that a large amount of information can be quickly assessed to identify any clear patterns and trends [see Figure xxx, courtesy xxx].

Insert a summary analysis form

These reports can be produced semi-manually by performing the appropriate cross-tabulations and filling in a form in MS Excel or similar, or they can be generated automatically by dedicated crash data system software.

Stick Analysis

Another useful and established method to analyse the crashes at blackspots is ‘Stick Diagram Analysis’. This method allows the safety engineer to view groups of crashes with each individual record being represented by a column or ‘stick’ of information. By moving these ‘sticks’ of information around, or highlighting similar factors, the safety engineer can often discover patterns in the crashes at a particular location, and this can help them to identify some underlying causes.

The sticks can be produced by hand with the diagrams being filled from the individual records by pen or pencil on simple paper forms or grids (Figure xx and Figure xx). The individual sticks can be cut out so they can be manually sorted by the different row values. This method has the advantage that it makes the engineer look carefully at the individual crashes which can also be a useful process.
Section 4: Blackspot Analysis

Using specific stick analysis software modules in crash data systems can make stick sorting and shuffling easier and the addition of different fields can be done much more quickly and flexibly. The sticks can use simple abbreviations or the numerical values for the fields of interest to show a great deal of information on a single sheet with the use of icons and colour can make the patterns more readily

**Figure xx: Sample Completed Grid**

<table>
<thead>
<tr>
<th>Accident No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference No.</td>
<td>348604</td>
<td>J228300</td>
<td>J251500</td>
<td>J430700</td>
<td>J012001</td>
</tr>
<tr>
<td>Day</td>
<td>Sunday</td>
<td>Friday</td>
<td>Tuesday</td>
<td>Thursday</td>
<td>Saturday</td>
</tr>
<tr>
<td>Time</td>
<td>14.50</td>
<td>9.00</td>
<td>16.07</td>
<td>18.01</td>
<td>18.29</td>
</tr>
<tr>
<td>Severity</td>
<td>Fatat</td>
<td>Slight</td>
<td>Slight</td>
<td>Slight</td>
<td>Slight</td>
</tr>
<tr>
<td>Dark/light</td>
<td>Daylight</td>
<td>Daylight</td>
<td>Daylight</td>
<td>Darkness</td>
<td>Darkness</td>
</tr>
<tr>
<td>Street lights present</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, lt.</td>
<td>Yes, lt.</td>
</tr>
<tr>
<td>Weather</td>
<td>Fine, no high winds</td>
<td>Fine, no high winds</td>
<td>Fine, no high winds</td>
<td>Fine, no high winds</td>
<td>Fine, no high winds</td>
</tr>
<tr>
<td>Road Surface</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Wet/Damp</td>
</tr>
<tr>
<td>No. vehicles</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Vehicle 1</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
</tr>
<tr>
<td>Vehicle 2</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
</tr>
<tr>
<td>Vehicle 3</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
<td>Car</td>
</tr>
<tr>
<td>No. casualties</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Casualty 1</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>Passenger</td>
</tr>
<tr>
<td>Age</td>
<td>31</td>
<td>32</td>
<td>59</td>
<td>41</td>
<td>46</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Female</td>
</tr>
<tr>
<td>Casualty 2</td>
<td>Pedestrian</td>
<td>Passenger</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
</tr>
<tr>
<td>Age</td>
<td>21</td>
<td>40</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
</tr>
</tbody>
</table>

Description:

- V1 travelling NW on A184 had overtaken stationary vehicles at lights was pulling back over to left at j/w old fold rd and struck pedestrians crossing from s/side of A184.
- V2 travelling SW on Neilson Rd stopped at the traffic lights. V2 crossed A184 when lights turned green. V1 travelling NW and failed to see red traffic light. V1 strikes V2 on the nearside.
- V2 and V3 travelling west on A184 waiting to go ahead at traffic lights j/w Neilson Rd. V1 approaching lights failed to stop and skidded into rear of V3 shuttling it into V2.
- V1 travelling west on A184 without侦察. V2 brakes and skids on damp surface colliding with rear of V2.
apparent (see Figure xxx).

Insert a sample stick diagram

Stick analysis is usually limited to groups of 5 to 30 crashes or less, since it is about seeing associations and applying it to very many crashes may mean that the patterns are missed.

One of the most useful analyses is to re-order the sticks by time (hours) to see if any types of crashes are occurring at particular times of day. For example, it may be that turning crashes are mostly occurring at the morning peak or that cycling crashes are happening after dark.
SECTION 5: Site Investigation

5.1 Site Visit

It is always necessary to inspect the site where the accidents have happened, because you will learn things that are not evident from a study of the accident data. But to avoid jumping to conclusions do not do this until you have carried out the preliminary analysis of the accident data. Take the accident reports and analyses with you to the site. There are two main reasons for doing the site inspection:

- to accurately assess the road conditions and other site factors which may be relevant
- to try and experience the problems that road users are facing.

Try and make the site visit at the same time of day as when the dominant accidents occur (if time-of-day is identified as an important factor). Ideally the investigator should walk, drive and perhaps cycle through the site in both day and night-time conditions, and should carry out the manoeuvres that have been causing problems. It is rarely practicable to do all this, but a lot can be learnt from just walking and driving through the site. Look out for crash evidence, such as broken glass, skid marks, and broken walls and trees. It will help confirm the exact location of the accidents and what exactly happened. You then have to try and understand why a minority of road users are failing to cope with the situation. Where possible take photographs of the site and each approach, as it can be difficult to visualise it exactly once you are back in the office.

Remember that accidents are multi-factor events, so look beyond what may be the obvious cause. You are searching for underlying factors for which there is a known countermeasure. In many cases these underlying factors will not appear in the accident form. Common examples include:

- obstructions to visibility, such as parked cars, roadside furniture, trees
- lack of visual clues, e.g., it is difficult to recognise that there is a bend or junction ahead
- lack of pedestrian facilities.

Talking to the local people who live and work near the site can often be very rewarding, as they may have witnessed many of the accidents, but remember that what they say may not be wholly reliable. It is always useful to have the Police with you as well as the PWD engineer responsible for the road; apart from them being able to tell you what they know of the accident situation, it gives you an opportunity to discuss your initial diagnosis with them and this will probably make it easier to get their agreement to the countermeasures.

Bring the following items for the site visit:

- A camera for site photographs;
- Tape measures (50m and 30m are useful) or distance measuring wheel;
- A radar gun for measuring speeds;
- Pen/pencil and a survey pad for recording details;
- Survey plan or scheme drawings on which to plot site details;
- Reflective/safety jackets;
- Copies of the Summary Analysis Form, the collision diagram, and the Site Investigation Form. Adopt the following safety protocol for all site visits:
  - Ensure personal safety/team safety (e.g., wear reflective jackets, pay attention to the movement of traffic, if working in the carriageway have someone next to you whose sole duty is to watch for traffic);
  - Ensure public safety (e.g., do not park on the road, obstruct traffic, or obstruct the sight visibility of other road users, switch hazard lights on if appropriate).
5.2 Site Investigation Form

Use the Site Investigation Form to record findings. It contains a Site Factors Diagram (Fig 5.1), Physical checklist (Fig 5.2), and an Operational checklist (Fig 5.3). The Form can be modified in the light of experience, and to suit the way you like to work.

**Figure 5.1 Site Factor Diagram**

**Site Reference:** .................................................................
Sate. ............................................... , District .....................................
Road No. and chainage: .................................................................
Location description: .................................................................
Police station: ..............................................................................
Landmarks ..................................................................................

<table>
<thead>
<tr>
<th>MARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Road names</td>
</tr>
<tr>
<td>• Markets</td>
</tr>
<tr>
<td>• Schools</td>
</tr>
<tr>
<td>• Bus stops</td>
</tr>
<tr>
<td>• Trading</td>
</tr>
<tr>
<td>• Parking</td>
</tr>
<tr>
<td>• Road humps</td>
</tr>
</tbody>
</table>

Hazardous potholes North

Arm 1, main road Arm 2, main road Arm 3, main road Arm 4, main road

**PHOTOS**

Arm 1: 50 and 150m Arm 2: 50 and 150m Arm 3: 10 and 50m Arm 4: 10 and 50m

Sections and bends: every 100m or as appropriate
**Figure 5.2 Physical checklist**

**Site Reference: .................................................................**

Were accidents caused by the physical condition of the road, such as sight obstructions, blind corners, wrongly-sited islands, road signs, or adjacent property? Can the physical conditions leading to the accidents be corrected?

1. Is the street alignment adequate?
2. Are lane widths adequate? (turning lanes: minimum 3.0 m; other lanes: minimum 3.25 m)
3. Are there adequate facilities for pedestrians?
4. Should pedestrian crossings be relocated / repainted?
5. Are the road signs adequate in terms of their message, size, placement, or conformity?
6. Are the signals adequate in terms of their placement, conformity, number of signal heads, or timing?
7. Are road markings adequate in terms of type, clarity and location?
8. Is traffic properly channelised to minimise the occurrence of accidents?
9. If night-time accidents represent a considerable proportion of the total number of accidents, is the street lighting or the number of reflectors adequate?
10. Are parking arrangements adequate?
11. Are the bus stops located in a safe place?
12. Does the road geometry encourage safe speeds?
13. Is the road surface adequate? Does it drain properly?
14. Are there obstructions in the road or close to the edge?

**Comments:**

**Figure 5.3 Operational checklist**

**Site Reference: .................................................................**

Is the driver's view of other vehicles / pedestrians obstructed?

1. Do drivers respond incorrectly to signals, signs, or other control devices?
2. Do drivers have trouble understanding and finding the correct path through the location?
3. Are there hidden hazards - such as a sharp bend beyond a crest?
4. Are vehicle speeds excessive for this situation? Are there speed differences? If yes, in which driving direction?
5. Are parking or other traffic regulations regularly violated?
6. Are vehicles delayed? Can the delays be reduced?
7. Are there traffic flow deficiencies or traffic conflict patterns associated with turning movements?
8. Would one-way operation make the location safer?
9. Is the traffic volume causing problems? Are there sufficient gaps in the main road traffic to enable drivers from side roads to enter the main road without excessive delay?
10. Are there sufficient gaps in the traffic to enable pedestrians to cross the road without excessive delay?
11. Are pedestrians crossing the road at the safest places? Can they see whether it is safe to cross?
12. Is there need for effective/selective enforcement or effective/selective maintenance?
13. Are buses and bus passengers using the facilities that have been provided for them?

**Comments:**
SECTION 6: Final Diagnosis & Develop Countermeasures

6.1 Final Diagnosis

It may sometimes be necessary to carry out additional surveys and studies in order to help confirm your analysis and prepare the way for designing countermeasures. These could include:

- detailed examination of witness statements in the Police case file
- traffic counts
- surveys of vehicle turning movements at junctions (always necessary before redesigning junctions)
- pedestrian counts (to determine where most people cross or which side of the road they use)
- surveys of pedestrian crossing behaviour (do they cross in one movement or stop in the middle? - what do they find most difficult? - do they make a detour to find a safer place to cross?)
- measurement of road surface skid resistance
- speed surveys
- measurement of visibility distances
- conflict studies (observing the interaction of traffic (including pedestrians) at a site and recording the conflicts or "near-misses")

The next stage is to summarise the results of the analysis. The findings must be soundly-based and clearly expressed, because they are the basis for selecting the countermeasures. Remember that the aim is to identify contributory factors that we might be able to change - for example:

- poor visibility where a side road meets a main road
- excessive speeds through a village
- drivers having difficulty in judging the sharpness of a bend
- pedestrians taking risks in crossing a busy, wide road

Make another site visit to test the conclusions of the analysis. It helps if a second officer can undertake an independent review of the analysis so as to ensure that the conclusions are valid and that nothing has been overlooked.

The analysis should yield two types of locations:

1. Locations where distinct problems are identified;
2. Locations where the analysis was inconclusive.

6.1.1 Identify Distinct Problem

Where clear problems are identified (Case 1), continue the treatment process as outlined in the next section. In Case 2, where the analysis does not identify distinct problems, this should be discussed and the site should be reassessed in 12 months, when more accident data may be available. If after 12 months the analysis is again inconclusive, the site should be held under observation or the investigation should be terminated. Either way, the result should be reported. If the file is closed, it should be labelled "No identified problems found in the analysis”.

6.2 Develop Countermeasures
If you have identified one or more dominant accident types and have reached some conclusion about the causal factors involved (and these causes are capable of being treated or remedied) it is now time to match solutions (countermeasures) to problems. The solutions should accomplish at least one of the following:

- Remove the conflict causing the problem;
- Improve the situation (e.g., provide earlier warning so that road users can cope better); or
- Reduce the speed, thus reducing the accident risk and accident severity.

Specific countermeasures vary from country to country depending on the road users’ traffic culture and the level of development of the road and traffic system. It will take some time to identify which are the most appropriate countermeasures for state or region specific accident problems.

6.2 Further Consideration

When thinking about countermeasures you need to consider the following:

- *is the remedy cost-effective?* - some measures may be effective without being cost-effective - generally we should be looking for low-cost measures;
- *is it likely to be long-lasting?* - some speed-reduction measures for example have an immediate effect but this wears off as drivers get used to them;
- *will it result in an excessive increase in other types of accidents?* - for example, in some circumstances the introduction of traffic signals can result in an increase in rear-end collisions;
- *will it have any unacceptable effects on traffic or the environment?* - road humps for example can cause traffic noise nuisance as vehicles brake, and may result in traffic diverting onto other less suitable roads;
- *will it be very unpopular with road users?* - if so, you could come under strong pressure to remove it;
- *will it need to be heavily enforced by the Police or need considerable publicity and education?* - if so, consider whether this is really achievable.

6.3 Cost-benefit analysis for Selecting a Countermeasure

When accidents are costed, many accident remedial schemes pay for themselves in a matter of months, especially in the first years of implementing a systematic blackspot treatment programme. At any one site, several different countermeasures could reduce the number of road accidents: the engineer must select one that is cost-effective.

The standard way of ranking schemes according to cost-effectiveness is to do a cost-benefit analysis comparing the value of the likely accident savings with the estimated cost of the scheme. The easiest and most widely-used method is to calculate what is known as the First Year Rate of Return (FYRR). This is simply the net monetary value of the accident savings expected in the first year of the scheme, expressed as a percentage of the total capital cost.

The main steps are:

- estimate the capital cost of the scheme
- estimate the likely number of accidents to be saved in the first year
- calculate the monetary value of those savings
- adjust the gross value of accident savings to a net amount by taking account of other consequential changes in accidents (some types of accidents may increase) possible increased maintenance costs, and other disbenefits
- express the net value of accident savings as a percentage of the capital cost
The scheme cost should be estimated by adding up the cost of each component (road signs, markings, road humps, traffic islands, etc). A list of standard costs (2001 prices) is given in Appendix C. This will need to be updated regularly to reflect price changes, and any changes in standards and construction methods.

Estimating the likely accident saving may seem difficult, given that we have little experience so far, but it is unlikely to be so different from British and Australian experience which is described in various reference works (note especially: Ogden, "Safer Roads, A Guide to Road Safety Engineering", and Ogden, Traffic Engineering Road Safety: A Practitioners Guide"). In most cases it can be assumed that the average reduction in accidents of the kind being treated will be about one-third. In a few cases, such as putting in road humps to cut pedestrian accidents, you might get a reduction of two-thirds, but this is unusual. Signs and road markings when used on their own tend to reduce accidents by around 15% - this might not seem much, but it is often enough to give a good rate of return on the investment involved.

It is standard practice to work with casualty accidents only (because of poor reporting of damage-only accidents) but take account of damage-only accidents in the costings. The cost to use is the cost of the average casualty accident with an allowance for damage-only accidents. This is calculated by dividing the estimated total cost of all road accidents (casualty and damage accidents) by the estimated number of casualty accidents.

6.3.1 Example of First Year Rate of Return (FYRR) calculation

**Scheme:** installation of a chevron sign at a bend in order to reduce loss of control accidents  
**Accident record:** average of 5 casualty accidents per year (4 x single vehicle loss of control and 1 x pedestrian/vehicle, - so, there are 4 treatable accidents)

**Estimated accident saving in first year:** 15% reduction in treatable accidents, - so 0.6 accidents prevented

**Cost value of accident savings:** 0.6 x INR X, where X cost of an accident

**Capital cost of sign (including installation):** INR Y

\[
\text{FYRR} \, (\%) = \frac{\text{Accident Savings} \times 100}{\text{Capital Costs}} = \frac{0.6 \times \text{INR X} \times 100}{\text{INR Y}} = 160\%
\]

This may seem an incredibly high rate of return, but experience from other countries proves that such returns are achievable, especially in the early years of an accident remedial programme.

For major remedial schemes with a significant maintenance and renewal cost element (such as the installation of traffic signals) it will be better to use an economic assessment method such as **Net Present Value** which takes account of costs and benefits over a number of years.

6.3.2 Determining priorities

Ranking the potential schemes by FYRR will give you an initial priority ranking, but other considerations could include:

**Demonstration value:** give high priority to innovative schemes which could have a wide application - especially if they are low-cost and very cost-effective

**Views of the Police, the PWD Executive Engineer, and senior PWD management:** give priority to schemes which they are enthusiastic about, because their support could be critical to getting the schemes implemented and working properly
Likelihood of public support: give high priority to schemes that are highly visible, will work well, and be well understood and liked by the public, because public support for accident remedial work (as reflected in media interest for example) could be valuable in promoting expansion of the programme.

After completing this analysis you should be in a position to decide whether to proceed to detailed design.

6.4 Countermeasures

The section here list out each of the common types of accidents. They are based on experience in Europe, Australia and elsewhere. Generally the countermeasures at the top of the list are likely to be the most effective. It is worth emphasizing once again the importance of: studying the accident data, identifying the dominant accident types, identifying the causal factors, and selecting remedial measures which are likely to be effective in remedying the deficiencies that have been found. Do not select countermeasures from these lists without doing this analysis.

The countermeasures are listed by accident type. Note that it is sometimes difficult to classify accident type precisely. Some could be put in more than one type. The accident types used are:

- Single vehicle accidents
- Pedestrian accidents
- Accidents for vehicles driving in the same direction
- Accidents at junctions
- Accidents between vehicles travelling in opposite directions
- Rail crossing accidents

This list has been extensively adapted from one in "Manual on Road Safety Improvement by Use of Low-Cost Engineering Countermeasures", National Highway Authority, Pakistan.

6.4.1 Single vehicle accidents

6.4.1.1 Subtypes:

A. "Ran off road (no collision)"
B. "Hit object on / off the road"

A. B.
Causes

- Excessive speed
- Tiredness, darkness
- Road alignment is unclear
- Sharp bend after straight section
- Sharp sag or crest curve
- Incorrect superelevation
- Tree / pole / bridge parapet / other hazard is too close to the edge of the road and is poorly marked
- Steep gradient
- Potholes or depressions in road surface
- Road surface is slippery when wet
- Ponding of water on the road
- Attempt to avoid collision
- Traffic island that is difficult to see
- Vehicles are parking on the road at places where the visibility is limited

6.4.1.2 Countermeasures

Improve signing

- Install warning signs (e.g. sharp bend chevrons, "Reduce Speed Now" signs, and other appropriate signs)
- Install delineator posts
- Consider advisory curve speed signing
- Consider applying speed limits
- Ensure that all traffic islands, medians are well signed
- Install hazard markers on obstructions close to the edge of the road and / or paint the obstruction with black and yellow stripes
- Install advance direction signs or junction warning signs for all junctions

Improve road markings

- Mark centre and edge lines - use extra-wide lines for added emphasis
- Consider using reflective road studs on the centre and edge lines
- Apply hatch markings in advance of medians and traffic islands
- Mark stop lines / give way lines at all junctions.

Improve visibility

- Remove bushes, trees, advertising hoardings if they are obstructing visibility
- Consider installing street lighting if site is in an urban area

Soften the roadside environment
Final Diagnosis & Develop Countermeasures

- Remove roadside obstacles or move them further back from the road
- Consider installing guardrail
- Consider re-forming embankments and cuttings to make the side slopes less steep

Improve the geometry
- Eliminate sharp changes in alignment - re-align the road completely - use transition curves
- Ease gradient
- Widen the road at a curve
- Correct the superelevation if faulty

Improve the road surface
- Fill any potholes and repair damaged edges
- Improve drainage if water ponding is a cause of accidents or pothole formation
- Improve skid resistance, especially if there is a high incidence of wet weather accidents

Speed limiting measures
- Install rumble strips with signs
- Consider installing speed breakers with signs
- Encourage active police enforcement of speed limits.

For accidents involving parked vehicles
- Consider a ban on parking
- If angled parking is involved consider conversion to parallel parking
- Consider increasing the clearance between the parking bays and through traffic lanes
- If many of the accidents are at night consider provision of street lighting.
6.4.2 Pedestrian accidents

6.4.2.1 Subtypes

A. "Pedestrians walking along the road in direction of traffic or towards the traffic";
B. "Pedestrians crossing the road";
C. "Pedestrians standing on/by the road";
D. "Pedestrians crossing the road and obscured by stopped / parked vehicle";

Pedestrian = O or 4

A.  

B.  

C.  

D.  

6.4.2.2 Causes

- Negligent crossing / walking
- No footway or footway in poor condition
- Narrow road
- Poor visibility for pedestrians
- Poor visibility for drivers
- Wide road to cross
- Excessive speeds
- Heavy traffic volumes - few gaps in which to cross
- No crossing facilities or clear places to cross
- Darkness
- Children playing in the road

6.4.2.3 Countermeasures

Improve facilities for pedestrians walking along the road

- Widening/construction of shoulders
- Mark edge line to separate shoulder from carriageway
- Construct footways
- Painting of edgelines to separate shoulders from carriageway.

Improve facilities for pedestrians crossing the road

- Mark zebra crossing where this is justified by the volume of pedestrians and traffic
- Provide rumble strips on both sides of a zebra crossing
- Erect advance warning signs for pedestrian crossings
- Channel pedestrians to safe crossing sites by means of pedestrian guardrail
Final Diagnosis & Develop Countermeasures

- Construct pedestrian refuge (with barrier kerbs or with over-runnable kerbs) to enable pedestrians to cross wide roads in two stages
- Provide a line of reflective studs on both sides of a zebra crossing
- Construct raised zebra crossing (with warning signs)
- Construct overbridge or underpass
- Provide signal-controlled crossing
- If accidents are at a signal-controlled intersection, consider provision of pedestrian signals and an exclusive pedestrian phase

Speed limiting measures
- Speed limit signs
- Construction of speed limiting measures, such as speed breakers (highly effective in reducing pedestrian accidents)
- Active police enforcement.

Improve visibility
- Prohibit parking
- Removal of sight-limiting obstacles
- Where there is on-street parking, construct a build-out to improve visibility for pedestrians
- Consider street lighting (especially of crossing sites) if site is in an urban area
- Re-site bus stops so that buses do not obstruct visibility
6.4.3 Accidents between vehicles driving in the same direction (other than at junctions)

6.4.3.1 Subtypes:

A. "Side swipe - changing lanes or collision while overtaking";

B. "Hit from rear (nose-to-tail)"

6.4.3.2 Causes

- Lack of lane markings
- Lack of lane discipline
- Confusion over which lane to be in
- Lanes are too narrow
- Dangerous overtaking
- Careless driving - following too closely
- Vehicle ahead stops suddenly (bus, taxi, auto)
- Stopped vehicle sets off suddenly
- Excessive speed
- Dangerous U-turn

6.4.3.3 Countermeasures

Improvement of road markings/signs

- (Re)paint lane markings and centrelines
- Supplement road markings with reflective studs
- Mark lane direction arrows where appropriate
- Mark no-overtaking zones
- Ban U-turns
- Erect warning signs and advance direction signs for junctions (consider overhead signs).

Improvement of road facilities

- Consider provision of wider lanes
- Block gaps in median to prevent U-turns
- Provide bus bays where possible.

Speed limiting measures

- Speed limit signs
- Construction of speed limiting measures, such as speed breakers or rumble strips
- Active police enforcement.
6.4.4 Accidents at junctions

6.4.4.1 Subtypes:

A. "Hit from side" - vehicle from side road hits a vehicle on the main road
   Two distinct types: Overshoot and Restart
B. "Hit from side" - vehicle turning out of main road is hit by oncoming vehicle
C. "Hit from rear" - vehicle going ahead or turning out of main road is hit by a following vehicle
D. "Hit from side" - vehicle in the roundabout is hit by an entering vehicle
E. "Hit object on road" or "Ran off road" - vehicle entering the roundabout loses control

6.4.4.2 Countermeasures

Subtype A: "Hit from side" - vehicle from side road **overshoots** the stop / give way line and hits a vehicle on the main road

- Ensure adequate warning signs / advance direction signs on the side road
- Ensure there is a clearly visible Give Way or STOP sign
- Install a splitter island in the side road
- If a cross-roads, consider altering it to a staggered junction
- If a skew junction consider re-aligning the minor road so that it joins the major road at a right angle
- If a lot of the accidents are at night consider installing / improving street lighting
- Consider installation of rumble strips or other traffic calming measures in the side road
- If the junction is signal-controlled improve the visibility of the signals (additional signal heads, overhead signals, backing boards)

Subtype A: "Hit from side" - vehicle from side road **hits a vehicle on the main road after restarting** from the stop / give way line

- Improve visibility at the stop / give way line by clearing obstructions
• If a skew junction consider re-aligning the minor road so that it joins the major road at a right angle
• Consider installing traffic signals if visibility cannot be improved
• Consider installing traffic signals or roundabout if the volume of traffic on the main road is so high that there are few gaps for side road traffic to turn into

**Subtype B: "Hit from side" - vehicle turning out of main road is hit by oncoming vehicle**

• Clear any obstructions to visibility for vehicles waiting to turn right out of main road
• Consider providing protected turning lane
• Consider prohibiting the right turn and U-turn if it can be catered for more safely at another junction
• If the junction is signal-controlled consider provision of a fully-controlled right turn phase
• If a right turn phase exists consider provision of a right turn red arrow to prohibit the turn during the remainder of the signal stage (a fully controlled right turn phase)

**Subtype C. "Hit from rear" - vehicle going ahead is hit by a following vehicle**

• Improve the warning signs / advance direction signs
• If there are a lot of wet weather accidents check skid resistance and drainage
• At signal-controlled junctions check stopping sight distance to "tail of queue", and duration of amber signal - improve the visibility of the signals and consider provision of overhead signals

**Subtype C. "Hit from rear" - vehicle turning out of main road is hit by a following vehicle**

• Improve the warning signs / advance direction signs
• Provide protected right / left turn turning lane
• Consider prohibiting the right turn if it can be catered for more safely at another junction

**Subtype D. "Hit from side" - vehicle in the roundabout is hit by an entering vehicle**

• Improve the warning signs / advance direction signs
• Provide Give Way signs and markings at the entries to the roundabout
• Remove any obstructions to visibility close to the give way lines
• Consider altering the geometry of the approach arms so as to encourage slower speeds (increased deflection)

**Subtype E. "Hit object on road" or "Ran off road" - vehicle entering the roundabout loses control**

• Improve the warning signs / advance direction signs
• Put Turn Left and Chevron signs on the centre island opposite each entry
• Provide Give Way signs and markings at the entries to the roundabout
• Consider altering the geometry of the approach arms so as to encourage slower speeds (increased deflection)
• If there are a lot of wet weather accidents check skid resistance and drainage
• Consider installing rumble strips or other traffic calming measures on the approaches
6.4.5 Accidents between vehicles travelling in opposite directions

Subtypes:
A. "Head-on collision while overtaking";
B. "Other head-on-collisions"

B. ▲▼

6.4.5.1 Causes
- Excessive speeds - loss of control
- Careless overtaking
- Drivers get frustrated because there are few opportunities to overtake
- Short straight road section after a long hilly and curvy one
- Steep hills with slow heavy traffic
- Slow traffic uses centre of road
- Vehicles "cut the corner" at bends
- Poor forward visibility
- Vehicle swerves to avoid pothole
- Vehicle swerves to avoid bad edge
- No centreline
- Narrow road

6.4.5.2 Countermeasures

Improve control
- Mark edge and centre lines
- On wide roads mark lane lines
- Mark no overtaking zones and consider installing no overtaking signs
- Supplement markings with reflective studs
- Use "ladder" hatch markings on centreline to create a painted median - and reinforce the markings with rumble strips
- Install warning signs (e.g., for bends, junctions, narrow roads)
- Install delineator posts
- Install speed limit signs and provide active police enforcement
- If there is a median, consider: improving the signing / marking, widening of the median or provision of a median barrier.

Improve the road surface
- Patch potholes
- Repair damaged edges.

Improve the alignment
- Improve sight distances by improving geometry or/and by clearing bushes or obstructions
- Increase the number of sections with opportunity for safe overtaking
- Construct overtaking/crawling lanes.
Upgrade the road

- Consider widening the lanes and / or shoulders (but note that excessive width might encourage dangerous overtaking)
- Upgrade the road to a dual carriageway.

6.4.6 Rail crossing accidents

6.4.6.1 Causes

- Excessive speed
- Poor visibility
- Careless overtaking
- Inattention by driver
- Failure of crossing control system
- Crossing may be narrower than approach roads

6.4.6.2 Countermeasures

- Improve visibility of the crossing - and any light signals associated with it - consider road re-alignment where economically justified
- If the crossing is unmanned improve the visibility along the rail track on the approach to the crossing
- Upgrade the signing and marking so that no-one can be in doubt that they are approaching a crossing - consider using "countdown posts"
- Discourage overtaking by means of signs and markings
- Install speed reducing measures (rumble strips, road humps, etc) on the approaches
- Consider provision of street lighting if many of the accidents are happening at night
- Consult the railway authority about changing the control system (unmanned to manned or automatic)
- Consult the railway authority about widening the crossing if it is narrower than the approach roads
- Consider replacing the crossing with an overbridge or underbridge
SECTION 7: Prepare Scheme Drawings & Implementation Plan

7.1 Detailed Design

The amount of work involved in the detailed design depends very much on the complexity of the scheme. It is always advisable to produce a scheme drawing, even if all you are doing is installing a few signs. Scheme drawings:

- force you to think through what are you proposing
- enable you to check how everything will fit on the site, and whether there will be any conflicts or other problems
- enable tenderers to better understand what is involved and thus give you a realistic price
- provide a basis for controlling the construction work on site

If there are road markings, or islands, or alterations to kerb lines and carriageways, you will need to prepare a scale drawing (preferably to a scale of 1:250). Finding a drawing of the site to this scale can be difficult. You may be able to find an old drawing which you can update by doing your own field survey (using simple methods such as triangulation and datum lines). Otherwise you will have to commission a surveyor to produce the site plan.

Accident countermeasures will only be successful if they are carefully designed with a lot of attention to detail and positioning. For this reason it is recommended that all accident schemes be designed by trained road safety engineers.

It is always good to **discuss the scheme with the people living and working around the site.** Try to explain to them what you are doing and why. You may need to convince them that they will have to be a bit more disciplined (e.g. in where they cross the road, or park their vehicles) in order to reduce accidents. Without the support of local people your scheme might fail, and the signs and other equipment may be vandalised or stolen.

When finalising designs for junction improvements and any works in the road, make the following checks:

- will it be clear to road users what they are meant to do?
- can all vehicle manoeuvres be made easily and safely? - use turning circle templates to check that trucks and buses can get through easily
- will any of it present a hazard to road users? - especially at night and to motorcyclists

Try and visualise what it will be like to drive through the scheme - from all approaches and making all possible manoeuvres. Consider how the scheme might be abused by lazy or errant road users. Schemes which require a constant police presence to make them work are not feasible. It is good practice to arrange for a safety audit to be done, preferably by a member of Road Safety Cell staff who has not been involved in the design work.

7.2 Site trial

A trial of the scheme on site can give you a good idea of how well it will work. It is particularly appropriate for urban schemes where you are introducing new features (e.g. splitter islands, refuges) on the road. And it is probably essential, if you have had to design the scheme without an accurate site map. It also gives you an opportunity to demonstrate the scheme to the Police and key NHAI/PWD staff. The simplest way of doing the trial is to mark out the new kerb lines and islands with traffic cones and, if possible, install temporary traffic signs. You can then observe how well road users cope with the new layout. If the cones get knocked out of place it may indicate that the layout is too restrictive. You can use sandbags or concrete blocks instead of traffic cones, but be careful not to create a hazard at night.
7.3 Bill of Quantities (BoQ)

This document is critical for the costing and tendering, and should be prepared with considerable care. You need to think through the tasks that will have to be done, including the preparation of the site, and any tidying up afterwards. Having detailed specifications (written specifications and standard drawings) which, for example, explain how signs should be made, or how traffic islands should be constructed, makes things easier, because you do not then have to detail every individual stage in the BoQ.

7.4 Scheme Report

It is useful to prepare a brief report on each scheme, and submit details of its programme before funding will be approved. Suggested structure is as follows:

- A description of the site and its accident history;
- A summary of the identified problems (collision diagram) and recommended solutions;
- Relevant photographs;
- Summary of what is proposed;
- Accident reduction expected;
- Estimated cost - anticipated rate of return.

A colleague should review the draft report before it is finalised. Make sure that a copy goes on file.

7.5 Implementation

The implementation process ideally involve:

- Preparation of tender documents
- Pre-bid meeting
- Evaluation of tenders
- Pre-commencement meeting
- Construction supervision

7.6 Tender documents

Ensure you follow PWD standard practice when preparing the tender documents.

7.7 Construction supervision

The Engineer plays a crucial role in ensuring that the scheme is implemented in a satisfactory manner and performs as intended. He (she) must be on-site whenever the contractor is working.

The importance of good site supervision by a knowledgeable safety engineer cannot be over-emphasised. All the planning and design effort will be wasted if it all goes wrong on site. Where there is any confusion in the drawings and specifications, or there is a lack of detail, the Engineer must give clear instructions. All signs, markings, kerbing, road humps etc., must be set out first (preferably using paint marks) by the contractor and then be checked and approved by the Engineer. Sign visibility distances, mounting heights, orientation, and clearance from the edge of the road need to be checked.

The blackspot improvement scheme must set a good example to others on how to ensure safety at road works. Insist that the work site is properly signed and that there is a clear and efficient system of traffic control where necessary. This will be easier to achieve if works site signing is included as a specific item in the BoQ. Use standard roadworks signing plans, and include these in the tender documents. Clarify what is required with the contractor before work commences. The Engineer should be prepared to take whatever sanctions are available under the contract if the contractor fails to provide adequate signing and traffic control.
7.7 Scheme Implementation Record

Make sure that the work is properly recorded in the accident site file. The dates when things were done are particularly important - it is difficult to evaluate the effectiveness of a scheme when you cannot remember what was done when. It is also vital to keep a record of the costs. The SCHEME IMPLEMENTATION RECORD (Figure 7) should be used. When follow-up work is done at the site enter the details onto the record form. Over time this will become a valuable history of what was done at the site.

**Figure 7 Scheme Implementation Record**

**Site:** Karani NH47 km540.200

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>13/10/00</td>
<td>2 chevron signs (TA3) installed at bend. Cost: Rs 40,000</td>
</tr>
<tr>
<td>5/7/01 to</td>
<td>Centre line and edge line marked</td>
</tr>
<tr>
<td>8/7/01</td>
<td>(Thermoplastic) on 200m section through bend. Cost: Rs 36,000 2 warning signs (Fig.14.1) installed on approaches to bend. Cost: Rs 14,000</td>
</tr>
</tbody>
</table>

When the scheme requires road users to do something that is unfamiliar to them, consider mounting a publicity campaign to tell them why it has been done and how to use it safely. This is particularly important if the scheme could be hazardous to those who do not understand it or misuse it. You are unlikely to be able to afford to mount a major campaign that will reach most road users, but even putting a few notices in the daily newspapers is well worth doing. It demonstrates that we have a caring attitude to the safety of road users and helps prevent criticism arising from misunderstanding of what has been done. If road users are likely to resist using the scheme properly you may need to have policemen on site to enforce it, at least during the first few weeks. This will need to be agreed in advance with the police. Bear in mind that, although the police are usually very willing to help, it is unrealistic to expect them to maintain a presence at the site for more than a few weeks.
SECTION 8: Monitoring & Evaluation

8.1 Introduction

Proper monitoring and evaluation of the work is of fundamental importance. Much of what is being done is new and untried, and some of it is quite expensive. Only by monitoring its performance closely will we learn what is cost-effective - and such information will help us gradually build up a sound basis for road safety engineering in a region. Evaluation is not easy and it will rarely be possible to obtain 100% clear proof that particular measures have prevented accidents, but it can give indications which are helpful in developing future accident countermeasures programmes. In addition to measuring cost-effectiveness, we should be looking for any unintended effects (on road user behaviour, traffic patterns, etc.) and trying to gauge public acceptability of what we have done. Finally, remember that the scheme needs to be soundly-based, if you are going to be able to learn anything useful from it - this means that there must have been a clear statement of the objectives of the scheme, a prediction of its effects, and a logical link between the treatment and its effects.

8.2 Initial observations

It is advisable to monitor the scheme particularly closely in the first few days and weeks after completion. You can expect that road users will take a little time to get used to new traffic schemes, and junction improvements, etc, and a few accidents may happen during this time, but you should be ready to review the scheme and alter it (or even change it back to the way it was before) if there is evidence of serious problems. Schemes may work well generally but cause problems for the drunk or reckless driver, and in these cases judging whether the costs are beginning to exceed the benefits is not always easy. This is the time when there may be public criticism of the scheme, and you should be prepared to respond promptly to this - by explaining what has been done and why, and showing that you are taking a responsible attitude to any problems that are occurring.

8.3 "Before" and "after" studies

The basic method of measuring the effect of a scheme is to compare the situation before it was implemented with that after it was implemented. It seems simple, but there are some complications, including the need to make allowance for:

- extraneous factors (e.g. changes in weather, traffic patterns, vehicle mix, traffic rules) which could account for some or all of the change that has been observed
- the fact that accidents are to some extent random, which adds extra variability into the accident data, thus making the effects of the scheme more difficult to detect
- the likelihood that for a site chosen on the basis of its high accident numbers there would be a reduction in accidents over time regardless of whether anything was done (called the regression to the mean effect)
- the likelihood that scheme construction will disturb the traffic situation for a little while - for this reason, data on the traffic and accident situation during and immediately after the construction period is usually ignored

Remember also that the accident data you are using is far from accurate. Some casualty accidents will not have been reported to the Police and thus will not appear in your data. The amount of under-reporting is not constant and is impossible to predict, so, if there is more under-reporting in the "after" period than in the "before" period, you will over-estimate the effectiveness of the scheme.

8.4 Short-term measures of performance

The most important measure of success is whether the scheme has improved the accident situation at the site, and the statistical analysis required for this will be discussed in the next section. However it takes three years to build up the data necessary for a proper statistical analysis, and you are likely to want to make some assessment of scheme performance long before then. In most cases there are other variables which when
measured "before" and "after" will give you an indication of whether safety at the site has improved. Examples include:

- **traffic speeds** - many schemes aim to improve safety through reducing traffic speeds, so speed surveys will tell you whether the hoped-for reduction has occurred
- **conflicts** - a "before" and "after" conflict study can show whether the conflicts that were causing the problem have reduced
- **the number of pedestrians using crossings** - a simple count can show whether measures to promote the use of crossings (better signing, refuges, etc) has increased usage
- **road user perception** - it can sometimes be useful to interview road users to see whether they think the road is now easier and safer to use

### 8.5 Statistical tests

There are a number of statistical tests for comparing the safety performance at a site before and after a scheme has been implemented, but the most commonly-used are:

- the Tanner k test
- the Chi-squared test.

Both these tests involve comparing before and after data from the treated site with before and after data from similar but untreated sites, known as control sites.

**Before and after periods** - These must be long enough to even out the random variations in accident frequency, and it is generally assumed that three years is enough (i.e. three years before and three years after). The test can be used with less data, but the margins of error are larger. The periods must be the same for both the treated site and the control sites.

**Choosing control sites** - The purpose of comparing the treated site with the control sites is to take account of the extraneous factors such as weather and traffic flow changes which may be causing an area-wide change in the accident situation. The best control sites are those which are similar to the treated site and in the same area - in this way you can be sure that both sites have been similarly affected by local variation in extraneous factors. In practice this is difficult, especially as you need enough control sites to give you about ten times as many accidents as at the treated site(s). You may have to take control data from a wider area, but try and ensure that the sites are broadly similar to the treated site.

**Correcting for the regression to the mean effect**

This complicating factor, sometimes called "bias by selection" arises when sites are chosen on the basis of having a very high number of accidents in the previous one or two years. Accident rates at individual sites vary from year to year. So, if you choose a site when the accident rate is at its peak, the accidents in subsequent years will tend to reduce even if no treatment is applied. Statisticians call this "regression to the mean". There is less likelihood of bias if longer periods of time are selected for study. It is recommended that you make allowance for regression to mean by applying the factors set out in the following Table, which are based on studies in Britain.

#### Factors to be used to allow for "regression to the mean"

<table>
<thead>
<tr>
<th>Period of accident data considered</th>
<th>Regression-to-mean change in annual accident rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>One year</td>
<td>15 to 26 per cent</td>
</tr>
<tr>
<td>Two years</td>
<td>7 to 15 per cent</td>
</tr>
<tr>
<td>Three years</td>
<td>5 to 11 per cent</td>
</tr>
</tbody>
</table>

Note: To correct for the regression to the mean effect in the examples given below you would reduce the "before" accident total for the site by 5-11% and then calculate the k value and the Chi-squared value.

**Worked example of the Tanner k Test**

Traffic calming was done three years ago at a village on a busy main road and the effect of the scheme on accidents needs to be checked. The control data is from other villages on busy main roads over exactly the same 3-year before and 3-year after period. The accident data is arranged as shown in the following Table:

<table>
<thead>
<tr>
<th></th>
<th>Accidents at site</th>
<th>Accidents at control sites</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>10 (a)</td>
<td>75 (c)</td>
<td>85 (g)</td>
</tr>
<tr>
<td>After</td>
<td>2 (b)</td>
<td>66 (d)</td>
<td>68 (h)</td>
</tr>
<tr>
<td>Total</td>
<td>12 (e)</td>
<td>141 (f)</td>
<td>153 (n)</td>
</tr>
</tbody>
</table>

The data is then entered into the following formula:

\[ k = \frac{b}{a} \frac{d}{c} \]

*note: if any of the frequencies are zero, then A should be added to each, i.e \( k = \frac{(b+)}{(a+)} \frac{(d+)}{(c+)} \)*

This gives:

\[ k = \frac{2}{10} = 0.227 \]

\[ \frac{66}{75} \]

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 if \( k > 1 \) then there has been an increase relative to the control

The percentage change at the site is given by:

\[ (k-1) \times 100\% \]

Therefore as \( k < 1 \) there has been a decrease in accidents relative to the controls of: \( (0.227 - 1) \times 100\% = 77.3\% \)

**Worked example of the Chi-Squared Test**

This test indicates whether there is a significant difference between the site data and the control data. Consider the same example as used above. The following formula is used:

\[ x = \frac{(ad - bcj - n/2)^2}{n} \]

This gives:

\[ ([10\times66 - 2\times75] - (153/2))^2 \times 153 \times \frac{12\times141\times85\times68}{n} \]

\[ x^2 = 2.939 \]

The result can be interpreted by using the table below:

<table>
<thead>
<tr>
<th>Chi square value</th>
<th>Significance level</th>
<th>Confidence level</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2.71</td>
<td>10%</td>
<td>90%</td>
<td>Fair</td>
</tr>
<tr>
<td>&gt;3.84</td>
<td>5%</td>
<td>95%</td>
<td>Acceptable</td>
</tr>
<tr>
<td>&gt;6.635</td>
<td>1%</td>
<td>99%</td>
<td>Highly acceptable</td>
</tr>
</tbody>
</table>

This means that in the example given above there is less than a 10% likelihood that the change in accidents at the treated site is due to random fluctuations. Looked at the other way it means that there is a better than 90% probability that a real change in accidents has taken place at the site.

**Checking whether it makes sense**
The test tells you nothing about how the change in accidents came about. So before you use the test result to demonstrate how well your scheme has worked it is important to check that the accident data supports your case. Usually your scheme will have targeted a particular type (or types) of accident, so check (by repeating the collision diagram) that this type of accident has in fact decreased. And ask yourself whether there is any other plausible reason why the accidents may have decreased at the site. Once you have discounted any other possibility you are left with the probability that the decrease in accidents has come about as a result of your improvement scheme.

8.6 Economic analysis

It is worth calculating the First Year Rate of Return again (see Module 7) now that you know the actual costs of the scheme and the accident saving. It will be instructive to compare the result with that which you calculated at the earlier stage, and this should help you to improve the accuracy of your forecasts. It is important to be able to demonstrate that the accident sites programme gives good value for money.