Existing Roads: Reactive Approaches
Existing Roads: Reactive Approaches
Foreword

Every day thousands of people die, hundreds of thousands injure, and enormous amount of resources lose in road crash worldwide. Developing countries account for the overwhelming part of these losses. Africa takes the highest share of the road crash burden relative to its low level of motorization and road network density and experiences the highest per capita rate of road fatalities. The characteristics of road crash victims in the region signifies that over 75% of the casualties are of productive age between 16-65 years; and the vulnerable road users constitute over 65% of the deaths. Road crash costs African countries 1-5% of their GDP every year. These figures clearly indicate the direct linkage and the impact of road crash in worsening poverty in Africa. The regional features such as road network expansion and improvement, rapid motorization, population growth, urbanization, unsafe vehicle fleet and mixed traffic inevitably will worsen road crash deaths and injuries unless African countries invest on road safety. The situation demands African countries to increase their level of investment and attract international cooperation for financial and technical support on crash prevention and reduction measures.

Africa is investing a great deal on road infrastructure to enhance competitiveness and realize sustainable socioeconomic development. The African Development Bank (AfDB) is widely engaged in national and multinational road infrastructure projects in African countries. Alongside with the road infrastructure financing, the Bank has mainstreamed road safety to scale-up and consolidate its efforts to support comprehensive multisectoral road safety investments to reduce the increasing losses caused by road crashes. The Bank focuses on interventions that generate and transfer knowledge, strengthen capacity, achieve quick and visible results.

In line with this, the Bank developed three road safety manuals for Africa based on the safe system approaches and best practices tailored to African conditions to support road infrastructure safety practices in Africa over the next decade. The developed manuals include: (i) New Roads and Schemes: Road Safety Audit; (ii) Existing Roads: Proactive Approaches; and (iii) Existing Roads: Reactive Approaches. These manuals are designed to enable African countries adequately consider and manage road infrastructure safety during design, construction and operation. The intervention contributes to the achievement of the goal of the African Plan for the Decade of Action for Road Safety 2011-2020. The “Existing Roads: Reactive Approaches” manual is one in a series of three manuals which will be used by road authorities and road safety practitioners to conduct blackspot analysis and investigation, route/corridor analysis and investigation, and area analysis and investigation where crash data including precise location coordinates are available in order to identify hazardous locations and put remedial measures in place to minimize crashes on the road network.

The Bank recognizes that the development of the manuals alone will not make a substantive difference to road safety unless they are mainstreamed properly into relevant policies and procedures. As a way forward for overcoming this challenge, the Bank plans to embed the manuals into AfDB policy/procedures, disseminate the manuals to create awareness on the use and embed them in African countries, support training of road safety professionals to build capacity, and facilitate knowledge exchange, case studies and evaluation. As part of these endeavours, the first road safety training was held in Abidjan from 7 July to 10 July 2014 and successfully delivered to road safety professionals from seventeen African countries.
At this juncture and in line with the Decade of Action for Road Safety (2011-2020), I am calling on all road and traffic authorities, road safety practitioners from the private sector, and local authorities and other relevant stakeholders in African countries to play their part in ensuring that safety is integrated in planning, design, construction, operation and maintenance of road infrastructure. I believe quite strongly that we can make a difference by developing together safe road networks in the continent of Africa.

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1. Introduction to this Manual

This manual is one of a series of three which deal with distinctive, but related, safety review methodologies. It is recommended that these three manuals should be read alongside one another. The three manuals are:

- New Roads and Schemes - Road Safety Audit (RSA)
- Existing Roads - Proactive Approaches: This manual provides guidance on proactive Road Safety Inspection and Assessment methods
- Existing Roads - Reactive Approaches: This manual provides guidance on reactive methods for the identification and treatment of hazardous locations, roads and routes

The manuals have been developed based on best practice from a number of countries worldwide, including current practices in Africa. They adopt a ‘Safe System’ approach throughout which is concerned with engineering the road environment so that only low severity crashes are possible when users make mistakes. The approach described in this manual has been tailored for practical application in Africa. It cannot cover explicitly the conditions in every country; therefore users will need to consider local conditions in applying the techniques and processes described throughout this manual.

1.1 How this Manual Relates to the Other Manuals in the Series

The other two manuals (‘New Roads and Schemes – Road Safety Audit’ and ‘Existing Roads – Proactive Approaches’) describe methods that can be considered ‘proactive’ in that they aim to identify safety deficits before crashes begin to accumulate. Using crash data to take a reactive approach is a reliable and effective way to identify and treat road safety problems across the road network. This manual provides guidance on the improvement of crash data and how to use data to identify and treat high risk locations.

1.2 How to Use this Manual

This manual has been developed as one of three independent documents covering the main tools for road safety engineering to reduce road crashes on a country’s road network through a systematic approach to crash reduction and prevention.

This manual can be read as a complete document, but is more likely to be used as a reference document in relation to specific aspects of reactive approaches.

It has been developed to provide a consistent framework for data analysis, site investigation and treatment across the member countries of the African Development Bank (AfDB). It is recognised that not every country will be at the same stage of development or application of reactive approaches. It is therefore a document that can be repeatedly referred to as organisations develop their own processes. The manual has been designed so that, regardless of the quality or availability of crash data, there is useful guidance on either how to improve crash data or how to use data while systems are being enhanced.
The manual is set out in the following sections:

- Section 2 provides information on how reactive approaches can become embedded into practice in a country
- Section 3 provides an overview of the reactive approach concept
- Section 4 provides guidance on the importance of data and how to improve the quality, availability and utility of crash data
- Section 5 provides information on three types of reactive techniques (blackspot analysis and investigation, route/corridor analysis and investigation, area analysis and investigation) and development of a treatment plan
- Section 6 provides guidance on monitoring and evaluating treatments as they are implemented
- The appendices provide information on typical solutions and example reports and calculations

The manual can be used by anyone involved in undertaking reactive approaches to road safety management; experienced practitioners, those considering the introduction of reactive approaches into their organisation or those responsible for the development of reactive approach procedures for their country.
2. Embedding Reactive Approaches

Reactive approaches rely on the collection and use of reliable intelligence to target road safety improvements in a systematic and consistent manner. This requires significant investment and diligence particularly in the collection, processing and analysis of police crash data. The following steps outline a process for ensuring that reactive approaches become embedded in road safety practice for prioritising and developing treatments for existing roads.

**Figure 1: Embedding reactive approaches**

**Step 1:** Establish a legal basis for undertaking reactive approaches.

Many countries have a legal requirement for the road authority to investigate and improve safety problems. Reactive approaches are one method for achieving this legal responsibility. Responsibility should rest with the relevant authority for safety which must be supported at the highest political level (i.e. President/Prime Minister).

**Step 2:** Formalise protocols and procedures.

The road authority needs to write and adopt a formal protocol or procedure for undertaking reactive approaches for safety investigation. This should include specification of:

- The person or department with specific responsibility for investigation of road safety issues. This would normally be the responsibility of a Road Safety Unit (RSU) in a Road Authority. The RSU needs to be a dedicated team of professionals whose focus is entirely on safety issues. They need to be trained and provided with high quality advice and technical assistance until they gain experience.

- The level of resources (financial and personnel) necessary to achieve a focussed improvement in road safety. The level of resources required will depend on the extent of the road network for which the road authority is responsible. At a very minimum, there will need to be data analysts and road safety engineers so that the statistical analyses can be undertaken and then investigated through site visits and remedial treatments planned.
The detailed process to be followed as set out in formally approved manuals or guidelines. These documents should specify the approach to be taken in analysing data to identify high priority locations, undertaking site visits and development of a treatment plan.

Requirements for the level of improvement to be achieved and over what period. This may be a numerical target associated with treatment of a proportion of the highest risk sites/sections or roads. Longer term casualty reduction targets that can be associated with the improvements can also be developed.

Mechanisms for monitoring performance. These may include formal monitoring of casualty numbers or the evaluation of remedial treatments.

**Step 3: Identify a road safety team.**

A team of appropriately trained personnel with mathematics, engineering or statistical training to undertake the analyses of collected information needs to be identified to determine appropriate actions in line with the processes defined in the approved manuals. Initially this team may have limited knowledge and experience of road safety analyses, comparable with the level of detail that they are required to assess. They may be part of the general engineering department given responsibility for road safety as part of other network management duties. However, as part of the organisational responsibility they will be a requirement to develop these skills and experience over time to provide improved accuracy and detail of analyses. In order to deliver this reliable performance, the organisation will need to develop and offer structured training to the team to enable them to undertake blackspot analysis, route/corridor analysis and/or area analysis.

In addition to the analysis team, experienced road safety engineers are required to investigate the results of the analyses undertaken and develop appropriate countermeasures and prioritised road safety investment plans.

**Step 4: Identify a budget for the treatment of existing roads and adopt a business case approach.**

There is no point undertaking reactive approaches without the financial resources to implement a planned programme of changes. Therefore an annual budget needs to be established for the treatment of road safety problems identified on the existing road network – irrespective of how these have been identified.

Section 5.5.1.3 outlines several different approaches to Economic Appraisal. In order to adopt a business case approach these methods will need to be considered and a formal protocol for Economic Analysis developed.

**Step 5: Collect the required data and undertake preparation work.**

The reactive techniques described in this manual require the systematic collection of data (the detail and complexity of the data vary for any of the techniques discussed in this manual). The collection and improvement of crash data is described in detail in Section 4.4. In particular the collection of precise crash locations is important for the undertaking of blackspot analysis.
Regular and systematic collection of traffic flow and speed data is also recommended, along with comparable population and network length data.

Traffic flow data significantly enhances the quality and utility of route/corridor studies. Population data can enhance the quality of area studies. Often these data are collected by a road authority for other projects (e.g. planning, environmental impact studies etc.) and so may already be available. Collating such information with other departments is advisable.

Speed data can also be extremely useful when undertaking site reviews. Speed is a key factor in determining both the likelihood of a crash occurring and its severity. Speed data can be collected at the same time as traffic flow surveys.

In addition to the collection of data, other preparations are required in order to undertake some of the approaches outlined in this manual. For example, route/corridor analysis requires the road network to be considered in homogeneous sections (see Section 5.3.2.1).

**Step 6: Increase local capacity and awareness**

The Road Authority may wish to undertake the following activities:

- Offer training to staff (and potentially local consultants/practitioners)
- Offer mentoring to staff (and potentially local consultants/practitioners) so that they gain experience and fulfil the experience requirements for those undertaking site visits and development of a treatment plan
- Training for designers on road safety engineering in order to adequately interpret the treatments proposed

**Step 7: Monitor and Review**

Before implementing proposed treatments it is normally necessary to assess their potential impact in order to make a business case for investment. Information on the effectiveness of treatments has generally been compiled from research undertaken in countries in Europe and in USA and Australia. Relatively little is known about the true effectiveness of the treatments under different circumstances in Africa. An understanding of local effectiveness will only be established if road authorities monitor and evaluate the performance of any measures implemented. Organisations therefore need to introduce a system for monitoring and reviewing the performance of any implemented treatments (see Section 6). Such evidence can subsequently be used to identify the most appropriate safety improvements to incorporate in revised design standards. This is particularly important in any country where development of the road network is occurring at a fast pace and where research concerning road characteristics and their impact on road safety outcomes is not available.
3. The Reactive Approach Concept

Using intelligence to direct and inform road safety programmes and individual interventions is known as taking a ‘reactive’ approach. This involves using crash data to identify high risk locations (known as blackspots, hazardous locations or hotspots), routes or areas across the road network. Once a high risk location has been identified, the site is reviewed in detail and a treatment programme devised.

3.1 How Reactive Approaches Fit into Wider Road Safety Management

The objective of Road Safety Management is to integrate all road safety activities such that a systematic approach is taken to reducing death and serious injury throughout the project lifecycle. Effective road safety management programmes need to provide an optimal balance between reactive and proactive strategies.

In order to undertake blackspot analysis, crash data must include precise coordinates for the location of crashes rather than sketch drawings or road names. It is possible to derive crash coordinates from sketches and other descriptions however this is a very labour intensive process and one in which introducing significant error is hard to avoid. Crash data can be improved through the introduction of systems described in Section 4.4. In the meantime, it may be possible to use road names or sections to identify routes/corridors that are high risk through route/corridor analysis (Section 5.3). This can only be done if...
crash data are systematically collated in a crash database and if road names are spelt and entered in a consistent manner.

If road names are not recorded in a sufficiently accurate or systematic manner, it is sometimes possible to undertake area analysis (Section 5.4) using the police area code which is often included in a crash report pro-forma.

Figure 3: Road safety management methods for use on existing roads

### 3.2 Reactive Approaches and the Safe System

The Joint Transport Research Committee (JTRC) of the OECD (Organisation for Economic Co-operation and Development) produced a report in 2008 titled: ‘Towards Zero: Ambitious Road Safety Targets and the Safe System Approach’. This describes the Safe System approach as one that re-frames the way in which road safety is managed and viewed, emphasising the importance of a ‘shared responsibility’ among stakeholders. It means addressing all elements of the transport system in an integrated manner to ensure that the human is protected in the event of a crash. Importantly the OECD (2008) report suggests that Safe System working is suitable for all countries at differing levels of road safety performance, but that slight variations in the interventions might be appropriate.

The aim is to develop a road transport system that is able to accommodate human error and takes into consideration the vulnerability of the human body. It recognises that even the most law-abiding and careful humans will make errors. The challenge under a Safe System is to manage the interaction between vehicles, travel speeds and roads to not only reduce the number of crashes but, arguably more importantly, to ensure that any crashes that occur do not result in death or serious injury.

The Safe System needs to ensure that road users that enter the ‘system’ (in an overall sense) are competent, alert and compliant with traffic laws. This is achieved through road user education, managing the licensing of drivers and taking action against those who break the rules.
Once drivers enter the Safe System, there are three core elements that need to work together to protect human life:

- **Safe vehicles**: Vehicles that have technology that can help prevent crashes (for example electronic stability control and Anti-lock Braking System (ABS) brakes) and safety features that protect road users in the event of a crash (for example airbags and seatbelts). This requires the promotion of safety features to encourage consumers and fleet operators to purchase safer vehicles.

- **Safe roads**: Roads that are self-explaining and forgiving of mistakes to reduce the risk of crashes occurring and to protect road users from fatal or serious injury. This requires roads and road-sides to be designed and maintained to reduce the risk and severity of crashes.

- **Safe speeds**: Vehicles travel at speeds that suit the function and the level of safety of the road to ensure that crash forces are kept below the limits where fatal or serious injury results. This requires the setting of appropriate speed limits supplemented by enforcement and education.

The Safe System approach is also supported by effective road safety management and post-crash response.

The Safe System philosophy requires a shift in thinking away from blaming the driver for the mistakes they make. The Safe System challenges those responsible for designing the road transport system to share the responsibility so as to manage the interaction between road users, vehicles, travel speeds and roads.

### 3.2.1 The Importance of Speed

At lower speeds a driver will have greater opportunity to react and avoid a crash. Speed also affects the severity of crashes. Higher speed crashes involve more kinetic energy (kinetic energy is proportional to the speed squared) and the more energy that is dispersed in a crash, the more severe it tends to be.

There are four main crash types that account for the majority of fatal and serious injuries:

- Crashes involving Vulnerable Road Users (VRU’s) i.e. pedestrians, motorcycle riders, pedal cyclists, public transport users and road-side vendors.

- Side impact crashes at intersections

- Head-on

- Run-off

Though other crash types do occur across the road network these are less likely to have fatal or serious consequences.

Wramborg (2005) used in-depth crash data to plot collision speeds against fatality risk for three of the main crash types.
As speed increases, the fatality risk increases very sharply for each of the crash types. This leads to several guiding principles for survivability:

- Where conflicts between pedestrians and cars are possible, the speed at which most will survive is 30 km/h – this is represented by the red line
- Where side impacts are possible at intersections (e.g. cross roads and T-intersections), the speed at which most will survive is 50 km/h – this is represented by the green line
- Where head-on crashes are possible (e.g. where there is no median separation), the speed at which most will survive is 70 km/h – this is represented by the blue line

Similar research on run-off crashes has been completed by Stigson (2009). According to this work, a road is considered ‘safe’ (or survivable) for run-off road crashes if it has a:

- Speed limit not higher than 50 km/h, or
- Safety zone of at least 4 metres and a speed limit not higher than 70 km/h, or
- Safety zone of at least 10 metres and a speed limit higher than 70 km/h.

These principles are not necessarily speed limit suggestions, but a guide to managing conflict points on a road network.

### 3.2.2 Applying Safe System Principles to Reactive Approaches

The collection and use of data is very much at the heart of the Safe System philosophy. The target of reduced or even zero road fatalities and serious injuries must be attained in the most efficient and economical way possible.
Safe System working has a clear emphasis on monitoring and evaluation to identify what works and what does not. Monitoring and evaluation can only be undertaken if a range of data are systematically collected and analysed. The strongest focus of the Safe System is to reduce road fatalities and serious injuries, this ‘ultimate’ goal can only be assessed by using crash data from police or medical sources. In addition to crash data, intermediate indicators of road safety performance can be measured and used to inform approach. In particular, speed data can be particularly useful when considering engineering treatments.

At the heart of any effective programme targeted to significantly improve road safety there must be the credible and systematic use of data to guide decision making. There needs to be well thought-through analysis to develop strategies based on the best evidence available and also objective efforts to monitor the performance. Safe System working strongly recommends the proven Public Health approach as a basis for improving road safety. This way of working is relevant to tackling road safety which, at its heart, is a very much public health problem. In this approach data are used to identify issues, develop treatments and then continually assess the impact of interventions.

Although it is often said that ‘we know what works to improve road safety’, most approaches and treatments have generally only been evaluated in countries which have been systematically tackling their problems for many years and have very different traffic mixes and driver behaviours compared with typical African conditions. Safe System working emphasises that research is vital to identify specific local issues and effective treatments. Currently there is a major gap in knowledge of how measures actually perform in any LMICs, chiefly because data are not of sufficient quality and because robust evaluation is rarely a priority. Therefore the collection and analysis of data, evaluation and monitoring of the effectiveness of treatments must emerge as a priority to ensure an effective road safety programme in the future.

Proactive approaches such as Road Safety Audit, Road Safety Inspection and RS Assessment can be undertaken while high quality crash data are collected and accumulated. However, without data it will not be possible to determine the true impact of these approaches or the treatments that are recommended as a result.

### 3.3 An Overview of Reactive Approaches

Application of reactive approaches can be done at three distinct levels of detail dependent upon the quality of the initial data available. These are described in turn in the sections that follow.

#### 3.3.1 Blackspot Analysis and Treatment

Blackspot analysis is concerned with identifying locations on the network where there is a concentration of crashes. Problem locations are identified by reviewing the crash history across the network and locating short sections which have higher crash occurrence than would otherwise be expected given the road character and features.

The crashes at the identified blackspots are analysed to identify common patterns that may relate to an underlying safety problem. Site visits are then undertaken to identify aspects of the road that could be treated to reduce the types of crashes that have occurred. Where a clear localised road defect can be identified this can often be treated
very cheaply and effectively (it may simply require some maintenance attention). This means that blackspot analysis and management can be a very cost effective way to improve road safety. More detail regarding blackspot analysis is contained within Section 5 of this manual.

Blackspot analysis requires the accurate location of all crashes on the network using precise geospatial coordinates. These may not always be available. If this is the case, route/corridor analysis or area analysis may be possible.

### 3.3.2 Route/Corridor Analysis and Treatment

Route/corridor analyses are undertaken to identify high risk sections that require further investigation and treatment. The high risk sections are then reviewed in depth during a site visit and treatments developed.

Ideally, route/corridor analysis will be undertaken alongside blackspot analysis since they tend to find slightly different issues. Whereas blackspot analysis is concerned with identifying localised safety problems; route/corridor analysis is concerned with identifying longer road sections which may be treated in a consistent manner to improve safety.

Once high risk sections have been identified, the character of the crashes occurring on each section is analysed, the site is visited and treatments developed. Route/corridor analysis is typically applied on the higher flow rural network rather than on local urban roads and streets since rural roads tend to be more homogenous in character and lend themselves to consistent treatments. This approach is covered in more detail in Section 5.3 of this manual.

### 3.3.3 Area Analysis and Treatment

Area analysis can be applied where it is possible to identify common crash themes by area, often using a police area code. In order for this to be successful the areas need to be relatively small and have a very high concentration of crashes. Therefore this approach lends itself to application to urban areas. Identification of common crash types can help identify potential area-wide remedial treatments. This approach is described in more detail in Section 5.4 of this manual.

### 3.4 Benefits of Taking a Reactive Approach

Taking a reactive approach has a number of clear benefits:

- Interventions can be targeted and designed to be as effective and efficient as possible
- Effectiveness of treatments can be evaluated

Without evidence-led working, interventions may be inefficient at best and at worst may have a negative impact.

Taking a reactive approach mirrors the approach taken for other public health issues (Figure 5).
It is typically reported that major blackspot programmes overall have a benefit to cost ratio of 10 or more to one. It is also reported that blackspot treatments will reduce crash occurrence between 20% and 40% for relevant crash types. Individual treatments of some blackspots have been reported to be extremely effective.

The impact of route/corridor and area analyses and treatment is not documented as well as blackspot programmes since these are relatively new approaches.
4. 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.

Many African countries 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.

4.1 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 quality of crash data and also of other sources such as medical information on road casualties tends to be poor, especially in LMICs. The poor quality and availability of the range of crash and injury data in many countries remains a major impediment to obtaining significant and measured improvements in road safety levels in Africa - and across the world.

4.2 Sources and Types 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, route/corridor and area analyses. Other data are considered to be complementary and can ‘fine tune’ interventions.

4.2.1 Crash Data

Police crash report information is the main source of data used for road safety engineering analyses. It should be noted that increasingly toll road franchises/concessionaires/PPPs are being made responsible for safety on the routes they operate and may also be required to collect similar crash data.
In almost all countries police collect information on crashes that occur across the road network (see Figure 6); this is generally a statutory requirement when injury crashes occur. Data collection by the police is undertaken in a wide range of ways from country to country. 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 many countries the traffic police have agreed to collect information on crashes on a structured pro-forma questionnaire (see Figure 7). This has significant advantages since it helps the officer to collect a wider range of consistent details which are useful for road safety purposes. A short ‘tick box’ form is most likely to be filled in.

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 8). 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.
### Data Collection

**EXISTING ROADS: REACTIVE APPROACHES**

#### Crash related
- Crash identifier (unique reference number assigned to the crash, usually by police)
- Crash data
- Crash time
- Crash municipality / place
- Crash location
- Crash type
- Weather conditions
- Light conditions
- Crash severity

#### Road related
- Type of roadway
- Road functional class
- Speed limit
- Road surface conditions
- Intersection
- Traffic control at intersection
- Road curve
- Road segment grade

#### Vehicle related
- Vehicle number
- Vehicle type
- Vehicle make
- Vehicle model
- Vehicle model year
- Engine size
- Vehicle special function
- Vehicle manoeuvre (what the vehicle was doing at the time of the crash)

#### Person related
- Person ID
- Occupant’s vehicle number
- Pedestrian’s linked vehicle number
- Date of birth
- Sex
- Type of road user
- Seating position
- Injury severity
- Safety equipment
- Pedestrian manoeuvre
- Alcohol use suspected
- Alcohol test
- Drug use
- Driving licence issue date
- Age

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**Figure 7:** Simple example crash reporting form (larger version available in Appendix B)

**Figure 8:** 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 4.4.2.

**Figure 9: Entering crash data into a MAAP database in Ghana at BRRI**

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 10).

**Figure 10: Crash data plotted for Gaborone, Botswana - 3 months, 1 year and 2 years (January-March 2011 (left), all 2011 (middle), and 2011 and 2012 (right))**
Police crash data are broadly categorised into different severities based on the level of the worst injured casualty. Crashes are generally categorised 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 hospitalised 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.

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.

### 4.2.2 Health System Data (Hospitals/Ambulance Service)

Data on deaths and injuries resulting from road crashes may also be available from medical databases and, in the case of fatalities, vital registers. 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 the major cause of unintentional injuries which require treatment in most countries. In Africa, road traffic injuries account for 25% of the fatalities resulting from unintentional injuries and this figure matches violence as a major cause of death (AfDB, 2013).

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 record and share information systematically.

A medical or public health data source which may potentially hold information on road fatalities is known as ‘a vital register’. A vital register is concerned with recording births, migration and deaths for planning purposes. Since population size and age/gender distributions have a fundamental effect on how a government should spend resources and especially medical provision, the vital register tends to be associated with the medical sector. Cause of death should be recorded in a standard vital register and if a death is from injury, it should be recorded whether this was due to involvement in a road crash.
The bodies of those killed immediately in crashes may be transported directly to mortuary facilities; whilst these may be located at hospitals this is not always the case and their information will not be collected in the same way as for those injured. Post-mortem examinations should ideally be carried out on anybody who dies violently; though in reality, these detailed examinations may not be carried out systematically in many LMICs.

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 categorisation 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. It is also possible that the fire service may also keep records on where they attend road crashes.

### 4.2.3 Other Useful Data Types and 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
  - Micro/macros texture
  - Condition information

- **Speed data**
4.3 Common Quality and Availability Issues

It is vital that anyone using crash data to guide road safety activities and to develop treatments understands the data that they are using and especially any short comings. These are described in the sections that follow.

4.3.1 Under Reporting

Although it is not feasible for the police to report on 100% of crashes (particularly less severe and damage only crashes), under-reporting is one of the main issues to impact adversely upon data quality. The level of under-reporting will impact greatly on the degree to which the data are an accurate sample of all of the crashes occurring across the network. The better the reporting level, the more representative the sample will be, and the more useful and reliable data will be to identify safety issues. It is generally considered that an effective crash database should include all fatal crashes (those where a casualty dies within 30 days of the crash), and the vast majority of serious injury crashes as a minimum.

Most countries generally have a legal requirement for crashes involving injuries to be reported; however under-reporting will arise for a variety of reasons, these being:

- The police are not informed of the crash by those involved because:
  - Those involved are not insured
  - The involved persons do not want to become involved with the legal system
  - There is a fear of corruption
  - The involved parties agree compensation between themselves
  - The police cannot be contacted due to poor communications or because the public do not know how to inform the police or that it is necessary to do so

- The police are informed but cannot (or do not) attend or report the crash because:
  - Lack of personnel and vehicles
  - The crash scene cannot be located before those involved leave the site
  - Other tasks take a higher priority at that point in time

- The police record the crash but the record is not captured in the database or filing system, because:
  - Paper filing system:
    - The form is lost or damaged
    - The form is mis-filed
  - Computerised system:
    - The record does not arrive with the data entry team
    - The record is not entered into the database
These issues mean that reporting rates tend to be highest for crashes involving fatalities and reporting rates may decrease greatly for those which result in slight injuries. In some instances, different rules and provision for reporting damage-only crashes can mean that these may be reported more accurately than injury crashes.

There can be high levels of under-reporting of crashes involving Vulnerable Road Users (VRUs), especially those where pedal cyclists and pedestrians are injured. Reporting rates also tend to be worse for rural areas where it can be harder to report the crash since telephone connectivity may be limited and the crash is likely to be a greater distance from police stations.

Under-reporting is indicated by relatively low ratios of fatal to serious and slight crashes. Where reporting rates are good it is expected that the ratio of serious to fatal crashes should be about 10 to 1 and the ratio of slight to fatal may be in the order of 1:100, however in many countries these ratios are considerably lower (Table 1).

Table 1: Ratio of serious and slight to reported fatal crashes in Botswana and Great Britain, 2012

<table>
<thead>
<tr>
<th>Severity</th>
<th>Botswana</th>
<th>Great Britain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Serious</td>
<td>2.4</td>
<td>12.8</td>
</tr>
<tr>
<td>Slight</td>
<td>7.5</td>
<td>75.2</td>
</tr>
</tbody>
</table>

Some of the differences in the ratios of fatal to serious and slight crashes may result from a higher than average severity of crashes resulting from:

- Poor or absent access to medical care
- Poor vehicle standards (lack of protective equipment such as airbags, lack of seatbelt and child restraint use etc.)
- Poor driver behaviour standards (e.g. non-compliance with speed limits etc.)
- Poor passive safety (forgivingness) of road designs

Nevertheless under reporting is still likely to account for a large portion of the differences in these ratios.

4.3.2 Incomplete Records or Inaccurate Records

In addition to the problem of under-reporting, mistakes in filling in data fields are quite common, and frequently important fields are left blank. Some of these errors can be identified or corrected by automated validation checks when the data is entered into a computer database system. If the data are collected by being entered directly into a mobile electronic device by the reporting officer, it is possible to add checks which mean that the quality of the information is improved as it is actually initially captured.
4.3.3 Reliability of Crash Severities

It should be noted that significant concerns about the consistency of the definitions of injury and crash severity between (and even within) countries exist and police personnel typically receive little or no training to help them assess injury severities.

4.3.4 Lack of Precise Information on Crash Locations

In many countries worldwide, the precise location of crashes is not recorded by the police. This information is simply not required by the police for use within the legal system and so is not considered a priority. Engineers however require this information in order to perform spatial analyses such as blackspot analysis.

4.3.5 Access to Collected Data

Getting access to crash data can be difficult since some police organisations can regard the information as being sensitive and are therefore unwilling to share it. However details which could easily be used to identify individual drivers, casualties or vehicles involved in crashes are not required by road safety engineers in order to perform effective analyses. Therefore it is possible to establish data sharing protocols and agreements whereby engineers are provided the data with sensitive fields removed. Modern database systems can also allow ready access to data by a range of users while closely controlling access to sensitive fields, on an organisation, department or individual user basis.

4.4 Improving Data Availability and Quality

The World Health Organisation (WHO) Data Systems manual (2009) gives comprehensive information on accessing and improving crash data and implementing associated systems. Some of the key requirements are reviewed in this section.

A key starting point is to conduct an open and objective ‘situational assessment’. This is a detailed review of data sources and current collection practises which may be available. It also includes the assessment of the requirements for data of all road safety stakeholders. The process needs to be conducted openly and with full cooperation of all stakeholders and needs to develop a realistic and costed development plan to improve the data systems.

A first step in this situational assessment is to find out exactly what crash data are collected, how the data are stored and consistency across regions and nationally. This requires the development of a good working relationship with the traffic police and with medical administrative staff. If there is a functioning and effective National Road Safety Council or Lead Agency, this body may be able to make the introductions needed or they could be administering access to crash data already. However, collecting crash data is not a key priority for any police service, despite its actual importance for saving lives, so focus and persistence will be required.
When completing the situational assessment it is important to verify practices in the field first hand by accompanying traffic police to crashes to see how they manage the scene and the data collection. The reality of the processes may be very different from any declared policy/procedure.

Once the situational assessment is complete, improvements can be designed relating to the collection of data, crash databases and analysis functionality, and data sharing.

### 4.4.1 Collecting Data

The most straightforward, and still the most common, way data are collected by police is by pen and paper methods using paper pro-formas. The simplest way to improve this system is to get the police to record information about crashes on a standard pro-forma which has predominantly coded fields (i.e. tick boxes for set options). An idealised crash reporting form is provided in Appendix B. This system encourages the collection of a consistent set of information and will help ensure that key details are captured. The best situation is for the attending police officer to complete a crash report form since they have the best, first-hand knowledge of the details of the crash. Where police collect information as a narrative description in their note books this can be transcribed onto a standard reporting form by civilian staff; this has been the practice in Ghana for many years.

The form should be designed to pick up a number of key vehicle, injury and crash which will help the safety engineer to investigate common crash features (see Section 4.2.1). Many of the key fields required by engineers are also useful for police purposes to investigate individual crashes and also to assist with the intelligence-led targeting of enforcement activities.

A crash pro-forma needs to be concise and it must be possible to fill it in quickly at the roadside otherwise it will not be filled in completely or with accuracy.

Mobile devices such as larger smart phones or tablets can also be used to collect the data. These have some significant benefits:

- They can allow direct entry of data into the database (either through the mobile data network) or through uploading the data once back at the station into a database. This completely removes the need for labour-intensive and potentially error prone data entry.
- Photographs or videos can be captured using the device and automatically attached to the crash data record.
- Smart phone or tablet devices have in-built GPS systems that can allow auto-population of the precise crash location (provided that the details are taken at the site and not within the police vehicle remote from the scene).
Case study: Data collection in Ghana

In Ghana, a considerable amount of road safety research has been undertaken using local crash data. The police do not collect the crash data using a standard reporting form, the information is collected as plain language descriptions and these are filed in each main police station. Staff from the Buildings and Roads Research Institute (BRRI) collect the crash data with funding from the National Road Safety Council (NRSC). They annually go to each police station in the country and fill in the details from the filed descriptions onto forms. The data from these forms are then entered into a computer crash data system (iMAAP). BRRI also determine the crash location coordinates based on the collected police information.

4.4.1.1 Crash Locations

Crash locations are critical for road safety engineers. There are a variety of methods for capturing crash locations with varying degrees of sophistication and accuracy:

- Chainage
- Crash location sketches
- GPS
- Mobile data capture

Chainage

In most countries distance marker posts are a design standards requirement on trunk or strategic roads (see Figure 12). Kilometre position along roads is a commonly used method to locate places, boundaries (see Figure 13) and also assets and features along major roads. These can be used by the police as a way to indicate the location of crashes with a degree of accuracy.
In its simplest application, the police indicate that the crash occurred between ‘marker post x’ and ‘marker post y’. The order in which the marker posts are entered can also be used to indicate which direction the driver at fault was travelling prior to the crash. This system gives the location of crashes at best within a defined 1km road section which is not particularly accurate. A better accuracy is achievable if marker posts are also present at 100m or 200m intervals, although this will be rare in Africa.

Another way to get better accuracy is if the police express the crash location as a distance in metres from marker post ‘x’ and to marker post ‘y’. This can achieve an accuracy of between 100m and 10m. Features such as bridges and culverts along routes can also be given known kilometre locations on strip maps which could also be used as a relatively simple way to give the location of the crash sites. Figure 14 gives an example of a strip map.

This system can only be used on major roads which have consistent and clearly provided and maintained marker posts in place along the route. It is also reliant on the police being diligent in carrying out the reporting to a good standard.

Precise crash coordinates would still need to be determined from this kilometreage information by staff using mapping systems in the office.
Figure 14: Example of a strip map

Benefits:

- Low-cost option for use on rural roads with kilometre marker posts
- Accuracy can be enhanced through the use of a strip map

Considerations:

- Not suitable for use in urban areas
- Poor levels of accuracy
- Requires high levels of diligence
- Accurate crash coordinates will still need to be coded by office staff on the basis of information provided

Crash Location Sketch

A common way that police indicate the crash position on report forms is by means of a location sketch. The officer draws a simple diagram which shows the crash location in relation to identifiable locations on the road network. These diagrams should provide enough information so that data entry staff are able to give the crash an accurate map coordinate using digital maps when they are entering the record into the computer database system in the office.

A simple way to enable good map locations to be obtained is to relate the crash position in terms of distance in metres to major intersections. Intersections should be relatively easy to locate on digital mapping.

Ideally the sketches are accurate enough such that the task of allocating a map coordinate is not too difficult; however it is common that the quality of the sketch is not good enough in a significant number of cases. It is often the case that the police have no understanding of what the sketch is used for, what constitutes a useful sketch and
what features should be included (see Figure 15 and Figure 16). A dialogue between the office data entry staff and field officers can improve the quality through constructive feedback. In addition, it should be possible to contact the individual police officer that originally filled in the form to check key details if information is missing or looks wrong. An important reason to contact the officer that collected the data is to check that the location is correct.

The location sketch can also be supported by a written description of the crash location and clues are often given in any written description of the crash.

Figure 15: Some typical mistakes made in a location sketch (Uganda)

Figure 16: Example of a sketch map
Benefits:

- Low-cost option

Considerations:

- Often sketches are vague and do not contain the required information for accurate allocation of a crash coordinate by office staff
- Accuracy low

**Global Positioning System (GPS)**

The use of GPS (Global Positioning System) units has become far more feasible and inexpensive in recent years and can radically improve the accuracy of crash location map coordinates. GPS units use the differences in time that radio signals take to be received from a number of orbiting satellites to obtain very accurate map coordinates at a given point on the earth’s surface.

The price of GPS handsets (see Figure 17) has reduced significantly in recent years and battery use has also improved greatly making these a viable method for police to collect map coordinates for crashes. The units need to pick up a number of satellite signals, the more strong signals that are locked onto, the more accurate the coordinates will be. Obtaining the lock can take a few minutes, but the unit can be left on top of a car roof whilst the officer attends to other tasks. They work best with a clear view of the sky. Tree cover and tall buildings have been reported to cause some issues with obtaining accurate positioning using GPS.

**Figure 17: Using a GPS unit**
The main problem with GPS is that a unit needs to be with the officer when they attend the crash site, it must have charged batteries and the police staff must remember to actually use it. The unit needs to be set to the correct coordinate system and the officer needs to correctly transcribe the reading onto the paper form. Accuracies of between 1 and 3 metres are readily obtainable which is sufficient for spatial analyses such as blackspot analysis.

Benefits:
- High level of accuracy
- Low levels of error

Considerations:
- Relatively high cost
- GPS units can struggle to work where there are very tall buildings and under dense tree coverage
- Units need to be maintained and charged
- Accurate transcription is required

Mobile Data Capture

Mobile data capture using smart phones or tablets is now also a possibility since these generally have GPS capabilities. As these devices become less expensive they become an option not only for the recording of crash coordinates but also filling in the crash report form electronically. Capture and attachment of photographs and videos to the crash file is also possible with these devices. Using such an approach can remove the need for labour intensive and error prone data entry since the data are uploaded directly to the crash database either remotely through the mobile data network or through a USB (Universal Serial Bus) connection at the police station. Validation/completeness checks can also be undertaken at the point of data collection.

Benefits:
- High level of accuracy
- Low levels of error
- Removes the possibility of transcription error
- Removes need for data entry in the office
- Validation of data/checking for completeness can be undertaken at the time of data collection

Considerations:
- Relatively high cost
- Smart phones/tablets need to be maintained and charged
- High sun levels may mean using smart phones/tablets outdoors is problematic (details can be filled in at the police station by the attending officer as an alternative)
4.4.2 Crash Databases and Analysis Software

Whilst it is possible to store data using paper based filing systems, there are some significant disadvantages:

- Paper records can become spoilt, torn, faded or even lost, photocopies or duplicates can be poor quality
- Meticulous filing of records is required in order that they can be accessed in the future
- Even the most basic of analyses can be extremely time consuming (e.g. if a particular junction needs to be investigated all crashes occurring at that junction must be found)

Whilst using a crash database system is recommended, it can also remove the engineer from the realities of the raw data. It is still suggested that original records are accessed to check information. Many electronic systems do not hold scanned copies of the form (and crucially copies of crash sketches) together with the coded data.

**Computerised Systems**

There are many advantages to digitising crash data:

- Individual crash records can be found easily
- Sorting and analysis of data becomes less labour intensive
- Monthly or annual reports can be generated more easily
- Results of analyses can be checked and statistical methods applied
- Analyses can be replicated over different time periods
- Personnel can undertake more productive tasks in comparison to manually sorting through data
- Data can be shared with stakeholders such as Engineers or Educationalists

Dedicated computerised crash database systems can make the task of blackspot identification and other spatial analyses much easier than manual methods, providing the system has a Geographical Information System (GIS) mapping module (that can identify high density locations), if the crashes have map coordinates accurately assigned. This also permits the replication of analyses so that work can be easily checked and rechecked, it will permit individuals to identify sites much more quickly, and dedicated systems can also be used effectively by staff with less training and less capacity compared with more manual processes and systems.

Systems can vary greatly in cost and complexity, from the use of existing databases and GIS software systems, to internally developed systems, to bespoke and Commercial Off The Shelf (COTS) systems. The appropriate system will depend on the size of the country or jurisdiction, the numbers of crashes which are typically recorded each year and available budgets.

There are several options for introducing computerised systems for the recording and analysis of crash data:
Database software products (e.g. MS Access or SQL Server) can be fairly readily configured to handle crash data by staff with the appropriate training. Ideally these solutions should be able to handle “relationally” structured and linked records, because the crashes may have a “one to many” relationship with varying numbers of vehicle records and casualty records. Database software should have macros and front-end development tools which mean that developing more sophisticated data entry screens with validation and data integrity checks should be possible. This type of software doesn’t have GIS functionality built in, so there may be a requirement to link to other products such as ArcView or MapInfo which can handle the mapping functions required.

More sophisticated Crash Database Systems which have been developed to run on full “data servers” also need very careful care by qualified database manager staff. It can be difficult to keep the software and hardware running consistently.

If IT staff with the correct skills and understanding are available it is possible to build Crash Data Systems locally, either in-house or on a contract basis potentially using local firms, however, this will have benefits and also potential problems. The benefits can be that a highly customised system can potentially be produced tailored to precise requirements, however it can be expensive. It is important that the contracting organisation has an extremely clear idea of the functionality and analyses capabilities that are required for the final product and can also rigorously test the product. Organisations who do not have significant experience of managing software development can find this a challenging task and may not end up with the required product at the end of the process.

There are risks of becoming dependant on one or two individuals who are the only staff understand the system and can make any required changes or fixes, which need to be considered and understood. This applies if bespoke software is developed either within in-house or by a developer.

System Capabilities

Figure 18 details the features and capabilities that are recommended in good systems according to the WHO (2009).
Data Collection
EXISTING ROADS: REACTIVE APPROACHES

Research on 11 ‘good practice’ crash database systems in Asia, Europe and North America identified several useful features:
- Built-in quality checks (algorithms and logic checks).
- GIS linkage to allow accurate identification of crash location.
- Ability to add new data fields without re-developing the database.
- Database navigation features such as drop-down menus, clickable maps.
- Pre-defined queries and reports.
- Option for customized, user-defined queries and reports.
- Mapping ability, for data entry, crash selection and presentation of aggregated crash information.
- Ability to export data entry to third-party applications (e.g., Microsoft Excel, Statistical Analysis Software (SAS)) for further statistical analysis.
- Inclusion of crash narrative sketches of crash scene, photographs and videos linked to crash.
- Automatically generated collision diagrams.

Figure 18: Recommended crash data system features (WHO, 2009)

Ideally a crash data system will have the following functionality:

- A data entry module

An interface that enables staff to enter data rapidly (preferably using only the keyboard for speed). Note that for mobile solutions this step may be removed. This interface should also allow the editing and updating of data records. Ideally there should be functionality for checking validity and completeness of crash records which have been entered or imported to identify a range of missing data or logic errors (algorithms that interrogate the consistency of information entered).

The interface should present data in a logical order (consistent with the crash reporting form).

- Analysis capabilities that allow staff to identify and work with subsets of data

The system should have comprehensive query capabilities so that the database can be sifted for subsets of the data which can then be further analysed. Good query systems typically use the mathematical operators (<, >, = etc.) so that coded and numeric fields can be interrogated. The system will ideally have a wizard or simplified interface allowing staff to easily develop complex multi-line queries without the need to understand the query language (such as Structured Query Language) which are difficult to use without extensive training.

- Analysis capabilities to identify patterns in the data

Data systems should have functionality which allow staff to cross tabulate coded and numeric fields against one another to produce pivot style tables. These can be used to report the data and also to look for patterns that can give insight into road safety issues. More advanced and modern systems may have specific blackspot functionality. These advanced systems should have statistical capability.
to support monitoring and evaluation and advanced analyses to produce crash diagrams and stick analysis.

- GIS or other modules that allow staff to plot crashes and support spatial analyses

The ability to plot crashes on digital mapping so that crash density can be analysed is especially important to assist users to identify blackspots. These modules should allow weighting of crashes by severity to help the production of priority lists of sites. The modules should ideally be able to make use of free internet mapping such as “Openstreet” which now has a fairly comprehensive coverage globally.

- Modules which allow the easy production of standard and user defined report.

Templates for reports that are produced frequently should be available. These should be visually pleasing and easy to interpret. Users should also be able to define their own reports. It should be possible to include charts and graphics to illustrate the reports.

- Audit trail to enhance transparency.

Modern systems should provide an audit trail that shows changes made by users.

### 4.4.3 Data Sharing

It is vital to ensure that engineers and other road safety practitioners gain access to data to help them to develop targeted interventions. It is important to have a clear agreement in place between the data collector and other users to share the data. It is recommended that this be in the form of a Memorandum of Understanding (MoU) which sets out the basis on what is to be shared, how frequently and through what mechanism.

In some locations the police use duplicating paper forms which create multiple copies as the information is collected. Typically three copies are created, with one staying in the local police station, one being sent to police headquarters and one to the engineering department. This can mean that several organisations enter the same information into different databases, which leads to unnecessary duplication of effort. The quality of these multiple copies can also be difficult to read, leading to additional data entry errors.

If data are held in an electronic database, then the information can be shared relatively easily. Web-based data systems are particularly useful in ensuring consistency of information and can allow very easy data sharing. Different stakeholders can access the same dataset using different log-in details that permit them to see different data fields and use different data analysis tools. This addresses concerns the police may have about the sharing of sensitive information such as vehicle registration numbers, names and addresses etc. These can be made so they are simply not accessible to those that do not need to view or analyse them.
5. Data Analysis and Investigation

There are three types of data analysis and investigation techniques described in this manual. The requirements for them are broadly similar and so are described in Section 5.1 to avoid repetition.

5.1 Requirements

5.1.1 Equipment

For the desk-based analyses, the following software may be required or will make it easier to undertake the analyses:

- Blackspot 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
- Route/corridor analyses – assigning crashes to sections may be done using GIS software, otherwise analysis of patterns can be done using basic spreadsheet software (e.g. MS Excel); crash data analysis software can make analysis of patterns significantly more straightforward
- Area analyses – can be undertaken using basic spreadsheet software (e.g. MS Excel)

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.

5.1.2 Personnel

Data analyses can be undertaken by a member of staff 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 the New Roads and Schemes – Road Safety Audit Manual and the Existing Roads – Proactive Approaches manual). 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.
5.2 Blackspot Analysis and Investigation

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 4.4.1.1. 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 those described in Section 5.3 and 5.4 of this manual 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”.
5.2.1 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 regions and stations 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.

5.2.2 Methodology

Blackspot analysis is undertaken in 7 steps, as described in the sections that follow and shown in Figure 19.

![Figure 19: Blackspot analysis and treatment steps](image)

It should be noted that once blackspots have been identified these need to be fully investigated through a site review and a treatment plan developed if appropriate.

5.2.2.1 Step 1: Investigate Background Data

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

The main types of information required are:

- General trends in the data across the available years of data
- Typical numbers of casualties per crash severity
  - Separately for high speed and urban roads if possible
General and Longer Term Trends

It is extremely useful to understand the general patterns and trends which are occurring to crash patterns across the country over time; also for different geographical regions and different road types. Typically where vehicle ownership is increasing markedly with economic development, it is expected that crashes and casualties will increase in relationship with growth in traffic. This is especially true in Middle Income Countries (MICs) if the significant and effective programmes needed to counter the road safety problems associated with increasing traffic volumes and roads trips are not being funded.

If there are significant increases annually in road crashes and injuries, this has implications for the potential crash reductions that can realistically be expected at treated locations. For example, if a post implementation strategy is expected to reduce crashes in the after period by 25% and yet crashes are generally increasing by 25% in the same period, then a result of no reduction can actually indicate success.

Casualties per Crash by Severity

The number of casualties per crash varies. As part of the exercise to economically appraise efforts, it is useful to understand the average number of casualties of different severities in each severity of crash.

By definition:

- A fatal crash must have at least one fatality and any number of serious and slight casualties
- A serious crash must have at least one serious casualty, no fatalities and any number of slight casualties
- A slight crash has no fatalities or serious injuries but any number of slight casualties
Table 2 shows the average numbers of casualties for different crash severities by land use type. Crashes on faster roads are expected, on average, to be more severe than those on lower speed roads, though in many African countries the high incidence of pedestrian casualties may skew this. Crashes occurring on rural roads are likely to have higher severity due to increased speeds, though this could also result from lower reporting rates of less severe crashes compared to villages and urban crashes.

These statistics can be used to calculate average crash costs (also by land use type) if casualty costings by severity are known.

**Table 2: Average casualties by severity and land use type (Ghana data 2005-2011)**

<table>
<thead>
<tr>
<th></th>
<th>Fatalities</th>
<th>Hospitalised</th>
<th>Slight Injuries</th>
<th>Injured persons per crash</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatal</td>
<td>1.1</td>
<td>0.5</td>
<td>0.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Hospitalised</td>
<td>1.3</td>
<td>0.5</td>
<td>0.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Slight Injuries</td>
<td>1.5</td>
<td></td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Village</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatal</td>
<td>1.3</td>
<td>1.1</td>
<td>0.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Hospitalised</td>
<td>1.7</td>
<td></td>
<td>0.9</td>
<td>2.6</td>
</tr>
<tr>
<td>Slight Injuries</td>
<td>2.3</td>
<td></td>
<td></td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Rural</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatal</td>
<td>1.4</td>
<td>1.8</td>
<td>1.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Hospitalised</td>
<td>2.2</td>
<td></td>
<td>1.6</td>
<td>3.8</td>
</tr>
<tr>
<td>Slight Injuries</td>
<td>2.8</td>
<td></td>
<td></td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Normal Crash Rates**

To understand whether a cluster that has been identified from the network screening process (see Step 2) really represents a site with excessive occurrence of crashes, it helps to understand what a ‘normal’ or ‘expected’ rate of crashes is for different road types and junction types.

Ideally crash rates by traffic volume (per 100 million vehicle kilometres) should be calculated however, the assumption is that there will not be enough consistent flow data to permit estimation of these rates systematically across networks in most African countries. Instead, crash density (number of crashes divided by length of road) can be calculated.

It is frequent practice in many countries to identify sites with the most crashes and worst severities of crashes, and to construct lists of these without referring to expected numbers of crashes (see Section 5.2.2.3). This simple approach has been successful in many countries. Arguably methods that compare
crash occurrence at suspected Blackspots with normal or expected crashes are accepted as being superior, since this should help to reduce the instance of investigating “false positives”.

5.2.2.2 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 since patterns in crash reporting and occurrence vary so greatly. Typical values are discussed below for clusters of crashes within a 30 - 50m radius.

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) it may be necessary to use up to five years of data.

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 at 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 21). 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 21: Nearest neighbour clustering

This method can be undertaken in GIS packages such as MapInfo and ArcView and is also implemented in Crash Data Software such as TRL’s iMAAP (see Figure 22) and MAAP for Windows.

Figure 22: Cluster analysis module in iMAAP 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.

An example of the use of Heat map analysis for crashes in Ouagadougou in Burkina Faso is shown in Figure 23 (supplied by Emmanuel Bonnet of IRD – Umi Resilences, Ouagadougou).

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

Figure 23: Heat map analysis for Ouagadougou in Burkina Faso
Data Analysis and Investigation

EXISTING ROADS: REACTIVE APPROACHES

**Fixed Length Methods (Highways)**

Where crashes are assigned to more major highways by their location relative to marker posts (typically located every kilometre or 500m, 200m or 100m), these section positions can be used as a search basis for identifying blackspot sections. If the crashes are located only as accurately as being within a given 1km section, this will constrain the size of the possible blackspots to 1km which will make finding a discrete or localised problem difficult within the identified length. For this level of accuracy it may be more appropriate to consider a route/corridor analysis (See Section 5.3). This method should also ideally take into account whether a junction/intersection is present; ideally link and junction sections should be analysed separately as far as possible, since crashes can cluster naturally at intersections.

![Figure 24: Kilometre analysis system, Ghana data in MAAP for Windows](image)

**Pin Maps – By Eye Method**

Some countries, including Germany (Elvik, 2008), are reported to still use visual methods to identify clusters from a ‘pin’ map. These are often physical maps displayed on a wall where every crash is identified by a pin. Different colours can be used to denote casualty severity, or road user group. It is limited in the number of variables that can be displayed in this way for each individual pin. It does give a quick visual identification of the locations that might be worthy of further investigation, but does not allow robust comparisons. This may work, especially when dealing with small numbers of crashes; however it is likely to lack objectivity and repeatability. It is possible to maintain a digital form of this method.
5.2.2.3 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 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 3.

**Table 3: Pros and cons of approaches to severity weighting**

<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></td>
<td></td>
<td>Added complexity</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 discourages internationally</td>
</tr>
</tbody>
</table>

Practitioners should test different weighting schemes to check that they are performing in a desired way. Ideally sites should also be filtered and prioritised by comparing the crash occurrence at identified potential blackspots to the average occurrence for similar road sections which have similar flow levels.

**5.2.2.4 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:

- If a high proportion of crashes in the cluster involved pedestrians it could be due to a lack of appropriate provision for the non-motorised demand
- If a large number of crashes are shunts (nose to tail) it could be a light phasing issue, a surface friction problem, or a general speed related problem
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 25 for an example, courtesy of Allan Jones).

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.

![Figure 25: Standard report developed for Ghana](image)
Cross-Tabulation

Cross-tabulation is a way of summarising and presenting information relating to subsets of the data. It can also be used for looking for patterns between different fields that are recorded in the crash data form. It is a method that does the same as the ‘pivot table’ function in spreadsheet programs. This analysis method allows the investigator to look for less obvious patterns across all the coded fields in the data from an individual cluster for example. It can be used to supplement the information that is set out in the standard report.

Figure 26: Typical cross-tabulation output (iMAAP)

Ideally it should be easy to perform and access cross-tabulation on the crashes which are included in an individual blackspot. The following examples of cross-tabulation are all run on the crashes located in the blackspot shown in Figure 27.

Figure 27: Analyses techniques available through clicking on individual blackspots (data from Accra, Ghana)
Some typical cross-tabulations that might be done are Day of the Week against Time of day (see Figure 28) and Crash Type against Casualty Class (Figure 29) for example.

![Figure 28: Time of day versus day of the week](image)

If a cross-tabulation identifies a very clear pattern, this may suggest a further useful tabulation that could help identify issues at a blackspot. From the cluster identified in Accra, Ghana, shown in Figure 27, a cross-tabulation of casualty class against the crash type clearly shows that almost all the injured were pedestrians (see Figure 29).

![Figure 29: Cross-tabulation of casualty class versus crash severity](image)

From this result it is worth looking into what the pedestrians were doing when killed or injured. In this case this can be done by tabulating the field ‘Pedestrian Action’ against ‘Casualty Class’. Figure 30 shows that the pedestrians were mostly crossing the road when injured, however a significant number were at the roadside when hit by vehicles (especially when the numbers for these similar codes are amalgamated).

![Figure 30: Cross-tabulation of casualty class versus crash severity](image)
These patterns are supported by the results of tabulating ‘Crash Code’ against ‘Casualty Class’ (Figure 31).

![Cross-tabulation of casualty class versus crash code](image)

**Figure 31: Cross-tabulation of casualty class versus crash code**

These cross-tabulation results above indicate that there are likely to be significant issues with provision of facilities for pedestrians crossing and moving along the road. The site visit should therefore concentrate on these issues and particular attention should be given to observing pedestrian behaviours.

**Crash Diagrams**

The construction of ‘crash diagrams’ is used as a further way to identify potential sources of conflict between road users at blackspots. Crash diagrams give an indication of the types of crash that are occurring at specific locations – this is typically, but not exclusively, used at junctions. The methodology is used to identify more clearly the types of crashes that are occurring and therefore help the engineer identify better the possible countermeasures which may be appropriate.

The method requires that individual crashes have been given precise crash coordinate locations (ideally within 3m accuracy) and also that of the appropriate fields are filled in on the reporting form. Most importantly, it requires that the manoeuvres (as compass directions, for movement from and to) are listed for individual vehicles and road users.

In addition to an indication of the crash types, other important information can be indicated, such as the severity of the individual crashes and also the date when they occurred (see Figure 32). In addition indications of whether the crashes occurred under daylight or darkness and in wet or dry conditions are also indicated in the simple symbols for each crash.
The engineers at Transport for London (TfL), which is responsible for road safety in the UK’s capital, have developed a consistent and clear system of symbols which are used to produce crash diagrams for all blackspots identified (see Figure 32). Variations on this symbol set are used in many different countries and data analysis systems.

**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 33 and Figure 34). 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.

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**Figure 32:** Standard TFL crash plots – hand generated TFL, June 2006

**Figure 33:** Grid pre-prepared for manual stick production
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 (see Figure 35), however the use of icons and colour can make the patterns more readily apparent (see Figure 36).

**Figure 34: Sample completed grid**
**Figure 35:** A stick analysis developed by BRRI in Ghana, sorted by severity, applied to the blackspot shown in Figure 27

**Figure 36:** Stick using icons to represent field values
Stick analysis is usually limited to groups of 50 to 100 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.

5.2.2.5 Step 5: Investigate Sites

Once the pattern of crashes has been identified, the sites need to be physically examined.

Aim of the Site Visit

The aim of the site visit is to establish the underlying factors that are contributing to the dominant crash types identified from the analysis. For instance there may be a large number of pedestrian casualties even though a crossing is provided. During the site visit the investigation team may find that the pedestrian crossing is not co-located with desire lines or public transport facilities. Simply relocating a bus stop may encourage pedestrians to use the facilities. Similarly a high incidence of turning vehicle crashes may require a minor modification to the junction layout.

The Prompts included as an Appendix in the ‘New Roads and Schemes – Road Safety Audit’ manual and the ‘Existing Roads – Proactive Approaches’ manual may be useful in undertaking a site investigation but should be used in light of the crash data analyses to direct the investigation.

Planning

Site visits:

- Should be undertaken at times when crashes are occurring. The crash patterns may indicate that it is important to visit the site during darkness, during rush hour or when it is raining for example.
- Need to allow the investigation team to take the perspective of road users represented in the crash data.
- Must be undertaken safely. The safety of the investigation team, other road users and construction or other personnel must not be compromised by the site visit.

Site visits for larger or more complex roads will often need to take place over several days and careful planning will therefore be necessary.

Different Viewpoints

The site visit should allow the investigators to take the perspective of different road users, particularly those over-represented in the crash data. Note that this should not put the investigation team at risk – for example if motorcyclists are over-represented in the crash data the investigation team should not ride the route on a motorcycle if they are unfamiliar with this mode of transport.
Recording Findings

Video cameras, or digital cameras and voice recorders, enable images of the site to be recorded along with a spoken commentary of issues. This is extremely useful when later collating the observations and the images can also form a very informative part of the report.

It is recommended that a full video of the site/road is recorded and that many photographs are taken during the site visit. These are important in order to provide a reminder of key issues when writing the report and provide a record of the conditions during the site visit.

Taking videos and photographs in a systematic manner will help when reviewing them later. Always start a video sequence speaking to the camera and naming the site, identifying the personnel involved, stating the date and time and by specifying direction of travel. It can also be helpful to provide a video commentary. Photographs should also be taken in a systematic manner so as to assist with subsequently identifying features and locations. For example, ensure that landmarks are included and always progress around an intersection in a clockwise direction. It may also be helpful to photograph a written card which describes the location prior to taking a sequence of photographs.

Copies of plans should also be used to record any specific features seen during the visit for later reference.

Community Intelligence and Consultation

When a site visit is undertaken it can be very useful to consult with local interest groups and the wider community. This has a number of advantages:

- Further intelligence can be gathered on the crashes that have occurred and any concerns the community has
- The transport and safety needs of the local community can be taken into account when developing a treatment plan
- The local community can be educated on safe use of the road

Conflict Studies

A conflict study can provide useful information that is complementary to crash data. A conflict or encounter often involves a road user (a pedestrian, a pedal cyclist or the driver of a motorised vehicle) taking some form of evasive action. One definition of a conflict (from Ross Silcock, 1998) is: two traffic participants maintain such a course and speed that a sudden evasive manoeuvre of one of the two participants is required to avoid a crash.

Conflict studies can be undertaken by making, and recording, observations from the road-side or by observing interactions on video. It should be noted that whilst the most common conflicts are often similar to the most common manoeuvres, this is not always the case. In some instances, movements which are less common can be disproportionately over-represented in conflicts. Therefore, as well as identifying information about conflicts, it is also necessary to record some indicative traffic counts so as to help to understand the rate of risk exposure associated with any particular conflict.
The assessment of conflicts involves an element of subjective judgement and it is therefore important to ensure that suitably skilled personnel undertake the analysis and that it is undertaken in a consistent manner. It is recommended that five classifications of conflict severity are used (Table 4).

**Table 4: Conflict classifications**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Encounter, Precautionary action</td>
<td>Pedestrian stopping in carriageway to allow vehicle to pass</td>
</tr>
<tr>
<td>2</td>
<td>Controlled action</td>
<td>Pedestrian deviates from route or vehicle undertakes controlled braking</td>
</tr>
<tr>
<td>3</td>
<td>Near miss</td>
<td>Rapid deceleration, lane change or stopping</td>
</tr>
<tr>
<td>4</td>
<td>Very near miss</td>
<td>Emergency braking or violent swerve</td>
</tr>
<tr>
<td>5</td>
<td>Crash</td>
<td>Contact between two parties</td>
</tr>
</tbody>
</table>

As well as identifying the manoeuvres and the types of traffic involved in a conflict it is also necessary to consider the severities of conflicts along with the rate of exposure to risk. The study will therefore include representative traffic counts and a categorisation of each observed conflict.

Conflicts can be recorded on site using very simple sketches. These sketches record the manoeuvres and the road user types involved in each conflict, along with the frequency and the severity. Examples of this are reproduced in Figure 37.

**Figure 37:** Example of a conflict study sheet for pedestrian movements (left) and intersection (right)
Safety Considerations

Throughout any site visit it is important to maintain the safety of the investigation team. The investigation team should be aware that the sites they are investigating are high risk (otherwise they would not be investigating them) and so extra care and caution should be exercised.

If a site visit cannot be done safely then it should not be done at all.

Site visits need to be carefully planned as personnel will need to stop at several locations where safety hazards will be present. A full risk assessment should be undertaken. The risks, and the precautions which are necessary, will vary from site to site. However, general principles include:

- **Planning and administration**
  - A manager should be notified of any deviations from planned schedules
  - A mobile telephone should be provided for emergencies and for checking in with the line manager at the start and end of each day.
  - The investigation team must be equipped with sufficient supplies of drinking water and food.

- **Vehicle safety**
  - Vehicles must be roadworthy and properly equipped with suitable reflective materials and lighting bars. They should generally travel at the prevailing traffic speed.

- **Site/operational issues**:
  - Site visits must always involve at least two personnel - one should act as a look out when the other is preoccupied (e.g. taking photographs).
  - Appropriate traffic management should be requested if it is otherwise unsafe to inspect the site.
  - The investigation team should park safely so as to not obstruct traffic flow or obscure sightlines.
  - The investigation team must be aware of risks from beyond the road. For example, the risks of sunstroke, personal attack or animal bites (including insect or snake) should be evaluated.
  - Appropriate Personal Protective Equipment (PPE) must always be worn. Different PPE will be appropriate for different situations but it is likely to include reflectorized vests or jackets and possibly trousers and sunshades. Suitable footwear is essential and might include steel toe cap boots. Hard hats or eye goggles will be necessary in some situations.
  - The investigation team must never use video cameras, cameras, mobile phones or other equipment while they are driving.
  - Investigations must be made from safe locations such as footways, hardened verges or overbridges. Investigators should not stand in the road and they should only cross the road in suitable locations and with care.
  - The investigation team should avoid walking with their backs to traffic where possible.
  - The investigation team must not expose themselves or other road users to risks during adverse weather conditions such as high winds or heavy rainfall. It is possible however to undertake some observations from a safe place (e.g. pedestrian behaviour in the rain).
The investigation team should not intervene in incidents or direct traffic unless they are specifically trained and equipped to do so. Well-intentioned intervention of this type can make matters worse and it is better to call the Police or other emergency services in such situations.

The investigation team should stop work and leave the site if unforeseen risks are identified. They should consult with a manager to determine a way forward.

5.2.2.6 Step 6: Identify Solutions

For each site, countermeasure options are ‘tested’ for their potential to reduce the occurrence of fatal or serious crashes that have occurred at the location. For example, if there are many serious pedestrian crashes, and pedestrians are observed crossing the road away from crossing facilities then provision of pedestrian crossings and guard rail may be appropriate. Similarly, if there are substantial numbers of crashes occurring at night at an intersection, it may be appropriate to provide lighting or improved warning signs/delineation.

A list of potential treatments relevant to different crashes is given in Appendix A. It provides high-level, indicative, guidance as to the type of safety improvement measures which might be appropriate under different circumstances.

5.2.2.7 Step 7: Report

Once the analysis and preferred solution(s) have been identified the whole investigation needs to be summarised in a report to management for appropriate action. The report will review the process that has been followed, starting with the initial identification of the problem through data analysis. This will be followed by a description of the findings of the site visit that identify the factors contributing to the crash problem and the reasoning behind the identification of proposed solutions.

This will then be taken forward to the development of a treatment plan described in Section 5.5.

An example blackspot analysis report can be found in Appendix C.

5.3 Route/Corridor Analysis and Investigation

Route/corridor analysis aims to identify road sections that are performing badly from a road safety point of view in comparison to the average for other similar roads. In this technique roads with a high potential for crash reduction are those where the crash density is much worse than the average for that road type.

Once road sections that have a high potential for crash reduction have been identified, they should be investigated through a site visit to see if there are treatments that will raise the standard of that road to at least average for the road type. The person undertaking the site review will need to take into account the type of crashes occurring on the section to determine whether any treatments are likely to rectify the underlying crash problem.
5.3.1 When to Undertake Route/Corridor Analysis

Route/corridor analysis should be undertaken on an annual basis. These analyses will require a minimum of three years of crash data. In some countries with high rates of under reporting it may be necessary to use up to five years of data. As with blackspot analysis there is a balance to be reached between having sufficient data for the analyses to be robust and having data that reflects the current road network.

As an approach, route/corridor analysis is particularly useful since it does not necessitate the precise crash coordinates necessary for blackspot analysis. Route/corridor analysis should be undertaken alongside blackspot analysis since the two approaches will highlight different issues; route/corridor analysis may uncover issues that pertain to longer sections but are not concentrated enough to appear as blackspots.

Whilst route/corridor analysis does not require precise crash coordinates, some information about crash locations is necessary in order to attribute crashes to road sections. This information can be in the form of crash coordinates or it can be the road number, road section, link node location, or chainage along a road (see Section 4.4.1.1 for more information on these types of crash locators). For the results to be the most use this would be recorded and available for all crashes over the whole road network.

5.3.2 Methodology

A step-by-step procedure for undertaking route/corridor analysis and investigation is outlined in Figure 38 and described in the sections that follow.

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Figure 38: Route/corridor analysis and treatment steps
5.3.2.1 Step 1: Section the Road Network

This first task should only be undertaken once so that, as much as possible, consistent road sections are used every year (substantial changes to the road network including new roads will of course need to be reflected in the dataset). This will allow the monitoring of high risk sections year by year.

Ideally road sections should be:

- Homogenous in character (the section should have similar design features and similar traffic flows)
- Between 10km and 150km in length (and ideally as similar in length as possible)
- Meaningful e.g. road x between junction y and junction z or between two settlements

Road Safety Inspections (RSI) as described in the Existing Roads-Proactive Manual requires a similar process to be undertaken. It would be advantageous and efficient to use the same road sections for both route/corridor analysis and RSIs.

The way in which the network is sectioned will need to reflect the way in which crash locations are recorded by the police. It will be necessary in Step 3 to assign crashes to each length. This means that it must be possible to determine which crashes were on each length. In the worst case, this may restrict network sectioning to road names (preferably by jurisdiction). This may impact upon quality of the results and the ability to be precise about priorities across the network since most roads will be much longer than the ideal road section length.

Figure 39: Latitudes and longitudes using Google Maps
If police crash data are already recorded using a link-node system then it may be best to use this as a basis for sectioning the network.

Each section should be given a unique identifier and sufficient location details recorded such that the section is identifiable on the network (i.e. latitude and longitude, road numbers or settlement names at the start and end points).

Some free-source web-based mapping provides a latitude and longitude information if the location is clicked upon and selected.

The road sectioning data could look similar to that provided in Table 5 if latitude and longitude references are used.

**Table 5: Road sectioning data using latitudes and longitudes**

<table>
<thead>
<tr>
<th>Section ID</th>
<th>Road Number</th>
<th>Start Point</th>
<th>End Point</th>
<th>Length of section (kms)</th>
<th>Road Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Latitude</td>
<td>Longitude</td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>1</td>
<td>B141</td>
<td>-5.748694</td>
<td>34.814515</td>
<td>-5.710357</td>
<td>34.765437</td>
</tr>
<tr>
<td>2</td>
<td>B129</td>
<td>-5.748694</td>
<td>34.814515</td>
<td>-5.782108</td>
<td>34.900425</td>
</tr>
<tr>
<td>3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

If road names and settlement references are used, then this may look like Table 6.

**Table 6: Road sectioning data using road names and settlement names**

<table>
<thead>
<tr>
<th>Section ID</th>
<th>Road Number</th>
<th>Start Point</th>
<th>End Point</th>
<th>Length of section (kms)</th>
<th>Road Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A104</td>
<td>Iringa town junction with A7</td>
<td>Iringa Nduili Airport</td>
<td>19.3</td>
<td>Single</td>
</tr>
<tr>
<td>2</td>
<td>A7</td>
<td>Iringa town junction with A104</td>
<td>Viwengi</td>
<td>12.8</td>
<td>Single</td>
</tr>
<tr>
<td>3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

**5.3.2.2 Step 2: Categorise Roads**

The next step is to categorise each section. The categorisation provided in Table 7 is a guide for use in Africa; however, ideally traffic flow categories should be allocated so that 1/3 of each road type falls into each flow category. This will vary significantly from country to country.
### Table 7: Road classifications guide

<table>
<thead>
<tr>
<th>Category</th>
<th>Approximate Traffic Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual/divided carriageway - high traffic flow</td>
<td>&gt;20,000 vehicles/day</td>
</tr>
<tr>
<td>Dual/divided carriageway - medium traffic flow</td>
<td>5,000-20,000 vehicles/day</td>
</tr>
<tr>
<td>Dual/divided carriageway - low traffic flow</td>
<td>&lt;5000 vehicles/day</td>
</tr>
<tr>
<td>Single carriageway - high traffic flow</td>
<td>&gt;5,000 vehicles/day</td>
</tr>
<tr>
<td>Single carriageway - medium traffic flow</td>
<td>1,000-5,000 vehicles/day</td>
</tr>
<tr>
<td>Single carriageway - low traffic flow</td>
<td>&lt;1,000 vehicles/day</td>
</tr>
</tbody>
</table>

Ideally, traffic flow data should be collected in a robust and reliable manner. This would involve undertaking detailed traffic surveys across the road network. Often these will be done by different departments in the road authority (for projects concerning planning or environmental impact etc.). If traffic flow data are not available, these can be undertaken based on considered estimates, though the results may not be as robust.

**5.3.2.3 Step 3: Assign Crashes to Sections**

The process for assigning crashes to sections will depend on the detail of data available.

If the network sectioning has been undertaken to fit precisely with police crash data link-node locations, or if the police are able to add the ‘route/corridor analysis section’ to the list of fields they record, then this process has already been completed.

If crash coordinates are available in a database then these will need to be assigned to the road sections. This can be done using a GIS mapping program or website, or by comparing the crash coordinates with the latitudes and longitudes of the end points of the road sections with the same road number.

Note that it is more reliable to use crashes rather than casualties for this kind of analysis since counting casualties can skew data due to crashes involving many casualties (e.g. mini-bus crash).

**Table 8: Assignment of crashes**

<table>
<thead>
<tr>
<th>Section ID</th>
<th>Road Number</th>
<th>Start Point</th>
<th>End Point</th>
<th>Length of section (kms)</th>
<th>Road Type</th>
<th>Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Latitude</td>
<td>Longitude</td>
<td>Latitude</td>
<td>Longitude</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>B141</td>
<td>-5.748694</td>
<td>34.814515</td>
<td>-5.710357</td>
<td>34.765437</td>
<td>7.1</td>
</tr>
<tr>
<td>2</td>
<td>B129</td>
<td>-5.748694</td>
<td>34.814515</td>
<td>-5.782108</td>
<td>34.900425</td>
<td>11.3</td>
</tr>
<tr>
<td>3</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>

If severity information on crashes is available and reliable, weightings can be applied to the number of crashes in a similar manner to that undertaken in blackspot analysis (see Section 5.2.2.3).
5.3.2.4 Step 4: Calculate Crash Density

Crash density is a measure of the concentration of crashes along a section; it is defined as the number of crashes on the road section (in a chosen time period) divided by the length of the road section. The time period chosen will depend on the number of crashes recorded (the higher the number of crashes per road section the shorter the amount of time required), however, it is suggested that a period of three years would be a good starting point.

Crash densities show where most crashes are occurring across the network. Crash density is highly influenced by traffic flow and so it is often the case that such analyses just show where the greatest traffic flows are across the network. Therefore ideally, crash risks are also computed, however these require accurate traffic flows to be recorded for each of the road sections used in the route analysis.

5.3.2.5 Step 5: Calculate Crash Risk (Optional)

Crash risk is the risk to an individual per billion vehicle kilometres driven. Accurate traffic flow data are required for each road section in order to calculate crash risk. This measure effectively controls for traffic flows to find intrinsically high risk sections. Care should be taken with the results of risk analysis since high risk sections may not have the greatest treatment priority. Simply focussing on high risk sections alone may mean investment is made on roads with low traffic volumes so the casualty reduction potential may not be at its greatest. The routes most suitable for treatment are likely to be those with a moderate to high crash risk and also a moderate to high crash density.

5.3.2.6 Step 6: Identify High Priority Sections

It is unlikely to be possible to investigate all routes/corridors 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.

In this step, the highest priority sections for treatment need to be identified. In terms of risk and potential for crash reduction, three sub-steps are needed:

- Step 6a: Calculate the average crash density for each road category. It is important to ensure that this is calculated as total number of crashes on road category divided by the total length for road category (rather than averaging the calculated densities).
- Step 6b: Calculate the difference between the crash density for each section and the average for its road category and rank the sections on this basis.
- Step 6c: Calculate the potential for crash savings by multiplying the potential crash savings per km per year by the length of the road section.
Table 9: Route/corridor analysis results

<table>
<thead>
<tr>
<th>Section ID</th>
<th>Road category</th>
<th>Number of crashes</th>
<th>Road length (km)</th>
<th>Crash density (per km per year)</th>
<th>Average crash density for road type (per km per year)</th>
<th>Potential crash savings per km per year</th>
<th>Potential crash savings per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single – medium</td>
<td>10</td>
<td>7.1</td>
<td>1.41</td>
<td>0.95</td>
<td>0.46</td>
<td>3.26</td>
</tr>
<tr>
<td>2</td>
<td>Single – high</td>
<td>18</td>
<td>11.3</td>
<td>1.59</td>
<td>1.20</td>
<td>0.39</td>
<td>4.44</td>
</tr>
</tbody>
</table>

*Rank for further review based on potential crash savings per km per year.

At least the top 10% of sections (more if possible) should be investigated through the analysis of crash types and patterns and the undertaking of a site review.

It is possible also to calculate the potential casualty savings by multiplying the potential crash savings per km per year by the average number of casualties per crash. Although this will not further aid prioritisation, it may be a useful calculation in order to make the case for investment.

5.3.2.7 Step 7: Analyse Crash Types and Patterns

Once high priority sections have been identified, the character of the crashes that have occurred needs to be analysed. This can be undertaken in a similar manner to that described in Section 5.2.2.4.

5.3.2.8 Step 8: Investigate Road Sections

In this step an investigation team will visit the road section and, equipped with knowledge of the type of crashes occurring, will investigate the section to determine if any treatments might reduce risk.

A route/corridor visit is similar to those undertaken for blackspot sites in that:

- The aim is to identify the underlying factors contributing to the dominant crash types identified in the analysis
- Visits need to be planned so that timings are in accordance with crash patterns (e.g. undertake visits in the night as well as during the day if a large proportion of crashes occur at night)
- The investigators must adopt the viewpoint of different road users (particularly those represented in the crash data analysis)
- The safety of the investigation team must be taken into consideration and equipment provided
- Findings should be recorded and documented using videos and photographs
- Community intelligence and consultation can provide useful additional information

A route or corridor visit differs from a blackspot site visit since the same level of detail is not required. Moreover conflict studies are not relevant.
Investigators need to examine the road characteristics and features of the road that appear to be causing road users a problem. During the visit, there may be clues regarding the location of crashes (e.g. damaged or missing roadside furniture or vegetation, or even vehicle debris or tyre marks on the road surface) that will allow more targeted treatment.

Note that it can be beneficial to investigate the best performing roads to understand why they are performing so well, and whether any lessons can be learned for application of those features across the road network.

5.3.2.9 Step 9: Identify Solutions

For each section, countermeasure options are ‘tested’ for their potential to reduce the types of crashes known to occur on the section. Emphasis should be given to the reduction of serious or fatal crashes. For example, if there are many pedestrian crashes, and pedestrians are observed crossing the road away from crossing facilities then provision of pedestrian crossings and guard rail may be appropriate. Similarly, if there are many run-off road crashes occurring at night then it may be appropriate to provide improved warning signs and delineation along the section. In addition it may be necessary to remove any roadside obstacles or provide a vehicle restraint system.

In route/corridor studies it is possible to develop a treatment plan that provides consistency of treatment along an entire route or corridor. Although treatments will need to be more extensively applied, there may be cost savings associated with treating longer stretches of road at once and consistency will improve road user experience.

A list of potential treatments relevant to different crashes is given in Appendix A. It provides high-level, indicative, guidance as to the type of safety improvement measures which might be appropriate under different circumstances.

5.3.2.10 Step 10: Report

A route/corridor analysis report should contain:

- A description of the methodology used (corresponding to those applicable steps described in Section 5.3.2)
- A summary of the results showing:
  - 10% best road sections for each road category
  - 10% worst road sections for each road category

This may take a similar format to that shown in Table 9, with the sections ranked by crash density
- The full database showing the results for all road sections should be appended to the report
- Results of the site review
- List of proposed treatments for further review and prioritisation (see Section 5.5)
- Once several years of data have been analysed, it will also be possible to include a performance tracking section
If Road Safety Inspections (RSIs) are also being undertaken (see Existing Roads-Proactive Manual Section 5), it would be advantageous to share the results of the route/corridor analysis with the RSI Manager and, if possible, combine the resultant data sets. This would mean that the Road Safety Assessor would be able to interrogate the performance of a road section alongside the characteristics of the section.

Crash Maps (Optional)

Should a GIS map of the road sections be available, maps showing the crash densities and crash risks along sections can be produced. The road sections can be grouped into bands according to their crash densities (and then crash risks) and then the map coloured according to this bands so that low density (or rate) sections are coloured a different colour to higher density (or rate) sections.

Maps similar to those produced using the iRAP Risk Mapping Protocol can be developed (see Figure 40).

Figure 40: EuroRAP risk mapping

5.3.2.11 Step 11: Track Performance

Each year the process should be repeated with the most up to date data available. Since these analyses often warrant around 3 years of data, this would mean comparing, for example, the dataset from 2009, 2010 and 2011 with the dataset from 2012, 2013 and 2014.

The performance of sections previously identified as high risk should be reviewed, particularly those sections that have been treated. This step should also include the identification of any sections where the crash density and/or risk has changed a lot from year to year – even if this is a reduction it needs to be understood.
5.4 Area Analysis and Investigation

As discussed in previous sections, there are varying degrees of road safety data available in countries across Africa. Detailed blackspot and route/corridor analyses can only be undertaken effectively where there are accurate and consistent data available. Both approaches require some information about the location of crashes. If crash locations are not recorded, the police may still record information on the area in which the crash took place. This may take the form of a police area code or similar.

Area analysis seeks to identify types of treatment that will be effective in areas experiencing higher than expected crashes of certain types. It is therefore important to be confident that the treatment being considered will be effective for particular types of crash.

5.4.1 When to Undertake Area Analysis

Area analysis should be undertaken on an annual basis.

These analyses will require a minimum of three years of crash data. In some countries with high rates of under reporting it may be necessary to use up to five years of data. As with blackspot analysis there is a balance to be reached between having sufficient data for the analyses to be robust and having data that reflects the current road network.

5.4.2 Methodology

A step-by-step procedure for undertaking area analysis and investigation is outlined in Figure 38 and described in the sections that follow.

Figure 41: Area analysis and treatment steps

5.4.2.1 Step 1: Analyse Network-Wide Crashes

The initial step is to assess the available data for the whole country, network or jurisdiction to gain a broad understanding of the current situation and overall trends. This will require a comparison of several years of data in a consistent format.
Possible analyses will depend on the crash characteristics recorded by the police. The ideal analyses are as follows (it is likely many of these will not be possible):

- Fatalities by year (to be able to identify overall trends)
- Fatality rate per 100,000 population per year (number of fatalities divided by the population of the country, then multiplied by 100,000)
- Distribution (%) of crashes by:
  - Road type (single carriageway, dual carriageway; paved, un-paved)
  - Time of day (day versus night)
  - Crash type (ideally head-on, run-off, side swipe, vulnerable road user etc.)
  - Location type (rural, urban, semi-urban)
  - Road character (straight and flat, bend, slope, bend and slope, narrow, bridge, rail crossing)
  - Median presence (divided, undivided)
  - Junction type
  - Number of lanes
  - Road user type (pedestrians, motorcyclists, pedal cyclists, light vehicle occupants, trucks, mini-bus, buses, agricultural etc.)
  - Manoeuvre (turning, changing lanes, reversing, parking, overtaking etc.)
  - Road condition (good, poor)
  - Weather conditions (dry, wet, snow/ice)
  - Road works (present, not present)

5.4.2.2 Step 2: Undertake Area Analysis to Identify Common Crash Themes

The next step is to undertake the same analyses that were possible under Step 1 but this time for each area of interest. The way in which areas are allocated may vary. As a general rule, the smaller the area, the better to allow a more targeted approach in the completion of the site visit in Step 4.

5.4.2.3 Step 3: Compare Area Results to National Trends

Initially the number of fatalities by area should be reviewed. This can be used to see if any trends are emerging where there are steeper than expected increases in fatality numbers in a particular area.

If population data are available by area, then it may be possible to calculate the fatality rate per 100,000 population per year by area. This may identify poor performing areas (though it should be noted that not all road users will stay within their home area so this analysis is not without fault).

- Fatalities by year (to be able to identify overall trends)
- Fatality rate per 100,000 population per year
Comparisons of pure counts (not rates) between individual areas and the whole network can be made statistically using a chi-squared goodness of fit test. This will test to see if the distribution of accidents or fatalities is the same in each area as the national figures.

For example, if comparing the distribution of males and females killed in road accidents in one area compared to the national figures (using hypothetical figures).

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National</td>
<td>Area 1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>50</td>
<td>6</td>
</tr>
</tbody>
</table>

**Figure 42:** Distribution of males and females killed Area 1 versus National figures

**Step 1:** Factor the National figures so that the total national figure is the same as the area total.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National</td>
<td>Area 1</td>
<td>National (factored)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>100</td>
<td>10</td>
<td>=SUM($C$2:$C$3)*B2/SUM($B$2:$B$3)</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>50</td>
<td>6</td>
<td>=SUM($C$2:$C$3)*B3/SUM($B$2:$B$3)</td>
</tr>
</tbody>
</table>

**Figure 43:** Formula for calculation of National (factored)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National</td>
<td>Area 1</td>
<td>National (factored)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>100</td>
<td>10</td>
<td>10.67</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>50</td>
<td>6</td>
<td>5.33</td>
</tr>
</tbody>
</table>

**Figure 44:** Result of National (factored) calculation

**Step 2:** Compare the factored national figure with the area figures using a chi-squared statistic: \((\text{observed}-\text{expected})^2/\text{expected}\).

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National</td>
<td>Area 1</td>
<td>National (factored)</td>
<td>Chi sq</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>100</td>
<td>10</td>
<td>10.67</td>
<td>=(C2-D2)^2/D2</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>50</td>
<td>6</td>
<td>5.33</td>
<td>=(C3-D3)^2/D3</td>
</tr>
</tbody>
</table>

**Figure 45:** Formula for calculation of chi-squared
### Data Analysis and Investigation

**Existing Roads: REactive Approaches**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National</td>
<td>Area 1</td>
<td>National (factored)</td>
<td>Chi sq</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>100</td>
<td>10</td>
<td>10.67</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>50</td>
<td>6</td>
<td>5.33</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Figure 46: Result of chi-squared calculation**

**Step 3:** Identify the number of degrees of freedom: this is the number of rows (number of categories) – 1. In this case this is 2 (males and females) – 1 = 1.

**Step 4:** Sum the chi-squared statistics and compare them to the chi-squared standard distribution with the appropriate degrees of freedom (this can be done automatically using Excel or can be looked up in statistical tables). Excel will do this with the function ‘chidist’. This is the p-value.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National</td>
<td>Area 1</td>
<td>National (factored)</td>
<td>Chi sq</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>100</td>
<td>10</td>
<td>10.67</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>50</td>
<td>6</td>
<td>5.33</td>
<td>0.08</td>
</tr>
<tr>
<td>4</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>=sum(E2:E3)</td>
</tr>
<tr>
<td>5</td>
<td>p-value</td>
<td></td>
<td></td>
<td></td>
<td>0.72</td>
</tr>
</tbody>
</table>

**Figure 47: Chi-squared statistics**

**Step 6:** Interpret the p-value: if this value is smaller than 0.05, then the distribution of males to females in area 1 is statistically significant different (at the 95% level) to that across the whole network. In other words, the spread of male and female fatalities is not the same in area 1 as it is across the whole network. In the example, the p-value is greater than 0.05 and therefore there is no significant difference between the spread of female and male fatalities in area 1 compared to the national figures.

Comparisons of counts between areas can be made using a chi-squared test of independence, note that this is different to the chi-squared goodness of fit test shown above. Comparisons of rates between areas can be computed using a Mann-Whitney U-test or a Normal t-test if the parametric assumptions have been achieved.
The results should indicate characteristics of crashes that differ from those observed across the whole road network.

### 5.4.2.4 Step 4: Area visits

In this step, an investigation team will visit the area and, equipped with knowledge of the type of crashes occurring in the area, determine if any treatments might improve the situation. These area visits are undertaken using similar principles to those adopted for route/corridor investigations (see Section 5.3.2.8).

### 5.4.2.5 Step 5: Identify Solutions

Solutions should be identified in the same way as for route/corridor analysis (see 5.3.2.9).

### 5.4.2.6 Step 6: Report

A route/corridor analysis report should contain:

- A description of the methodology used corresponding to the steps taken
- A summary of the results for Steps 1, 2 and 3
- The full database should be appended to the report
- Results of the site review
- List of proposed treatments for further review and prioritisation (see Section 5.5)
- Once several years of data have been analysed, it will also be possible to include a performance tracking section

### 5.4.2.7 Step 7: Track Performance

Once several years of data have been compiled it will be possible to undertake performance tracking for each area. This will allow the identification of any emerging trends by area. Once again the granularity of performance tracking by area will depend on the data recorded by the police.

### 5.5 Development of a Treatment Plan

Treatment plans are a prioritised list of countermeasures that are estimated to offer cost effective improvements to reduce risk.

The site investigations undertaken in response to the analyses described in Sections 5.2, 5.3 and 5.4 will allow the identification of potential treatments for application across the network. Often it will not be possible to implement all potential treatments and so these will need to be prioritised. One way of doing this will be through Economic Appraisal (see Section 5.5.1) to ensure that the best impact is achieved for the investment. Before undertaking the reactive techniques described in this manual it is necessary to ensure that a budget is in place to implement recommended treatments.
It will rarely be possible to implement all possible treatments and so it will be necessary for the treatments to be prioritised. One way of doing this will be through Economic Appraisal (Section 5.5.1) to ensure that the best impact is achieved for the investment.

It should be noted that there will be some recommendations that can be put into a dedicated schedule of safety improvements. Others may require immediate action. Further treatments may be more suited to incorporation into maintenance activities at little, or no, additional cost.

Typically, minor modifications to improving the road environment through signing and lining can be implemented fairly easily, whilst even modest changes such as implementing guardrail or vehicle restraint systems need a specific budget allocation. More major interventions such as junction widening, control or pedestrian provision may even require additional design before appropriate measures can be fully implemented. However, the scale of work and potential benefit needs to be assessed in order to determine a list of priority schemes to fit any budget allocation.

### 5.5.1 Economic Appraisal

Economic Appraisal (EA) should be performed for all proposed treatments and is a means of prioritising a treatment programme.

Economic Appraisal is the formal estimation of the potential benefits of implementing a specific measure or scheme, usually in terms of the expected longer-term financial return on the initial investment, versus the costs. EA is a key method to help engineers make decisions on which schemes should be implemented when budgets are constrained since it provides a reasonably objective measure of expected performance that can be compared between schemes. It will therefore help staff make decisions on which measures should be implemented.

There are several techniques that can be used, from the more complex full Cost Benefit Analysis (CBA) which requires an extensive set of supporting information and parameters, to more straightforward techniques that include First Year Rate of Returns (FYRR) and Cost Effectiveness (CE). If there are no accepted crash costing values in a country then it may be necessary to rely on CE calculations. It should be noted that EA is a rule of thumb method which should be done as well as practically possible and the results of EA are seldom used as the sole justification for making a decision on whether to fund a scheme.

For all of the methods, it is necessary to identify the number of relevant crashes and estimate the potential effectiveness of treatments. These are described in the sections that follow.

#### 5.5.1.1 Identify Relevant Crashes

The first step is to identify the number of crashes that are relevant to a particular treatment. So, for example, if the treatment is to install a vehicle restraint system, relevant crashes would be ones involving a vehicle.
running off the road. For the installation of a pedestrian crossing, relevant crashes would be those where pedestrians were crossing (rather than walking along) the road.

### 5.5.1.2 Effectiveness of Treatments

Countries which have been performing road safety management and evaluation for many years may have gathered evidence on the effectiveness of treatments. In this case it is beneficial to use local evidence concerning the likely effectiveness of a treatment. However, the availability of such information in Africa is likely to be somewhat limited. Instead it is necessary to use information about the effectiveness of treatments from other regions of the world and apply road safety engineering judgement and experience when considering the likely impact in the African context.

One significant benefit to improving the quality and analysis of crash data is that it will become possible to evaluate the impact of treatments in the African context. Building a regional resource containing evidence on the impact of treatments should be considered a priority. Sharing such results will allow a significant evidence base to be built relatively quickly. Section 6.2 provides guidance on simple approaches to evaluation that can be used to start to build an evidence base.

There are several international sources on the likely effectiveness of treatments. The first source that can be consulted is the iRAP Road Safety Toolkit (toolkit.irap.org). The iRAP Toolkit compiles best practice information on road safety treatments from across the world. In the toolkit there is information about the effectiveness of a treatment, relative cost, implementation issues and references to sources that provide more detail. Some information within the iRAP Toolkit is contained in Appendix A.

A further source that can be consulted is ‘The Handbook of Road Safety Measures’ (second edition) (Elvik, Vaa, Hoye, and Sorensen, 2009). This source compiles similar information in greater detail.

According to the iRAP toolkit, installation of a vehicle restraint system has an effectiveness of 40-60% in reducing run-off crashes. If an average (over 3 years) of 10.5 run-off crashes occur on a road section each year, and a conservative estimate of effectiveness of 40% is taken, then 4.2 crashes may be saved through the installation of a vehicle restraint system.

### 5.5.1.3 Economic Appraisal Methods

#### Full Cost Benefit Analysis

Full Cost Benefit Analysis is an extremely demanding task to perform properly. It requires all significant monetised costs and benefits to be assessed typically over a scheme’s lifetime. It should include annual maintenance costs, all environmental and social impacts; all costs need to be moved into a single base year value and GDP growth across the assessment period needs to be taken into account. It is an in-depth process that can require significant effort and so is not be suited to smaller schemes.

To do full CBA, the following information is generally required:
To calculate costs:
- Treatment implementation cost
- Approximate annual maintenance costs
- Treatment lifespan

To calculate benefits
- Treatment effectiveness
- Treatment lifespan
- Value of a life, serious injury, slight injury and damage only crash

Standard official inflator factors/GDP growth factors/Discount rates

These items are then used to calculate a Net Present Value (NPV).

ROSPA (1995) suggests that in some cases it may be advisable to carry out an evaluation which expresses the difference between costs and benefits that may accrue over several years (e.g. if the installation covers more than one year and there are known to be inevitable new maintenance costs in future years. The accrual needs to be against a common year price base.

In the NPV approach there is a need to take account of money having a changing value over time because of the opportunity to earn interest or the cost of paying interest on borrowed capital.

The major factors determining present value are the timing of the expenditure and the discount (interest rate). The higher the discount rate, the lower the present value of expenditure at a specified time in the future. If the discount rate for highways is 6% then $1 of value this year, if it accrues next year would be valued at 6% less (i.e. 94 cents and the following year 88 cents etc.).

The overall economic effectiveness of a scheme is indicated by the NPV, which is obtained by subtracting the Present Value of Costs (PVC, which must also be discounted if spread over more than one year) from the Present Value of Benefits (PVB).

**First Year Rate of Returns**

First Year Rate of Returns (FYRR) is commonly used for appraising low cost schemes. In this method crash costings are required along with estimated treatment costs and crash savings.

The simplest FYRR will be estimated as the number of crashes in the 12 months before installation minus the predicted number of crashes in the 12 months after installation multiplied by the average cost of a crash. The formula is:

\[
\text{FYRR} = \left( \frac{(\text{crashes in year before} - \text{crashes in year after}) \times \text{average cost per crash}}{\text{Total cost of the scheme}} \right) \times 100
\]
Table 10 provides prioritised FYRR calculations for a treatment plan.

**Table 10: Prioritised FYRR**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian crossings (signalised)</td>
<td>970,000</td>
<td>600,000</td>
<td>3.7</td>
<td>30%</td>
<td>1.11</td>
<td>69%</td>
<td>14</td>
</tr>
<tr>
<td>Pedestrian crossings (signalised)</td>
<td>900,000</td>
<td>600,000</td>
<td>4.4</td>
<td>30%</td>
<td>1.32</td>
<td>88%</td>
<td>13</td>
</tr>
<tr>
<td>Relocate bus stop</td>
<td>250,000</td>
<td>600,000</td>
<td>5.2</td>
<td>20%</td>
<td>1.04</td>
<td>250%</td>
<td>10</td>
</tr>
<tr>
<td>Relocate bus stop</td>
<td>250,000</td>
<td>600,000</td>
<td>3.2</td>
<td>20%</td>
<td>0.64</td>
<td>154%</td>
<td>11</td>
</tr>
<tr>
<td>Pedestrian crossing (refuge)</td>
<td>900,000</td>
<td>600,000</td>
<td>7</td>
<td>30%</td>
<td>2.1</td>
<td>140%</td>
<td>12</td>
</tr>
<tr>
<td>Clean roadway and require farmers to wash vehicles</td>
<td>50,000</td>
<td>600,000</td>
<td>12</td>
<td>15%</td>
<td>3.6</td>
<td>2160%</td>
<td>1</td>
</tr>
<tr>
<td>Close right turn and sign alternative route</td>
<td>200,000</td>
<td>600,000</td>
<td>7.3</td>
<td>25%</td>
<td>1.825</td>
<td>548%</td>
<td>8</td>
</tr>
<tr>
<td>Vehicle restraint barrier</td>
<td>200,000</td>
<td>600,000</td>
<td>3</td>
<td>50%</td>
<td>1.5</td>
<td>450%</td>
<td>9</td>
</tr>
<tr>
<td>Advance signing of intersection, traffic islands</td>
<td>150,000</td>
<td>600,000</td>
<td>6.3</td>
<td>30%</td>
<td>1.89</td>
<td>756%</td>
<td>6</td>
</tr>
<tr>
<td>Advance signing of intersection and improved marking</td>
<td>80,000</td>
<td>600,000</td>
<td>4.3</td>
<td>20%</td>
<td>0.86</td>
<td>645%</td>
<td>7</td>
</tr>
<tr>
<td>Advanced warning sign for bend and chevron signs</td>
<td>50,000</td>
<td>600,000</td>
<td>3.7</td>
<td>20%</td>
<td>0.74</td>
<td>888%</td>
<td>4</td>
</tr>
<tr>
<td>Remove bollards and improve VRS installation</td>
<td>150,000</td>
<td>600,000</td>
<td>4.5</td>
<td>50%</td>
<td>2.25</td>
<td>900%</td>
<td>3</td>
</tr>
<tr>
<td>Remove fence and install VRS</td>
<td>75,000</td>
<td>600,000</td>
<td>3.6</td>
<td>50%</td>
<td>1.8</td>
<td>1440%</td>
<td>2</td>
</tr>
<tr>
<td>Extend the VRS, close gap, replace fishtails</td>
<td>75,000</td>
<td>600,000</td>
<td>2.1</td>
<td>50%</td>
<td>1.05</td>
<td>840%</td>
<td>5</td>
</tr>
</tbody>
</table>
**Cost Effectiveness**

The simplest method for carrying out EA is called ‘Cost Effectiveness’ (CE). In CE the cost that needs to be expended for each crash saved in alternative and competing schemes is estimated to help with the prioritisation of investments.

Care must be taken when assessing the likely effectiveness of treatments since these are unlikely to be additive. In some cases, calculations have been seen where the estimated effectiveness of several treatments is greater than 100%. This is clearly not possible. Road safety engineering judgement needs to be applied in combining the likely effectiveness of treatments.

The main parameters required are:

- The number of crashes per year
- The estimated effectiveness of each scheme as an expected reduction in crashes after implementation
- The total estimated cost of the proposed schemes

To calculate the CE for each site, section or area the total scheme cost is divided by the number of crashes saved per year in the after period. It is important to use the number of ‘relevant’ crashes in the calculation – i.e. those which will be impacted by a measure. For example, if there are 10 crashes per year assumed in a section being assessed, 3 of which occurred in day time and 7 at night time. If the proposed measure is to put in street lighting, this measure cannot be expected to reduce the 3 daytime crashes, so the relevant number of crashes is 7 rather than the total.

Using the same example as described earlier the following calculation can be performed.

- Number of relevant crashes per year: 10.5
- Expected reduction or measure effectiveness: 40%
- Expected saved crashes per year: 4.2
- Cost of measure: $40,000
- Cost Effectiveness is: $9,524 (40,000/4.2)

This gives a value which represents the cost required to save a single crash for each proposed scheme. The potential schemes can be ranked by the calculated CEs in descending order and those schemes with the smallest values should be implemented preferentially.

This method does not require crash cost estimates, although estimates of the effectiveness of treatments are required. Disadvantages include that the approach does not take into account crash severity. Clearly this does require an estimate of the number of crashes, and in some countries this can be difficult to achieve.
## Table 11: Provides prioritised CE calculations for a treatment plan.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost (Local engineering knowledge required)</th>
<th>Relevance Average Crashes/Year (see Section 5.5.1.1)</th>
<th>Effectiveness Estimate (see Section 5.5.1.2)</th>
<th>CE (A/D)</th>
<th>Crash Savings (C*D)</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian crossings (signalised)</td>
<td>970,000</td>
<td>3.7</td>
<td>30%</td>
<td>873,874</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Pedestrian crossings (signalised)</td>
<td>900,000</td>
<td>4.4</td>
<td>30%</td>
<td>681,818</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Relocate bus stop</td>
<td>250,000</td>
<td>5.2</td>
<td>20%</td>
<td>240,385</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Relocate bus stop</td>
<td>250,000</td>
<td>3.2</td>
<td>20%</td>
<td>240,385</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Relocate bus stop</td>
<td>250,000</td>
<td>3.2</td>
<td>20%</td>
<td>240,385</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Pedestrian crossing (refuge)</td>
<td>900,000</td>
<td>7</td>
<td>30%</td>
<td>428,571</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Clean roadway and require farmers to wash vehicles</td>
<td>50,000</td>
<td>12</td>
<td>15%</td>
<td>79,365</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Close right turn and sign alternative route</td>
<td>200,000</td>
<td>7.3</td>
<td>25%</td>
<td>79,365</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Vehicle restraint barrier</td>
<td>200,000</td>
<td>3</td>
<td>50%</td>
<td>133,333</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Advance signing of intersection, traffic islands</td>
<td>150,000</td>
<td>6.3</td>
<td>30%</td>
<td>133,333</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Advance signing of intersection and improved marking</td>
<td>80,000</td>
<td>4.3</td>
<td>20%</td>
<td>86,667</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Advance warning sign for bend and chevron signs</td>
<td>50,000</td>
<td>3.7</td>
<td>20%</td>
<td>66,667</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Remove bollards and improve VRS installation</td>
<td>150,000</td>
<td>4.5</td>
<td>50%</td>
<td>66,667</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Remove fence and install VRS</td>
<td>75,000</td>
<td>3.6</td>
<td>50%</td>
<td>41,667</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Extend the VRS, close gap, replace fishtails</td>
<td>75,000</td>
<td>2.1</td>
<td>50%</td>
<td>71,429</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
5.5.2 Implementing a Treatment Plan

Once a treatment plan has been devised and prioritised, implementation should follow. Where there are major changes to a site, section or road, these should be subjected to Road Safety Audit (see New Roads and Schemes – Road Safety Audit Manual).

All road safety treatments should be subjected to Monitoring and Evaluation (see Section 6 of this manual) as an integral part of implementation.
6. Monitoring and Evaluation

Monitoring and evaluating the impact of treatments is critical to refining and improving the treatment of high-risk locations or sections over time. Building an evidence base on the effectiveness of treatments under different conditions in the African context is particularly important. Ideally such evidence will be shared among similar countries through a road safety observatory or through collaborative initiatives.

Reliable crash data are required for formal evaluation.

6.1 Monitoring

Monitoring is the operational checking that a scheme is performing as expected. This may involve site visits to physically monitor the site to ensure road users understand the change and also the review and analysis of crash data.

Crash occurrences should be reviewed after six weeks, a year and three years. Statistical methods can be applied after one and three years of data have accumulated, though statistical significance would rarely be reached using just one year of ‘after’ data.

6.2 Evaluation

Evaluation is a formal process to check the impact of a treatment/combination of treatments on crash and casualty numbers. It is used by practitioners to understand what has worked, and what has not. It is a vital part of effective road safety management because intelligence on the impact of treatments under different conditions is important if limited resources are to be spent in the most effective manner possible.

Evaluation is rarely done, and if it is done it is often not done as well as it could be. Simply comparing the number of crashes in a time period before and after treatment can be very misleading due to random statistical fluctuations and ‘regression to the mean’.

Empirical Bayes method is often recommended for undertaking before and after studies (see OECD, 2012) though it is rarely used because of its complexity.

The three most commonly used statistical approaches to structure before/after testing are the ‘Naïve’, the ‘Yoked Site/Comparator’ and the ‘Unpaired Site/Comparator’ methods. All of these require crash data. These are summarised as follows:

- The naive before/after method is largely discredited because it fails to take into account any external potentially confounding issues. The crashes before the treatment are compared simply with the crashes in the after period. The results from this method are likely to be very inaccurate since no account of any longer-term trends is taken.
For the yoked site/comparator method, treated sites are paired (individually) with similar but untreated sites for the analysis. Thus the number of crashes in the after period needs to be reduced significantly when compared with any reductions observed at the comparator. This method takes account of some confounding effects, though it does not take account of regression to the mean. It is technically difficult to identify suitable untreated comparator sites since often all sites with a particular problem will be treated in a programme.

In the unpaired site/comparator method, the analysis is similar to the yoked design; however the comparator does not need to be similar to the site in its features. It does however need to be significantly larger than the site with many more crashes in it. It is much easier to identify the required comparators for this method.

(Adapted from ITE, 2009).

Generally the chi-squared ($\chi^2$) test has been used to assess whether the after crashes have changed significantly. This is a very easy test to perform which does not require any assumptions to be made about the underlying statistical distribution of the data.

These tests have all been widely used for road safety analyses and are still being taught to engineers on road safety courses around the world. None of them address regression to the mean but the site/comparator approaches do take some account of other potentially confounding issues.

Given the balance between performance, rigour and ease, the unpaired site comparator method is clearly the best methodology to use. This method is commonly used with the chi-squared statistical test.

Further guidance can be found in the example evaluation calculations found in Appendix D.
References


**Glossary**

**Area Analysis:** Reactive analysis technique that aims to determine crash themes within geographic areas, and determine the main crash causes for high risk areas.

**Blackspot Analysis:** Reactive analysis technique that aims to identify high risk locations across the road network. Sometimes known as hazardous locations, hotspots or clusters.

**Conflict Study:** The undertaking of study observations and the recording and evaluating of ‘near misses’ in order to supplement the analysis of crash data and gain a more complete understanding of risks at a site.

**Crash:** A rare, random, multifactor event in which one or more road users fails to cope with their environment, and collide with each other or an object. This includes crashes resulting in casualties or those that are damage-only.

**Crash Data:** Information about a crash normally collected by the Police and recorded in a systematic manner.

**Crash Density:** The number of crashes occurring on a pre-defined section of road divided by the length of that section.

**Crash Diagram:** A pictorial representation of crashes occurring at a location.

**Crash Investigation:** The collection and examination of historical crash data over a period of time in order to identify patterns, common trends and factors which may have contributed to the crashes.

**Crash Map:** The spatial display, using mapping, of crashes that have occurred across the road network. The metric may be crash risk (risk per billion vehicle kilometres driven), crash density (crashes per kilometre) or crash reduction potential.

**Crash Report Pro-Forma:** A form used by the police to record information about crashes.

**Crossfall:** The surface of a road or footpath sloping to one side only.

**Damage-Only Crash:** A crash where there are no injured or killed casualties.

**Delineation:** Road lining treatments and other measures to indicate the path of traffic lanes. Can include marker posts and reflective road studs etc.

**Duplication:** Building of a second carriageway to create a divided road.

**Economic Appraisal:** The formal assessment of the potential benefits of implementing a specific measure or scheme, usually in terms of the expected longer-term financial return on the initial investment, versus the costs.

**Errant Vehicle:** A vehicle that strays or deviates from its regular or proper course.

**Fatal Crash:** A crash where at least one person died as a result. 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.
Fatality Rate: A standardised rate that provides the number of fatalities per population per year. This is often used for comparing the road safety situation between different countries. This is calculated by dividing the number of fatalities in a given year by the population.

Forward Visibility: The clear distance that can be seen ahead.

Geographic Information System (GIS): A system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data.

Global Positioning System (GPS): A space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

Grade Separation: A free-flowing junction where turning movements are completed at different levels.

Hazard: An aspect of the road environment or the operation of the road which has the potential to cause harm. Risk is the likelihood of harm occurring.

Head-On Crash: Crash between two vehicles travelling in opposing directions.

Health and Safety: Activities or processes that focus on the prevention of death, injury and ill health to those at work, and those affected by work activities.

Horizontal Realignment: Change in road direction/path in a horizontal plane. Usually straightening to reduce the severity of bends.

International Road Assessment Programme (iRAP): A charitable organisation with a mission to reduce the number of high risk roads in the world. iRAP can also be used to refer to the road inspection technique developed by the charity.

Intersection Crash: Crash that occurs at an intersection/junction.

Kerb: Stone or concrete edging to a pavement or a raised path.

Kinetic Energy: The energy an object possesses due to its motion.

Lane Change Crash: Crash occurring when a vehicle changes lane and strikes another.

Latitude and Longitude: A geographic coordinate system for specifying a specific location on the surface of the earth.

MAAP/iMAAP: TRL Limited’s crash database system products.

Manoeuvring Crash: Crash that occurs when a vehicle is entering or leaving the carriageway, making turns (other than at intersections) or parking.

Median: The median is the area of the road that divides opposing traffic. It may be painted, planted, raised or contain a VRS.

Nearside: Side of the road nearest to the verge or footpath. The outer edge.

Network Screening: A process used to identify high risk locations or sections across a road network.
Node-Link-Cell: A system where each junction or section of road is given a unique node number. Links or stretches of road can simply be defined by the nearest node number on each side.

Offside: Side of the road nearest to the centreline or median.

Pedestrian Refuge Island: A kerbed area in the middle of the roadway designed to protect pedestrians when crossing more than one lane. It also simplifies crossing movements for pedestrians.

Personal Protective Equipment (PPE): Workwear such as hard hats, steel toe-cap boots or reflective clothing which is provided to safety assessors, auditors, and inspectors or others who attend a road site.

Proactive Approaches: Techniques that use ‘known relationships’ between road characteristics and crashes to identify and treat priorities across the road network.

Reactive Approaches: Techniques that use crash history data and other intelligence to identify and treat priorities across the road network.

Retro-Reflectivity: Optical phenomenon in which reflected rays of light are preferentially returned in certain directions. If you shine a light on retro-reflective materials they will appear to shine or glow in the dark.

Ribbon Development: Development that occurs along roads between settlements.

Right-Angle Crash: Crash between two vehicles where one is struck at right angles by the other.

Risk Assessment: The assessment of the risk associated with a hazard based on consideration of the severity and likelihood of a risk event occurring.

Risk Map: A means of displaying the number of crashes per billion vehicle kilometres driven (i.e. road user risk) spatially by presenting the results on a map.

Risk Matrix: A tool which can be used during risk assessment in order to produce semi qualitative risk ‘values’ which can enable a comparison to be between the risks associated with different hazards at a particular site or at different sites.

Road Access: Drive-ways, small private roads or car parks that intersect with a public road.

Road Authority: The authority ultimately responsible for the operation and maintenance of the road.

Road Safety Assessment: An intensive expert assessment of the safety of a road environment and the way in which road users interact with and use it. This process involves site inspection(s) and is undertaken in reaction to intelligence.

Road Safety Assessment Prompts: An aide memoire for use in Road Safety Assessment to ensure that the main road safety issues have been considered and that each physical element of the road has been considered.

Road Safety Assessor: Individual that undertakes Road Safety Assessment.

Road Safety Audit (RSA): A RSA is a formal systematic process for the examination of new road projects or existing roads by an independent and qualified audit team, in order to detect any defects likely to result in a crash or contribute to increased crash severity.
Road Safety Auditor: Individual that undertakes Road Safety Audit.

Road Safety Engineering: The design and implementation of physical changes to the road network intended to reduce the number and severity of crashes involving road users, drawing on the results of crash investigations.

Road Safety Inspection (RSI): The inspection of an existing road with the objective of identifying aspects of the road, or the road environment, which contribute to safety risk and where safety can be improved by modifying the environment.

Road Users: All persons located within the road reserve irrespective of the purpose of their trip or mode of transport. They include the visually and mobility impaired (i.e. wheelchair users).

Route/Corridor Analysis: A reactive analysis technique that aims to identify high risk sections across the road network.

Run-Off Crash: A crash involving an errant vehicle that leaves the carriageway.

Safe System: The Safe System aims to develop a road transport system that is able to accommodate human error and takes into consideration the vulnerability of the human body.

Severe/Serious Crash: A crash in which one or more person is seriously injured, but where no-one dies. A serious injury is where a casualty is hospitalised overnight or suffers life threatening injuries.

Shoulder: Area beyond the running lane that is also surfaced. A shoulder can be unsealed (no carriageway surfacing) or sealed.

Side-Swipe Crash: A side impact between two vehicles at less than 90 degrees.

Sight Distance: See forward visibility.

Skid Resistance: The ‘slappiness’ of a road due to the surface texture.

Slight Crash: A crash in which one or more person is slightly injured, but where no-one is seriously injured or dies. A slight injury is where a casualty suffers bruising or bleeding and only minor medical assistance is required for treatment.

Stick Analysis: A sorting method used to visually display the characteristics of crashes and quickly identify crash themes.

T-Intersection: An intersection or junction where one road intersects with another at right angles.

Temporary Traffic Management: The arrangement of temporary sign, markings and other devices to guide all road users safely through road works, whilst also ensuring the protection of works personnel.

Traffic Calming: Vertical, horizontal or psychological features installed on a road to control vehicle speeds.

Traffic Flow Data: Numerical information on traffic movements.

Transitions: Changes in the type of road (e.g. from dual/divided carriageway to single carriageway) or changes in the posted speed limit.
**Treatment Programme:** A programme of safety improvement works that are undertaken in response to a safety assessment.

**Two-Wheeled Users:** Pedal cyclists or motorcyclists.

**Vehicle Restraint System (VRS):** Safety barrier (or crash barrier) designed to contain a vehicle if struck.

**Vertical Realignment:** Change in road direction/path in a vertical plane. Usually flattening the road to remove dips and humps.

**Vulnerable Road User (VRU):** Someone with little or no external protection, or has reduced task capabilities, or reduced stamina/physical capabilities. They include pedestrians (including people with visual or mobility impairments, young children, older people), pedal cyclists, and wheelchair users. They may also include motorcyclists.

**Vulnerable Road User (VRU) Crash:** Crash involving one or more VRUs (normally pedestrians and pedal cyclists only).

**X-Intersection:** An intersection or junction where two roads cross.
Appendix A : Typical Road Safety Solutions

This section of the manual is intended to provide guidance as to the types of engineering measures which might be effective as safety improvements in different circumstances and in response to different types of collision. They should be applied with great care as their appropriateness is dependent upon particular local circumstances.

Engineers should consider carefully the local conditions under which any of these potential measures will operate before applying a particular solution.

Table 12 provides information about each treatment. Note that although a treatment may have a positive impact on one crash type, there may be negative consequences for other crash types and road users. For instance, the duplication of carriageways to reduce head on crashes can result in an increase in pedestrian risk and potentially higher speed lane change crashes.

### Table 12 : Treatment information

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Lane</td>
<td>High</td>
<td>Reduced risk of overtaking crashes.</td>
<td>The start and end points of additional lanes must be designed carefully. For example, sight distance must be suitable for the speed of traffic.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved traffic flow.</td>
<td>Signs telling drivers when an overtaking lane is ahead will reduce the likelihood of them overtaking in less safe areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Overtaking lanes should not be installed at sites which include significant intersections or many access points.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Vehicles travelling in the opposite direction to the overtaking lane must be prevented or discouraged from also using this lane.</td>
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<td></td>
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<td></td>
<td>Physical barriers may be required.</td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions
### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Hatching</td>
<td>Low</td>
<td>- Fewer head-on and overtaking crashes.</td>
<td>- If rumble strips, or other raised pavement devices are also used, the risk to motorcycles and pedestrians (trip hazard) must be considered.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Can provide refuge for turning vehicles away from through-traffic lanes.</td>
<td>- Can be used for opportunist overtaking opportunities increasing risk of collisions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Some reduction in speeds.</td>
<td>- Maintenance of markings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Possible (though limited) protection for pedestrians.</td>
<td></td>
</tr>
<tr>
<td>Central Turning Lane</td>
<td>Low</td>
<td>- Improved traffic flow.</td>
<td>- To be used only in areas with a high concentration of intersections/accesses.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Some reduction in speeds.</td>
<td>- Two way turning lanes should not be used at intersections.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Appropriate pedestrian protection should be used in areas with pedestrian activity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Two way turning lanes can encourage inappropriate development along the road, so they are best used as a solution for existing roads where more advanced access controls are not possible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Priority/usage should be clearly marked to avoid head-on crashes.</td>
</tr>
</tbody>
</table>
## Treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Delineation</strong> (includes lining, signing, marker posts etc.)</td>
<td>Low</td>
<td>Road markings are very cost effective. Delineation improvements have been shown to reduce head-on road crashes. Helps drivers to maintain a safe and consistent lateral vehicle position within the lane. Reduction in night-time and low-visibility crashes.</td>
<td>In many countries line-marking is ignored (and physical barriers to crossing the centre line are needed). Poorly designed or located delineators can add to crash risk. Too many signs can confuse drivers. Road studs require a good quality road surface. Delineation needs to be consistent throughout an entire country. The retro-reflectivity of lines and signs is an important consideration for road use at night and in the wet. Maintenance of markings.</td>
</tr>
<tr>
<td><strong>Duplication</strong> (changing a single carriageway road into a dual carriageway road)</td>
<td>High</td>
<td>Separation of the opposing traffic flows, and therefore reduced head-on crashes. Simpler traffic movements leading to less opportunity for conflict. Redirection of turning movements to safer locations. Protection for turning traffic. Reduced traffic congestion.</td>
<td>This treatment is costly, and other lower cost treatments (such as median barrier installation) should also be considered. Requires a large amount of land. Potential to increase pedestrian and lane change crashes. Community acceptance of the medians that restrict turning movements or restrict pedestrian movements may be an issue.</td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions

### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grade Separation</strong></td>
<td>High</td>
<td>Improved traffic flow.</td>
<td>A range of design options should be considered before a grade separated interchange layout is chosen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simplifies potentially complex movements typical at 'T' and 'X' intersections.</td>
<td>Adding on-ramps and off-ramps to a freeway can increase high speed weaving and merging crashes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can also include roundabouts for high traffic flows.</td>
<td>Interchanges can negatively impact the appearance of an area.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removes the cost of running at-grade traffic control hardware.</td>
<td>They may separate communities due to their size.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Difficult for pedestrians unless specific routes are provided.</td>
</tr>
<tr>
<td><strong>Horizontal Realignment</strong></td>
<td>High</td>
<td>Better traffic flow.</td>
<td>Road realignment is costly and time consuming because it usually involves rebuilding a section of road.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Horizontal realignments often include lane widening, shoulder improvement, and delineation treatments.</td>
<td>Horizontal curve realignments require considerable design and construction effort. These projects may also require the purchase of land.</td>
</tr>
<tr>
<td>Treatment</td>
<td>Cost</td>
<td>Benefits</td>
<td>Implementation Issues</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Inter-Visibility Improvement</td>
<td>Low to</td>
<td>Adequate sight distance provides time for drivers to identify hazards</td>
<td>Sight distance improvement can be high cost if crest and/or curve realignments are required or if the line of sight is outside the road reserve requiring land acquisition to remove obstructions such as embankments, buildings etc.</td>
</tr>
<tr>
<td>-Sight Distance</td>
<td>med.</td>
<td>and take action to avoid them.</td>
<td>In some situations such as intersection approaches, excessive forward visibility can lead to high speeds on approach and take attention away from the intersection.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate sight distance provides time for drivers to identify hazards</td>
<td>In very specific cases, adjustments to reduce sight distances can be helpful in reducing approach speeds. Particular care must be exercised when taking this approach.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and take action to avoid them.</td>
<td>At intersections sight lines and visibility splays are often required at larger angles to the user’s normal viewpoint (for example, in a motor vehicle the driver may have to look through the side windows).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate sight distance provides time for drivers to identify hazards</td>
<td>Ensure traffic signs and signal heads are not obstructed by vegetation or street furniture.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and take action to avoid them.</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions

### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lane Widening</strong></td>
<td>Med. to high</td>
<td>Additional manoeuvring space.</td>
<td>Lane widening can be costly, especially if land must be purchased.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Space for two wheeled users.</td>
<td>Making lanes wider than 3.6 metres does little to reduce crashes. A lane that is too wide might be used as two lanes and this can increase sideswipe crashes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Because vehicle speeds increase when roads are widened, lanes should be widened only when it is known that the narrow lane width is causing crashes.</td>
</tr>
<tr>
<td><strong>Median Crossing Control</strong></td>
<td>Low to med.</td>
<td>Reduction in intersection crash types.</td>
<td>Additional road space may be required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improves local access.</td>
<td>If the median crossing is used to access a side road, then intersection considerations for cross movements (such as visibility and stopping distance) will apply.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provides an additional emergency access point leading to improved emergency service response times.</td>
<td>Roadside hazards need to be removed or sufficiently protected.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Drainage structures and steep slopes within the median can increase risk. The slopes should be as flat as possible. If the slope cannot be made traversable, it should be protected by safety barrier.</td>
</tr>
</tbody>
</table>
### Median Shoulder Sealing

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Shoulder Sealing</td>
<td>Med</td>
<td>Wider shoulders provide opportunity for an errant vehicle to be recovered.</td>
<td>Shoulder widening and shoulder sealing can be done at the same time to reduce costs. Edge-lining can be improved at the time of upgrading the shoulder (especially when sealing). Shoulders should not be too wide or drivers may use them as an additional lane. Sealing can reduce ‘edge drop’ (where there is a difference between the height of the road surface and the height of the shoulder). Edge drop can make it harder for vehicles which have left the road to get back onto the road.</td>
</tr>
</tbody>
</table>

### Median Vehicle Restraint System (VRS) (Safety Barrier)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Vehicle Restraint System</td>
<td>Med. to high</td>
<td>Reduced incidence of head-on crashes. Can help to prevent dangerous overtaking manoeuvres. Can relocate turning movements to safer locations.</td>
<td>Median barriers can restrict traffic flow if a vehicle breaks down, and can block access for emergency vehicles. Pedestrians are often reluctant to make detours and may attempt to cross median. In some regions the materials used in median barriers may be at risk of being stolen. The ends of median barriers must be well designed and installed. Clearly visible signs and enforcement are needed to ensure that drivers do not drive on the wrong side of the median. Not all barrier types will adequately restrain all vehicle types. Barriers may be a hazard to motorcyclists.</td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions

### EXISTING ROADS: REACTIVE APPROACHES

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-Way System</td>
<td>Med.</td>
<td>Reduces head on collisions.</td>
<td>Because speeds can increase on one-way networks, traffic calming measures may be required (especially if the lanes are wide).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improves traffic flow.</td>
<td>Before a network is made one-way, traffic circulation in the area surrounding the network must be considered.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Converting a network to one-way can be costly as it may involve rebuilding traffic signals, repainting line-marking and replacing and adding signage.</td>
</tr>
<tr>
<td>Parking Control</td>
<td>Low to Med.</td>
<td>Converting angle parking to parallel parking provides extra road space.</td>
<td>Parking at the side of a road means pedestrian activity is inevitable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Banning parking lessens the potential for sideswipe or rear-end crashes.</td>
<td>Therefore speed limits should not exceed 50km/h where parking is provided.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Converting angle parking to parallel parking requires replacement of line marking. Changes to parking signs and kerbs may also be necessary.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The community and business owners often object to the removal of parking in commercial centres.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Parked cars can obscure crossing pedestrians, particularly children.</td>
</tr>
</tbody>
</table>
## Pedestrian Crossing – Unsignalised

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Crossing – Unsignalised</td>
<td>Low</td>
<td>A clearly defined crossing point where pedestrians are ‘expected’ to cross.</td>
<td>Un-signalised crossings – Not suitable where traffic volumes or speeds are high.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disruption to traffic flow is comparatively low.</td>
<td>Signalised crossings – Compliance with signals must be good if significant casualty reductions are to be achieved.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced pedestrian crashes if installed at appropriate locations, and if pedestrian priority is enforced.</td>
<td>Pedestrians will only use crossings located at, or very near, to where they want to cross. Pedestrian fencing can be used to encourage use of pedestrian crossings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Consider incorporating a pedestrian refuge island.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Through-traffic must be able to see pedestrian crossing points in time to stop. Advance warning signs should be used if visibility is poor. Other high visibility devices (such as flashing lights) may also be used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Parking should be removed/prohibited from near pedestrian crossings to provide adequate sight distance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crossing will only be effective if other road users give way to pedestrians. Education and enforcement may be necessary to ensure pedestrians have priority.</td>
</tr>
</tbody>
</table>

## Pedestrian Crossing – Signalised

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Crossing – Signalised</td>
<td>Med.</td>
<td>A clearly defined crossing point where pedestrians are ‘expected’ to cross.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced pedestrian crashes if installed at appropriate locations, and if pedestrian priority is enforced.</td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions

### Existing Roads: REactivE Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Fencing</td>
<td>Low</td>
<td>Helps to guide pedestrians to formal crossing points.</td>
<td>It is important that pedestrian fencing does not obstruct the drivers’ view of pedestrians on the footpath, or those about to cross the road.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can help to prevent unwanted pedestrian crossing movements.</td>
<td>The fence height, placement and construction material should be selected to minimise any potential sight obstruction between vehicles and pedestrians about to cross the road.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physically prevents pedestrian access to the carriageway.</td>
<td>Consideration should be given to the design of the fencing to ensure that the risk to errant vehicles is limited upon impact.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can help to prevent motorists from parking on the footpath.</td>
<td>When used at staged or staggered crossings on pedestrian refuges, fences should be aligned so that pedestrians walk along the refuge in the opposite direction to the flow of traffic they are about to cross, and face oncoming traffic as they are about to leave the median.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provides useful guidance for visually impaired pedestrians.</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Cost</td>
<td>Benefits</td>
<td>Implementation Issues</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>-------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Pedestrian Over-Bridge/underpass</td>
<td>High</td>
<td>Traffic flow improvements.</td>
<td>Pedestrians will only use crossing facilities located at, or very near, to where they want to cross the road. This is particularly the case for over-bridges since steps are normally involved. Pedestrian fencing can be used to encourage pedestrians to use crossing facilities. Cyclists may also be able to use the facilities – ramps would be required which need more land space. Personal security at underpasses should be considered.</td>
</tr>
<tr>
<td>Pedestrian Refuge Island</td>
<td>Low to med.</td>
<td>Separating traffic moving in opposite directions to reduce head-on and overtaking crashes. May slow vehicular traffic by narrowing the lanes. Ensures pedestrians need only cross one lane of traffic at a time.</td>
<td>Pedestrian refuge islands must be clearly visible to traffic during both day and night. Refuges islands should be placed where there is a demand from pedestrians to cross. Where cyclists are present, refuge islands must not narrow the lanes too much. Turning movements from driveways and intersections must be considered in planning the location of pedestrian refuges.</td>
</tr>
</tbody>
</table>
## Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulate Roadside Activity</td>
<td>Low to med.</td>
<td>Removal of commercial activity or relocation of bus stops at the side of the road may remove the need for drivers to take last minute evasive action to avoid these.</td>
<td>Roads should be designed to allow for changes in land-use over time. Building regulations should specify the limits beyond which buildings must not extend. Illegal development can only be controlled if there are alternative sites for commercial activity. Where activities near the road are permitted, countermeasures may be required to maintain safety and they should be restricted to one side of the road.</td>
</tr>
<tr>
<td>Restrict /Combine Direct Accesses</td>
<td>Med. to high</td>
<td>Reduces the number of potential conflict points.</td>
<td>In most situations, it would be difficult to justify and fund construction of a service road on its own merits due to high cost. This type of project is generally undertaken as part of a major road duplication project. Minor intersection closures can often be achieved in cooperation with the local road authority, especially when safety at these intersections has been a subject of repeated complaint.</td>
</tr>
</tbody>
</table>

**Treatment**

- **Regulate Roadside Activity**
  - **Cost**: Low to med.
  - **Benefits**: Removal of commercial activity or relocation of bus stops at the side of the road may remove the need for drivers to take last minute evasive action to avoid these. Reduction in VRU crashes.

**Restrict /Combine Direct Accesses**

- **Cost**: Med. to high
- **Benefits**: Reduces the number of potential conflict points. Reduces traffic friction and improves flow on the main road. Improved traffic management at upgraded access points.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roadside Hazard Protection</strong> (VRS)</td>
<td>Med.</td>
<td>If properly designed, installed and maintained, barriers should reduce the severity of crashes involving ‘out of control’ vehicles. Provides protection for substantial structures.</td>
<td>VRS should only be built if the existing hazard cannot be removed (see Roadside Safety - Hazard Removal). The terminals or end treatments of VRS can be dangerous if not properly designed, constructed and maintained. VRS should be located to minimize high impact angles and should also allow space for vehicles to pull off the traffic lane. Roadside barriers can be a hazard to motorcyclists. Ensure appropriate clearance behind safety barrier is considered particularly for flexible and semi-rigid barriers. Although concrete barriers do not deflect, allowance must be made for any hazards taller than the barrier to be offset far enough from the face of the barrier so that during impact vehicles (particularly tall ones) do not lean over the barrier and strike the hazard.</td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions

### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadside Hazard Removal</td>
<td>Low to med.</td>
<td>Reduced road furniture repair costs associated with crash damage.</td>
<td>The width of the safety zone required depends on traffic speeds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved recovery potential for vehicles.</td>
<td>After roadside hazards are removed, the roadside should be left in a safe condition. Large stumps and deep holes are hazards that may remain after removal of a tree.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved survivability of run-off road crashes.</td>
<td>Replacement of removed trees with more appropriate plants should be considered, otherwise re-growth or soil erosion may affect the site.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>It is not always possible to remove roadside hazards, particularly in urban areas where space is limited. Reducing vehicle speeds is an alternative solution.</td>
</tr>
<tr>
<td>Roundabout</td>
<td>Med. to high</td>
<td>Minimal delays at lower traffic volumes.</td>
<td>Solid structures should not be located on the central island.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Little maintenance required.</td>
<td>High painted kerbs around the island can reduce the risk of it being run into.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crash severity is usually lower than at cross road intersections or T-junctions due to angle of crash impacts and lower speeds due to deflection on approaches.</td>
<td>Poor visibility on the approach to roundabouts, or high entry speeds, can lead to crashes.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Facilities to help pedestrians cross the arms of the intersection should be provided in most urban locations.</td>
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<tr>
<td></td>
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<td></td>
<td>Roundabouts can be difficult for large vehicles, particularly buses, to use.</td>
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<td></td>
<td>Designers should be conscious of the risk that roundabouts can be present for cyclists and other slow vehicles, such as animal drawn vehicles.</td>
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<tr>
<td></td>
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<td></td>
<td>Care must be taken in the design of roundabouts to ensure adequate deflection upon approach to reduce vehicle speeds.</td>
</tr>
</tbody>
</table>
### Treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rumble Strips</strong></td>
<td>Low</td>
<td>Can be parallel or transverse.</td>
<td>Gaps in the rumble strips may be needed in some areas to allow water to drain from the road surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Warning to motorists approaching the centreline.</td>
<td>The noise made by rumble strips can be difficult for drivers of larger vehicles to hear.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved visibility of centre lines.</td>
<td>Consideration must be given to those living near to the road as rumble strips can generate noise.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raised awareness on the approach to other hazards or devices i.e. road humps.</td>
<td>Rumble strips can be a hazard to motorcyclists.</td>
</tr>
<tr>
<td><strong>School Zones</strong></td>
<td>Low to med.</td>
<td>School zones and crossing supervisors can reduce pedestrian risk.</td>
<td>Traffic signs and road markings must make it clear to motorists that they have entered a school zone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>School zones aim to reduce vehicle speeds.</td>
<td>Consider incorporating flashing beacons to complement the school zone signs and markings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>School crossing supervisors can help to control pedestrian crossing movements and provide a safe place to cross.</td>
<td>Through-traffic must be able to see pedestrian crossing points in time to stop for them.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Advanced warning signs should be located on approaches with adequate forward visibility.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Parking provision should be carefully considered within school zones with adequate sight distances at pedestrian crossings.</td>
</tr>
</tbody>
</table>
### Segregated Diverge Nearside - Signalised

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low to med.</td>
<td></td>
<td>Reduced crashes between turning vehicles and oncoming through-traffic.</td>
<td>Adding diverge signals reduces intersection capacity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced severity of crashes throughout the intersection.</td>
<td>It may be necessary to lengthen diverge lanes to fit longer traffic queues.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other signal changes can be used to improve intersection capacity when signalised turns are implemented.</td>
</tr>
</tbody>
</table>

### Segregated Diverge Nearside - Unsignalised

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low to med.</td>
<td></td>
<td>Reduced loss of control while turning crashes.</td>
<td>Painted diverge lanes must be clearly delineated and have good sight distance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved traffic flow.</td>
<td>Diverge lanes should be long enough to allow a vehicle time to stop within it (clear of through-traffic).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased intersection capacity.</td>
<td>If a diverge lane is too long, through drivers may enter the lane by mistake. Signs at the start of the diverge lane may help prevent this.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Installing diverge lanes can increase the width of the intersection and cause problems for pedestrians trying to cross. One solution is to provide a pedestrian refuge island between lanes.</td>
</tr>
</tbody>
</table>
## Segregated Facilities - Pedestrians

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low to med.</td>
<td>Improves facilities for pedestrians (improves accessibility).</td>
<td>A routine maintenance programme is needed to ensure that footpaths are kept clean and level, free from defects and to prevent vegetation from causing an obstruction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May help to increase walking as a mode of transport (environmental benefits and reduced traffic congestion).</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Walking can improve health and fitness.</td>
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<tr>
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<td></td>
<td>Signage should be used to warn drivers of pedestrians if the road shoulder is commonly used as an informal footpath.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Street traders, public utility apparatus and street furniture should not be allowed to obstruct the footpath.</td>
</tr>
</tbody>
</table>
### APPENDIX A: TYPICAL ROAD SAFETY SOLUTIONS

#### EXISTING ROADS: REACTIVE APPROACHES

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segregated Facilities – Pedal/</td>
<td>Low to</td>
<td>Increased use of pedal and motor cycles (reduced road congestion).</td>
<td>On-road cycle lanes are cheaper than off-road paths if shoulder sealing is not required. Though this does still lead to some interaction with motorised traffic.</td>
</tr>
<tr>
<td>Motor-Cycles</td>
<td>med.</td>
<td>Associated health and environmental benefits that come with increased</td>
<td>Traffic calming treatments or narrow road sections such as bridges can force pedal and motor cycles out into traffic, resulting in conflicts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pedal cycle use.</td>
<td>Parked vehicles may also force pedal and motor cycles out into main traffic, and so parking enforcement is very important for the success of on-road lanes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surface quality must be high or it will pose a safety risk.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cycle lanes should be maintained to ensure that it is preferable to use the facilities rather than the shoulder or roadway.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maintenance includes repairs to the pavement surface and vegetation clearance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adequate sight distance must be provided around bends and at path intersections. This also aids personal security.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cycle paths should be clear of obstructions and service covers. This includes keeping others such as vendors and adjacent land owners from encroaching on the path.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Where an obstruction is necessary, it should be made obvious, and lines should be used to guide cyclists safely past.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adequate crossing facilities need to be provided.</td>
</tr>
<tr>
<td>Treatment</td>
<td>Cost</td>
<td>Benefits</td>
<td>Implementation Issues</td>
</tr>
<tr>
<td>------------</td>
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<td>--------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Service Road</td>
<td>High</td>
<td>Can reduce the number of conflict points (intersections) along a route.</td>
<td>Service roads require large amounts of space. Where space is limited, a service road may fit behind the properties.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can be used by local traffic and vulnerable road users as an alternative to the (often higher speeds and higher volume) main road.</td>
<td>Parking and other potential visual obstructions should be carefully controlled where service lanes re-join the main road.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safer loading/unloading of commercial vehicles.</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix A: Typical Road Safety Solutions

### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
</table>
| Shoulder Sealing   | Med. | - Wide shoulders allow vehicles to pull off the road in emergency situations.  
                      |      | - Sealed shoulders can provide a cycling space and can be marked as cycle lanes.  
                      |      | - Provide structural support to the road pavement.                       | - Shoulder widening and shoulder sealing can be done at the same time to reduce costs.  
                      |      | - Sealing can reduce ‘edge drop’. Edge drop can make it harder for vehicles to get back onto the road. | - Edge-lining can be improved at the time of upgrading the shoulder (especially when sealing).  
                      |      |                                                                          | - Shoulders should not be too wide or drivers may use them as an additional lane.  
                      |      |                                                                          | - Controls may be necessary to prevent informal businesses from using shoulders. |
### Treatment

<table>
<thead>
<tr>
<th>Side Slope Improvement</th>
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### Cost

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<tbody>
<tr>
<td>Med.</td>
</tr>
</tbody>
</table>

### Benefits

- This will reduce the likelihood of rollover in a run-off road/loss of control crash and may also reduce the severity of these types of crashes.
- Flatter side slopes are generally less likely to erode.
- The cost of providing a traversable slope may be less than the cost of stabilising and maintaining steep slopes.

### Implementation Issues

- Side slopes should be free of hazards and objects that may cause vehicle snagging.
- Maximum traversable gradient is 1:3.
- On downward slopes, a clear run-out area may also be required at the base of the slope.
- The provision of traversable side slopes may require the removal of native flora, which can result in erosion, sedimentation of waterways and removal of animal habitats.
- The provision of traversable side slopes may have property impacts and require extensive land acquisition.
- In areas where the side slope transitions from an upward slope to a downward slope (and vice versa), the rate of change in gradient of the crossfall should be gradual to ensure that the side slope can be traversed.
### Appendix A: Typical Road Safety Solutions

#### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
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<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signalisation</strong></td>
<td>Med.</td>
<td>Can increase intersection capacity.</td>
<td>Signalising an intersection may have no safety benefit where compliance is poor and can reduce the capacity of an intersection.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can reduce certain types of crashes (especially right-angle crashes).</td>
<td>Drivers need to be educated so they understand the meaning of the signals.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can improve pedestrian and cyclist safety.</td>
<td>Signals used at intersections with low traffic flows and fixed timings are likely to be disobeyed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Well-designed traffic signals will usually reduce total crashes but will sometimes increase specific (low severity) crash types (e.g. rear-end crashes).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Traffic signals should not be used in high speed locations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In urban areas it can be difficult to ensure that traffic signals have sufficient visibility.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Before installing traffic signals, information on traffic volumes, pedestrian volumes, intersection approach speeds and previous crashes at the site should be considered.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Traffic signals need continuous power.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Traffic signals and vehicle detection equipment are prone to malfunction so good maintenance is required.</td>
</tr>
</tbody>
</table>
### Signing

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signing</td>
<td>Low</td>
<td>Signs help drivers to adjust their behaviour to deal with approaching hazards or decision points. If reflective, they can help reduce night-time/poor visibility crashes.</td>
<td>Poorly designed or located signs can add to crash risk. The message they convey needs to be clear and unambiguous. Too many signs can confuse drivers. The retro-reflectivity of signs is an important consideration for road use at night and in the wet. Maintenance of signs in rural and isolated areas can be problematic. Signs may be stolen in some areas.</td>
</tr>
</tbody>
</table>
### Appendix A: Typical Road Safety Solutions

#### EXISTING ROADS: REACTIVE APPROACHES

<table>
<thead>
<tr>
<th>Treatment</th>
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<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skid Resistance</strong></td>
<td>Low to med.</td>
<td>Improved safety for roads where many crashes happen in wet weather.</td>
<td>Skid resistance improvements gained by retexturing and resurfacing will lessen over time, especially on roads with lots of heavy vehicle traffic and in tropical climates. As such, regular monitoring of skid resistance is important.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resurfacing provides an opportunity to fix other road surface problems, such as crossfall and rutting.</td>
<td>The skid resistance of the entire road surface (right up to the edge) should be maintained for the safety of pedal cycles and other slow-moving vehicles.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provides the opportunity for adding or replacing road surface delineation such as painted markings or reflective road studs.</td>
<td>Warning signs should not be considered a solution to the problem of poor skid resistance. Warning signs can be used temporarily, until other solutions are carried out.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can extend life of pavement surface.</td>
<td>Existing road surface must be sound, therefore pre-patching and repairs may be necessary prior to application.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retexturing has environmental benefits (lower cost and energy) over some traditional hot mix asphalt resurfacing.</td>
<td>These treatments will not typically add any strength to the road pavement.</td>
</tr>
<tr>
<td>Treatment</td>
<td>Cost</td>
<td>Benefits</td>
<td>Implementation Issues</td>
</tr>
<tr>
<td>--------------------</td>
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<td>---------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Speed Management</td>
<td>Med</td>
<td>Reductions in travel speeds save lives and prevent injuries.</td>
<td>Reduced speed limits need to be signed clearly and repeater signs used to remind road users of the speed limit.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower speeds can reduce the severity of all crashes.</td>
<td>Road engineering treatments should ideally accompany reduced speed limits in order to encourage compliance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced speeds will also reduce the likelihood of crashes occurring.</td>
<td>Enforcement may be necessary to achieve compliance. Speed limits should appear credible so that drivers will adhere to them.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The wider benefits of reducing speeds include improved fuel consumption,</td>
<td>Where there is a significant drop in speed limit (e.g. on approach to a village/urban area), gateway treatments are recommended (these use a combination of treatments including prominent signs, road markings, pinch-points, coloured surfacing to make the change in road type clear).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lower greenhouse gas emissions and less traffic noise.</td>
<td>Vertical traffic calming measures (e.g. speed humps, bumps and tables) should only be used in low speed environments. Horizontal traffic calming measures (e.g. chicanes and pinch-points) may offer significant benefits.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Speed humps and other devices need to be well designed to provide maximum safety benefits and located appropriately.</td>
</tr>
</tbody>
</table>
### Appendix A: Typical Road Safety Solutions

**Existing Roads: Reactive Approaches**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street Lighting</td>
<td>Med</td>
<td>Street lighting helps to reduce nighttime crashes by improving visibility.</td>
<td>Traffic calming devices can impede emergency vehicles and cause discomfort for bus passengers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can reduce pedestrian crashes by approximately 50%.</td>
<td>Some traffic calming devices are hazardous to motorcyclists.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can help to aid navigation.</td>
<td>Community support and consultation is recommended before speed limits are changed or traffic calming installed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Street lighting helps people to feel safe and can help to reduce crime.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Route lighting can help to reduce glare from vehicle headlights.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The provision of street lighting poles can introduce hazards to the roadside.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frangible poles should be considered particularly in areas where there is low pedestrian activity. Alternatively, the poles can be protected by roadside safety barrier.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>It is important to achieve the correct spacing of lamp columns to prevent uneven lighting levels along a route.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The provision of street lighting requires an electricity supply and is associated with ongoing power costs. Solar panels may be considered as an alternative power supply.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adequate clearance must be provided to overhead lines.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low pressure sodium lamps may be used to reduce light pollution particularly in urban areas.</td>
</tr>
</tbody>
</table>
## Turing Pockets Offside — Signalised

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low to med.</td>
<td>Reduced crashes between turning vehicles and oncoming through-traffic. Reduced severity of crashes throughout the intersection.</td>
<td>Adding turn signals reduces intersection capacity. It may be necessary to lengthen turn lanes to fit longer traffic queues. Other signal changes can be used to improve intersection capacity when signalised turns are implemented.</td>
</tr>
</tbody>
</table>

## Turing Pockets Offside — Un-signalised

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low to med.</td>
<td>Reduced loss of control while turning crashes. Improved traffic flow. Increased intersection capacity.</td>
<td>Painted turn lanes must be clearly delineated and have good sight distance. Turn lanes should be long enough to allow a vehicle time to stop within it (clear of through-traffic). If a turn lane is too long, through drivers may enter the lane by mistake. Signs at the start of the turning lane may help prevent this. Installing turn lanes can increase the width of the intersection and cause problems for pedestrians trying to cross. One solution is to provide a pedestrian refuge island in the median.</td>
</tr>
</tbody>
</table>
### Appendix A: Typical Road Safety Solutions

#### Existing Roads: Reactive Approaches

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Benefits</th>
<th>Implementation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Realignment</td>
<td>High</td>
<td>Reduced risk of vehicle equipment failure (steep grades).</td>
<td>Vertical curve realignments require a lot of design and construction effort, and a lot of time and money. It is much better to design the road well before it is built than to rebuild it.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More uniform traffic flow.</td>
<td>Horizontal and vertical alignments should be considered together. Poor combinations of vertical and horizontal alignment can confuse drivers and lead to dangerous situations.</td>
</tr>
</tbody>
</table>
Appendix B : Sample Crash Data Form
**Appendix B: Sample Crash Data Form**

**EXISTING ROADS: REACTIVE APPROACHES**

### Vehicle 1

<table>
<thead>
<tr>
<th>1. Vehicle Type</th>
<th>2. Vehicle Manoeuvre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle</td>
<td>Right turn (Junction)</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>Left turn (Junction)</td>
</tr>
<tr>
<td>Car</td>
<td>U turn</td>
</tr>
<tr>
<td>Minibus</td>
<td>Going ahead</td>
</tr>
<tr>
<td>Bus</td>
<td>Changing lanes</td>
</tr>
<tr>
<td>3-Wheeler</td>
<td>Overtaking</td>
</tr>
<tr>
<td>5. Other</td>
<td>Reversing</td>
</tr>
<tr>
<td>6. Other</td>
<td>Sudden start</td>
</tr>
<tr>
<td>7. Not checked</td>
<td>Sudden stop</td>
</tr>
<tr>
<td>8. Lights</td>
<td>Parked OFF road</td>
</tr>
<tr>
<td>9. Other</td>
<td>Parked / stopped ON road</td>
</tr>
<tr>
<td>10. Other</td>
<td>Did not Give Way</td>
</tr>
<tr>
<td>11. Other</td>
<td>Other</td>
</tr>
</tbody>
</table>

### Driver 1

<table>
<thead>
<tr>
<th>1. Licence Type</th>
<th>2. Driver Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full licence</td>
<td>None</td>
</tr>
<tr>
<td>Learner licence</td>
<td>Not concentrating</td>
</tr>
<tr>
<td>No licence</td>
<td>Too fast</td>
</tr>
<tr>
<td></td>
<td>Too close</td>
</tr>
<tr>
<td></td>
<td>No signal</td>
</tr>
<tr>
<td></td>
<td>Bad overtaking</td>
</tr>
<tr>
<td></td>
<td>Bad turning</td>
</tr>
<tr>
<td></td>
<td>Did not Give Way</td>
</tr>
<tr>
<td></td>
<td>Other</td>
</tr>
</tbody>
</table>

### Vehicle 2

<table>
<thead>
<tr>
<th>1. Vehicle Type</th>
<th>2. Vehicle Manoeuvre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle</td>
<td>Right turn</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>Left turn</td>
</tr>
<tr>
<td>Car</td>
<td>U turn</td>
</tr>
<tr>
<td>Minibus</td>
<td>Going ahead</td>
</tr>
<tr>
<td>Bus</td>
<td>Changing lanes</td>
</tr>
<tr>
<td>3-Wheeler</td>
<td>Overtaking</td>
</tr>
<tr>
<td>5. Other</td>
<td>Reversing</td>
</tr>
<tr>
<td>6. Lights</td>
<td>Sudden start</td>
</tr>
<tr>
<td>7. Multiple defects</td>
<td>Sudden stop</td>
</tr>
<tr>
<td>8. Other</td>
<td>Parked OFF road</td>
</tr>
<tr>
<td>9. Not checked</td>
<td>Parked / stopped ON road</td>
</tr>
<tr>
<td>10. Other</td>
<td>Did not Give Way</td>
</tr>
<tr>
<td>11. Other</td>
<td>Other</td>
</tr>
</tbody>
</table>

### Driver 2

<table>
<thead>
<tr>
<th>1. Licence Type</th>
<th>2. Driver Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full licence</td>
<td>None</td>
</tr>
<tr>
<td>Learner licence</td>
<td>Not concentrating</td>
</tr>
<tr>
<td>No licence</td>
<td>Too fast</td>
</tr>
<tr>
<td></td>
<td>Too close</td>
</tr>
<tr>
<td></td>
<td>No signal</td>
</tr>
<tr>
<td></td>
<td>Bad overtaking</td>
</tr>
<tr>
<td></td>
<td>Bad turning</td>
</tr>
<tr>
<td></td>
<td>Did not Give Way</td>
</tr>
<tr>
<td></td>
<td>Other</td>
</tr>
</tbody>
</table>

### Passengers killed or injured

*Complete Passenger Position and Passenger Action using codes from bottom panel*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>First passenger</td>
<td>Male</td>
<td>23</td>
<td>Fata</td>
<td>No</td>
<td>No</td>
<td>Yes No</td>
</tr>
<tr>
<td>Second passenger</td>
<td>Male</td>
<td>23</td>
<td>Serious</td>
<td>No</td>
<td>No</td>
<td>Yes No</td>
</tr>
<tr>
<td>Third passenger</td>
<td>Male</td>
<td>23</td>
<td>Slight</td>
<td>No</td>
<td>No</td>
<td>Yes No</td>
</tr>
<tr>
<td>Fourth passenger</td>
<td>Male</td>
<td>23</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes No</td>
</tr>
<tr>
<td>Fifth passenger</td>
<td>Male</td>
<td>23</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes No</td>
</tr>
</tbody>
</table>

**Pedestrians killed or injured**

**Complete Pedestrian Action using codes from bottom panel**

<table>
<thead>
<tr>
<th>1. Which vehicle hit them (circle)?</th>
<th>2. Sex</th>
<th>3. Age</th>
<th>4. Injury</th>
<th>5. Pedest Action**</th>
<th>6. Alcohol suspended?</th>
</tr>
</thead>
<tbody>
<tr>
<td>First pedestrian</td>
<td>Male</td>
<td>23</td>
<td>Fata</td>
<td>No</td>
<td>Yes No</td>
</tr>
<tr>
<td>Second pedestrian</td>
<td>Male</td>
<td>23</td>
<td>Serious</td>
<td>No</td>
<td>Yes No</td>
</tr>
<tr>
<td>Third pedestrian</td>
<td>Male</td>
<td>23</td>
<td>Slight</td>
<td>No</td>
<td>Yes No</td>
</tr>
</tbody>
</table>

**Codes to use for Passengers and/or Pedestrian Options**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Front seat</td>
<td>Sitting</td>
<td>1. On Path</td>
</tr>
<tr>
<td>Rear seat</td>
<td>Standing</td>
<td>2. Crossing road</td>
</tr>
<tr>
<td>Motorcycle passenger</td>
<td>Getting on/Off</td>
<td>3. Walking along Shoulder</td>
</tr>
<tr>
<td>Bus passenger</td>
<td>Falling</td>
<td>4. Walking along Road edge</td>
</tr>
<tr>
<td>Back of truck/pickup</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Sample Blackspot Analysis and Management Report

This appendix details the information that should be collated to develop typical reports on individual Blackspots which need to be assembled by organisations undertaking such programmes. The aim of such reports is to summarise the analyses undertaken and to set out the thinking behind any countermeasures proposed.

(The site screening section is not strictly required for a blackspot report, though is included here to demonstrate the process.)

The Case Study developed here relates to a real cluster site that was identified in Accra, Ghana, using local crash data for a project for the Department of Urban Roads.

The report that follows sets out the analyses results which were used to assess the crash information from the cluster, to identify the issues and to help the engineers to develop an appropriate treatment plan. Although the majority of the report is factual, some aspects have been elaborated and steps simulated to offer more complete guidance.

C.1 Site Screening

Screening for sites was done using the Cluster Analysis feature in MAAP for Windows. The original analysis was done in 2004 and the latest whole year of data available was 2003. A variety of search parameters were tested on the Accra plots to identify a setting that identified sites which were reasonably discrete, but which had sufficient crashes within them to allow the identification of patterns. 3 years of crash data were used (2001-2003 inclusive).

Figure 49: Using search parameter 1) 30m and 2) 45m

The search parameter of 35m was used in all screening, which gave clusters ranging from about 20m in length to few that were as long as 100m.
Figure 50: Typical cluster pattern using search parameter distance of 35m
A range of locations were identified from the cluster analysis; these were supplied as a prioritised list by descending order of their weighted scores (Figure 51).

**Figure 51:** List of the top eight sites from the cluster screening
C.2 Report Sites 1 and 3, Ring Road, Accra

Sites 1 and 3 were identified using the cluster function in MAAP; 3 years of data (2001-2003 inclusive).

Because Site 1 and 3 are adjacent and show the same pedestrian problems, this whole link section is being treated as a single site. The whole site extends from under the overpass in the west, Kwame Circle side, stretching east along the Ring Road to the next major junction (see Figure 53).

The sites identified had the highest and 3rd highest scores using the standard weighting scheme of Fatal 10, Serious 5 and Slight 1 as a result of the screening.

The road is a dual carriageway with service or frontage roads on each side; this is more developed on the north carriageway. The site stretches for about 250m along the Ring Road.

Figure 52: Sites 1 and 3 clusters

Figure 53: Location using OpenStreet mapping
### SUMMARY ANALYSIS FORM

**Site:** 1 and 3, Ring Road Accra  
**Years:** 2001-03

<table>
<thead>
<tr>
<th>Collision type</th>
<th>Casualty crashes</th>
<th>Damage crashes</th>
<th>Casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year</td>
<td>3-yr total</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>01</td>
<td>02</td>
<td>03</td>
</tr>
<tr>
<td>Head on</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rear end</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Right angle</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Side swipe</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Overturned</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hit object on road</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hit object off road</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hit parked veh</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Hit pedestrian</td>
<td>13</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>23</td>
<td>17</td>
</tr>
</tbody>
</table>

**Night:** 27 50%  24  KSI Index: 0.50  
**Day:** 27 50%  13  

**Wet:** 54 37  
**Dry:** 0 0

Query: >= 2001 and <= 2003  
Polygon = Site 1 Site 3  
Date of analysis: 13/10/04

---

**Figure 54:** Standard report for the crashes from Sites 1 and 3
The standard report (Figure 54) identifies a major pedestrian casualty issue; ‘Hit Pedestrian’ is the crash type for 70% of the injury collisions, with 14 such crashes on average each year. These crashes included 8 reported deaths, 18 serious casualties and 19 slight casualties over the three years. There are also an issue with side swipes and rear end crashes but these result in damage only crashes on the whole and a few slight casualties.

Initial conclusion indicates that there is a severe pedestrian safety issue at these sites, a site visit and further investigation is strongly warranted.

C.3 Additional analysis

Cross tabulations were conducted to analyse the sites and to help identify the potential safety issues.

There is variability in the patterns in crashes occurring by severity year-on-year. There is some indication that the severity is higher in the last three years (2001-2003 inclusive).

**Table 13: Crash severity by year**

<table>
<thead>
<tr>
<th>Crash severity</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Hospitalised</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>9</td>
<td>11</td>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td>Injured Not-Hospitalised</td>
<td>15</td>
<td>3</td>
<td>9</td>
<td>10</td>
<td>12</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Damage Only</td>
<td>18</td>
<td>9</td>
<td>20</td>
<td>13</td>
<td>18</td>
<td>7</td>
<td>85</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>18</td>
<td>36</td>
<td>33</td>
<td>43</td>
<td>18</td>
<td>188</td>
</tr>
</tbody>
</table>

Table 13 shows the pattern in injury crashes by time of day and by day of the week (6 years of data). Crashes are highest between 20:00 and 22:00, when it is dark and the traffic may be fast since the peak flows will have reduced by that time in the evening.

Crashes are highest on Friday and Sunday.
Table 14: Day of week versus time of day

<table>
<thead>
<tr>
<th>Time</th>
<th>Mon</th>
<th>Tues</th>
<th>Weds</th>
<th>Thurs</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 - 02</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>02 - 04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>04 - 06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>06 - 08</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>08 - 10</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>10 - 12</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>12 - 14</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>14 - 16</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>16 - 18</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>18 - 20</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>20 - 22</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>22 - 24</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>19</td>
<td>11</td>
<td>18</td>
<td>103</td>
</tr>
</tbody>
</table>

As is typical in most crash statistics, more males than females are injured at the sites by more than 2 to 1. The 21-50 age ranges are most frequently injured.

Table 15: Casualty gender by casualty age

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 10</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11 - 20</td>
<td>8</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>21 - 30</td>
<td>20</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>31 - 40</td>
<td>15</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>41 - 50</td>
<td>16</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>51 - 60</td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>61 - 70</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>71 - 80</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>71</strong></td>
<td><strong>31</strong></td>
<td><strong>102</strong></td>
</tr>
</tbody>
</table>

Cars are most frequently involved in the high severity crashes. Buses are also highly represented in the crashes which resulted in injuries.
Table 16: Vehicle type versus casualty severity

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Fatal</th>
<th>Hospitalised</th>
<th>Injured Not-Hospitalised</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>12</td>
<td>26</td>
<td>42</td>
<td>80</td>
</tr>
<tr>
<td>Bus</td>
<td>5</td>
<td>7</td>
<td>17</td>
<td>29</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Pick-up</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Cycle</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
<td><strong>40</strong></td>
<td><strong>67</strong></td>
<td><strong>128</strong></td>
</tr>
</tbody>
</table>

The majority of those injured and especially those seriously injured and killed were pedestrians and these were almost all struck by vehicles when in the road whilst crossing the road.

Table 17: Pedestrian location versus pedestrian activity when injured

<table>
<thead>
<tr>
<th>Pedestrian action</th>
<th>On pedestrian crossing</th>
<th>Within 50m of crossing</th>
<th>In road centre</th>
<th>On footpath/verge</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing road</td>
<td>1</td>
<td>0</td>
<td>71</td>
<td>0</td>
<td>0</td>
<td>72</td>
</tr>
<tr>
<td>Walking along road</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Walking along edge</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>On Footpath</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
<td><strong>72</strong></td>
<td><strong>4</strong></td>
<td><strong>8</strong></td>
<td><strong>86</strong></td>
</tr>
</tbody>
</table>
Figure 55: Collision diagram analysis (not for this site)

The stick analysis diagram shows that the majority of the crashes which resulted in death and serious injury were single vehicle crashes where a pedestrian was struck. The other serious injury crashes tended to involve collision between a car or bus and a vulnerable road user.

Figure 56: Stick analysis
C.4 Site visit

A site visit was undertaken to gain a better understanding or the environment and actual road user behaviour.

Figure 57: General view looking east towards the fly over and Kwame Circle beyond

Figure 58: Detailed view looking west towards the flyover and Kwame Circle beyond
Most crossing is done just in front of the flyover, although there is crossing throughout the 100m of the blackspot. There is no signing to indicate that there is a formal crossing, although there are some bollards in the central reservation and also dropped kerbs indicate that it is a crossing point.

**Figure 59: View of current crossing facilities**

**Figure 60: Looking east away from the U turn facility**
Figure 61: Site features
Figure 62: Pedestrian crossing survey results

Site solution countermeasure proposal:

- Install light controlled pedestrian crossing facility at key desire line to west of the flyover location
- Move U turn facility back
- Install extensive pedestrian guard rail to ensure high usage of crossing facility provision
- Speed hump on frontage road (north side) to reduce speeds significantly
- Appropriate advanced of crossing warning signs installed

Figure 63 shows a detailed design for the proposed scheme.
Appendix C: Sample Blackspot Analysis and Management Report

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Figure 63: Detailed design proposal
The scheme is expected to cost $110,000 to construct.

The crash reduction expected for pedestrian collisions is estimated to be a 25% reduction. This is on the low side despite the scheme including a number of measures which are individually associated with a reduction in casualties of between 25% and 40%. However, the scheme may not affect all the pedestrian crashes which are occurring right along the whole site length. 25% is therefore considered to be a conservative and realistic estimate.

C.5 Summary Economic Appraisal

- Scheme cost estimate: $110,000
- Annual relevant casualty crashes per year: 14 per year
- Average cost per Crash = $30,000 – adjusted for high severities: $60,000
  (Crash cost figure based roughly on BRRI/NRSC 2004 estimates)
- Expected crash reduction: 25%
- Crash per year saving: 3.5
- Total monetary savings: $210,000
- FYRR: 191%
Appendix D : Evaluation Example

D.1 Introduction

Evaluation is a vital part of road safety management. Good monitoring and evaluation provide robust and transparent methods that can demonstrate effectiveness. These methods also provide the information that builds up into the intelligence on what works well and what does not, so the methodology feeds into the process to fine tune treatment choice in the future.

Evaluation is often not done very well. It is common practice to simply compare the number of ‘before’ crashes with the number of ‘after’ crashes without applying any statistical techniques or making comparisons with control sites. These approaches are unacceptable, particularly where blackspot analysis based on the use of crash data has been applied. The same crash data can be used to statistically assess performance of measures and schemes in a more robust fashion.

Statistical analysis will give a clearer indication of the robustness of any decreases (or increases) in crashes. Statistical analyses indicate whether any reduction could, in terms of probability levels, have been the result of random variation or factors. If a statistical result is significant at the 5% level (P<0.05) then we can be reasonably sure that the change observed was ‘real’.

When using an unpaired control method to perform statistical analyses, there are two techniques which have been used widely to 1) obtain the size of the reduction at the site or scheme and 2) to assess the statistical significance of any change in crash occurrence. These are the Tanner K test and the chi-squared (X2) test respectively:

- The Tanner K test provides a way to estimate the size of the change in crash numbers (as a proportion or percentage) in relation to any change at the control site before and after
- The chi-squared test provides an indication of statistical significance

These will be applied to the scheme in Accra which has been outlined in the Reactive Approaches manual. Real measures were implemented at that site to improve safety; however, the data numbers in the after period are simulated since we do not know exactly what was put in place and the timings.

The Tanner K and chi-squared tests both require crash figures in the before and after periods, the easiest approach is to use before and after periods that are equal in length.

The data come from the site and also a large unpaired Control area which is larger (with up to ten times more crashes).

Both methodologies require the crash data totals to be formatted as per Table 18.
Table 18: Crash totals matrix

<table>
<thead>
<tr>
<th></th>
<th>Crashes at site</th>
<th>Crashes at Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>a</td>
<td>c</td>
<td>g</td>
</tr>
<tr>
<td>After</td>
<td>b</td>
<td>d</td>
<td>h</td>
</tr>
<tr>
<td>Total</td>
<td>e</td>
<td>f</td>
<td>i</td>
</tr>
</tbody>
</table>

D.2 Tanner K Test

The Tanner K test formula (in terms of the before after crash number matrix in Table 18) is as follows*:

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

if \( k < 1 \) then there has been a decrease in crashes 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
* if any of the crash figures in any cells are zero, then 0.5 should be used instead of zero.

The result can simply be presented as a percentage difference which is calculated as follows:

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

D.3 Chi-Squared Test

The chi-squared (X²) test formula (in terms of the before after crash number matrix as set out in Table 18) is as follows:

\[ X^2 = \frac{[(ab-bc)-n/2]^2 \times n}{(efgh)} \]

The resulting statistic needs to be compared to values in a standard chi-squared distribution table with degrees of freedom = 1 for \( X^2 \) which is being applied to a 2 X 2 matrix of data). Further guidance on completing chi-squared analyses can be found in most statistics books.

D.4 Worked Example

Figure 64 shows the site location and the larger control by polygons which can be used to capture the number of crashes occurring in the before and after period.
Ideally these polygons are saved in a crash database system so that the tests can be repeated exactly after different time periods.

Crash data numbers from the site and controls for three years are shown in Table 19.

**Table 19: Crash numbers at the treated site in the before and after periods (3 years)**

<table>
<thead>
<tr>
<th>Site 1, 3</th>
<th>Fatal</th>
<th>Hospitalised</th>
<th>Injured</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1</td>
<td>9</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2002</td>
<td>2</td>
<td>9</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>2003</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Works done</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>2007</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

**Table 20: Crash numbers at the untreated control site in the before and after periods (3 years)**

<table>
<thead>
<tr>
<th>Site 1, 3</th>
<th>Fatal</th>
<th>Hospitalised</th>
<th>Injured</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>10</td>
<td>23</td>
<td>22</td>
<td>55</td>
</tr>
<tr>
<td>2002</td>
<td>15</td>
<td>15</td>
<td>28</td>
<td>58</td>
</tr>
<tr>
<td>2003</td>
<td>8</td>
<td>20</td>
<td>19</td>
<td>47</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Works done</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>10</td>
<td>17</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>2006</td>
<td>8</td>
<td>16</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>2007</td>
<td>9</td>
<td>3</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>
Table 21: Total injury crash numbers at site and control in the required matrix (as per Table 18)

<table>
<thead>
<tr>
<th></th>
<th>Total injury crashes at site</th>
<th>Total injury crashes at control site</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>54</td>
<td>160</td>
<td>214</td>
</tr>
<tr>
<td>After</td>
<td>23</td>
<td>125</td>
<td>148</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>285</td>
<td>367</td>
</tr>
</tbody>
</table>

D.4.1 Worked Example of the Tanner K Test

\[
    k = \frac{b/a}{d/c} = \frac{(23/54)}{(125/160)} = 0.55
\]

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
Therefore as \( k \) is less than 1 there has been a decrease in accidents relative to the control site.

The percentage change at the site is given by:

\[
    k = (k-1) \times 100 = (0.66-1) \times 100 = -45\%
\]

D.4.2 Worked Example of the Chi-Squared Test

\[
    \chi^2 = \frac{(((54 \times 125) - (23 \times 160)) - 362/2) \times 362}{77 \times 285 \times 214 \times 148} = 3021368202
\]

\[
    \frac{3021368202}{695042040} = 4.347
\]
Looking up in the chi-squared tables, the value (4.347) falls between the values (for 1 degree of freedom) which correspond to $p=0.05$ and $p=0.025$ (see Table 22).

This means the result is significant at the 5% ($p<0.05$) level, which is the level accepted to indicate that the result is unlikely to occur by chance.

Results which have a $p$ value of 0.01 or less are described as being highly significant.

**Table 22: Chi-squared values**

<table>
<thead>
<tr>
<th>df</th>
<th>0.25</th>
<th>0.20</th>
<th>0.15</th>
<th>0.10</th>
<th>0.05</th>
<th>0.025</th>
<th>0.02</th>
<th>0.01</th>
<th>0.005</th>
<th>0.0025</th>
<th>0.001</th>
<th>0.0005</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.32</td>
<td>1.64</td>
<td>2.07</td>
<td>2.71</td>
<td>3.84</td>
<td>5.02</td>
<td>5.41</td>
<td>6.63</td>
<td>7.88</td>
<td>9.14</td>
<td>10.83</td>
<td>12.12</td>
</tr>
<tr>
<td>2</td>
<td>2.77</td>
<td>3.22</td>
<td>3.79</td>
<td>4.61</td>
<td>5.99</td>
<td>7.38</td>
<td>7.82</td>
<td>9.21</td>
<td>10.60</td>
<td>11.98</td>
<td>13.82</td>
<td>15.20</td>
</tr>
<tr>
<td>3</td>
<td>4.11</td>
<td>4.64</td>
<td>5.32</td>
<td>6.25</td>
<td>7.81</td>
<td>9.35</td>
<td>9.84</td>
<td>11.34</td>
<td>12.84</td>
<td>14.32</td>
<td>16.27</td>
<td>17.73</td>
</tr>
</tbody>
</table>

Table from: http://www.unc.edu/~farkouh/usefull/chi.html

Alternatively this can be done in programs such as MS Excel, using the CHISQ.TEST function. This requires that the Expected values are calculated.
Existing Roads:
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