

**Technical Note 214**

**Guide to Road Safety Part 2: Safer Roads Supplementary  
Guidance**

**July 2025**



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## **Preface**

This document contains Queensland specific guidance for road safety practitioners. It is intended to serve as supplementary information to the *Queensland Guide to Road Safety (QGRS) Part 2: Safer Roads* and as such, must always be read in conjunction with that document. All referenced documents in the QGRS Part 2 also apply to this document.

Queensland-specific advice includes practices which vary from national practice to account for local factors such as environmental conditions (such as geography, soil types, climate); different funding practices; research; legislation requirements; as well as to expand instruction on particular issues.

This guidance comprises 4 parts:

1. Part 1: Treatment of Crash Locations
2. Part 2: Supplementary Technical Guidance
3. Part 3: Driver fatigue – Guidelines for road-based driver fatigue in rural areas, and
4. Part 4: Local Government and Community Road Safety.

## **Part 1: Treatment of crash locations**

### **1 Introduction**

#### **1.1 Purpose**

This Part of the document provides technical guidance for road safety practitioners covering the targeted process for addressing crash risk at high crash locations in Queensland. The process specifically applies to designing targeted interventions for treating locations with a persistent and demonstrated crash risk with timely and cost-efficient countermeasures.

The contents of this document are in addition to the general process for identifying and addressing road safety risks as outlined in the *Queensland Guide to Road Safety (QGRS) Part 2: Safer Roads*.

The approach requires the availability of good quality road safety data (including crash data, which is of greatest relevance to this document). There is also a reliance on appropriately trained staff (whether inside road agencies, or outside). Although this document provides information on the appropriate processes to be undertaken when addressing risk, there is reliance at all stages on experts who will often be called upon to use their professional judgement throughout. Involving well trained and experienced personnel is required to ensure the success of the risk assessment and crash reduction methodology described in this guidance.

#### **1.2 Developing a program to address high crash risk locations**

Comprehensive programs to identify and treat high crash risk locations are required by all road agencies, whether at national, state or local government level. This also implies coordination between these different levels of government. Such programs should be undertaken in the context of Safe System objectives. When establishing such programs it is important to demonstrate the significance of the road safety problem (in terms of fatal and serious crash outcomes as well as the full impact on communities and economic well-being). It is also important to demonstrate that the problem can be addressed in a cost-effective manner. This includes the requirement to understand the benefits that targeted road infrastructure improvements can provide. With knowledge of these issues, a case can be developed to ensure appropriate investments are made in road infrastructure.

For any road agency, reducing crash risk requires a strategic approach, addressing different elements of a crash within their areas of responsibility. Local government, as well as being the local road agency, is responsible for a range of other activities into which road safety can be integrated. Similarly, many state road agencies are also responsible for activities like data collection, driver and vehicle registration and vehicle operation where good practices can enhance road safety. Further information on these broader issues, including the development of road safety strategies can be found in the QGRS Part 7: *Road Safety Strategy and Management*.

As part of a treatment program, a clear process needs to be put in place to identify high risk locations, analyse the risk at these locations, select appropriate responses, prioritise these, and monitor and evaluate the outcomes from these efforts. This document focuses on these aspects as they relate to existing high crash locations.

The Australian Government's Black Spot Program is one such program. See details at <https://investment.infrastructure.gov.au/about/local-initiatives/black-spots-program>.

### 1.3 **Crash risk**

As risk is the product of 3 elements: likelihood, exposure and severity, a road safety strategy must address all 3 elements. For a road agency these may include examples such as:

- Influencing the likelihood of a crash:
  - applying sound traffic engineering and road safety engineering techniques in the development of new road designs and the treatment of known crash sites
  - modifying road user behaviour by appropriate design elements
  - using well targeted education and enforcement programs
  - applying appropriate speed management, including speed limits, and
  - independent auditing of proposed treatments.
- Influencing the exposure to a crash:
  - providing alternative, safer routes for vulnerable road users
  - promoting safer forms of transport in preference to less safe forms
  - Influencing the severity of a crash
  - providing a more forgiving roadside environment (e.g. safety barriers)
  - providing appropriate speed management, and
  - providing good access for emergency services to reach crash sites.

It can be seen that the treatment of crash locations is just one element of a road safety strategy, but it is an important and potentially very cost-effective part. Further details on these issues can be found in QGRS Part 7: *Road Safety Strategy and Management*.

### 1.4 **What is a crash location?**

A crash location (sometimes called a blackspot or hazardous road location) may be:

- an individual site (e.g. an intersection or a bend in a road)
- a length of road (which could be e.g. urban or rural)
- an area of the road network (e.g. residential precinct, local traffic area or an entire suburb), and
- locations across the road network which have a common hazardous feature (e.g. substandard guard fence end treatments) and/or crash type (e.g. pedestrians).

The prevalence of crashes at only some locations, and the clustering of crash types at a single location usually indicates that there are common causes for the crashes. It is the objective of crash location treatment to identify these common causes and to counter them by applying appropriate countermeasures.

As more individual sites are treated, the number of sites featuring crash clusters will continue to diminish. At a certain point, the number of fatal and serious injury (FSI) crashes occurring at a particular site cannot necessarily indicate a likelihood of a recurrence of similar crashes. At this point, the focus of road safety practitioners needs to shift to proactively treating high-risk sites and routes, including those that may not yet have a crash history but have potential for FSI crashes.

For instance, a large number of FSI crossover crashes occurring along a particular road could be easily addressed through the introduction of wire rope safety barriers along the median. There is a high likelihood that this treatment would reduce the occurrence and severity of this crash type.

### **1.5 Treating Crash Locations**

The treatment of crash locations involves a step-by-step process, described below. Each of these steps needs to be followed. Further, resources need to be applied, firstly to provide the crash information on which all investigations are based, secondly to permit investigations and analysis to take place and thirdly to permit the identified problems to be treated. For example:

- A data collection and verification system and a crash positioning protocol are needed, so crash locations can be identified as accurately as possible.
- A comprehensive data base is needed, which includes details about a sufficient number of crashes and crash features, so that problem locations and common crash features can be identified.
- An appropriate criterion needs to be selected for defining 'high' crash locations. These criteria may vary as the number of 'high' crash locations are effectively treated. The criteria may also differ across programs funded by different levels of government (i.e. national, state and local).
- A thorough diagnosis of the crash problems at a location is needed, so that the correct conclusions may be drawn about contributing factors.
- Countermeasures need to be selected on the basis that they are known to be effective against the particular problems identified, so that the problems are resolved.
- Safe design principles and road safety audit need to be applied to countermeasure design, so that the countermeasure does not cause harm or result in new types of problems.
- An appropriate project ranking system is needed so that scarce resources can be applied effectively to a program of potential countermeasures.
- Monitoring and evaluation of the effectiveness of countermeasures at site, route or network level is needed to ensure that the targeted remedial treatments achieve their intended purpose, while also continuing to improve knowledge associated with the treatment of crash locations.

Implementation of Safe System involves first consideration of countermeasures which eliminate occurrence of fatal and serious injuries (primary solutions). In some situations, such options will not be feasible due to project constraints dictated by budget, site, conflicting road user needs, or the environment. If so, the next safest project-feasible solution needs to be identified (supporting solutions). This process requires a clear Safe System-based hierarchy of solutions. (Refer to the QGRS Part 2: *Safer Roads* for guidance on selecting appropriate countermeasures).

### **1.6 Who should investigate crash locations and develop solutions?**

Most of the steps in the crash location treatment process can be undertaken by a practitioner with an analytical mind who has had training and experience in an engineering or scientific field. However, the following steps will require the inclusion of someone who also has road safety engineering skills and experience:

- drawing conclusions from the crash data and site inspection, and
- selecting countermeasures which address the factors leading to the types of crashes which are happening.

These tasks are considered to be a professional engineering service which are to be undertaken by a Registered Professional Engineer of Queensland (RPEQ), under the *Professional Engineers Act 2002* (Queensland) with the Board of Professional Engineers of Queensland.

A professional engineering service is an engineering service that requires or is based on the application of engineering principles and data to a design or to a construction, production, operation, or maintenance activity relating to engineering and does not include an engineering service that is provided only in accordance with a prescriptive standard.

The *Professional Engineers Act 2002* provides that a person who is not a Registered Professional Engineer of Queensland (RPEQ) must not carry out professional engineering services, except that a person who is not an RPEQ may carry out professional engineering services while under the direct supervision of an RPEQ who is responsible for the engineering services being undertaken.

It is also better at these stages of the process to use a team (ideally 2 to 5 people), rather than one person. The benefits of having a multi-member team include:

- the diverse backgrounds and different approaches of different people
- the cross-fertilisation of ideas which can result from discussions, and
- simply having extra sets of eyes/different perspectives of each member.

The types of skills and experience which should be considered for a crash location study team include:

- someone experienced in road safety engineering (essential)
- someone with local knowledge (e.g. a state road agency or local government engineer involved with traffic management)
- emergency services personnel (typically a serving traffic police officer) who has experience in traffic and safety and who is familiar with the location, and
- someone involved with the behavioural aspects of road safety.

### **1.7 What are road safety engineering skills?**

A road safety engineer may be described as a practitioner with:

- a formal degree in an engineering field
- sound knowledge in traffic engineering and road design practice
- an appreciation of road user behaviour and the contribution it makes to road crashes

- competency in crash investigation (i.e. crash data analysis, and identification of crash causation and severity factors), and countermeasure development (i.e. identification of targeted cost-effective remedial treatments), and
- competency in monitoring and evaluation methods.

## **1.8 Steps in the crash location treatment process**

### **1.8.1 The steps**

The treatment of crash locations should be a methodical, step-by-step process. The steps are illustrated and briefly outlined in this section and further explained in the following sections of this guide.

#### **1. Decide on the criteria for listing crash locations**

Define the physical limits of individual locations, so that sections with similar characteristics are considered together. Decide on the time period over which crash patterns are to be investigated (typically the most recent 5 years). All sites need to be compared using an agreed selection criterion. The preferred criterion is 'cost of crashes by crash type' rather than a number of or rate of crashes. If necessary, select a crash threshold, above which locations will be considered for inclusion as crash locations.

#### **2. List all crash locations to investigate**

Examine the information in the crash data base to identify locations which meet the definition of crash location. Establish the cost of crashes at each location, over the agreed time period. Make a list of all the locations which meet the minimum cost threshold selected. Ensure that locations are sensibly defined, so that no location worthy of investigation is missed through being subdivided in the data. Plan ahead for later monitoring.

Having identified all the sites worthy of investigation, each one should be examined in a step-by-step fashion to identify the factors leading to crashes, develop solutions and organise having those solutions implemented, as set out below.

Then, for each crash location:

#### **3. Obtain all the relevant information**

Obtain the crash data for the location. Be aware of the limitations on the availability and accuracy of crash data. Obtain other information such as traffic volumes, recent changes in the road network or traffic generating land uses, and any documented concerns about safety at the location.

#### **4. Diagnose the problems**

This is a three-step process:

- a. Analyse the crash data (including crash rates and densities) for any clustering by common crash types or factors such as common approach legs, common weather or daylight, common age of those involved, etc. Construct a factor matrix and draw a collision diagram. Is examination of the original crash report forms warranted?

- b. Inspect the site from the perspective of the involved road users, as well as undertaking a close-up examination of the site's features and its users' behaviour.
- c. Make any other investigations, then draw conclusions about the likely causes of crashes for which there are common factors. There may be other types of contributing factors (e.g. speeding), but focus on what it is about the road or traffic environment which is leading to crashes.

#### **5. Select the countermeasures**

Match the solutions to the problems. The selection of countermeasures will consider the particular crash types which have been identified in the diagnosis phase and which are amenable to treatment with road or traffic engineering measures. Select the countermeasure(s) and take account of the crash modification factors for each countermeasure. Consideration should also be given to the prevention of other types of crashes which could result in death or serious injury. A hierarchy of treatment selection is given in the QGRS Part 2: *Safer Roads*. Preference should always be given to the use of "primary" Safe System treatments (i.e. those which virtually eliminate the risk of death or serious injury due to a particular crash type) ahead of "supporting" treatments (which typically address the likelihood of crashes only)

#### **6. Prepare a preliminary design**

A preliminary design is required, so that its practicality can be confirmed, and the cost of the remedial treatment can be estimated. The design should be subjected to a review process which may include a Safe System Assessment (if one is warranted and has not been undertaken at an earlier stage) and/or a Road Safety Audit. Prior to implementing the project, the design needs to be finalised, taking account of any recommendations of the review process.

#### **7. Establish the benefits and costs**

Undertake an economic appraisal. Establish the costs (i.e. the initial design and construction costs only) and the benefits (including reductions in crash costs by crash type). Decide whether to use net present value (NPV), benefit / cost ratio (BCR) or another appropriate metric. Conduct sensitivity testing.

#### **8. Document the findings**

Draw together the documentation which has been undertaken through Steps 3 to 7 and set it out in a format which allows this project to be assessed against other potentially worthy crash countermeasure projects.

#### **9. If there are several locations to treat - rank all treatments**

Compare all projects' NPV or BCR. An alternative 'goals achievement approach' can be used, whereby projects are ranked but no attempt is made to assess their economic benefits against their costs. These formalised forms of appraisal are simply an aid for decision making. They should not be the only criterion for selecting safety improvement projects and their numerical answers should not be a replacement for sound decision making.

## 10. Implement the treatment

Once the countermeasure treatment has obtained funding it can be installed. It is important that the design which is being implemented accords with the results of the crash investigation. During the implementation phase, traffic safety will continue to be important. Once the works have been completed, the project should (where feasible) be the subject of a pre-opening road safety audit.

## 11. Monitor the treatment and evaluate its effectiveness

Monitoring is the systematic collection of data about the performance of road safety treatments after their implementation. Evaluation is the statistical analysis of that data to assess the extent to which the treatment (or a wider treatment program) has met crash reduction objectives. These tasks are important to ascertain the positive and negative effects of a treatment and thus improve the accuracy and confidence of predictions of that treatment's effectiveness in subsequent applications. It may take a number of years to collect sufficient data.

## 2 Road crash data

The process of accurately investigating, analysing and effectively treating crash locations relies on the use of comprehensive and accurate crash data and data related to the road and traffic characteristics at the crash locations.

Comprehensive and accurate data enables the:

- crash locations to be accurately determined
- events associated with crashes to be identified
- identification of crash contribution and severity factors, thus providing the basis for selecting targeted remedial treatment options
- identification of common factors across a number of crashes
- cost consequences of a single crash, all crashes at one location or several crashes with common factors to be identified, and
- crash sites to be ranked so that treatment can be applied to those sites that will derive the greatest safety benefits.

### 2.1 Data sources and codes

There is a minimum set of data about each crash which is necessary as a basis for the sound and satisfactory identification and investigation of a crash location. Although all states and territories in Australia have agreed to work towards a minimum common dataset there are a number of differences between jurisdictions. A reasonable knowledge of crash data definitions and limitations is required to accurately interpret this information in any given jurisdiction.

All jurisdictions have requirements for reporting casualty crashes to the police (i.e. fatal and injury crashes must be reported). At the other end of the severity scale, some jurisdictions require property damage (non-injury) crashes to be reported. There is a high level of reporting of the most severe injury crashes and a lower level and variable amount of reporting of lower cost crashes.

From a road safety perspective casualty data is the key indicator of the road safety problem. More recently, and in close alignment to Safe System principles and objectives, fatal and serious injury crashes and casualties are used as road safety key performance indicators. Lower severity outcomes as well as property damage data (where this is available) can provide valuable additional data that can support proposed countermeasure treatments.

The different crash severities are generally defined as follows:

- fatal crashes (one or more persons killed or died within 30 days)
- serious injury crashes (one or more persons admitted to hospital, although this is more typically based on whether a person was injured and taken by ambulance to hospital)
- minor injury crashes (one or more persons injured who is not admitted to hospital, although this is more typically based on a person not being taken by ambulance to hospital but requiring medical treatment), and
- non-injury crashes above threshold values which may vary across jurisdiction, plus those where the property owner is not present.

In Queensland there are 4 levels of crash severity:

- Fatal crash – A road traffic crash which resulted in at least one fatality.
- Hospitalisation crash – A road traffic crash which resulted in the most severe casualty outcome, being a person hospitalised.
- Medical treatment crash – A road traffic crash which resulted in the most severe casualty outcome, being a medically treated casualty.
- Minor injury crash – A road traffic crash which resulted in the most severe casualty outcome, being a minor injury.

## **2.2 Sources of crash data**

Road crash information is used by a wide variety of people for a wide variety of purposes including:

- road safety practitioners, for developing remedial or pro-active road and traffic measures
- police, who may be investigating whether they will charge a person with a criminal offence in relation to a specific crash
- hospitals and health centres to monitor their health service requirements
- lawyers acting for clients in civil litigation, especially compensation for injuries and other losses
- insurers, seeking facts before settling an insurance claim
- those with responsibility for road safety education and publicity, to ensure that their efforts are well-targeted
- media
- police, in relation to enforcement activities, such as establishing the location for speed cameras or breath testing stations
- safety administrators, exercising a duty to report statistical information on road crashes

- researchers, who need access to an accurate, reliable data base in order to conduct rigorous research projects, and
- vehicle and component manufacturers and suppliers of highway materials, who wish to assess the safety of their product, perhaps from a viewpoint of litigation, marketing or product enhancement.

As the primary purposes for data collection within different organisations vary, the information collected, the way in which data bases are established, the opportunities for data aggregation and analysis, and interpretation of information will vary; the opportunities to supplement information on one data base with information from another will be severely limited. For example, the data base of a motor vehicle insurance company may not code crash location by a numerical geographic system, as this information is peripheral to concerns of insurance claim assessment and financial management. The total information on the data base is then not in a format which can be used by someone seeking information about the safety performance of a particular location.

### **2.2.1 Primary data sources for crash reduction programs**

The primary source of road crash information across Australia and New Zealand is the police crash report form. In Australia, each state and territory have its own report form and it is usual for every crash attended by a police officer to result in a report form being generated. There are guidelines or directives about which crashes should be attended by the police. In general police will attend any crash involving a fatality or serious injury. However, often these crash outcomes are only known after the event, so police will sometimes attend relatively minor crashes and (less often) will not attend some serious crashes.

In most jurisdictions the facility exists for the generation of a crash report form for crashes not attended by the police, e.g. with a crash being reported at a police station. This form can be different in format and less detailed than the form filled out by an attending police officer.

The information on both these forms is usually entered into a police data base and a copy given to the road agency to be entered into the agency's data base along with additional road information (so long as it meets the coding criteria). In New Zealand, the Crash Analysis System (CAS) data base is managed by a central government organisation and made available on-line to any organisation or individual with a user licence. The primary sources of information are thus:

- the road agency / New Zealand data base (which is the most commonly used information, and which is usually in an electronic form which permits data manipulation)
- the police data base, and
- the police report form (which can provide a greater amount of detail regarding the crash circumstances, for detailed analysis of individual sites; reference to police crash report form details is usually necessary if a collision diagram is to be prepared).

In Queensland, Transport and Main Road's Crash Analytics Reporting System serves as the primary source for injury related crash reporting data. User registration is required prior to accessing the database. See more details on the website at: <https://cars.tmr.qld.gov.au/cars/>

The department's Safer Roads team is also able to provide different forms of crash analysis reports to support crash-based programs upon request from other road agencies. Practitioners may contact [SaferRoads@tmr.qld.gov.au](mailto:SaferRoads@tmr.qld.gov.au) for specific requests.

## 2.2.2 Other data sources

This list of other sources is not exhaustive, it contains common alternatives to the primary sources of data listed above – but practitioners may identify further sources if deemed appropriate by the crash-based program the applies.

**Traffic data** such as traffic volumes (including turning volumes), pedestrian flows and vehicle speeds may be helpful, depending upon the particular circumstances and problems at the site. In some cases, these will be available, but in other cases they may need to be collected.

**Hospitals record the causes of injuries** as well as their nature, extent and treatment. Crash data sourced from police information may indicate whether someone was taken by ambulance or not, but typically does not give information as to whether that person was hospitalised, for how long, or whether the injuries sustained resulted in long-term impairment. With advances in technology, and greater collaboration between agencies, it is possible to link this information together, allowing for road safety treatments to be focused on those resulting in the most debilitating injuries.

In special circumstances, provided confidentiality of patient information is secure, hospital data may be made available for research purposes. This has been done with good effect in the development of countermeasures to reduce the severity of road crash injuries.

**Insurance companies** require claimants against policies to provide a description of the circumstances in which the loss, damage or injury occurred. This information is not usually released, although it has been released as consolidated data by some insurers. It provides a potential for establishing the true extent of lower cost crashes which are not reported to the police. Unfortunately, it is generally not in a form which is compatible with the needs of crash location analysis and treatment.

A further source of information on crash occurrences is tow truck operators' records, although there is no system in place for collecting this information.

From time-to-time **in-depth crash studies** are undertaken into the nature and causes of crashes in a particular area. These studies are costly to undertake and involve specialist teams attending crash scenes and taking measurements and recording crash features. The results are usually published in special reports.

**Local knowledge** is an important source of information about safety problems on the road network. Subjective information about crash problems must be regarded cautiously, but it can be a pointer to problems or prompt further investigation. Information sources can include local residents, businesses, safety groups, emergency service personnel, local medical practitioners, maintenance contractors and local authority staff.

**Interviews with road users**, including people who have been involved in a crash at a site of interest, in a structured format have been used by some traffic authorities to gain information for the development of crash countermeasures.

**Traffic conflict surveys** may be used where the collection of crash data is not practical. These involve field observations or video recording of conflicts (near misses).

**Coroners' reports** can be a useful source of additional information concerning specific fatal crashes.

**Site investigations** are a necessary component of any countermeasure development program and will often yield insights into the crash history at a site.

**Speed survey data** also provides a source of information regarding speeding behaviour.

**The Queensland Police Service (QPS)** no longer includes non-injury related crashes in its formal reporting. However, these crashes may provide an early insight into emerging road safety risks at various locations. As such, practitioners are encouraged to request non-injury related crash data from their local QPS branch on a case-by-case basis. This data is invaluable supporting information for nominations towards crash related programs, especially for proactive submissions.

### **2.3 Limitations and accuracy of crash data**

It is crucial that practitioners using road crash data understand the limitations of the data and take steps to resolve any anomalies which may occur. The limitations include:

- **Under-reporting of crash data** – although significant attempts are made to collect and record all relevant crash data, not all non-fatal crashes make their way to the relevant crash data base. Surveys conducted in New Zealand and in some Australian states have tried to compare data from crash data bases with information from hospital admissions and other sources. Information from New Zealand indicates only around 60% of serious crashes make it to the crash data base, with the percentage significantly less for minor injury crashes (Alsop & Langley 2001). Australian based research has also identified similar under-reporting of injury crashes (Cercarelli 1998). A review conducted for Austroads identified that reporting rates also varied by type of crash. For example, reporting rates were lower for cyclists, pedestrians and motorcyclists.
- **Systematic reporting bias** – this bias can result from the regulations or policies covering the reporting of crashes. Reporting criteria vary between jurisdictions, resulting in crash experience not being comparable. Numerically, property damage (non-injury) crashes constitute the bulk of crashes: there may be as many as 41 non-injury crashes for every casualty crash (James 1983). However, in some jurisdictions they are not reported, or are not recorded in the data base. This results in an incomplete and systematically biased crash picture.
- **Random reporting bias** – Crashes involving children, cyclists, pedestrians and minor injury are substantially under-reported (James 1991). A similar situation applies to crashes involving illegal activity, such as under-age driving, driving while intoxicated, riding a motorcycle exceeding regulated capacity and carrying a pillion passenger when not permitted to do so by regulation.
- Further, it is common for some human factors (e.g. alcohol and drugs) and roadway factors (e.g. the presence of a roadside culvert) not to be recorded. The absence of this information on the crash report form may mean the absence of the factor or the failure to record it. Erroneous conclusions can be made from the wrong interpretation of this absence of data.
- **Subjective bias** – some crash forms require an assessment of possible contributing causes of the crash. This in itself adds a subjective element, as the range of possible responses to the question will be affected by the recorder's experiences and the purposes (other than crash recording) to which the information may be put. For example, 'failure to give way' may be seen as a cause by someone regularly involved in traffic law enforcement, whereas the same situation may be seen as 'control device not visible' by someone regularly involved with road environment safety. One examination of the frequency of reported causes revealed distinct differences between police districts (Vincent 1996). Similarly, speed and fatigue are not typically based on direct observation.

- **Reporting errors** – it is important to recognise the circumstances under which a police officer obtains information to complete a crash report. There will often be more pressing matters at a crash scene. The officer may not have local knowledge or adequate training in incident investigation, so some data items may be inadequately or wrongly recorded. Crashes do not always fit 'standard' formats and there may not be the motivation to fill in the form.
- **Coding errors** – these can occur throughout the process from filling out the crash report form to the data entry at the computer terminal. It is estimated that errors of this type are present in 5% of crash files (Ogden 1996). They are unlikely to be revealed unless the data are used for detailed investigation at individual sites. Typical problems include wrong direction for the north point, wrong direction for one of 2 vehicle movements, selecting the wrong road user movement (DCA code), for example 'rear-end' instead of 'rear end into right turner', and numerical coding errors.
- **Location errors** – the location may be imprecise or wrong in the original police report form and this will be carried through into the data base. If this continues through into coding, crashes at one location may appear in 2 separate parts of the crash data base. The location reference system may also be imprecise, so that a user of the data may not be able to accurately determine the location (e.g. all mid-block crashes may be recorded as being halfway between the adjacent intersections).
- **Discontinuities over time** – definitions or interpretations of field data may be changed over time by those responsible for coding and reporting, so that data from one time period cannot be compared with that of another. An abrupt change in recorded crash experience at a site should lead an analyst to enquire whether there has been any discontinuity of this kind.
- **Delays** – agencies responsible for data processing may not be sufficiently resourced: it may be many months before information is available for analysis. Data may only be released annually. This means that countermeasure development may be responding to historical crash patterns which may be out of date.
- **Masked or hidden problems** – it may be the case that a location is perceived as being so dangerous that people avoid using it. In this situation the safety problem results in a reduction of amenity (e.g. as pedestrians choose to cross the road somewhere regarded as safer) rather than resulting in crashes. The use of the other data sources outlined in Section 3.2 of Part 1 can help overcome this kind of data limitation.

## **2.4 Coding of Crash Types**

Refer to the department's *Queensland Road Safety User Technical Volumes (QRSTUV): Guide to Coding Crashes* for guidance on coding crashes in Queensland. Queensland is transitioning towards adopting the Descriptive Road User Movement (DRUM) coding system, which is an evolution of the DCA system described in this guidance.

### 3 Identify crash locations

The crash location treatment process can be applied to individual sites, to routes and to areas (i.e. a network of roads) where crash clusters occur. As more crash locations are treated, identifying further sites for improvement can become more difficult, particularly with the ultimate objective of eliminating fatal and serious injury outcomes. In some areas the numbers of fatal and serious crashes are too low to be used as a metric to assess risk or undertake a crash reduction study. There are various responses to this challenge, including lowering threshold levels (as discussed in Section 4.1.3 of Part 1), although this can only occur to a certain point. An alternative metric that has been adopted in some jurisdictions (e.g. New Zealand) is the use of FSI casualty equivalents. Other responses include greater use of route or area-based approaches and taking a broader risk assessment approach, including a mixture of reactive and proactive approaches. For information on more proactive solutions refer to *Austrroads Guide to Road Safety Part 2: Safer Roads*.

#### 3.1 Defining the Locations

Intersections are typically defined as the area bounded by the projections of the property boundaries, plus 10 m of the approach roads. Crashes occurring within this area are classified as intersection crashes and all others as mid-block crashes. However, some crash types (e.g. rear end or lane change crashes resulting from traffic control at an intersection) can occur much farther away than 10 m. These should be included in the investigation of the intersection.

In urban areas with frequent minor intersections on arterial roads, individual mid-block sections and minor intersections may need to be grouped together into a complete route length between major intersections. If this type of grouping is not undertaken, the fragmentation of crash information in the data base may hide a serious crash problem along a route.

When subdividing a route into sections, bear in mind that (Ogden 1996):

- Roadway and traffic characteristics should be fairly uniform within the section.
- The section length should be in keeping with the level of precision and degree of error in reporting crash locations.
- Statistical reliability should be maintained.

Regarding the last point, it is obvious that as the section length becomes very small the probability of either zero or one crash in the period increases. Conversely, as the section length becomes very large, the effects of isolated hazardous features will be submerged and lost. Zegeer (1982) suggests that data for road segments less than about 0.5 km long or carrying less than 500 vehicles per day are unreliable.

The crash location treatment process can also be applied in area based and mass action programs to address:

- groups of crashes of a similar type (e.g. run-off-road), occurring across several sites
- a series of crashes that have common features, such as road features (e.g. curves, bridges), vehicle features (e.g. bicycles), road user features (e.g. pedestrians) or contributory features (e.g. driver fatigue), and
- a series of 'high profile' crashes such as those involving vehicles carrying dangerous goods, or crashes at railway crossings.

In this case the location will be numerous locations with common characteristics.

Crash location countermeasures can be applied on a site/route area or mass action basis. A brief discussion of these various actions is outlined in Sections 4.1.2 and 4.5 of Part 1.

### **3.1.1 Deciding on a time period**

Crash data for a 5-year period is typically used, as this period usually provides statistical reliability. A 3-year period may be adequate, for example if the data base includes property damage crashes and crash frequencies are high at the sites being considered. A period longer than 5-years can be used (e.g. for remote or low volume roads), but it is more likely that changes to road features will have occurred which will affect crash causes. A data interrogation system which looks at both short term (one year) and long term (3 or 5 years) data will allow problem locations to be identified sooner.

Individual crash-based programs may nominate specific time periods for eligible crash locations. Practitioners should consult program guidelines on a case-by-case basis to confirm the applicable information.

When deciding on the time period to be used:

- avoid environmental trends (e.g. traffic growth), other trends and changes to road layouts or roadside activity which could affect results
- use crash data for whole years to avoid the effects of cyclic or seasonal variations in crash occurrence, and
- be aware of any changes in data base definitions which might introduce discontinuities in the data.

### **3.1.2 Criteria for selecting locations to investigate for countermeasures**

There will be many crash locations vying for countermeasures. There is a requirement to select those which are most worthy of treatment. Consistent with the Safe System approach, the focus should be on preventing future FSI crashes. In order to achieve this, roads that have a high number of fatal or serious injury crashes should be prioritised over roads that have a high number of minor injury or property damage only crashes.

Several criteria have been developed to identify locations worthy of investigation, but there is little consensus on which is the most appropriate. Selection criteria should be chosen in consideration of overall road safety program objectives, which may indicate the criteria that will be the most efficient.

The list of criteria in this section is not exhaustive, and simply comprises commonly applied criteria for site selection in crash-based programs.

### **Crash cost criterion**

Generally, the recommended method is to compare locations using the cost of crashes by crash type (Andreassen 1992a; 1992b) as the criterion. This is done by assigning a crash cost to each crash type. For this purpose, several crash types are grouped together. Standard crash costs by crash type are different in each state and territory, depending on a number of factors including the reporting rates of non-injury crashes compared to casualty crashes. Consequently, these averaged crash costs by crash type already account for severity and there is no need to assign different costs to different crash severities within a particular crash type. This is a far more accurate way of establishing crash costs than by using separate average crash costs for all fatal crashes, all serious injury crashes, all minor injury crashes, etc. The use of crash cost by crash type also overcomes the problem of a single fatal crash (which is very rare) distorting the analysis because of its high cost.

The crash costs by crash type are assigned to each crash at every location where there has been a crash. This allows the locations to be ranked and those with the highest total crash costs to be identified. However, some crash locations will not experience a clustering of common crash types. These locations with single unrelated crash types are more difficult to treat, as there is no obvious crash pattern. Consequently, it is important to include for consideration more locations than will ultimately be treated, as some locations with significant total crash cost values may not be economically treatable due to a lack of common crash factors.

For uniformity of comparison, the total crash costs at all locations should be expressed as a cost per year over the appraisal period. Locations are then ranked according to decreasing crash costs. Crash cost by crash type is also the recommended costing method used in economic appraisal discussed further in this guidance.

### **Other criteria**

Other, more minor, selection criteria are described below. By comparison with the recommended criterion, they are all less effective, as they are less accurate in identifying the costs of crashes at a location and therefore less efficient in ranking sites to maximise the benefits of crash countermeasures:

- The number (i.e. frequency) of crashes (or crashes per kilometre of road) within the adopted time period. This takes no account of exposure or the different costs/severities of different crash types. This method may be appropriate in managing the allocation of resources in programs that treat a single crash type or where the overall program objective is to reduce crash numbers.
- The rate of crashes (per volume of traffic) within the adopted time period. This takes account of exposure. Rates are usually expressed in terms of crashes per 100 million vehicle kilometres travelled for road sections. The accuracy of a rate is dependent on the accuracy of traffic volume information.
- The number or rate of crashes both exceeding some defined threshold value.
- The rate of crashes exceeding a critical value, derived from statistical analysis of rates at all sites. This method determines whether the crash rate is significantly higher than a predetermined rate for similar locations, based upon a Poisson distribution (Zegeer 1982).

- The difference between the observed and expected crash numbers, calculated from the site and traffic flow characteristics (McGuigan 1981; 1982). It is similar to the previous method, using frequencies (number of crashes) instead of rates.

Whichever method is used to determine whether a location is hazardous (and is thus worthy of consideration for treatment), there needs to be sufficient flexibility to ensure that:

- sites which have recently become a problem for obvious reasons do not have to experience another 2 or 4-years of crashes before they are considered.
- sites with few crashes but requiring low-cost treatments are not excluded.

### 3.1.3 Using a threshold method

If the crash data base does not allow the cost of crashes at each location to be directly compared, then a threshold method can be used to obtain an initial list of sites. Once these sites have been listed, crash costs by crash type can be applied so the sites may be ranked.

A threshold can also be used to provide an initial indication about whether a particular location has a crash problem.

The threshold could be in terms of the total number of crashes, but a threshold which identifies a pattern for a particular crash type may be more useful. Table 3.1.3 below shows an example of threshold (or trigger) numbers used in one jurisdiction with high volume roads, some non-injury crashes reported and a limited crash treatment budget. In other jurisdictions, or under other budgetary conditions, the values in a table like this may be considerably lower.

**Table 3.1.3 – An example of threshold numbers used to identify sites for investigation**

Type of location and criteria	Number of tow away and casualty crashes in five years						
	Pedestrian	Intersection	Rear-end, overtaking, vehicle turning	Right-turn-against, oncoming	Off-road, lost control, head-on	Manoeuvring	Total
Cross-intersection (not signalised or roundabout)		3	5	5			13
Non-signalised intersection (not roundabout or cross-intersection)		4	5	5			14
Signalised intersection		5	9	5			18
Roundabout		5	5				10
Rural intersection (give way or stop control)		3	4	4		3	14

Type of location and criteria	Number of tow away and casualty crashes in five years						
	Pedestrian	Intersection	Rear-end, overtaking, vehicle turning	Right-turn-against, oncoming	Off-road, lost control, head-on	Manoeuvring	Total
Urban mid-block location			4	4	3	4	15
Rural mid-block location			3	3	3		9
Mid-block location with a pedestrian crash problem	3						3

Notes:

- Urban = 80 km/h or lower; rural = over 80 km/h.
- 'Mid-block' means a length of road between intersections.
- For intersection locations, include crashes within 30 m (urban) or 100 m (rural).
- For mid-block locations, length of location is 100 m (urban) or 300 m (rural).
- If considering greater lengths than the above, be aware that the more distant crashes of the same crash type may be due to different contributing factors.

### 3.1.4 Chance variation

Crash data are subject to random fluctuations, and it is therefore possible to subject them to statistical analysis in order to distinguish between significant factors and those occurring through chance variation.

In particular, it is important to assess whether an abnormally high number of crashes in a time period (e.g. one year) should be taken as evidence that the site has become hazardous or whether the fluctuation can be taken as mere chance variation. The practical example in Appendix C.2 provides an assessment method. It uses the concepts of the true underlying crash rate of crashes and critical changes in a mean value. The graphs in Appendix F (Nicholson 1987) are used for this purpose.

### 3.2 Intersections

Crash data are subject to random fluctuations, and it is therefore possible to subject them to statistical analysis in order to distinguish between significant factors and those occurring through chance variation.

In particular, it is important to assess whether an abnormally high number of crashes in a time period (e.g. one year) should be taken as evidence that the site has become hazardous or whether the fluctuation can be taken as mere chance variation. The practical example in Appendix C.2 provides an assessment method. It uses the concepts of the true underlying crash rate of crashes and critical changes in a mean value. The graphs in Appendix F (Nicholson 1987) are used for this purpose.

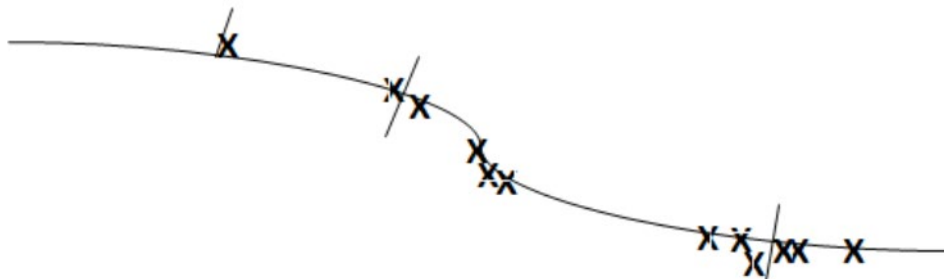
### 3.3 Routes

A treatment of a route or road section will involve systematically investigating crashes along a section of road where the road character is relatively homogeneous. This study must include investigations of each site and road section with repeated crash types, similar to a site investigation.

However, an attempt should also be made to see if there are common features in crashes (and treatments) along the entire route. For example, a scenic route may feature a high number of coach buses or motorcyclists, and infrastructure may need to be upgraded to accommodate these vehicles. In addition, particular crash types (for example run-off-road crashes) may have occurred at specific locations, but there may be locations of equal or even higher risk elsewhere on the route. This is particularly the case on lower volume roads.

Figure 3.3 below illustrates a route along which high numbers of crashes have occurred. Some of these have occurred in clusters (e.g. near intersections or at a curve), while others are more scattered.

**Figure 3.3 –Example crash sites along a route**



### 3.4 Areas of the Road Network

Treating areas of the road network involves systematically investigating crashes throughout an entire area (e.g. a local traffic area or an entire suburb). The objective is to correlate crash problems over the area and investigate overall solutions, even though the study area may include individual problem sites and/or routes. Issues in area studies may include traffic management and network problems, such as short cuts through residential streets. The area of interest may fall across different geographic boundaries (e.g. across local government boundaries) and so responses may require more than one agency.

### 3.5 Mass Action

This involves applying a particular evidence-based remedial treatment (or package of treatments) to address a hazardous feature or crash type. Common features might include road features (e.g. inadequate shoulders on curves; unprotected bridge ends), vehicle features (e.g. bicycles), or road user features (e.g. pedestrians). Crash types might include specific crash types (e.g. run-off-road) or contributory factors (e.g. driver fatigue). Typical mass action treatments include delineation improvements and shoulder sealing on rural road curves, and the duplication of intersection control signs on wide approach roads in country towns by installing median islands.

Treatments should be assessed for use at locations where the feature is present, irrespective of whether crashes have yet occurred at all of them. All crashes attributable to the feature should first be identified. Then, locations with this feature should be identified and the viability of applying a proven treatment to all of these locations should be assessed.

## 4 Diagnosing the crash problem and selecting treatments

Crash data analysis and interpretation is the foundation on which the selection of effective countermeasures is based. Countermeasures need to be targeted and be able to address crash causation factors and factors that may increase crash severity.

The aim of the analysis therefore is to identify the factors which are contributing to crash occurrence and severity at the location under investigation. This requires more than identifying the result of the crash (e.g. a car left the road and hit a tree). It requires understanding the road environment factors which led to it and identifying the problems to be resolved (e.g. presence of a curve, inadequate superelevation, poor location or delineation, inadequate skid resistance). This requires knowledge of:

- road and roadside features that have proven themselves to contribute to crash occurrence and severity, and
- cost-effective proven remedial treatments.

The Safe System pillars should be used to structure the analysis task. In particular, refer to the QGRS Part 2: *Safer Roads* and QGRS Part 3: *Safe Speeds*. Other pillars include safe people and safe vehicles but are not directly relevant to the crash treatment methodology detailed in this document.

Practitioners in Queensland should also refer to guidance such as the department's Movement and Place Operational Framework to better understand the functional context of their selected location and to inform and add value to the analysis.

### Analysis of crash data

The first step involves obtaining the detail of each of the recorded crashes that had occurred at the site under investigation. This then enables in-office analysis to be undertaken to identify predominant crash types (e.g. rear-end, head-on, etc.), and common crash characteristics (e.g. time-of-day, day/night/dusk, etc. of the occurrence of all of the recorded crashes). Discussion of this analysis task is provided in Section 5.1 of Part 1.

### Obtain other relevant information

The second step is to consider other information that may be relevant to the site, such as community concerns and traffic demands.

### Inspect the site (or route or area)

The third phase is an on-site analysis involving observation of road features and road user behaviour. The road needs to be driven, walked, ridden, etc. at normal speeds and also observed at close quarters.

### Finalise the assessment and draw conclusions

Any additional studies, such as speed surveys, traffic counts, geometric checks, skid resistance tests, turning manoeuvres or conflict analyses are organised. Using all the information which has been collected and observed, conclusions are drawn about the contributing possible crash factors.

## **4.1 Analysis of crash data and interpretation**

The primary sources of data for crash investigation are:

- the state or territory road agency crash data base (the most commonly used information and usually in an electronic form which permits data manipulation)
- the police crash data base, and
- the individual police crash report forms (which can provide a greater amount of detail regarding the crash circumstances; the use of police crash report form details are highly desirable if a collision diagram is to be prepared).

### **4.1.1 Examine crash types (DCA or other similar codes)**

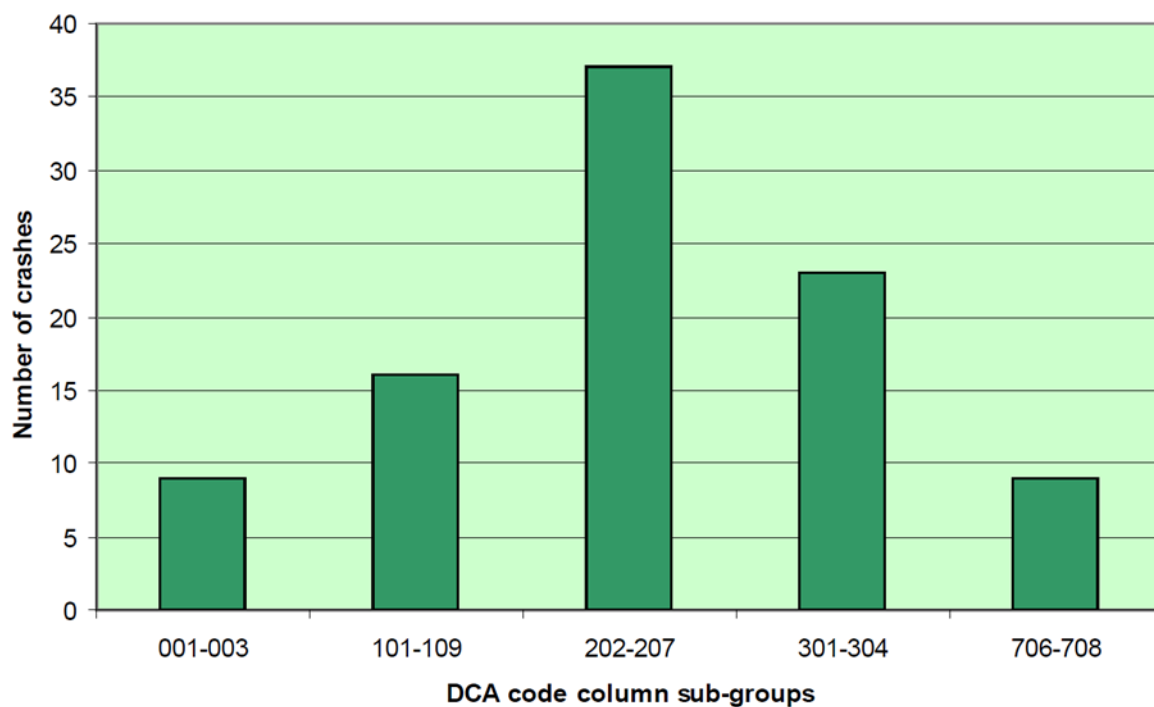
Crash types or DCA codes categorise crashes by the movements or activity of the involved road users. NOTE: Refer to Section 2.4 above for the latest guidance on coding crashes. (Note: the DRUM code system operates similarly to DCA codes and the approach to analysis remains the same for both).

Dominant DCA types often provide the most reliable guide to the remedial action, since they are likely to be indicative of the future crash patterns at the site, if it is not treated. For most DCA types there will be one or more specific countermeasures which are applicable. Typical DCA types might include:

- collisions between vehicles entering from intersecting streets
- collisions involving vehicles turning from the opposite direction
- rear-end collisions
- collisions between vehicles and pedestrians
- collisions between vehicles travelling in the same direction
- vehicles running off the road
- collisions with fixed objects off the road, and
- collisions with parked vehicles.

An example frequency histogram showing the distribution of sub-groups of DCAs occurring at the site is a useful, quick way of getting a first idea of possible clustering by crash types, as illustrated in the figure below. It shows that DCA codes are grouped by column, or sections of a column, into similar types (e.g. all the pedestrian crashes are grouped in the first column, but the thick horizontal lines divide this column into 4 separate sub-groups).

Where any column is divided by thick horizontal lines, each sub-group should be listed separately in the frequency histogram. However, a frequency histogram is not a substitute for a factor matrix or a collision diagram and it is rarely used in later analysis as it provides insufficient detail for tracking down crash causes. An alternative to the frequency histogram is the pie chart as shown in Figure C.3(c).

**Figure 4.1.1 – Example crash frequency histogram based on DCA code sub-groups**

#### 4.1.2 Construct a crash factor matrix

DCA codes do not give a full picture of all factors. By examining the mass crash data and constructing a factor matrix (see the example in Table D.4) any patterns in these other factors can become apparent.

Construction of a factor matrix can allow quick and easy assessment of key crash characteristics that may be associated with many or all of the crashes at a site. Along with the DCA code, other relevant factors should also be included, for example:

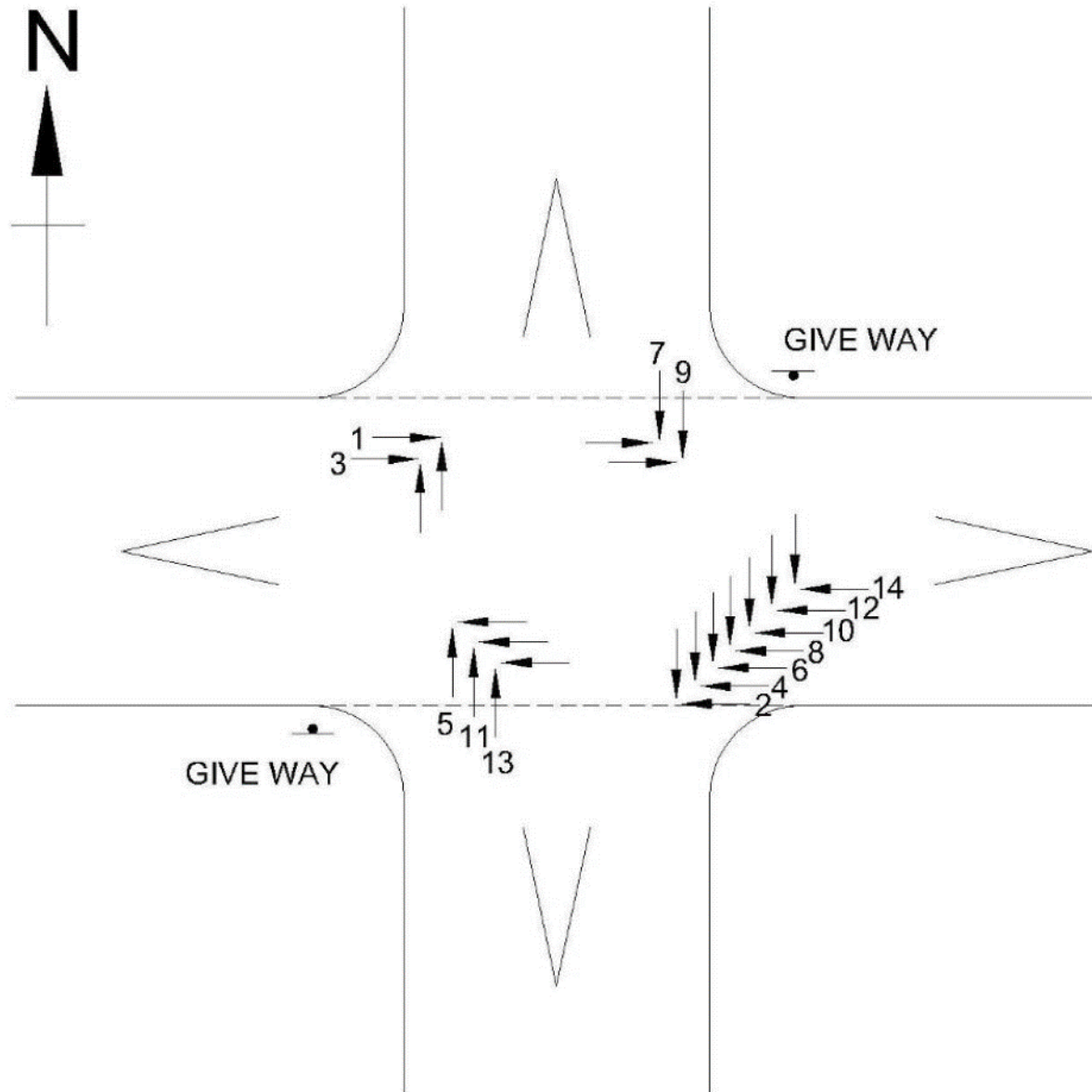
- time of day and day of week (this may, for example, help identify if a crash was in the weekday commuter peak, or during darkness)
- road surface condition (may indicate if a crash occurred in wet conditions)
- involvement of alcohol and speed, or other behaviour factors
- the number of crashes involving pedestrians, and
- any vehicle factors (e.g. motorcycle involvement).

Where there are small numbers of crashes it may be useful to record each crash as a separate row in the factor matrix. Where there are a larger number of crashes, for each combination of DCA code and key direction (usually the direction of travel involving the error) which has experienced more than one crash, details can be recorded on one line of the Factor Matrix form. A blank form is provided in Appendix B. Note how the crashes in the case study example in Table D.4 are repeated for each factor across the matrix (e.g. on each line the crashes are all listed under Surface as well as Light Condition, etc.). Also, the northbound DCA 201 crashes are listed separately from the southbound DCA 201 crashes.

### 4.1.3 Draw a collision diagram

The fundamental tool used in crash diagnosis is the collision diagram, which is a schematic representation of all crashes occurring at a given location, route or area over a specified period (typically 3-5 years). An example is provided in the Figure 4.1.3 below (this also appears in Practical Example 6 in Appendix C.6).

**Figure 4.1.3 – Example collision diagram**



Each crash (or each group of crashes with the same DCA code and involving the same approach direction) is represented by a small diagram similar to that shown for the crash movement type codes in identified, oriented in the true direction of road users involved in the collision. Each crash type code diagram in these figures typically contains one or 2 arrows, one for each vehicle and/or pedestrian involved, to indicate the type of crash and directions of travel. On the collision diagram the date, time, day / night, wet / dry surface, vehicle type, etc., can be labelled along one of the arrows or beside each crash type code diagram.

The collision diagram should contain street names, the locality name, a north point and GPS coordinates wherever available, and need not be to scale. It may also include road features such as intersection type and control, traffic lanes, islands, markings and significant roadside features. However, if the inclusion of all these features would make the collision diagram too cluttered, they should be provided as a separate site sketch plan, with the collision diagram showing only the basic site layout.

In summary:

- **Sites:** prepare a collision diagram as discussed above.
- **Routes:** prepare a collision diagram for any sub-section of the route where there is crash clustering, as well as for the entire route.
- **Areas:** prepare a collision diagram for any site or precinct where there is crash clustering, as well as for the entire area.
- **Mass actions:** select several sites having large numbers of crashes involving the particular factor for study during field investigations. Draw a collision diagram for each of these sites.

Some crash data base systems are able to automatically generate a collision diagram. However, these should always be checked against crash data to ensure they have been produced correctly.

#### **4.1.4 Look for common factors**

Review the crash data, the factor matrix and the collision diagram and identify common contributing factors. What factors have led to each crash? It is normal for several factors to combine in leading to a crash.

List the common crash factors. These can provide a prompt to the factors to consider during the on-site investigations.

If there is not a dominant crash type, development of a remedial treatment can be difficult.

In many cases, there will be a relatively small number of crash types at any given site. In such cases the text on the crash report forms describing the crash can provide a greater insight. Valuable information can be gathered from reading the commentary provided by the road users involved in the crash from these forms. In some cases this information is available directly through the crash data base system (e.g. through scanned images).

The location of the crash may not be clear, or it may conflict with other information. Examining the crash report form can help clarify this. It is often difficult to construct a complete collision diagram without reference to the original crash report forms for at least some of the crashes.

Where no clear pattern arises about crashes at a location, the crash report form can provide clues about an underlying crash problem. Before the site is discarded for treatment, consider looking at the information in the crash report forms.

#### **4.1.5 Writing a preliminary report**

The information and analysis to this point is required for the immediate purpose of informing all the crash investigation team members, prior to the field investigation. Later it will be required as part of the crash location treatment report (Section 8 of Part 1). At this point the preliminary report should be written in a format suitable for that purpose (see the introduction and data analysis sections of the summary report framework described in this guidance. A practical example of a preliminary report can be found in Appendix C.3.

#### **4.2 Other relevant information**

As well as crash data, information should be obtained covering:

- traffic volumes
- significant changes to traffic patterns and land uses in the area
- surrounding land use, and
- concerns raised by interested people or organisations (often reported by the media).

Consideration of other data may help to highlight location specific concerns. For example, higher traffic volumes (especially motorcycles) occurring during weekends may indicate a high level of recreational travel, whilst the presence of a retirement complex would suggest a high level of elderly drivers in the area.

#### **4.3 Site investigation**

The objectives of the site inspection are to:

- identify any factors which may have contributed to crash occurrence and crash severity
- identify cost-effective targeted remedial treatment options.
- Environmental deficiencies that may have contributed to crashes can be many and varied but include:
  - STOP / Give Way lines concealed by an uneven surface
  - a line of poles which produces an illusion of continuous perspective through an intersection (often giving rise to overshoots)
  - lack of carriageway definition
  - horizontal curves concealed by a sharp crest in the carriageway
  - masking of pedestrians by street furniture, and
  - foliage obscuring regulatory signs.

To ensure that road deficiencies are identified it is essential that site inspections are carried out in an extremely systematic and purposeful manner. As indicated earlier, one option is to take a Safe System approach, using the pillars to structure the site inspection.

If the crash data show a cluster of a particular crash type, this means that several road users are misreading the situation as they approach, drive through, turn at, walk across, or otherwise negotiate the location. An assessment should be made of what is causing them to do this, or of what is misleading and what is difficult to deal with.

These issues cannot be identified only from crash data, crash report forms or photographs. It is essential to carry out a site inspection. When on-site, bear in mind the potential inadequacies in data and the reasons for them. The crash location investigation team will need to:

- view the location as the road users in a crash may have seen it (time of day, level of lighting, weather, eye height and position)
- check the surrounding road environment
- observe travel speed behaviour
- collect information about road features and traffic behaviour, and
- consider the Movement and Place characteristics of the site.

#### **4.3.1 Drive through the location**

To see the location as the road users in the crashes may have seen it, use the following techniques:

- select the driver on the basis of the person least familiar with the location, and the front seat passenger the second least familiar
- drive the roads at a range of speeds, determined by a local risk assessment
- drive all approaches and repeat the manoeuvres featured in the crash data
- try to do this in similar conditions to the crash conditions (e.g. same time, peak / off-peak, light / dark, wet / dry, etc.)
- have the driver comment on the road and any problems or surprises, and
- have the front seat passenger concentrate on the surrounding environment.

#### **4.3.2 Inspect the location**

To inspect the location:

- determine where the main crash patterns and directions are, on site
- observe traffic behaviour (including driver eye movements, vehicle paths, approach speeds, braking and pedestrian patterns, impairments to travel including parked vehicles)
- check from the point of view of a range of users, including vulnerable road user groups (e.g. from the eye height of drivers and young pedestrians, as appropriate)
- check and note relevant features (e.g. surface condition, lighting, crossfall, gradient, islands, signals, signs, markings and obstructions), and
- take video and photographs, as a record to use back in the office as required.

A suggested checklist of issues is provided in the following section. This should not be used to identify risks at the location (that is road safety auditing). Rather the checklist provides a prompt of possible issues the investigators can think about when trying to find a connection between the road and traffic environment and the crash types being investigated. An alternative approach would be to group these (and other) issues according to the Safe System pillars (see the *Austrroads Guide to Road Safety Part 1: Introduction and the Safe System* (Austrroads 2021a)).

A key aim of the site inspection is to identify any environment and traffic concerns which may have contributed to the recorded crash history. Conformity of the layout, signing, pavement markings, lighting, etc. with applicable standards or guidelines may be important, but it cannot be assumed that any non-conformity will necessarily have resulted in a safety problem, nor can it be assumed that a road designed according to standard will not have safety concerns. Road safety engineering judgement, based on experience, is vital in determining whether the absence of a standard treatment has contributed to a crash.

Video and photographs of the site, its problem areas and its approaches can be a valuable tool in crash investigation. Video-recording of the site can also help assess road user behaviour, and perhaps form the basis of a before-and-after study. This should serve as a supplement to a site visit and should not be used instead of a site visit by any of the crash investigation team members.

#### 4.3.3 Consider driver behaviour

In some cases, it may be helpful to have additional information on driver behaviour at the site. This behaviour (which may include late braking on entry to a sharp curve, evasive actions at an intersection, behaviour resulting from inadequate or misleading visual information) can be identified from observations or recorded more formally through a conflict study. Such studies involve direct observation of the site, or the use of video recording, in order to examine near-crashes as a means of gaining insight into crash problems at a site:

- **Sites:** inspect as discussed above.
- **Routes:** place heavy emphasis on route continuity and driver expectation. In sub-sections of the route with crash clusters, examine and report separately.
- **Areas:** drive through in a logical sequence. Look for signs of inconsistent road environments. Look at all locations with crash clusters.
- **Mass actions:** the first emphasis is on identifying all sites having the hazardous feature under investigation. Investigate the higher frequency sites in greater detail.

**Table 4.3.3 – An illustrative checklist of possible contributing factors, for use during site inspections**

Crash Type	Contributing Factors	
Right angle crashes	<ul style="list-style-type: none"> <li>• Width</li> <li>• Divided / undivided</li> <li>• Number of lanes</li> <li>• Crossfall</li> <li>• Gradient</li> <li>• Shoulder</li> </ul>	<ul style="list-style-type: none"> <li>• Verge</li> <li>• Median and openings</li> <li>• Footpath</li> <li>• Kerb, pram ramps</li> <li>• Drainage</li> <li>• Combination of factors</li> </ul>
Road surface	<ul style="list-style-type: none"> <li>• Type</li> <li>• Roughness</li> </ul>	<ul style="list-style-type: none"> <li>• Skid resistance ('friction') and texture / surface debris</li> <li>• Service access</li> </ul>
Road geometry	<ul style="list-style-type: none"> <li>• Curve</li> <li>• Gradient</li> <li>• Superelevation</li> </ul>	<ul style="list-style-type: none"> <li>• Crest</li> <li>• Sag at foot of hill</li> </ul>

<b>Crash Type</b>	<b>Contributing Factors</b>	
Intersection	<ul style="list-style-type: none"> <li>• Type</li> <li>• Number of legs</li> <li>• Channelisation</li> </ul>	<ul style="list-style-type: none"> <li>• Turn lanes</li> <li>• Turning radius</li> </ul>
Signs and markings	<ul style="list-style-type: none"> <li>• Which signs</li> <li>• Legibility</li> <li>• Conspicuousness</li> <li>• Comprehensibility</li> <li>• Credibility</li> <li>• Lane, centre and edgelines</li> </ul>	<ul style="list-style-type: none"> <li>• Other markings</li> <li>• Pavement markers</li> <li>• Post-mounted delineators</li> <li>• Hazard markers</li> <li>• Chevron alignment markers</li> </ul>
Traffic signals	<ul style="list-style-type: none"> <li>• Primary / secondary / tertiary</li> <li>• Intensity</li> <li>• Location</li> <li>• Turn control</li> </ul>	<ul style="list-style-type: none"> <li>• Pedestrian display</li> <li>• Detector type</li> <li>• Part of linked system</li> <li>• Cycle times and green splits</li> </ul>
Pedestrians and cyclists	<ul style="list-style-type: none"> <li>• Number and types</li> <li>• Crossing facilities</li> </ul>	<ul style="list-style-type: none"> <li>• Pedestrian barriers</li> <li>• Pedestrian refuges</li> </ul>
Lighting	<ul style="list-style-type: none"> <li>• Type</li> <li>• Height</li> </ul>	<ul style="list-style-type: none"> <li>• Intensity</li> <li>• Obstruction</li> </ul>
Parked vehicles	<ul style="list-style-type: none"> <li>• On-street parking</li> <li>• Off-street parking and access</li> <li>• Visibility</li> <li>• Clearway hours</li> <li>• Parking controls</li> </ul>	<ul style="list-style-type: none"> <li>• Loading facilities</li> <li>• Bus stops</li> <li>• Taxi rank</li> <li>• Physical obstruction</li> </ul>
Speed	<ul style="list-style-type: none"> <li>• Safe speed</li> <li>• Speed limit</li> </ul>	<ul style="list-style-type: none"> <li>• Vehicle speeds</li> <li>• Late braking</li> </ul>
Environment	<ul style="list-style-type: none"> <li>• Land uses</li> <li>• School children</li> <li>• Heavy vehicles</li> </ul>	<ul style="list-style-type: none"> <li>• Ambient noise</li> <li>• Ingress / egress problems</li> </ul>
Roadside	<ul style="list-style-type: none"> <li>• Poles, posts, etc.</li> <li>• Horizontal railings</li> <li>• Rock, trees, other hazards</li> <li>• Safety barriers, fences</li> </ul>	<ul style="list-style-type: none"> <li>• Side slopes</li> <li>• Culverts</li> <li>• Bridge abutments, railings</li> </ul>
Visibility	<ul style="list-style-type: none"> <li>• Poles, posts, etc.</li> <li>• Horizontal railings</li> <li>• Rock, trees, other hazards</li> <li>• Safety barriers, fences</li> </ul>	<ul style="list-style-type: none"> <li>• Of parked vehicles</li> <li>• Of bus stops</li> <li>• Over crests</li> <li>• Subliminal delineation</li> </ul>
Evidence of problem	<ul style="list-style-type: none"> <li>• Broken glass</li> <li>• Debris</li> </ul>	<ul style="list-style-type: none"> <li>• Skid marks</li> <li>• Damaged road furniture</li> </ul>

#### **4.3.4 Identifying the cause of the crash**

One type of crash may have different causes at different locations. Take, for example, right angle crashes at give way controlled intersections. Are drivers on the minor leg having crashes because:

- They cannot see the intersection, and drive through as if it was not there?
- They know there is an intersection, but they cannot see the give way position and they overshoot into the intersection?
- They know the intersection is there, they have stopped, but they make a mistake picking a gap in the traffic?

Each of these alternatives will be caused by different road or traffic factors. It is vital to understand which applies at the intersection in question, because each one will require a different countermeasure treatment to overcome it. For example, there is little point installing advance intersection warning signs as a solution, if the cause is poor judgement in gap selection.

A list of possible contributing factors for a selection of different types of crashes is provided below. Note that speed can contribute to the frequency and severity of all crash types.

#### **4.4 Identification of crash causation and crash severity factors**

Before completing the analysis and preparing a summary report, consider what other data is required but not yet provided. For example, does the crash information or the site inspection indicate that skid resistance testing should be undertaken? Do sight distances need to be measured?

##### **4.4.1 Draw conclusions**

With all the information available from the analysis and the field inspection, conclusions can be made about the underlying factors contributing to the crashes. An assessment should be made of what it is about the road or traffic environment which is leading to crash occurrence and/or crash severity.

##### **4.4.2 Write a crash summary report**

A crash summary report can then be prepared. This summarises the information available about the site and incorporates the introduction and data analysis sections discussed in Section 6.1 of Part 1. This summary report can form the first part of the final crash location treatment report which will include consideration of countermeasures and an economic appraisal of the proposed treatment.

At this stage, the crash summary report would typically include the following sections of the report framework set out in this document:

- Introduction
- Data analysis. As well as the information set out in Section 8 of Part 1, a crash histogram by DCA code column sub-groups (or VMC rows in New Zealand) may optionally be included in the preliminary report or the crash summary report
- Contributing crash factors, and
- Appendices.

An alternative example of a shortened crash summary report is shown in Table 5.3. Note how the identification of common factors leads to the description of the site's problems. Also, in this example, there are descriptions of possible remedial measures (which address these identified problems). The subject of countermeasures is dealt with in further guidance. Another alternative is to structure the report according to the Safe System pillars.

**Table 4.4.2 – Some possible contributing factors for different types of crashes**

Crash Type	Contributing Factors
Right angle crashes	<ul style="list-style-type: none"> <li>• Restricted sight distance</li> <li>• High approach speeds</li> <li>• 'See through' effect on a minor approach</li> <li>• Obscured control sign, control lines or signal lanterns</li> <li>• The presence of the intersection is not otherwise evident (at time of day)</li> <li>• Traffic volumes too high for Give Way or Stop controls (inadequate gaps)</li> </ul>
Right turn collisions with oncoming traffic	<ul style="list-style-type: none"> <li>• Restricted visibility</li> <li>• Queued oncoming right-turners block visibility</li> <li>• Insufficient number of gaps in oncoming traffic</li> <li>• Too many lanes of oncoming traffic to filter across</li> <li>• Complex intersection layout</li> </ul>
Straight ahead rear end crashes	<ul style="list-style-type: none"> <li>• Queued right-turn vehicles further ahead</li> <li>• Traffic signals around curve or over crest</li> <li>• Other unexpected cause of delay further ahead</li> <li>• Inadequate skid resistance or pavement drainage</li> <li>• Wrong offset timing of linked signals</li> <li>• 'See through' effect of consecutive traffic signals</li> <li>• Inadequate inter-green phase on signals</li> <li>• Presence of parked cars</li> <li>• Unstable flow on high speed road, including disturbance to traffic flow, such as from driveways and bus stops</li> </ul>
Right or left turn rear end crashes	<ul style="list-style-type: none"> <li>• Turning vehicles where they are not expected (e.g. just before or just after signals)</li> <li>• A left turn slip lane permitting high speed turns</li> </ul>
Hit fixed object crashes	<ul style="list-style-type: none"> <li>• Turning vehicles where they are not expected (e.g. just before or just after signals)</li> <li>• A left turn slip lane permitting high speed turns</li> </ul>
Crashes involving a parked vehicle	<ul style="list-style-type: none"> <li>• Islands not visible</li> <li>• Complex layout</li> <li>• Reasons as for run-off-road crashes</li> </ul>
Side-swipe crashes	<ul style="list-style-type: none"> <li>• Unexpected, parked vehicle in traffic lane</li> <li>• Edgeline not visible</li> <li>• Lanes too narrow</li> </ul>

Crash Type	Contributing Factors
Head-on crashes	<ul style="list-style-type: none"> <li>• Lanes too narrow (for traffic composition, speed or curvature of road)</li> <li>• Centreline not visible</li> <li>• Severity of curve cannot be judged</li> <li>• A hidden dip or crest</li> <li>• Insufficient overtaking opportunities</li> <li>• Road surface deficiencies</li> </ul>
Run-off-road crashes	<ul style="list-style-type: none"> <li>• Narrow lanes or narrow seal</li> <li>• Severity of curve cannot be judged</li> <li>• Edge of the road is not evident</li> <li>• Gravel shoulders do not allow recovery of control</li> <li>• Alignment of road is deceptive</li> <li>• Inadequate skid resistance or pavement drainage</li> <li>• Insufficient superelevation</li> </ul>
Pedestrian crashes	<ul style="list-style-type: none"> <li>• Too much traffic for adequate gaps</li> <li>• High speed, multi-lane and 2 way traffic</li> <li>• Complex or unexpected traffic movements</li> <li>• Traffic hidden by parked cars, other objects or excessive landscaping</li> <li>• A marked crossing which is not evident to drivers</li> <li>• Long signal cycles which encourage pedestrians to disobey signals</li> <li>• Inappropriate device or lack of devices for mix of pedestrians (e.g. disabled)</li> <li>• Inadequate lighting</li> </ul>
Railway level crossing crashes	<ul style="list-style-type: none"> <li>• Location of crossing is not evident</li> <li>• Impending presence of train is not evident</li> <li>• Form of control is not accurately identified (or is inconsistent)</li> <li>• Driver's attention distracted by intersection or other feature</li> <li>• Obscured control devices</li> </ul>

#### 4.4.3 Applying the process to area studies and mass action programs

##### Area studies

The usual context for crash diagnosis on an area-wide basis is that a particular area (say a residential precinct up to 5 km<sup>2</sup> or a shopping / commercial district) has been identified as having a safety problem. In diagnosing that problem, the task is to plot the location of all recorded crashes, together with a code indicating the road user movement or DCA. Since a focus of such studies may be vulnerable road users, an analysis and presentation similar to that described for site analysis is useful.

An explicit functional road classification scheme is important in this instance, since often in these types of study a solution involves adaptation of the road and street network to ensure that extraneous traffic is excluded or discouraged. This cannot be done until all the legitimate (and necessary) traffic routes have been determined.

Area studies will incorporate aspects of both site and route studies, to the extent that crashes cluster at these locations. However, one important objective of an area study is to consider all the crash problems of the area together, in a consistent manner. This may include road network problems which are contributing to the crash experience of the area (e.g. traffic using residential streets as a 'rat run'). Solutions resulting from area-wide studies should be integrated into a total scheme to ensure that new safety problems are not created elsewhere, either in a nearby street or a nearby area. Implementation will often require community consultation.

### **Mass action programs**

The approach to the diagnosis of crash patterns for mass action programs is a little different because the focus is not a particular site. Nevertheless, the basis of the investigation is again an interrogation of the mass crash data base. Crashes may be sorted by crash type (as described above) to identify the locations where a particular type of crash, amenable to a standard treatment, is occurring.

Examples, with possible countermeasures, might include:

- Crashes involving collisions with a bridge or structure (guard fencing and delineation).
- Rural single vehicle run-off-road crashes (sealed shoulders).
- Crashes with utility poles on bends (removal of poles, shielding them, making them frangible or improving skid resistance). Alternatively crashes may be sorted by road user, to identify where crashes involving those users are occurring. Examples might include:
  - crashes involving elderly or child pedestrians, and
  - crashes involving cyclists or heavy vehicles.

Under mass action programs, a large number of sites are often treated, irrespective of whether crashes have occurred at all of them. Care therefore needs to be taken when conducting economic appraisals for mass action, as the crash modification factors (CMFs) applicable at such sites may differ to those from where clusters of similar crash types occur (they may be lower). Similarly, there may be economies of scale when installing treatments that make the cost per unit installed less.

To the extent that there is a significant occurrence of crashes of a particular type or crashes with a common contributing factor revealed by such a study, the analysis could form the basis of a mass action program. If there is no significant occurrence by crash type, it is unlikely that a mass action program of engineering countermeasures is appropriate.

### **4.5 Countermeasure selection and design**

Having identified the elements of the road and traffic environment which contributed to the crashes and their severity, the next step involves consideration of countermeasures. For a solution to be effective, it must be applied to a particular problem which it is known to affect. It must be an effective countermeasure.

The aim of countermeasure development is to:

- select countermeasures which have been demonstrated to be effective in reducing the incidence and/or severity of target crash types
- check that adopted countermeasures do not have undesirable consequences, either in safety terms (e.g. lead to an increase in the number or severity of another crash type, or crash migration) or in traffic efficiency or environmental terms

- be cost-effective, i.e. maximise the benefits from the whole program of expenditure over a number of sites, and
- be efficient, i.e. produce benefits which outweigh the costs.

There are several criteria for countermeasure selection, including (Ogden 1996):

- **Technical feasibility:** can the countermeasure provide an answer to the safety problems which have been diagnosed and does it have a technical basis for success?
- **Economic efficiency:** is the countermeasure likely to be cost-effective and will it produce benefits that exceed its costs?
- **Affordability:** can it be accommodated within the program budget; if not, should it be deferred, or should a cheaper, perhaps interim solution be adopted?
- **Acceptability:** does the countermeasure clearly target the identified problem and will it be readily understandable by the community?
- **Practicability:** is there likely to be a problem of non-compliance, or can the measure work without unreasonable enforcement effort?
- **Political and institutional acceptability:** is the countermeasure likely to attract political support and will it be supported by the organisation responsible for its installation and ongoing management?
- **Legal conformity:** is the countermeasure a legal device, or will users be breaking any law by using it in the way intended?
- **Compatibility:** is the countermeasure compatible and consistent with other strategies, either in the same locality in similar situations elsewhere?

It can be seen that the decision to adopt a particular countermeasure may involve more than a simple matching of a solution to a problem.

#### 4.5.1 What is a safe road environment?

A safe road environment forms an integral part of a Safe System. Such an environment is one which recognises the realities and limitations of human decision making. In other words, the road environment must not place demands upon the driver, or other road users, which are beyond their ability to manage, or which are outside normal road user expectations.

A safe road may therefore be described as one which is designed and managed so that it:

- provides a safe speed environment
- warns the driver of any substandard or unusual features
- informs the driver of conditions to be encountered
- guides the driver through unusual sections
- controls the driver's passage through conflict points or sections, and
- forgives a driver's errant or inappropriate behaviour (e.g. has a safe roadside).

It should:

- provide no surprises in road design or traffic control (the design matches expectations)

- provide a controlled release of relevant information (the design matches information-processing abilities), and
- provide repeated information, where pertinent, to emphasise danger (again, to ensure the design matches expectations).

Designing a road according to these principles is not the same as designing a road which simply meets design standards. Lamenting the fact that decisions affecting the future safety of roads are so often strongly influenced by the habit of designing to standards, a safety review committee on one major road project commented 'this often means that minimum standards are just met. There is no reason to think that by meeting standards the appropriate level of safety is built into roads' (Professional Engineers Ontario 1997). A road designed to standards is not necessarily safe and a road which in some details fails to meet standards is not necessarily unsafe. There is no substitute for the application of sound road safety engineering experience and judgement, which is the basis of the principles outlined above.

Emerging approaches take a wider perspective on treatment options that include all pillars of the Safe System approach (see the QGRS Part 1: *Introduction*). However, only the Safer Roads and Roadside, and Safer Speeds pillars directly relevant to the approach described in this guidance. Investigations may highlight some issues involving Safe Vehicles and Safe Road Users which could be passed on to another party to follow up, thereby ensuring all parts of the system are addressed.

#### **4.5.2 Safe System treatments**

A challenge under a Safe System approach is to ensure greater usage of treatments that will provide Safe System outcomes (i.e. the elimination of death and serious injury). Due to cost considerations, safety improvements that have only moderate effects on fatal and serious crash outcomes are often used as these often produce a greater benefit-cost ratio (see Section 6 of Part 1). Although there is a place for such treatments in reducing crash risk, other treatments that produce greater benefits in terms of fatal and serious injury per dollar spent should be explored as first options where possible.

Refer to the QGRS Part 2: *Safer Roads*, for further discussion on the Safe System approach, the concept of harm minimisation and a hierarchy for Safe System aligned treatments.

#### **4.5.3 Speed management**

Speed is known to have a significant impact on the likelihood and severity of crashes. A good evidence base now exists regarding the survivability of road users for different crash types based on impact speed. This knowledge needs to guide the approach that is taken to the management of speed. The QGRS Part 3: *Safer Speed* provides guidance on speed management and the application of speed limits as a speed management tool.

#### **4.5.4 Enforcement**

A Safe System approach requires that road users operate within certain limits to ensure that the system can protect them. As a minimum, this means that road users are expected to comply with road rules, and particularly those directly related to safety such as speed limits, traffic signals, use of mobile phones and driving under the influence of alcohol or drugs. Enforcement of these rules is an important part of ensuring that road users operate within the limits of the system.

Generally, studies show that enforcement is effective at improving the behaviour being targeted (e.g. speed cameras increase compliance with speed limits) but also at reducing associated serious injury crash frequency (e.g. red-light cameras reduce right-angle crashes). Some enforcement activities are shown to be effective at improving a specific behaviour but do not show a corresponding reduction in crashes, and still others are only effective in some situations (Austroads 2020c).

#### **4.5.5 Match the solutions to the problems**

Often there will be a number of alternative countermeasures which could be applied at any specific crash location, either individually or in combination. The final choice about which countermeasure(s) to select requires road safety engineering experience and judgement about the factors which have led to the crashes and given the available resources. Table 4.5.6(a) through to Table 4.5.6(d) list a range of options which can be considered. For further guidance, including a hierarchy of treatments for infrastructure interventions, refer to the QGRS Part 2: *Safer Roads*.

Further sections provide more information on the likely crash modification factors (CMF) for various countermeasures to common types of crashes. Road agencies may also have expanded lists of countermeasures and may require the use of other values when applying for blackspot funding.

Whichever CMFs are used, it is important to remember that these countermeasures will only be effective if they really are a countermeasure for the type of crashes (and the particular causes identified) at the location in question. This underlines the point that the process must firstly identify whether the safety problem at a location is amenable to treatment, then determine what (if anything) that treatment should be.

The countermeasure for one crash problem is likely to be different from the countermeasure for another problem. In some cases, the countermeasures may possibly even be in conflict. For example, if there is a signalised intersection with a history of both pedestrian crashes and collisions between turning and oncoming vehicles, the latter can be tackled with fully controlled turn phasing of the signals, but this may make the pedestrian situation more complex, and perhaps even exacerbate it if the pedestrians do not obey WALK / DON'T WALK signals. In such cases road safety engineering knowledge and judgement is required to assess all possible positive and negative effects, including possible further countermeasures to address the negative effects.

#### **4.5.6 Select the solutions**

With some locations there may be a clearly defined crash pattern and an obvious countermeasure which can be confidently applied. In other cases, the crash pattern is unclear and/or the solution is not evident. It may be that 2 solutions are relevant, one being a relatively expensive one which overcomes a large percentage of the crash problems and the other being a lower cost solution which reduces the crash problem to a smaller degree. Until the stage of analysing the benefits and costs it may be a good idea to keep both treatment options under consideration.

The practical examples provided in Appendix C.1 show the basic process for investigating a high crash location and selection of treatments.

**Table 4.5.6(a) – Countermeasures for crashes at intersections and major driveways**

<b>Adjacent Crashes</b>	
<ul style="list-style-type: none"> <li>• Check sight distance available and where practical, clear obstructions (including parked vehicles) to provide the appropriate standard of sight distance. Where standards cannot be achieved, consider options for intersection controls or speed controls (avoid reliance on Stop signs where visibility remains poor at the stop line).</li> <li>• Check the minor road approaches to see if a driver's view is drawn to a distant feature, past the intersection. If so, highlight the intersection: consider a median island, larger or duplicated control signs, a roundabout if appropriate.</li> <li>• Check day and night visibility of traffic control devices and consider renewing, duplicating, delineating or enlarging the device.</li> <li>• Consider the installation of appropriate warning signs and devices.</li> <li>• At an unsigned T-junction, install a Give Way sign.</li> <li>• At signalised intersections, check adequacy of yellow phase and all-red clearance time. Also, consider red light safety cameras, larger diameter traffic signals, overhead mast arms and supplementary advance flashing yellow warning lights.</li> </ul>	<ul style="list-style-type: none"> <li>• Where a high frequency of night crashes is involved, consider adding or amending street lighting.</li> <li>• Consider installation of channelisation such as median islands to support control devices on side road approaches, wide median treatments (where appropriate) and staggered intersection treatments in rural areas.</li> <li>• Consider installation of a roundabout where the function of the 2 roads makes this appropriate.</li> <li>• At an existing roundabout consider realigning approaches to reduce speeds.</li> <li>• Consider installation of traffic signals where appropriate.</li> <li>• Install mast arms at existing signals.</li> <li>• At angled T-junctions, add a hazard board opposite the junction.</li> <li>• Check the speed limit is appropriate.</li> </ul>
<b>Straight ahead rear-end crashes</b>	
<ul style="list-style-type: none"> <li>• Check if these collisions are due to queuing by uninvolved right-turn vehicles. If this is the case, consider banning the turn or provision of a protected auxiliary turn lane. This may include a right turn just after a signalised intersection.</li> <li>• Where a high frequency of night-time crashes is involved, consider street lighting.</li> <li>• Where there is a red light camera at a signalised intersection, remove or replace with a red light speed camera.</li> <li>• Where there is a speed limit reduction located near to the intersection, relocate further downstream.</li> </ul>	<ul style="list-style-type: none"> <li>• If there is a high involvement of wet weather crashes, check skid resistance and pavement drainage.</li> <li>• At signalised intersections, check stopping sight distance to the 'tail of queue' and adequacy of the yellow phase or all-red clearance time. If there is poor visibility to signal aspects consider provision of an overhead mast arm signal.</li> <li>• Where closely spaced linked signals occur, check offset timing.</li> <li>• Where signalised intersections or crossings are close but can operate separately, check for a 'see through' effect of a distant green and near red signal.</li> <li>• Check that the speed limit is appropriate.</li> </ul>
<b>Right or left-turn rear-end crashes</b>	
<ul style="list-style-type: none"> <li>• As well as considering treatments for straight ahead rear-end crashes:</li> <li>• Provide protected right / left-turn auxiliary lanes or extend or supplement existing ones.</li> <li>• Consider prohibition of right-turns if this can be adequately catered for at other locations without adverse safety or environmental effects.</li> </ul>	

- If at a left-turn slip lane, modify the intersection angle of the lane with the intersecting road to 70 degrees minimum, or consider signalling it, or provide an added lane in the road being entered.

**Table 4.5.6(b) – Countermeasures for non-intersection collisions**

<b>Side-swipe crashes</b>	
<ul style="list-style-type: none"> <li>• Check the visibility of lane lines in daylight and at night.</li> <li>• In a rural area provide or check adequacy of centre and edgelines and, where relevant, lane line delineation. Supplement with retroreflective pavement markers (RRPMs).</li> <li>• Consider provision of wider lanes.</li> <li>• If at an isolated curve, consider adequacy of alignment design and superelevation. Aim to remove need for drivers to reduce speed at curves.</li> </ul>	<ul style="list-style-type: none"> <li>• On the approach to an intersection, consider improving direction signing including overhead lane use signs where relevant. Also consider adequacy or provision of auxiliary lanes for turning traffic.</li> <li>• If at a lane drop, check that warning signs and pavement markings are to standard.</li> <li>• Check that the speed limit is appropriate.</li> </ul>
<b>Head-on crashes</b>	
<ul style="list-style-type: none"> <li>• In a rural area check adequacy of centreline marking and consider supplementing this with RRPMs. If on a curve, check delineation of the curve as well.</li> <li>• If at locations where visibility is restricted, consider barrier lining.</li> <li>• If at a location of local widening (e.g. at an intersection), check that it does not look like an overtaking lane. Consider altering right turn lane markings.</li> <li>• Where justified, consider separation of opposing flows by means of a painted median with or without rumble strips or by means of a raised median where economically justifiable.</li> </ul>	<ul style="list-style-type: none"> <li>• Consider increasing the number of overtaking opportunities by duplication or overtaking lanes.</li> <li>• If occurring on a divided roadway, consider improving delineation, widening of the median, provision of a median barrier or, if due to wrong way manoeuvres at intersections, check design, signs and lighting at intersections.</li> <li>• Consider removing or relocating that may encourage drivers to drive further to the centre of the road. This includes poles, trees, and barriers in close proximity to the roadside.</li> <li>• Check that the speed limit is appropriate.</li> </ul>
<b>Run-off-road type crashes</b>	
<ul style="list-style-type: none"> <li>• Consider improved delineation, including post-mounted delineators, RRPMs, edgelines, tactile edgelines and chevron alignment markers.</li> <li>• Consider a delineation package to treat all curves on rural high-speed roads. The amount of delineation would match the risk level of the curve (difficulty). The higher risk, the more intense the delineation.</li> <li>• If at an isolated curve, consider adequacy of alignment design and superelevation. Aim to remove need for drivers to reduce speed at curves.</li> <li>• Widen the lanes or seal the shoulders.</li> <li>• If at critical curves, consider warning signs and advisory curve speed signing.</li> </ul>	<ul style="list-style-type: none"> <li>• Widen the edgeline on curves.</li> <li>• If in urban areas with a high night-time crash involvement, consider street lighting.</li> <li>• If there is a high incidence of wet weather crashes, check surface texture, skid resistance and pavement drainage.</li> <li>• Check that the speed limit is appropriate.</li> <li>• If a conflict point, such as an intersection, is placed towards the base of a long, steep gradient, consider removing or signalling conflict.</li> </ul>

<b>Hit fixed object crashes</b>	
<ul style="list-style-type: none"> <li>• As well as providing the run-off-road crash treatments listed above:                             <ul style="list-style-type: none"> <li>– Remove or relocate objects to less vulnerable positions.</li> <li>– Consider relocation or use of frangible lighting poles or sign posts.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• If an object cannot be relocated or made frangible, consider provision of guardrail, crash barriers or a crash cushion.</li> <li>• If an object is an island, illuminate or delineate it; provide linemarking beside and past it.</li> </ul>
<p>Note: removing a tree or object does not prevent the vehicle from being out-of-control, but this measure will be expected to reduce the crash severity outcome of this type of crash.</p>	
<b>Crashes involving a parked car</b>	
<ul style="list-style-type: none"> <li>• Prohibit parking.</li> <li>• Indent parking, clear of the traffic lane.</li> <li>• If angle parking is involved consider conversion to parallel parking.</li> <li>• Consider increasing the clearance between the parking and through traffic lanes.</li> </ul>	<ul style="list-style-type: none"> <li>• Delineate the edge of the traffic lane past the parking area.</li> <li>• If there is high night-time crash involvement, prohibit parking or consider adequacy of or the provision of street lighting.</li> <li>• Consider whether it is appropriate to implement treatments listed for run-off-road and hit fixed object crashes.</li> </ul>

**Table 4.5.6(c) – Countermeasures for pedestrian / vehicle crashes**

<b>Countermeasures for pedestrian / vehicle crashes</b>	
<ul style="list-style-type: none"> <li>• Consider provision of pedestrian operated signals (including pelican type).</li> <li>• If at a zebra crossing on a busy road, consider replacing it with a refuge, a median or pedestrian operated signals.</li> <li>• Install a pedestrian (zebra) crossing where this can be done safely (e.g. on left-turn slip lanes).</li> <li>• Consider barriers to inhibit jay walking.</li> <li>• Consider parking prohibition and/or provide footpath extensions (into a parking lane) to improve pedestrian sight lines and reduce pedestrian crossing distance.</li> <li>• Consider the installation of pedestrian refuge islands so pedestrians need find gaps in only one traffic direction at a time.</li> <li>• Where a high frequency of night crashes is involved, consider adding or amending street lighting.</li> </ul>	<ul style="list-style-type: none"> <li>• If there is a high pedestrian demand at an unsafe location, consider installing a pedestrian overpass.</li> <li>• Check that the speed limit is appropriate.</li> <li>• Consider local street traffic management measures such as road humps, raised pedestrian crossings, slow points, etc. to reduce vehicle speeds.</li> <li>• If at a signalised intersection consider adequacy of existing walk and don't walk intervals, consider provision of exclusive pedestrian phase, early start for walk display or ensure walk displays show on both sides of the intersection when button is pressed on one side.</li> <li>• If at mid-block pedestrian-operated signals, consider reducing delay to walk signal (e.g. double phasing within the cycle). If visibility is restricted: clear the sight lines or relocate crossing to where visibility is adequate.</li> <li>• Consider a lower speed limit. This measure may require traffic speed management treatments.</li> </ul>

**Table 4.5.6(d) – Countermeasures for railway level crossing crashes**

<b>Countermeasures for railway level crossing crashes</b>	
<ul style="list-style-type: none"> <li>• Check adequacy of advance warning signs and markings. Consider advance signals or vehicle-activated warning signs.</li> <li>• Check the sight distance available and improve if practicable. Consider road realignment where economically justified.</li> <li>• If there is a high night-time crash involvement, consider provision of street lighting.</li> <li>• Where no warning bells and lights exist, consider their provision where economically justified.</li> <li>• Consider lowering the speed limit on high-speed roads and heavy vehicle routes.</li> <li>• Check adequate stacking distance is available between adjacent control points (intersections) and rail, if not consider alternative routes for long vehicles.</li> <li>• Consider grade separation.</li> <li>• Consider overhead mast arm flashlights.</li> <li>• If the railway crossing is equipped with bells and lights, consider adequacy of their visibility and audibility.</li> <li>• Where justified, consider the provision of double-side boom barriers.</li> <li>• Make consistent with other nearby crossings.</li> </ul>	<ul style="list-style-type: none"> <li>• Where signals or booms are visible but ignored, consider red light cameras.</li> <li>• If flashlight controlled level crossing is adjacent to traffic signals, link to traffic signals to provide an early clearance phase.</li> <li>• Remove roundabouts installed close to level crossings as they can lead to queuing on level crossings.</li> <li>• If vehicles queue on a crossing add a queue detector downstream of the crossing linked to traffic signals upstream of the crossing to stop vehicles from entering the crossing when queues are present.</li> <li>• If vehicles queue on the crossing add yellow box hatching and 'keep crossing clear' signs.</li> <li>• If crossing has 2 tracks and trains can arrive from either direction at the same time, install boom barriers.</li> <li>• Provide rumble strips to highlight the approach to the crossing.</li> <li>• Provide visual traffic calming measures to encourage slower approach speeds towards the crossing.</li> <li>• Upgrade passive railway level crossing to active railway level crossing.</li> <li>• Provide median barriers.</li> </ul>

#### **4.6 Crash Modification Factors**

Detailed information exists on the expected benefits that are likely to come from different engineering treatments. The benefits are termed Crash Modification Factors (CMFs, expressed as a fraction, indicating the expected remaining crashes) or Crash Reduction Factors (CRFs, expressed as a percentage reduction). Ideally, the reduction in death and serious casualties would be used, but unfortunately information that breaks crash reduction down by severity is rare. Instead, the reduction in casualty crashes is often used as a proxy.

CMFs provide an indication of the expected remaining casualty crash rate following the implementation of a typical countermeasure. This will help the practitioner choose the treatments that are likely to bring about the greatest safety benefits depending on the crash types targeted.

The CMF serves as a simple multiplication factor applied to the existing crash rate. Therefore, a CMF of less than one indicates a reduction in the crash rate, whilst a CMF greater than one indicates an increase.

Reliable information on crash reduction has been produced by Austroads (2012c) for use in Australian and New Zealand conditions. Appendix E shows CMFs for various treatment options in Queensland. Please note: Queensland uses CRF's (expressed as a percentage reduction) and so will apply as the inverse of the equivalent CMFs as discussed in this document.

For example, if  $CMF(Treatment A) = 30\%$ ,  $CRF(Treatment A) = 70\%$  for DCA Group X crashes.

Extensive information on CMFs is also available from overseas (e.g. Elvik et al. 2009; CMF Clearinghouse from the US, see [www.cmfclearinghouse.org](http://www.cmfclearinghouse.org)). Overseas sources of information on CMFs should be used with caution, as the environment where such treatments were used may be different to local conditions. Evaluations of treatments also have variable quality, so care should be taken when selecting these.

Crash countermeasure selection is not as simple as identifying the treatment with the lowest CMF. The practitioner should identify the most applicable treatment for the crash type and road environment considered, and then consider the relevant CMF.

Crash Reduction Factors (CRFs) are often also referred to. These provide information on the expected percentage reduction (or increase) in casualty crashes (i.e. a CMF of 0.8 would be the same as a CRF of 20%).

Care should be taken when applying CMFs to ensure that the treatment type being considered will appropriately address the crashes of concern, and not result in any adverse impacts. Appendix C.4 presents practical examples of what to consider when applying CMFs.

The development of CMFs is an ongoing process (Beer & Beer 2017), with these values further refined as new information comes to light. Most jurisdictions provide their own list of CMFs. Austroads also conducts and publishes research in this field (see Austroads 2010d and Austroads 2012c).

#### 4.6.1 Multiple treatments

It is often the case that more than one treatment will be applied at the same location. As an example, at a rural bend where road users are running-off-road, and where site investigation justifies this, improvements could be made to the road surface as well as to delineation (e.g. new signs and road markings). An analysis of treated crash locations in New Zealand identified that around 80% of sites used a package of countermeasures to address crash risk (e.g. Turner & Tziotis 2006).

In such situations, CMFs cannot simply be added together. If this were to happen, inclusion of more treatments would eventually lead to a situation where the expected crash reduction would exceed 100%. Instead, a diminishing return is usually expected with each additional treatment type. A number of techniques exist to calculate the cumulative benefit of more than one treatment. The most common approach used is application of

$$CMF_t = CMF_1 \times CMF_2 \times CMF_3 \times \dots$$

where:

$CMF_t$  = total crash modification

$CMF_x$  = individual crash modification for treatment 'x'

Whilst each treatment acts to reduce crashes, the impact of each successive crash on reducing the numbers of crashes is diminished.

In some cases there will be diminishing returns similar to those identified in the formula above. In other cases, the addition of treatments may produce negligible additional benefit, or treatments may act together to provide benefits greater than the sum of the individual treatments. Professional judgement is required when making estimates of the combined benefits of more than one treatment.

#### 4.6.2 Step 1: Select the most appropriate countermeasure(s)

Using a combination of the treatment hierarchy discussed in previous sections and road safety engineering judgement, select either:

- one solution
- a combination of solutions, and
- two alternative solutions (e.g. lower and higher cost solutions with different crash reduction effects), for the repeated crash types at the location.

#### 4.6.3 Step 2: Apply CMFs

Use Appendix E (or alternative, robust sources of effectiveness values – noting that each crash-based program may have its own CMFs that apply) to determine the effect of the proposed treatment. The cost information in Appendix E will be used in Section 6 of Part 1 to estimate the economic benefit of the proposal.

Do not, as a first step, go to Appendix E to find a solution which produces a good benefit/cost ratio to justify a project. Step 1 must always be applied first, to match any solution to the factors contributing to the crash types.

For example, CMFs are available to estimate the crash reduction as a result of applying audio-tactile edgelines as a countermeasure to combat run-off-road crashes.

**Figure 4.6.3 – Audio-tactile edgelines as a remedial treatment for run-off-road crashes**



## Documentation

After these steps, document the selection of the countermeasure/s, in a format suitable as part of the final crash location investigation and treatment report (Section 8 of Part 1). It will include:

- a list of the proposed treatments which are designed to counter the identified crash causes (with mention made about which treatment is aimed at which problem), and
- a plan of the preliminary design of the countermeasures.

The document may put forward 2 or more options to be considered, i.e. each with unique costs and effects on crash reduction.

### 4.7 Implementing the treatment

#### 4.7.1 Designing a safe remedial treatment

##### Preparing a preliminary design: show the solution is practicable

The selected countermeasures need to be developed into a preliminary design in order to:

- show the general practicability of the countermeasures at this location
- check the compatibility of the proposals with the surrounding roads and intersections
- establish whether there is adequate space, or whether land acquisition is required
- check the vertical geometry for basic issues such as sight distance
- allow further consideration of options, and
- permit an initial cost estimate, so that an economic appraisal can be made

##### Have the design road safety audited (or Safe System Audited)

Once this is done, the preliminary design should be road safety audited. An audit is a formal examination of a design by a qualified team with experience in road safety engineering (see QGRS Part 6: *Road Safety Audits* and the QRSTUV: *Guide to Safe System Assessments*). An audit is an input into the design process. Its aim is to help the designer produce a safe design, by identifying any foreseeable safety problems that the design may contain.

Where feasible a road safety audit should be conducted at the following stages:

- the feasibility stage
- the preliminary design stage
- the detailed design stage, and
- prior to opening of the project.

Refer to the QGRS Part 6: *Road Safety Audit* for further guidance on conducting RSAs in Queensland.

The earlier a design is audited, the easier and more cost-effective it is to consider and incorporate changes, resulting in less wasted design time and effort.

Designs for crash remedial treatments should not be considered to be immune from potentially unsafe design flaws. Indeed, because the aim of a treatment is to reduce the number or severity of crashes, it would be unfortunate if new and unforeseen crash problems were to result from some aspect of the new design. The chances of this happening can be minimised by having the design road safety audited.

### **Completing a detailed design**

Detailed design can occur at any stage after the preliminary design. This may mean that it occurs well after the crash location treatment report (Section 8 of Part 1) is finalised.

The detailed design will incorporate all the information required to permit the treatment to be implemented safely. This will include details such as signs, markings, landscaping and lighting, as well as those recommendations from the preliminary design audit which the project manager has decided to adopt.

Depending on the scale of the project and the safety design issues identified in the preliminary design audit, the detailed design may also benefit from a road safety audit (see the practical example in Appendix C.5).

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### **Design of devices**

Devices are installed on roads for a range of reasons, for example:

- traffic management treatments to reduce speed
- kerbs, gutters and culverts to collect and disperse rainwater runoff
- guide posts to hold reflectors for night-time delineation
- signs to provide traffic control, warning or guidance
- posts to hold signs or delineators
- crash barriers to shield roadside hazards
- traffic signal poles to hold up traffic signal lanterns and detectors
- utility poles to provide services (generally a non-road function, or lighting), and
- medians and barriers to separate opposing flows.

Each of these devices has the potential to inflict damage and injuries in the event of a vehicle or vehicle occupant leaving the roadway. Recognition of the injury causing effects of device design has led to the concept of a clear zone, the development of frangible posts and barrier end treatments and the extensive use of low profile, mountable kerbs. But many devices are of the same fundamental design as they were before the safety of errant vehicles and vehicle occupants took on the importance it has today.

Practitioners are faced with a limited choice for the physical devices that they can use in traffic management: some devices which have undergone safety development have complex failure mechanisms and modification requires a detailed understanding of them (e.g. w-beam guard fence). However a broad understanding of the principles of safe design for traffic devices will allow practitioners to assess the suitability of existing devices and new products which may be marketed without specific consideration of impact safety.

Using standards does not guarantee a safe road design, but it is an important starting point. The intersection shown in Figure 4.7.1 is potentially confusing by having Give Way controls on 3 of the 4 legs, instead of just 2 opposing legs. The holding lines do not have an approach centreline, making them harder to detect. These matters are covered by the national standard on traffic control devices (Australian Standards AS 1742.2).

**Figure 4.7.1 – Example of an intersection where layout and priority are confusing**



#### **4.8 Implementing the treatment**

Once the countermeasure has obtained funding it can be procured and implemented. It is vitally important that the design which is being implemented accords with the results of the crash investigation: that it has not been modified or trimmed to the point where it will not have a meaningful effect on the crash problem. If it is being implemented in conjunction with other works at the site or nearby, it is important that these other works do not introduce any new safety problem. If there is any reason for concern, road safety engineering advice (e.g. in the form of a detailed design stage road safety audit) should be sought.

Prior to committing remedial works to commence practitioners should check that the assumptions upon which the report's conclusions and recommendations are based have not changed in the intervening period.

During the implementation phase, traffic safety will continue to be important. Works zones can be potential places for crashes, due to the changes in road layout and the temporary absence of permanent kerbing, delineation, markings or signs. Works zone traffic controls need to be planned before works commence and carried out in a manner which provides safety for the travelling public and works personnel. National and state guidelines on roadwork traffic management should be complied with. For larger, more complex projects, a road safety audit of the construction stage should be considered. This involves auditing the traffic management plans and undertaking site inspections during the construction.

Once the works have been completed, the project can be the subject of a pre-opening road safety audit, to ensure it is implemented as planned and with no unexpected road safety hazards introduced.

## **5 Economic appraisal**

The key objectives of economic appraisal are to ensure that treatments are cost-effective, and that they optimise road safety benefits producing the greatest reduction in fatal and serious injury based on available budgets. The term appraisal is used here to refer to the analysis of measures before they have been undertaken. By contrast, the word evaluation is used to refer to the analysis of measures after implementation. The word evaluation is sometimes used generically to refer to either process, but the terminology used here is consistent with current practice.

This section of the document provides an overview of the economic appraisal approach. Appraisal approaches include cost-effectiveness analysis (CEA) and benefit cost analysis (BCA) (also referred to as cost benefit analysis). Benefit cost analysis uses monetary values to compare total benefits with total costs of any given countermeasure indicating whether a project is worthwhile and to determine the applicability of an investment based on the total benefits and costs of the investment. It is also used to compare a project with any alternative projects, isolating and measuring the benefits and costs of each project.

The steps for conducting BCAs are outlined below and discussed in the following sections.

- Project definition: identify the crash problem, define the target and outline treatment options.
- Define base case and project options.
- Determine parameters (e.g. treatment life, discount rate, time frame etc.).

Identify and quantify all impacts (benefits and costs, in terms of treatment effectiveness i.e. the target number of crash reductions; implementation, maintenance and operation costs, social cost of crashes etc.).

- Convert all benefits and costs to present values (discounting).
- Calculate the benefit cost ratio and net present value.
- Sensitivity analysis.
- Report and present results.

Practical examples are provided in Appendix C.7.

## **5.1 Cost of crashes and remedial treatment options**

### **5.1.1 Treatment options**

The first step in the analysis is to identify the scale and nature of the road safety problem. This entails obtaining the number of observed crashes and injury types (e.g. fatal, serious, minor) over a specific period of time. The data forms the basis from which reductions in crash occurrence and severity, and thus benefits are estimated.

Countermeasure options generally differ in levels of expenditure and maintenance costs. Treatment options selected will depend on the direct impact on the identified crash problem. As discussed in previous sections, this involves selecting targeted remedial treatments that have been demonstrated to reduce the likelihood and/or severity of these crashes.

An assessment of the safety problems at a site may lead to recommendations for very low cost engineering treatments, such as a few signs, or some added line marking, or chevron alignment markers around a curve. The example in Appendix C.6 is an illustration of where a crash investigation team expected 6 signs and some minor line marking to have a significant effect on the crash type investigated – at least until a higher cost, permanent treatment could be funded.

If a very low cost treatment is judged to be an effective course of action, there is little point undertaking a full economic appraisal of it. It may well cost more in time and effort to justify the expenditure than to implement the treatment. It should simply be implemented as soon as possible, e.g. using a budget allocation for minor safety works or for maintenance. But keep in mind:

- Any very low-cost treatment must actually reduce the identified crash type(s).
- There is a limit to how effective very low-cost treatments can be; to treat most crash locations a significant expenditure of money will be required.
- Avoid the temptation to solve every problem by putting up a sign although it is also important to check existing signs are appropriate and well maintained.

### **5.1.2 Cost of crashes**

A key component of benefit cost analysis is the cost of crashes. The benefits from safety countermeasures over time are estimated by placing an economic value on crashes and applying this to the expected reduction in crashes (by injury or crash severity). This economic value, referred to as the social cost of crashes, is the value of property damage caused by vehicle crashes, medical and ambulance costs, insurance and administration costs, loss of output costs, police costs and human costs associated with the pain and suffering caused by death and injury. In Australia, the cost of crashes are calculated using both the human capital and the willingness-to-pay approaches while in New Zealand, the willingness-to-pay approach is used. The cost components are outlined in Table 5.1.2(a) below.

**Table 5.1.2(a) – Crash cost components for Australia and New Zealand**

Crash cost components for Australia	Crash cost components for New Zealand
<ul style="list-style-type: none"> <li>• Human costs - ambulance costs, hospital in-patient costs, other medical costs, long-term care</li> <li>• Labour in the workplace, labour in the household, quality of life</li> <li>• Insurance claims, criminal prosecution, correctional services, workplace disruptions, funeral, coroner</li> <li>• Vehicle costs- repairs, unavailability of vehicles, towing</li> <li>• General costs- travel delays; insurance administration, police, property, fire</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of life and life quality (permanent disability)</li> <li>• Loss of output (temporary disability)</li> <li>• Medical costs – hospital/medical costs, emergency/pre-hospital costs, follow-on costs</li> <li>• Legal and court costs</li> <li>• Vehicle damage costs</li> </ul>

Source: Ministry of Transport (2013) and Transport and Infrastructure Council (2015)

There have been many projects and considerable debate about the best way to determine crash costs but it is now generally accepted that only 2 methods should be considered: the willingness-to-pay (WTP) and the human-capital (HC) approaches. The WTP approach values society's willingness to pay for avoiding death, injury, and damage outcomes from road crashes. The HC approach is described as 'resting on accounting principles, the benefit of avoiding a premature death is given by the present value of the income flow the economy could lose in that case' (Rizzi and Ortuzar 2005). For a detailed description of these approaches, see *Bureau of Infrastructure, Transport and Regional Economics* (2006), Austroads (2012a), and the World Road Association (PIARC 2012).

Costs must be determined for crashes of varying levels of severity, that is, fatal, serious injury or minor injury. These severity levels have been defined in previous sections. The costs also vary by environment (urban and rural road environments) as outlined in the tables below showing the human capital and willingness-to-pay estimates respectively.

For example, see the tables below.

**Table 5.1.2(b) – Human capital average crash cost estimates for Australia at June 2013 prices (A\$)**

Jurisdiction	Rural			Urban		
	Fatal crash (\$)	Serious injury crash (\$)	Other injury crash (\$)	Fatal crash (\$)	Serious injury crash (\$)	Other injury crash <sup>(1)</sup> (\$)
Queensland	2 728 617	642 034	25 822	2 456 691	595 802	23 760

Note:

<sup>(1)</sup> Minor crashes.

The willingness-to-pay values for Australian jurisdictions were obtained using the willingness-to-pay estimates from Hensher et al. (2009) and crash data for 2010. The values were updated to June 2013 prices.

**Table 5.1.2(c) – Willingness to pay average crash cost estimates for Aus and NZ June 2013 prices (A\$)**

Jurisdiction	Rural			Urban		
	Fatal crash (\$)	Serious injury crash (\$)	Other injury crash (\$)	Fatal crash (\$)	Serious injury crash (\$)	Other injury crash <sup>(1)</sup> (\$)
Queensland	8 059 079	294 906	31 268	7 741 325	436 471	23 446

Note:

(1) Minor crashes.

For the purpose of prioritising actions aimed at reducing crash frequency, a single average cost for all injury crashes is generally considered sufficient, particularly in view of the difficulty in predicting the specific severities of crashes that might be prevented.

The value of the crash reduction benefits is calculated using the standardised costs of particular crash types (DCA codes). Table 5.1.2(d) illustrates this information for an Australian State. The dollar values in the table will be different in each state and territory as they are affected by the proportion of recorded crashes (by crash type) which are non-injury. This varies from jurisdiction to jurisdiction. Otherwise check with the road agency for up-to-date values applicable to the location being assessed.

**Table 5.1.2(d) – Example crash costs by crash type (A\$)**

DCA code group	DCA codes	Description	Low speed (<80 km/h) (\$)	High speed (80 km/h +) (\$)
1	100-109	Intersection, from adjacent approaches	93 440	213 559
2	201, 501		213 320	372 921
3	202-206		92 482	183 888
4	301-303		46 421	89 850
5	305-307, 504		72 502	223 250
6	308, 309		64 845	182 572
7	207, 304		88 654	187 826
8	401, 406-408		65 683	122 034
9	503, 505, 506		87 816	139 621
10	402, 404, 601, 602, 604, 608		65 802	147 756
11	903		256 262	822 591
12	001-009		196 929	347 437
13	605		89 611	151 705
14	609, 905		48 215	53 838
15	502, 701, 702, 706, 707		72 502	147 756
16	703, 704, 904		139 023	251 365
17	705		100 977	194 297

DCA code group	DCA codes	Description	Low speed (<80 km/h) (\$)	High speed (80 km/h +) (\$)
18	801, 802		122 871	216 909
19	803, 804		164 626	281 156
20	805, 806, 807		104 925	143 449
21	000, 200, 300, 400, 500, 600, 700, 800, 900, 901, 906, 907, 403, 405, 606, 607, 610	Crashes which are unlikely to be attributable to any road environment factor, and which are therefore unlikely to be addressed by any road-based remedial treatment. Crashes in this DCA code group will not be used in crash rates or BCR calculations or reports.		

For the latest WTP average crash costs, see Appendix A

## 5.2 Calculating the costs and benefits

### 5.2.1 Key parameters

The key parameters for estimating countermeasure benefits and costs include the countermeasure's treatment life, costs, benefits and the discount rate.

#### Treatment life

Project or treatment life refers to the time period over which a treatment will deliver safety benefits before major rehabilitation or replacement is required. The treatment life varies with type and scope of project, climate causing infrastructure to deteriorate, traffic volume either causing infrastructure to deteriorate or growth causing congestion requiring changes to infrastructure, local standards and resource availability affecting ability to replace infrastructure when due and level and regularity of maintenance (Austroads 2010c).

For projects involving multiple treatments e.g. network or national blackspot programs, the service life applied is that of the longest-lived component. According to Austroads (2010c), accurate information on a countermeasure's life helps determine the allocation of funds so as to achieve the most cost-effective returns in terms of injury and crash reductions. Table 5.2.1 below outlines example treatment lives for the different countermeasures.

**Table 5.2.1 – Treatment life examples**

Treatment type	Recommended maximum treatment life (years)
Grade separation	50
Realign curve	35
Stagger or realign intersection	35
Roundabout	30
Median barrier	30
Shoulder sealing or widening	25
Add or widen lane (including overtaking lane)	25
Provide acceptable superelevation	25
Railway level crossing barriers	20

Treatment type	Recommended maximum treatment life (years)
Median island (or other island)	20
Guardrail (roadside)	20
Street lighting	20
Remove roadside hazard (trees, pylons, etc.)	20
New traffic signals (hardware and/or software)	15
Improve sight distance by removing impediment on main road	10
Edge marker posts (guideposts)	10
Skid resistant surface	10
Signs (advisory, warning, parking, speed limit, etc.)	10
Linemarking (thermoplastic)	5
Raised reflectorised pavement markers	5
Linemarking (paint)	3

### Costs

Total countermeasure costs include: implementation (installation, material and labour costs), routine and periodic maintenance, and any operating costs (e.g. electricity supply).

There are different definitions of treatment costs with some texts defining costs as initial or upfront costs only and others treating costs as both initial and operating/maintenance costs. It is common practice to include changes in maintenance expenditure on the costs side of the equation, as these are a cost (or saving) to the road agency. This section will treat ongoing/operating costs as negative entries in the benefits balance sheet. Whichever definition is chosen, it is important that it be applied consistently, because criteria based upon dividing one number (e.g. costs) into another (e.g. benefits) will produce different values depending upon the definition of costs and benefits. Funding programs or government agencies (e.g. treasury) often specify what must be included in costs.

#### Initial cost (e.g. engineering and capital)

Initial costs refer to the costs incurred up-front, as the project is designed and built (implementation costs) e.g. installation, material and labour costs for each countermeasure. The costs differ by road environment type, traffic volumes, local environment, local labour costs and availability of materials (Australian Transport Council 2006, Austroads 2012a).

#### Annual maintenance and operating costs

These costs refer to routine and periodic maintenance costs and running costs. The level and regularity of maintenance and associated running costs depend on the countermeasure or in the case of multiple treatments, countermeasures.

## Benefits

The benefits of a safety countermeasure principally comprise savings in road crash costs which are estimated to result from its implementation. They are due either to a reduction in the number or the severity of crashes. Other significant cost reductions or increases resulting from the treatment should also be included. Unlike the cost, which is usually incurred in one (or possibly 2) years when the project is designed and built, the benefits are gained over the life of the project.

Benefits are expressed in terms of monetary savings from crash reductions or prevention of casualties (fatalities and injuries) over a given number of years. For example, in the case of crash location treatments, the estimate of resulting crash changes reflects the changes in target crashes (i.e. crash types the treatment is aiming to prevent).

The crash changes can be presented as crash rates (e.g. per 100 million vehicle-kilometres of travel) or as changes in the number of casualty crashes. The use of crash rates as an estimate of crash changes depends on whether they reflect the number of crashes and crash severity and how they are measured (Bureau of Infrastructure, Transport and Regional Economics 2012). In some cases, the crash rate may not fully reflect the changes in crash severity. The effectiveness and magnitude of crash changes vary, for example by road environments, i.e. built-up (urban) and non-built-up (rural); and the existing crash severity and type.

Treatment effectiveness is measured by crash modification factors (CMFs) as outlined in further sections. Different methods are used to obtain the numbers of crashes avoided and to estimate the treatment effectiveness. The estimate of treatment effectiveness depends on different factors including data availability related to the past performance of the treatment, estimation method (i.e. whether confounding factors are taken into account), local conditions and changes in traffic volumes over time. In the case of multiple treatments, evaluation studies traditionally identify and measure the effectiveness of the primary or main treatment.

### 5.2.2 Discounting

In any economic appraisal, it is important to identify a given base year from which all future costs and benefits can be assessed. This is because the value of a dollar received in the future is less than the value of a dollar now (also referred to as the time value of money). Crucial to this process is the appraisal period, base year and discount rate.

#### Appraisal period

The selection of an appraisal period has a critical impact on the value of benefits and costs. The potential economic / treatment life of the project should only be used as the appraisal period after careful consideration because traffic patterns, traffic management objectives, technology, etc. may all change over the whole economic life of the works.

For example, the period used for appraisal for road marking projects will usually be no greater than 5-years, while those for signing and road surface improvements will generally not exceed 10-years. For construction of new works, the appraisal period will generally be up to around 20-years, although in some circumstances (e.g. grade separation or curve realignment), the appraisal period may be far greater. Specialists in individual jurisdictions should be consulted regarding appraisal periods.

### Base year

The base year is the year to which all monetary values for the impacts (benefits and costs) of a treatment are discounted. According to Austroads, the base year for small projects is usually the first year of implementation but varies from the year preceding construction to the year preceding operation or the last year of construction.

### Discount rate

The discount rate is used to convert future benefits and costs to present values. The appropriate discount rate for this form of economic appraisal is often a matter of some disagreement. Often, it is prescribed by another arm of government (a treasury or department of finance) in order to maintain consistency across different agencies. In Australia, values of 4 to 7% are in common use while in New Zealand the discount rate is 8%. These are real values, i.e. the nominal value minus the rate of inflation.

The choice of discount rate can have significant effects on the desirability and selection of projects, especially where benefits and costs accrue later in the treatment's life. A higher discount rate reduces the value of benefits and costs occurring later in the treatment's life, favouring projects where benefits occur early in the project as illustrated in Table 5.2.2 below.

**Table 5.2.2 – Illustrating discount factors for different discount rates**

Year	Discount Rate			Year	Discount Rate		
	4%	7%	8%		4%	7%	8%
0	1	1	1	16	0.534	0.339	0.292
1	0.962	0.935	0.926	17	0.513	0.317	0.27
2	0.925	0.873	0.857	18	0.494	0.296	0.25
3	0.889	0.816	0.794	19	0.475	0.277	0.232
4	0.855	0.763	0.735	20	0.456	0.258	0.215
5	0.822	0.713	0.681	21	0.439	0.242	0.199
6	0.79	0.666	0.63	22	0.422	0.226	0.184
7	0.76	0.623	0.583	23	0.406	0.211	0.17
8	0.731	0.582	0.54	24	0.39	0.197	0.158
9	0.703	0.544	0.5	25	0.375	0.184	0.146
10	0.676	0.508	0.463	26	0.361	0.172	0.135
11	0.65	0.475	0.429	27	0.347	0.161	0.125
12	0.625	0.444	0.397	28	0.333	0.15	0.116
13	0.601	0.415	0.368	29	0.321	0.141	0.107
14	0.577	0.388	0.34	30	0.308	0.131	0.099
15	0.555	0.362	0.315	31	0.296	0.123	0.092

Note: Refers to the number of years from base year.

### 5.2.3 Calculating costs and benefits

Selection criteria in benefit cost analysis include the first-year rate of return (FYRR), the internal rate of return (IRR), benefit cost ratio (BCR) and incremental benefit cost ratio (IBCR) as well as net present value (NPV). However, the 2 main indicators in assessing a project or treatment are the BCR and the NPV. They indicate whether the benefits of the proposed treatment outweigh the costs and if the preferred treatment has the greatest net social benefit.

Benefit cost ratio (BCR) is defined as the present value of benefits (net operating and maintenance costs) divided by the present value of implementation costs. It is used to rank projects where there is a budget constraint and serves as an indicator of a project's economic efficiency.

$$BCR = \frac{PV(B - OC)}{PV(IC)}$$

where:

$PV$  = present value

$B$  = all benefits

$OC$  = treatment operation and maintenance costs

$IC$  = treatment implementation costs

A BCR greater than 1.0 indicates that the alternative is worthwhile, and the greater the BCR, the higher the benefits are. However, this says nothing in itself about whether a project should be undertaken. Although the approach can determine whether a project is worthwhile, ranking according to BCR will not necessarily maximise reduction in fatal and serious crash outcomes. BCR tends to provide more favourable outcomes to low-cost treatments, which may be less effective in terms of fatal and serious casualty reduction. For example, installation of warning signs, although providing a high BCR tend only to marginally reduce fatal and serious crash outcomes marginally. For this reason, it is recommended that BCR not be used on its own when prioritising options, but rather NPV also be used. See Section 5.3 of Part 1 for further information.

#### Net present value

Net present value (NPV) is the difference between the discounted (present value) monetary value of all the benefits and costs of a particular project or measure. A treatment with a positive NPV can be regarded as economically worthwhile, i.e. the community is better off to undertake it than not. A positive NPV therefore indicates an improvement in economic efficiency compared with the base case. The NPV is expressed as:

$$NPV = \sum_{t=0}^n \frac{B_t - OC_t - IC_t}{(1+r)^t}$$

where:

$t$  = time in years

$n$  = number of years during which costs and benefits occur

$B_t$  = benefits in year  $t$

$OC_t$  = operating and maintenance costs in year  $t$

$IC_t$  = Implementation costs in year  $t$

The major methodological advantage of the NPV method compared with the BCR method is that it provides a consistent, simple comparison of alternatives and is unaffected by interpretations or errors in deciding what is a cost or a benefit. Moreover, the NPV method is applicable where there is a budget constraint

### **Conduct sensitivity tests**

An economic appraisal should always be subjected to a sensitivity test. This is a test to determine how sensitive the results are to changes in the assumptions made about the values of variables.

In particular, a range of expected crash reduction percentages should be assessed, since one can never be certain about the actual outcome. Using a low and a high estimate of possible and realistic outcomes is always good practice. If the outcome is favourable, even when a pessimistic forecast of crash reduction is used, one can be confident that the project is worthwhile. Conversely, if the outcome is unfavourable even with optimistic assumptions, one can be confident that the project is unlikely to be worthwhile.

It is in the middle ground (favourable under optimistic assumptions and unfavourable under pessimistic assumptions) where effort should be put into refining the estimates of assumed values to get a better forecast of benefits and costs. Austroads (2012a) provides further information on sensitivity testing.

### **5.3 Ranking the treatment of crash locations**

Once each countermeasure has been subjected to an economic appraisal, all the candidate projects need to be ranked to decide which one to implement. Usually this means comparing all projects' NPVs or BCRs. The key objective is to provide the greatest benefit (reduction in fatal and serious crash outcomes) for the available budget. The economic appraisal is an aid to decision making. If all decisions are based on benefit / cost ratios alone, a situation can arise where, for example:

- a project is delayed until the number (cost) of crashes is sufficient to justify the project, even though at the time it is delayed it can be reasonably predicted that the rate of crashes will continue unabated
- the cost of a treatment is artificially restricted, and it does not include sufficient improvements to address the crash problems.

Consequently, the ranking procedures described in this section should not preclude decision makers from applying sound judgement to approve projects which need to be advanced, or which need adequate funding to achieve project objectives.

The choice of selection / ranking criteria depends primarily on available data as well as the scope of the treatment. The NPV provides information on the total welfare gain over a project's treatment life while the BCR highlights the relationship between the present value benefits and implementation costs of a project (PIARC 2012).

The NPV method is applicable where there is a budget constraint, and the aim is to select the most worthwhile set of projects. In this case, the solution is to 'combine those projects whose total initial costs are less than or equal to the budget constraint but whose combined total net value is the largest' (Wohl & Hendrickson 1984, p.173).

**The benefit / cost ratio itself must not be used to rank alternatives.** Rather, ranking involves a comparison of all alternatives with a BCR > 1. Generally, the NPV is the preferred criterion as it provides an estimate of the absolute size of the treatment's net social benefit. Table 5.3 below provides guidance on when to use the different criteria.

**Table 5.3 – Decision criteria for economic evaluation**

Criterion			
Budget	Decision	Net present value (NPV)	Benefit-cost ratio (BCR)
Unconstrained budget	Accept-reject decision	Accept if NPV is non-negative	Accept if BCR exceeds / equals unity
	Option selection	Select project with highest non-negative NPV	No rule exists
Constrained budget	Accept-reject decision	Select project such that NPV of project set is maximised subject to budget constraint	Rank by BCR until budget is exhausted or BCR cut-off reached
	Option selection	Highest NPV subject to budget constraint	No rule exists

An alternative approach is to apply the goals achievement approach, whereby projects are ranked but no attempt is made to assess their economic benefits against their costs.

For a comprehensive step-by-step approach on economic appraisals as well as a summarised discussion of the selection criteria, see Austroads (2005b), Australian Transport Council (2006), Bureau of Infrastructure, Transport and Regional Economics (2012), and the World Road Association (PIARC 2012).

### 5.3.1 A useful checklist

With economic appraisal of proposals increasingly required for road safety engineering projects, here is a useful checklist, particularly in conjunction with sensitivity testing (based on Andreassen 1992a, p.11):

- identify the project costs in terms of capital, maintenance and operating costs
- select an appraisal period
- chose a discount rate
- define the effects on various crash types
- differentiate between the effects of this treatment on (i) crash frequency (numbers) and (ii) casualty outcomes (severities)
- use robust data to estimate the effects of this treatment on the frequency of crash types
- identify the crash type or types in which this treatment is likely to have its greatest effect on the casualty outcome, and
- identify other crash types in which this treatment may have some effect on the casualty outcome.

## **5.4 Presenting the results**

Having conducted the economic appraisal, present the results in a form which allows the decision maker to review the values for net present worth of benefits and costs and the values of the selected relevant variables. Tabular or graphical presentations, highlighting the economic benefits, the crash savings and the expected performance against crash reduction targets can be helpful in explaining the results of the appraisal. Presentation of results is discussed further in Section 7 of Part 1.

## **5.5 Applying to routes, areas and mass actions**

### **5.5.1 Routes and areas**

Where a route or area-wide action is being considered, the route or area should be divided into individual components (usually by individual devices) and the benefits and costs calculated separately. The costs and benefits can then be aggregated over the entire scheme to arrive at the net present value or benefit / cost ratio. In some instances, separate NPVs or BCRs can be calculated for individual components of the scheme where it is considered that these components could be installed as stand-alone treatments. Take care, though, that this does not result in a route or area having a series of inconsistent layouts or treatments after only the high BCR sites are treated.

### **5.5.2 Mass actions**

For a mass action scheme the NPV or BCR should be calculated for the scheme as a whole. Mass actions are implemented on the basis that individual sites may not have a crash problem, but collectively the type of road feature is known to have a worrying incidence of crashes. It is thus not correct to calculate the BCRs separately for each site or for those sites having the greatest numbers of crashes.

## **5.6 Post-completion evaluation**

Post-completion evaluations are carried out after the project has been implemented. They assess the project's performance against the stated objectives and identify future improvements. They also provide feedback on the efficiency of implementation, the effectiveness of the measure, feedback on the project evaluation process, lessons learnt and indicate whether the investment was worthwhile.

The timing of post-completion evaluations should allow for the project effects to settle, meaning they should not be in the early stages of project implementation. The main component of post completion evaluations involve comparing the observed before and after crash rates and comparing these to the forecast crash modification factors to determine if the forecast effectiveness was realised. See Bureau of Infrastructure, Transport and Regional Economics (2012) and Austroads (2012b).

## **5.7 Alternatives to benefit cost approach**

### **5.7.1 The goals achievement approach to project appraisal**

#### **Cost-effectiveness**

Cost effectiveness analysis (CEA) involves comparing the cost of a proposed countermeasure with the effect it produces (see Equation 5). Within CEA, projects are ranked and screened according to their cost and effectiveness in improving road safety or achieving policy objectives. Effects are generally expressed in non-monetised units, e.g. the change in the number of fatal and serious injuries. CEA is mainly applied when comparing alternative projects, programs and policies with a similar outcome. The cost-effectiveness is expressed as the cost-effectiveness ratio (CER).

$$\text{Cost Effectiveness Ratio} = \frac{\text{number of crashes prevented}}{\text{cost of countermeasures}}$$

The cost-effectiveness approach to decision making is concerned with determining the extent to which each of a number of alternatives contributes to the attainment of prescribed objectives. It is most applicable where there is a fixed budget and the aim is to achieve maximum results from that expenditure and where there is a specified objective and the aim is to determine the cheapest way of achieving it.

This approach and all other goals assessment techniques differ from other economic appraisal techniques in that they say nothing about how worthwhile the objective is: there is no measure of worth or value about the objectives or the results of the analysis. Therefore, the cost-effectiveness approach has relevance to road safety project appraisal only to the extent that it assists in screening and ranking alternatives which are essentially similar in nature and which can be assessed with respect to a single objective, such as reduction in the number of fatal and serious casualties.

For example, if an agency has a simply expressed goal of reducing the number of fatal and serious casualties in total, then the economic benefits or other impacts of remedial schemes are essentially irrelevant to that goal. A cost-effectiveness approach which simply lists the expected crash reduction from each of various competing schemes would therefore be appropriate to that goal, as it would indicate to the decision maker the set of treatments which are expected to have the maximum potential to reduce crash frequency.

An approach used in several jurisdictions (including New Zealand and New South Wales) is the cost per fatal and serious injury (FSI) saved (or cost per death and serious injury, or DSI, as it is termed in New Zealand).

Death and Serious injury (DSI) casualty equivalents represent the average number of people that are killed or seriously injured for every reported injury crash. DSI factors have been calculated for intersections and midblock locations for a range of different crash types. The DSI factors take into account the relationships between speed environment, road form and crash type and is founded on knowledge that the changes in these factors affects the severity of crash outcomes.

The DSI casualty equivalents are applied to each reported injury crash to estimate the number of people that can be expected to be killed or seriously injured if current crash trends continue. The DSI casualty equivalents method acknowledges that actual fatal and serious crash data alone is not a good indicator of the underlying risk of a high-severity crash at many locations. The DSI casualty equivalents method allows parts of the road network with moderate crash numbers to be identified as high-risk if the type of crashes occurring are suggestive of a high likelihood that the next occurrence will be of high severity.

This approach is very consistent with the key Safe System focus of maximising the reduction in these severe crash types. As an example, the *New Zealand High Risk Intersections Guide* (New Zealand Transport Agency 2013a) provides a quick guide to conducting such an evaluation. This suggests the following steps:

- identify treatment options
- calculate treatment costs for each of these options
- each DSI saved for intersection projects is approximately NZ\$1M

- convert the annual savings to present value of the whole-of-life of a project with long-term benefits by multiplying by 16
- use this value to calculate DSI saved per \$100M
- projects with the highest DSI saved per \$100M spent would produce the best Safe System outcomes.

For example, Victoria's Safe System Road Infrastructure Program (SSRIP) includes additional metrics similar to the New Zealand approach in prioritising projects. These include Cost per Serious Casualty Saved per Year and the Number of Serious Casualties Saved per \$100M invested.

## 6 Monitoring and evaluation

Refer to the QGRS Part 2: *Safer Roads* for a details regarding the monitoring and evaluation process for supporting road safety initiatives.

In addition, see Appendix C of this document for a practical example.

## 7 Preparing a crash report

The documentation prepared in the sections above needs to be drawn together into a report which sets out the crash patterns, their causes and proposed solutions. If the documentation has not yet commenced, the following is a report structure which covers the topics to include:

- **Cover**
  - a title such as 'crash location investigation and treatment' or, if it embraces a wider investigation, 'crash location investigation and road safety audit' or other appropriate combination
  - a brief description of where the location is (e.g. street name, local authority area, highway kilometre post, GPS and map references)
  - the organisation for whom the investigation is being undertaken and a list of the investigation team members and affiliations
  - the name of the organisation in charge of the study, and
  - the date of the report (month and year).
- **Introduction**
  - the organisation for whom the investigation is being undertaken and a list of the investigation team members and affiliations
  - a detailed description of where the location is (e.g. street name, local authority area, highway kilometre post, GPS and map references)
  - an aerial view of the crash location (e.g. from Google Earth or NearMap), showing the location and direction of photos
  - reference to any previous crash reports and their outcomes, and
  - a description of the location (e.g. road geometry, environment, speed limit, volumes), including roadworks (if any) within the period of crashes being analysed.

- **Data Analysis**
  - a crash listing (showing the basic details of each crash):
    - location, distance
    - time
    - day of week
    - date (day, month, year)
    - crash type (DCA code)
    - direction of approach of Vehicle 1
    - severity
    - road surface (wet / dry)
    - light condition (light / dark / dusk or dawn)
    - traffic control.
  - a summary, for all crashes, of characteristics not in the factor matrix, e.g.: - total number of reported crashes and severities:
    - year of the crash, and
    - period of week (i.e. weekday or weekend).
  - the estimated cost of crashes for each separate crash code grouping
  - a factor matrix showing the number of crashes by the following factors:
    - crash type (such as DCA code)
    - direction of approach of Vehicle 1
    - vehicle types involved
    - road surface (wet / dry)
    - light condition (light / dark / dusk or dawn), and
    - any other common factors identified (alcohol, fatigue, roadside objects, driver age etc.).
  - a collision diagram, together with a copy of the DCA code table being used
  - a summary of common factors in the crashes, deduced from the above, and
  - measures previously implemented and their effectiveness.
- **Contributing Crash Factors - Deduced from the Data Analysis and Site Inspection**
  - conclusions about the road environment factors which have contributed to the particular crash groups for which there are common factors. These are the crash causes which are addressed in the next section. These factors could be structured based on the Safe System pillars to focus investigation and analysis, and
  - any identified vehicle or human behaviour factors.

- **Crash Countermeasures**

- a list of the proposed treatments which are designed to counter the identified crash causes (with mention made about which treatment is aimed at which problem). These treatments could be structured based on the Safe System pillars
- other safety problems warranting treatment: a section about minor items identified on-site which can be improved by very low-cost measures
- a plan of the preliminary design of the countermeasures, and
- this section may put forward 2 options with different costs and different effects on crash reduction.

- **Economic Appraisal**

- the cost of the crashes (by crash type)
- the effect on crash types expected (e.g. using CMFs) and the consequent benefits in crash reduction. This should be clearly tabulated, so that evaluation can take place at a later date
- other benefits
- the cost of design and construction of the proposed treatment, and
- the net present value and benefit/cost ratio.

- **Appendices**

- photographs of the site, relevant to the crash factors.

## Appendix A: Willingness to Pay Crash Costs

Refer to Table A.1 below for Willingness to Pay crash costs to use in Queensland in 2025.

**Table A.1 – Willingness to Pay Crash Costs (2024) for Queensland**

WTP Standardised DCA Crash Cost – 2024 dollar value		Casualty Crashes	
DCA Group	DCA Group Description	Low Speed	High Speed
1	Intersection, from adjacent approaches	\$467,811	\$1,084,066
2	Head-on	\$918,365	\$3,208,083
3	Opposing vehicles, turning	\$528,580	\$952,032
4	Rear-end	\$258,654	\$436,290
5	Lane change	\$369,412	\$444,510
6	Parallel lanes, turning	\$356,830	\$1,102,087
7	U-turn	\$532,071	\$899,241
8	Vehicle leaving driveway	\$398,999	\$1,124,186
9	Overtaking, same direction	\$614,649	\$1,067,987
10	Hit parked vehicle	\$446,121	\$582,599
11	Hit railway train	\$826,217	\$826,217
12	Pedestrian	\$761,750	\$3,767,556
13	Permanent obstruction on carriageway	\$380,344	\$380,344
14	Hit animal	\$450,385	\$600,011
15	Off carriageway, on straight	\$704,239	\$1,002,703
16	Off carriageway, on straight, hit object	\$566,613	\$1,101,744
17	Out of control, on straight	\$627,143	\$865,375
18	Off carriageway on curve	\$511,656	\$691,765
19	Off carriageway, on curve, hit object	\$783,598	\$1,349,391
20	Out of control, on curve	\$669,662	\$931,317
21	Other	\$588,657	\$1,060,428

For details on coding crashes refer QRSTUV: *Guide to Coding Crashes*.



## Appendix C: Examples

This appendix includes a number of examples illustrating some of the key concepts in this document. The examples provided are as follows:

- Practical Example 1: Investigation of High Crash Locations
- Practical Example 2: Chance Variation
- Practical Example 3: Writing a Preliminary Report
- Practical Example 4: Applying Crash Modification Factors
- Practical Example 5: Road Safety Audit of a Remedial Treatment
- Practical Example 6: Selecting the Countermeasures
- Practical Example 7: Economic Appraisal
- Practical Example 8: Monitoring.

### ***C.1 Practical Example 1: Investigation of High Crash Locations***

#### **C.1.1 Example 1A**

At a T-intersection in a semi-rural environment (Figure C.1.1(a)) there have been 10 recorded crashes in 3 years. Four involve vehicles turning right out of the side road colliding with vehicles on their right.

***Figure C.1.1(a) – T-intersection (example 1A)***



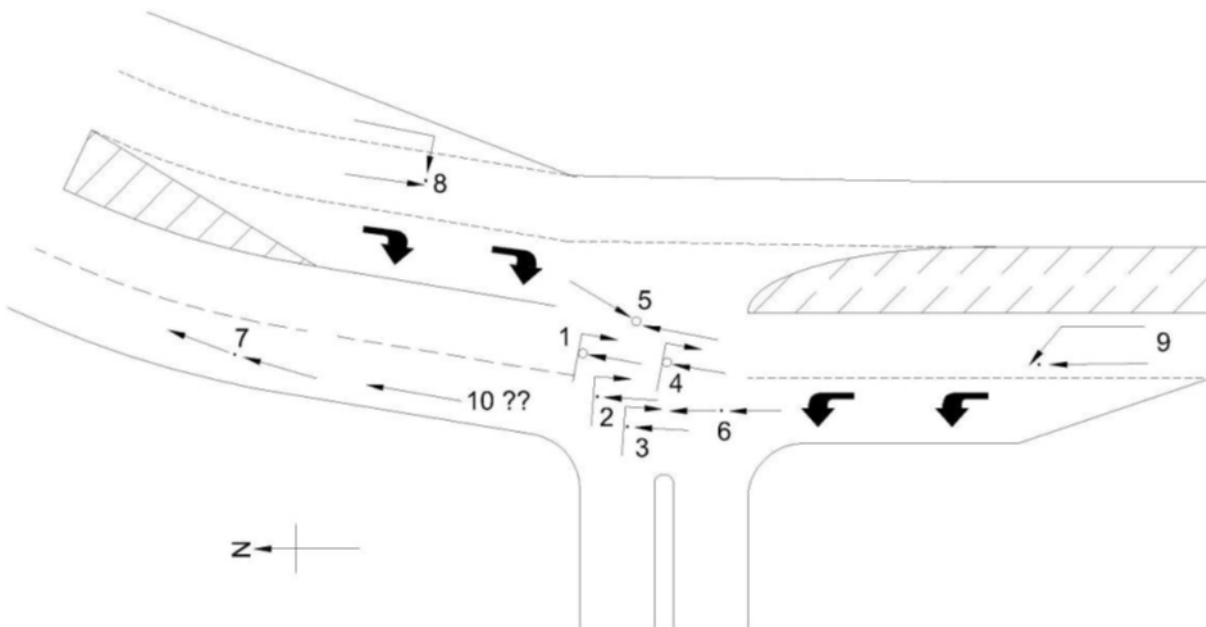
From the crash data (Table C.1.1) and collision diagram (Figure C.1.1(b)) it is evident that the 4 DCA 104 crashes are the only clustering of crash types. This type of collision involves a vehicle turning right, from the east, being struck by a northbound vehicle. The analysis also revealed that most (90%) of the crashes involved a northbound vehicle, while half had occurred when the road was wet. Other common factors are not apparent.

**Table C.1.1 – Crash data (example 1A)**

Crash number	Date: day - month	Date: year	Day of week	Time of day	Severity	Light condition	Road condition	DCA Code	Object 1	Object 2	Direction 1	Direction 2 (&3)
1	10-06	2004	Fri	17:10	Fatal	Dusk	Dry	104	Car	Light Truck	E	N
2	29-09	2004	Thu	10:15	Serious injury	Day	Dry	104	Heavy Truck	Car	E	N
3	20-04	2005	Thu	09:15	Serious injury	Day	Wet	104	Car	Car	E	N
4	08-12	2006	Sat	07:00	Minor injury	Day	Wet	104	Heavy Truck	Car	E	N
5	28-07	2004	Thu	08:52	Minor injury	Day	Wet	201	Car	Car	S	N
6	15-05	2005	Mon	16:40	Minor injury	Day	Dry	301	Car	Car	N	N
7	17-07	2006	Tue	17:10	Minor injury	Dusk	Dry	301	Car	Car	N	N
8	17-09	2006	Mon	05:45	Minor injury	Dawn	Wet	306	Car	Car	S	S
9	17-02	2005	Fri	20:00	Non-injury	Dark	Wet	307	Car	Car	N	N
10	13-10	2006	Sat	16:45	Non-injury	Day	Dry	400	Car	Car	N	N

Note: In this example, DCAs from Queensland have been used.

**Figure C.1.1(b) – Collision diagram (example 1A)**



From the site inspection it is evident that sight distance out of the side road is adequate. Vehicles in the left turn lane do not block the side road drivers' view to vehicles in the through northbound lane. The intersection geometry is poorly defined and there is no clear give way position. A large number of northbound drivers use the left turn only lane as a through lane, because the layout of the lane lining encourages it and there are 2 northbound lanes north of the intersection.

The site inspection also found that the road surface was poor, particularly for the southern leg of the intersection.

Assessment: It is likely that drivers in the side road are moving out into the intersection, expecting any vehicles in the northbound left lane to be turning left. When a vehicle in the left lane continues north, a crash occurs.

The relatively high number of crashes that occurred when the road was wet (50%) suggests that the road surface requires investigation, particularly on the southern leg of the intersection.

**Treatment:** As mentioned earlier, and common to all proposed treatment considerations, speed management through lower limits (with enforcement) or traffic calming or other engineering treatments or applied technology, should be considered and is consistent with the Safe System approach. In this example, from an engineering perspective it is important to ensure that northbound vehicles travel at speeds that will enable them to avoid or minimise the severity of a collision should it occur. As identified in *Austrroads Guide to Road Safety Part 3: Safe Speed*, side impact speeds of over around 50 km/h produce a chance of a fatal and serious injury outcome.

Ensure the northbound left turn lane is used only by left turners. This requires physical alteration to lines and islands: it cannot be achieved by instruction signs. Bring the Give Way line out to near the through lane; protect it by extending the kerbed island in the side road; delineate the island (e.g. with hazard markers) so it is visible to northbound traffic, day and night. A Give Way line and sign should be installed to make the holding position obvious (note: the treatment is different from Practical example 1B, despite the same crash type, because the causes were assessed to be different).

Ensure that the road surface is free of any irregularities and that the skid resistance is improved.

### C.1.2 Example 1B

At a T-intersection in a semi-rural environment (Figure C.1.2(a)) there have been 13 recorded crashes in 3 years. Five involve vehicles turning right out of the side road colliding with vehicles on their right. Six are rear end crashes on the side road and 2 are right turns colliding with oncoming traffic on the main road.

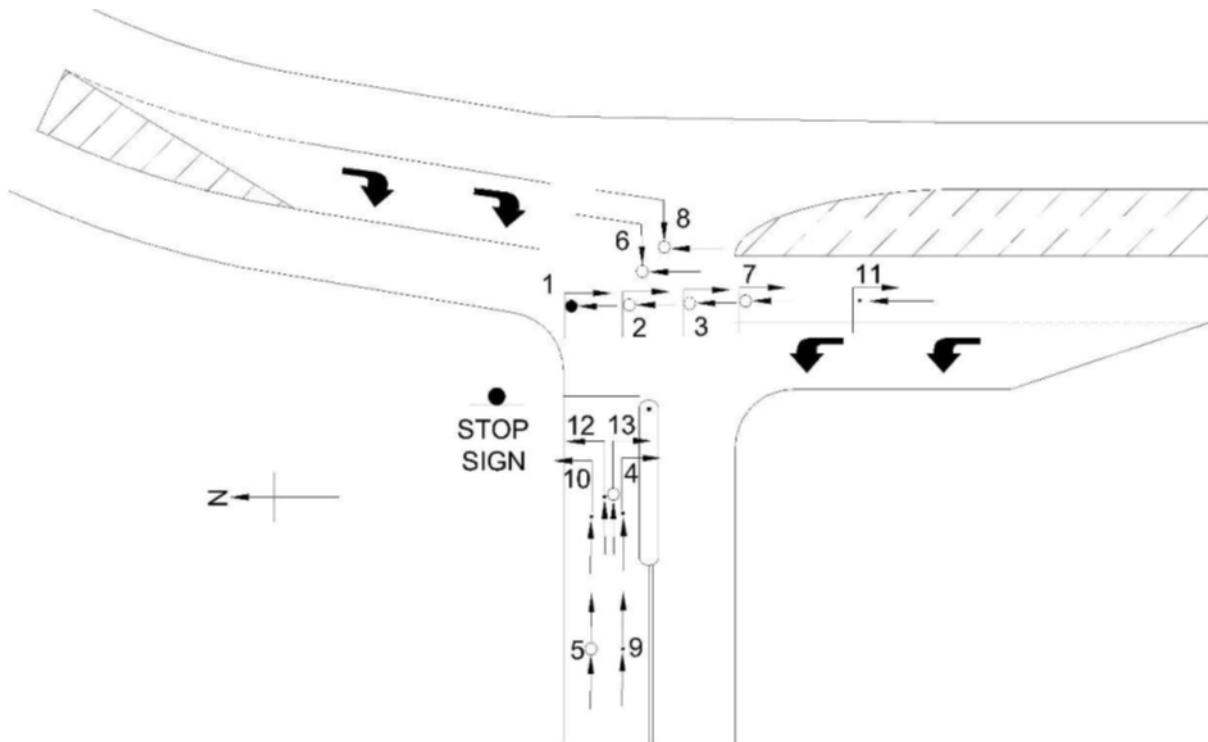
**Figure C.1.2(a) – T-intersection (example 1B)**



From the crash data (Table C.1.2) and collision diagram (Figure C.1.2(b)) it is evident that there are 3 distinct crash types with a clustering of crashes, namely rear-end (DCA 301, 2 and 3), through right (DCA 104) and right-turn-against (DCA 202). All of the rear-end crashes involved eastbound vehicles, while half occurred on wet roads. More than half (i.e. 7 of 13) crashes involved a northbound vehicle. Both DCA 202 crashes involved a northbound vehicle and had occurred during the afternoon, when northbound flows were heavy.

**Table C.1.2 – Crash data (example 1B)**

Crash number	Date: day - month	Date: year	Day of week	Time of day	Severity	Light condition	Road condition	DCA Code	Object 1	Object 2	Direction 1	Direction 2 (&3)
1	29-Jul	2007	Sun	16:43	Fatal	Day	Dry	104	Van	Car	N	E
2	20-May	2007	Sun	10:30	Serious injury	Day	Dry	104	Car	Car	N	E
3	4-Aug	2007	Sat	12:15	Serious injury	Day	Dry	104	Car	Car	N	E
4	12-Jul	2005	Tue	12:45	Minor injury	Day	Wet	303	Car	Car	E	E
5	1-Mar	2005	Tue	16:00	Minor injury	Day	Dry	301	Car	Car	E	E
6	22-Apr	2007	Sun	17:20	Minor injury	Dark	Dry	202	Car & trailer	Car	S	N
7	17-Jul	2007	Tue	11:45	Minor injury	Day	Dry	104	Truck	Car	N	E
8	12-Sep	2007	Wed	13:45	Minor injury	Day	Dry	202	Car	Car	S	N
9	12-Sep	2006	Wed	08:30	Non-injury	Day	Wet	301	Car	Car	E	E
10	21-Jan	2005	Fri	18:00	Non-injury	Day	Dry	302	Car	Car	E	E
11	23-Nov	2007	Fri	06:10	Non-injury	Day	Dry	104	Car	Car	N	E
12	11-Jul	2005	Mon	17:30	Non-injury	Dusk	Dry	302	Van	Car	E	E
13	12-Sep	2006	Wed	08:35	Non-injury	Day	Dry	303	Car	Car	E	E

**Figure C.1.2(b) – Collision diagram (example 1B)**


From the site inspection it is evident that visibility out of the side road to the south is blocked by vehicles in the left turn lane, due to the curve in the main road. On the side road, there is a long crest approaching the intersection, preceded by a left curve: the intersection may be a surprise, despite the presence of a 'Stop Sign Ahead' warning sign.

**Assessment:** Vehicles in the curved northbound left turn lane are hiding through-vehicles from the view of side road drivers. On the side road, the intersection or a queue of traffic may be unexpected; the road surface is adequate. Right turners into the side road may be having difficulty finding gaps in the heavy oncoming traffic flow.

**Treatment:** As indicated in the previous example, speed management options should be considered as a means of lowering vehicle approach speeds to the intersection. Reducing vehicle speeds will be expected to reduce the crash risk and the severity of any crashes that do occur at the site.

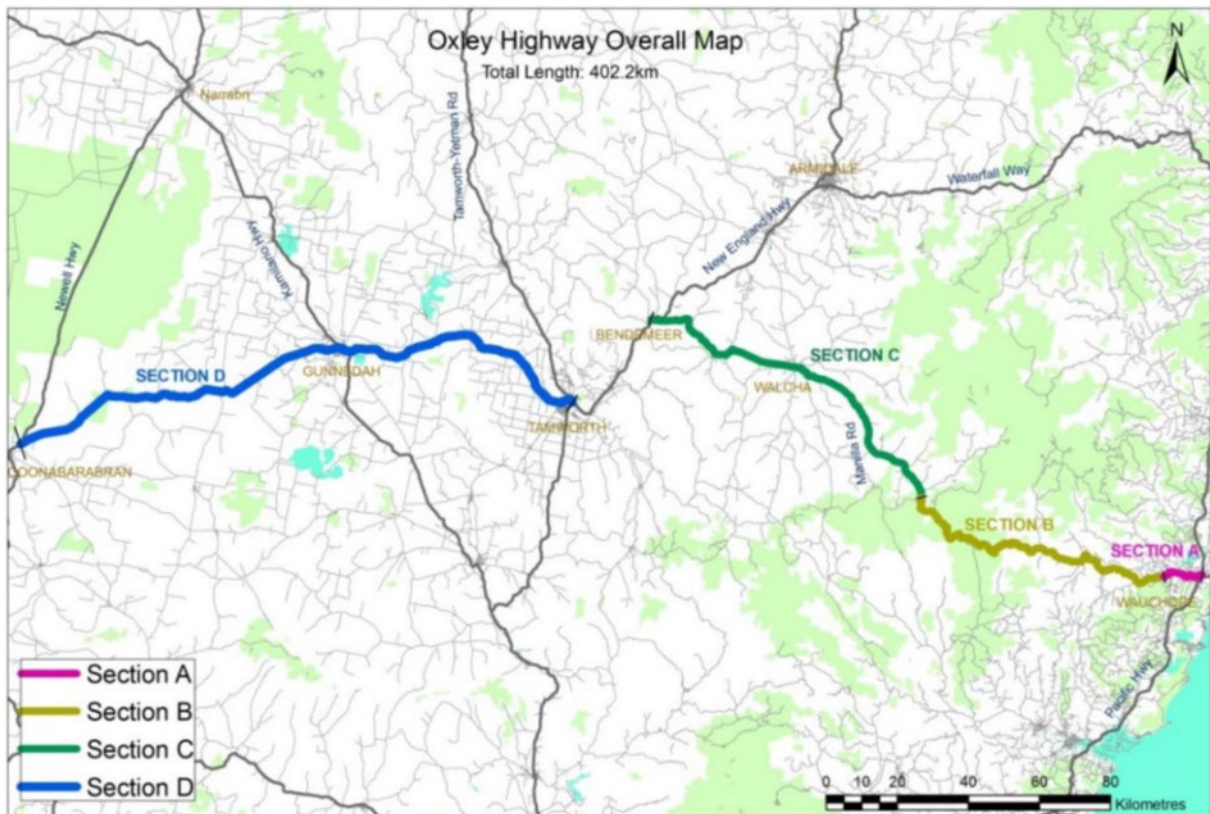
Straighten the left turn lane and taper it away from the through lane, to give side road drivers a clear view of northbound through traffic (note: the treatment is different from Practical example 1a for the same crash type because the causes were assessed to be different). On the side road, replace the 'Stop Sign Ahead' warning sign with a pair of W2-3 T intersection signs at the curve; raise the height of the hazard board opposite the intersection; replace the STOP sign with a large Give Way sign (visibility warrant for Stop sign not met). DCA 202 crashes can only be resolved by increasing gaps (e.g. by adding a second northbound through lane).

### C.1.3 Example 1C

The Oxley highway in central NSW is over 500 km long and crosses variable terrain ranging from urban roads to rural and remote. During a 5-year period there have been 318 casualty crashes comprising 14 fatalities and 395 injuries.

The Centre for Road Safety (CRS) assessed the Oxley highway in various sections rather than specific sites in order to identify effective road safety countermeasures. The highway was divided into 4 homogeneous sections that range from 12.7 to 178.9 km and are generally defined by the nature of the road and its environment as indicated in Figure C.1.3.

**Figure C.1.3 – Oxley Highway split in four sections**



Source: Eveleigh, Abeysekera & Tang (2014).

A road safety route review was undertaken as an initial stage of the project. This approach focuses on a single corridor, and includes analysis of crashes, and a physical review of the entire highway by a multidisciplinary road safety team that includes expertise in engineering, road design, behavioural science/psychology, statistics, and policing. The review process focuses on analysis of crash locations, and is not a review against standards.

The objectives of the route review were to examine the circumstances of fatal crashes and casualty crash clusters, the general road conditions, the facilities (including intersection treatments, safety barriers, signage, and line markings), the appropriateness of speed zones and priorities for rehabilitation and/or maintenance programs.

Further information on perceived risk locations were gathered through community consultation.

The Australian National Risk Assessment Model (ANRAM) was used to assess the likely benefit of treatment options. This tool combines information on existing crash locations and quantitative information about the likely safety impacts of existing infrastructure.

Based on the route safety review, the community consultation and the ANRAM results, CRS developed several program options, and assessed the cost-effectiveness of each. Each option included a range of engineering treatments. From ANRAM, a benefit cost ratio and a reduction of fatalities and serious injuries (FSI) was able to be estimated for each option.

Further information regarding this study can be found in Eveleigh, Abeysekera and Tang (2014).

#### **C.1.4 Example 1D**

This hypothetical example illustrates some of the key steps for treating crash locations along a route.

During the examination of crash data across a road agency's network, several high crash risk road corridors were identified. One of these was a rural route, connecting 2 towns. The total length was 13.2 km, and over a 3-year period there were 31 crashes, two-thirds of which resulted in either fatal or serious injury outcomes. The crashes resulted in 38 casualties of which 3 were fatal and 22 were serious. This resulted in an average of 0.96 casualties per km per year. The severe crash rate was 0.56 per km per year.

Data was analysed, with a crash matrix developed for the route as a whole, and for individual road segments. A collision diagram was also developed.

Analysis showed that most of the crashes occurred at curves and involved vehicles running off the road. Although there were several clusters of crashes at curves, many were scattered at isolated locations along the route. There were also several crashes at intersections, and a cluster of crashes at the eastern end of the route where the road entered a semi-urban area on the approach to a town. These crashes related to turning movements at intersections and rear-end crashes at these same locations.

A route inspection was undertaken on the route. This occurred both during the day and at night given there were a number of casualties during dark conditions. The inspection identified poor delineation at various points throughout the route, and inconsistent advance warning at curves. There was also a lack of adequately sealed shoulders throughout the route. Curves with a crash history generally displayed one or more of these deficiencies, although it was also noted that there were other curves with similar features which had not yet experienced crashes.

It was observed that there was also poor sight distance at one of the intersections, and a lack of turning facilities at another.

There was increased development at the eastern end of the route, although the current speed limit remained at 100 km/h which did not match the level of abutting roadside activity.

It was recommended that:

- Curves be assessed in a consistent manner to improve delineation, including advanced warning signs, guide posts and chevron alignment markers. This included recommendations for locations that had experienced crashes, as well as those that were substandard, but where no crashes had yet occurred.
- Shoulders be widened at critical locations, including through curves.
- Roadside barriers be installed at one severe curve where roadside hazards were present.
- Sight distance improvements were recommended at one intersection, with the stop line being brought forward, and vegetation cleared. At another intersection, a left turn deceleration lane was recommended along with an indented right turn lane.
- Due to the increased level of development at the eastern end of the route, the speed limit be lowered from 100 to 80 km/h.

Initial scoping work was conducted, and the costs and benefits calculated for the project. The BCR exceeded 1 meaning that the project delivered more benefits than costs. The Net Present Value (NPV) was also calculated to help prioritise this project amongst others being investigated by the road agency.

## **C.2 Practical Example 2: Chance Variation**

The crash history at a site for the past 6 years is 3, 1, 2, 1, 3 and 5 crashes per year. At the end of the sixth year there has been concern that a hazardous situation has developed, which has caused the apparently high number of crashes in that year.

How likely is it that this result may have occurred by chance?

In the previous 5 years the crash numbers were 3, 1, 2, 1 and 3. So at the start of the sixth year what range of crash numbers could be expected? The observed rate of occurrence is 2.0 crashes per year (i.e.  $[3+1+2+1+3] \div 5$  years). The lowest number to that time has been 1 and the highest has been 3.

From Appendix F, it can be seen that with  $c/n = 2.0$  and  $n = 5$ , the expected range of crashes (the 'true underlying rate' of crashes) per year is from 0.9 to 3.7 (i.e. from 1 to 4). The occurrence of 5 crashes in the sixth year is outside this range.

Also from Appendix F, it can be seen that with  $c/n = 2.0$  and  $n = 5$ , the 'critical change in the mean' is 1.6. i.e., any number of crashes 1.6 above (or below) the observed mean of 2.0 would be regarded as not occurring by chance. The occurrence of 5 crashes in the sixth year is thus very unlikely to be the result of chance.

It is thus appropriate to add the site to the list for investigation.

Also, it is important to check if there is a common pattern in the crashes, both in previous years and in the most recent year. Is there a new crash type occurring? Is there a common feature (direction of approach, type of road user, etc.)? Check if there has been any change to circumstances at the site. Has this contributed to the increase?

### C.3 Practical Example 3: Writing a Preliminary Report

This example has been adopted from an example report provided by Opus International Consultants, Tauranga, and Transit New Zealand (now the New Zealand Transport Agency).

A preliminary report has been prepared, to provide a crash location investigation team with information before its site inspection. Each team member receives a copy. The site is a crossroad intersection where the Highlands Highway intersects with Green Road and Black Road.

Several sites will be inspected and the report starts with a list of all the sites and a summary of the study procedures. For Highlands Highway/Green Road, the report contains a summary table which has space for the investigation team to provide comment under the headings of Discussion, Problem and Solution. It also includes a complete listing of all crashes for 5 years (not shown here), some graphical analyses of the crash data (crash severity not shown here), the collision diagram and a factor matrix (not shown here).

**Figure C.3(a) – Example of report**

<b>Site no.</b>	1
<b>LTSA no</b>	548376
<b>Location</b>	Highlands Highway/Green Road Intersection
<b>Description and history</b>	<p>This intersection was nominated to be reviewed in the study location Schedule (after analysis of the crash monitoring data) and the Council.</p> <p>The closest State Highway traffic count in this area is between Victoria Road and Auckland Corner which gives an AADT of 9 619 vpd with 19% HCV and 9.5% growth. The TDC traffic counts (Jan/Feb 2008) of the individual legs are:</p> <ul style="list-style-type: none"> <li>• Highlands Highway East 16 012</li> <li>• Highlands Highway West 17 068</li> <li>• Green Road 2 541</li> <li>• Black Road 2 240</li> </ul> <p>The surrounding land has since undergone extensive subdivision development on the eastern leg and the University is still in the process of expansion of its campus on the western leg.</p> <p>The prevailing speed limit is 80 km/h.</p> <p>Cross intersection: Give Way sign control</p> <p>Intersection was reconstructed in 2004.</p>
<b>Crash record</b>	<p>Refer attached collision diagram.</p> <p>This site had 31 crashes in the five year period, 2003–2007.</p> <p>50% of the crashes occurred between 3 pm and 6 pm.</p> <p>The majority of the crashes are intersection type, i.e.:</p> <ul style="list-style-type: none"> <li>• Crossing (vehicle l turning) 40%</li> <li>• Crossing (no turns) 20%,</li> <li>• Rear-End 17%.</li> </ul>
<b>Discussion</b>	The University has recently undertaken its own study.
<b>Problem</b>	<p>Busy crossroads during peak periods with a large number of conflicting movements.</p> <p>High speed on through road.</p>

A collision diagram for the site is shown in Figure C.3(b). This shows the direction and location of each crash and the number and nature of each crash type.

Figure C.3(b) – Collision diagram

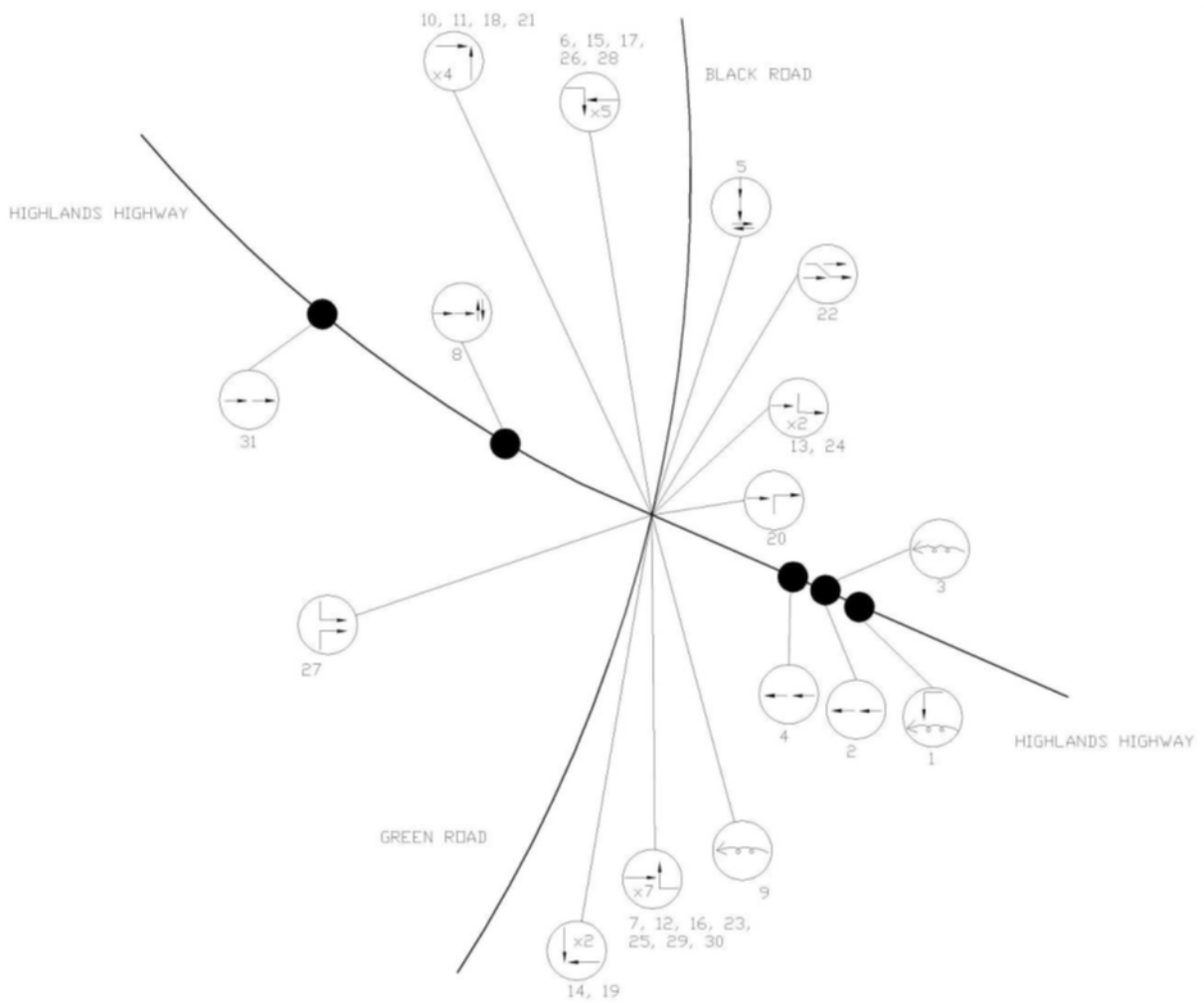
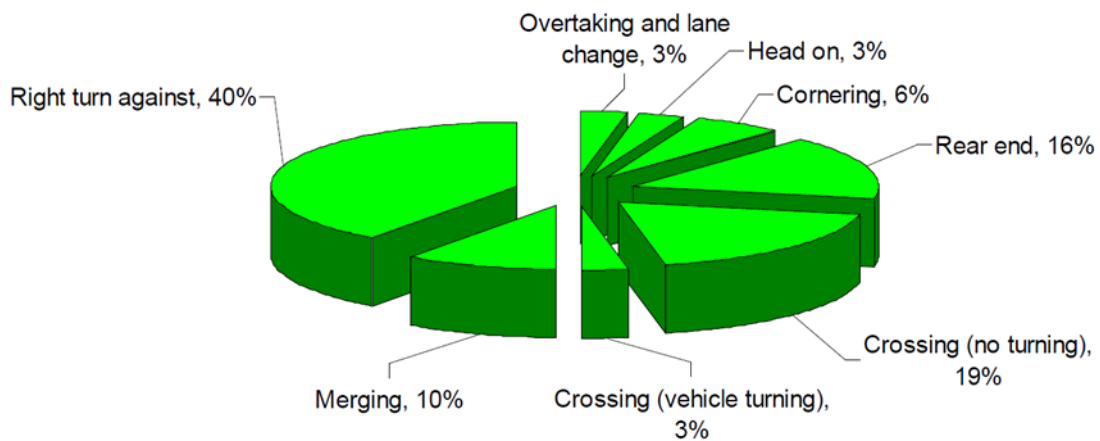
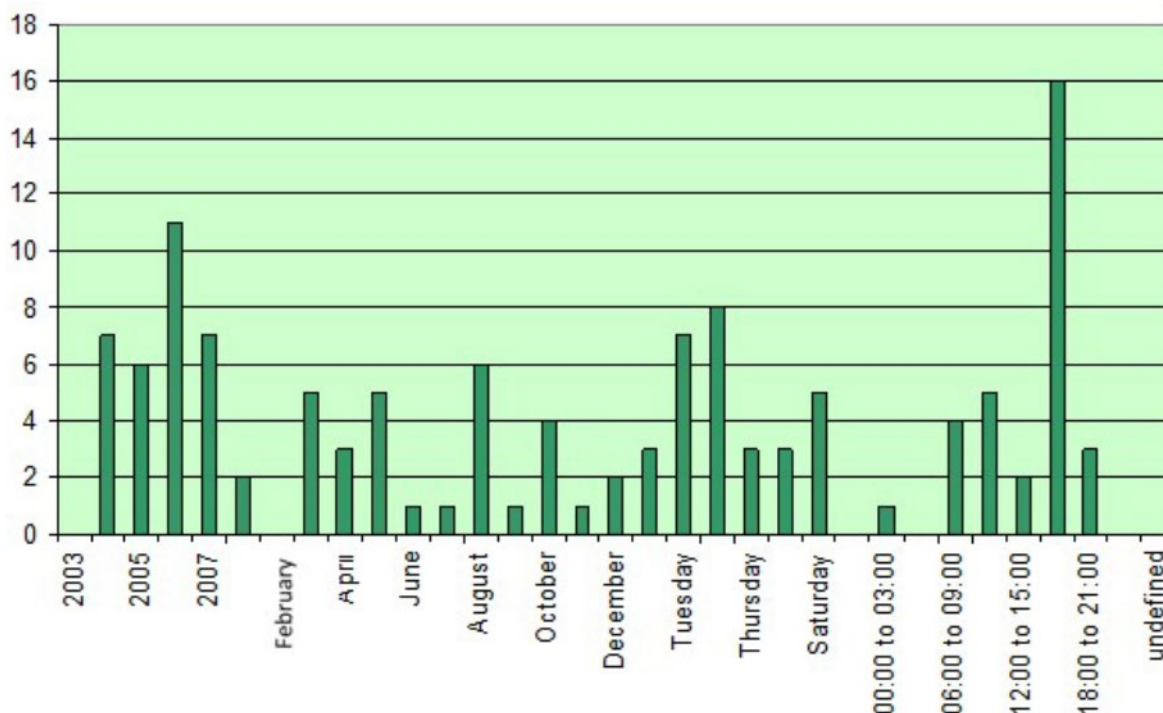


Figure C.3(c) – Movement category pie chart



Crash distribution by year, month, day and time as shown in Figure C.3(d) can reveal trends. The yearly figures allow the team to see that crashes have been occurring since the intersection's reconstruction. The monthly figures show nothing unusual. The daily figures suggest a further examination of crash type by day may be worthwhile. The hourly figures show the worst problem is in the afternoon peak. Which crashes are occurring then?

**Figure C.3(d) – Crash distributions – year, month, day and time**



Assessment: The investigation team used this information together with the site inspection, to consider the causes of the crashes. A common centreline was considered to be a key factor for the right turn against crashes: right turners could not see oncoming through traffic because their view was blocked by oncoming right turners. The solution would be to remark the right turn lanes 'head to head'. But this would not reduce the right angle and rear end crashes. Speeds are high, there is a tight curve just south of the intersection and traffic volumes are now too high for safe gaps in the major flows. It was recommended that a roundabout be installed here and at another crash problem site 700 m to the west on the Highlands Highway. In the interim, large crash hazard warning signs were installed.

#### **C.4 Practical Example 4: Applying Crash Modification Factors**

It is important to use expert judgement when applying CMFs, including those in Appendix E. When implementing a change to a traffic control to reduce one crash type, do not assume this will also reduce other crash types. In some cases a measure that reduces one type of crash may result in more crashes of another type.

##### **C.4.1 Example 4A**

There is clustering of several crash types at a signalised crossroad. One type is the DCA corresponding with a through-right collision. It is decided to fully control the right turn involved in these crashes by installing a red arrow. The 'remodel signals' treatment lists a CMF of 0.6 for these crashes (see Appendix E). But what about the CMF for other crash types with this treatment?

The intersection also has a DCA corresponding with through-through collisions, but if the only improvement is the new right turn red arrow, there will be no reduction in these crashes because the right turn red arrow will not affect them. Only if other works are undertaken to target these crashes, can the 0.7 CMF for crashes where signals have been remodelled be applied.

#### **C.4.2 Example 4B**

Consider the installation of a roundabout in a local street such as that shown in Figure C.4.2 as a countermeasure to intersection crashes. The only crash type is through-through collisions.

Appendix F indicates the 'roundabout' treatment has a CMF for these crashes of 0.3. But what about the changes to other crash types for this treatment? Only apply the percentage increases to crashes of the relevant types already reported. In this case there are none. But be realistic and use engineering judgement: are there high cyclist numbers, which would make cyclist crashes likely with a roundabout? Might rear-end crashes start to occur? How might they be avoided? To minimise the risk of new types of crashes, have the new design road safety audited.

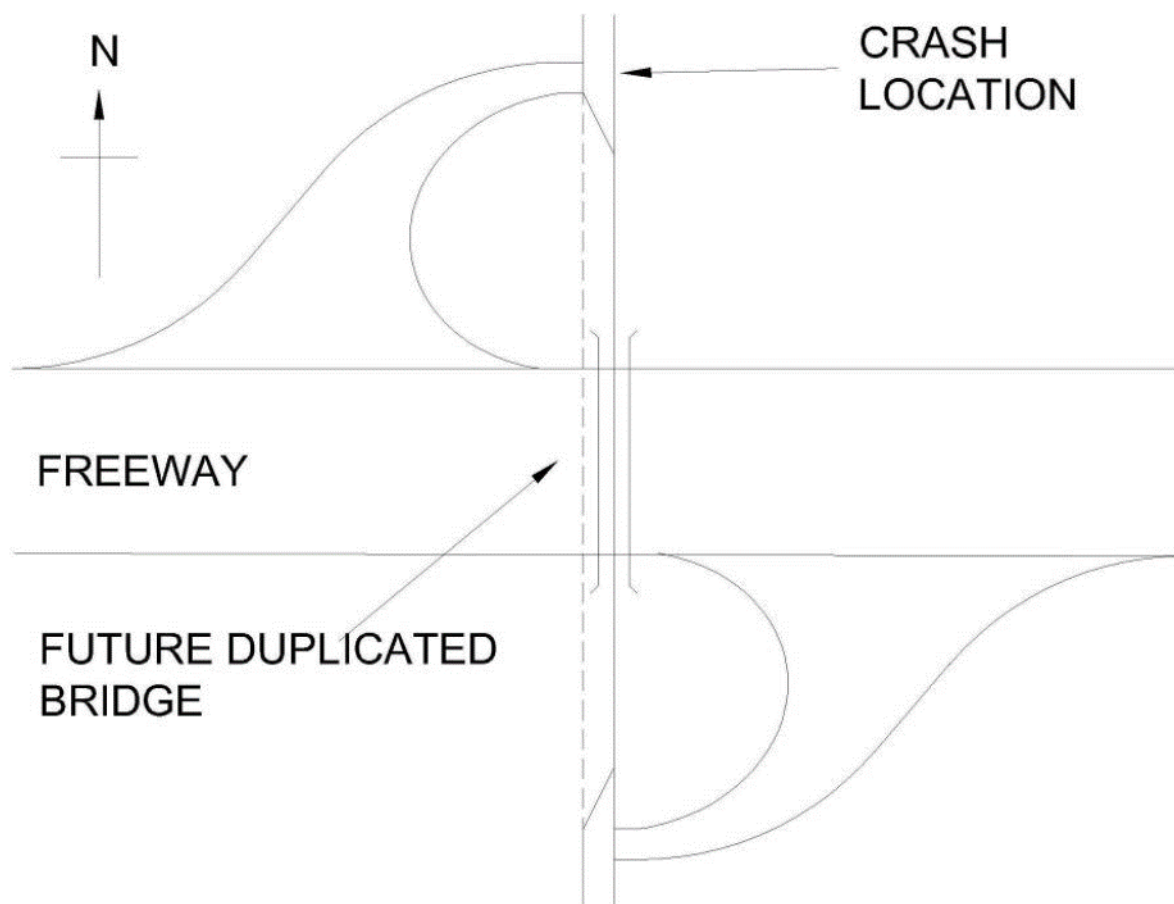
**Figure C.4.2 – Example of a roundabout installed within a local street**



#### **C.5 Practical Example 5: Road Safety Audit of a Remedial Treatment**

This example illustrates the need to road safety audit the design for a crash remedial treatment, to ensure that new crash problems are not created when existing problems are solved.

A freeway interchange was built at an arterial road and the ramp terminal intersections were controlled by Give Way signs. As traffic increased, there was an increase in DCA 104 crashes at the northern intersection (right turns from the exit ramp colliding with a vehicle on their right). Part of the problem was the offset freeway bridge and the space left for a duplicate bridge to the west of the initial one. Figure C.5(a) shows an indicative diagram of the location.

**Figure C.5(a) – Interchange used in practical example**


Both intersections at the interchange were signalised in 2005. As the abridged factor matrix (Table C.5) shows, the DCA 104 crashes ceased, but right-turn into-oncoming-traffic crashes started occurring, as well as rear-end crashes.

**Table C.5 – Abridged factor matrix**

DCA code 1	Key direction (to)	Number of crashes each year							Direction of other vehicle				Surface		Light condition				
		2002	2003	2004	2005	2006	2007	Total	To north	To east	To south	To west	Dry	Wet	Dawn	Daylight	Dusk	Dark	
102	E				1			1						1					1
103	E		1					1			1			1		1			
104	E	1	1	1	4			7	7		1		5	2		6			1
202	S					5	4	9	9				7	2	3	2			4
301	S					2		2			2		2			1	1		
301	W					1		1					1			1			
706	E					1		1					1						1
Totals		1	2	1	5	9	4	22	16	–	4	1	16	6	3	11	1		7

From the crash data and the factor matrix it is evident that DCA 104 crashes are no longer a problem. Since the signals were installed, DCA 202 crashes have become a problem. Rear-end crashes have also increased. This may be a particular problem or could be typical of signalised sites.

The site inspection showed that drivers turning right onto the freeway are permitted to 'filter' turn after the green arrow signal ends. However, they are positioned directly facing oncoming traffic, where it is very difficult to judge approach speeds as there is no lateral movement (Figure C.5(b)). This task is harder in poor light. Also, only the front vehicle is visible. It appears that right turners are misjudging speeds and picking a gap which is too short.

**Figure C.5(b) – Looking south from where right turners wait to turn**

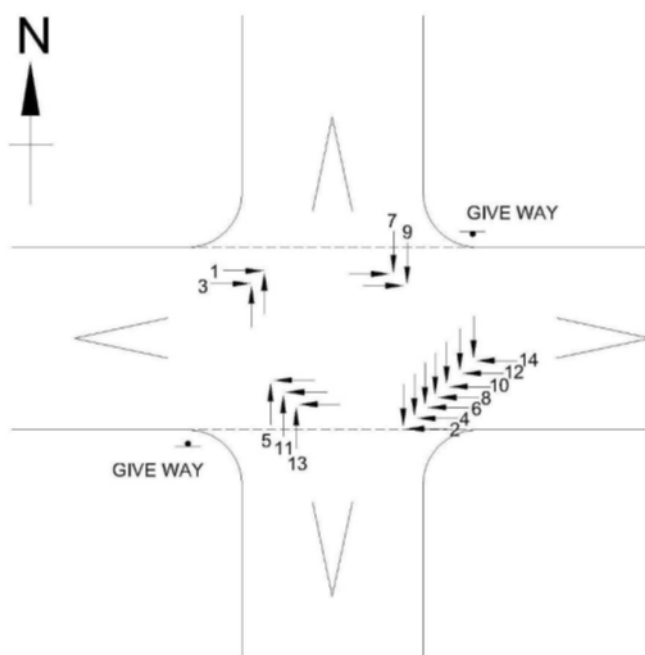


**C.6 Practical Example 6: Selecting the Countermeasures**

At an urban local street crossroad there have been 14 casualty crashes in 5 years. All are right angle crashes. The intersection is controlled by a Give Way sign on the north and south approaches.

From the crash data (Table C.6) and collision diagram (Figure C.6(a)) it is evident that two-thirds of the crashes involve southbound traffic (north approach). Half the crashes involve southbound vehicles striking westbound vehicles. One-third of the crashes are in daylight.

**Figure C.6(a) – Collision diagram for practical example**



**Table C.6 – Crash data for practical example 6**

Crash number	Date: day - month	Date: year	Day of week	Time of day	Severity	Light condition	Road condition	DCA Code	Object 1	Object 2	Object 3	Direction 1	Direction 2 (&3)
1	13-Jul	2004	Tue	17:00	Minor Injury	Dusk	Wet	101	Car	Car		N	E
2	4-Sep	2004	Sat	18:55	Minor Injury	Dark	Wet	101	Car	Car		S	W
3	19-Dec	2004	Sun	15:30	Serious Injury	Day	Dry	101	Car	Truck		N	E
4	8-Jun	2004	Wed	19:00	Minor Injury	Dark	Dry	101	Car	Car		S	W
5	3-Jul	2005	Sun	13:45	Serious Injury	Day	Dry	101	Car	Car	Car	N	W,E
6	7-Nov	2005	Mon	21:45	Minor Injury	Dark	Dry	101	Car	Car		S	W
7	30-Dec	2005	Fri	19:00	Minor Injury	Day	Dry	101	Car	Car		S	E
8	27-Feb	2006	Mon	12:20	Minor Injury	Day	Dry	101	Car	Truck	Car	S	W,N
9	3-May	2006	Wed	18:00	Minor Injury	Dark	Dry	101	Car	Car		S	E
10	24-Jul	2006	Mon	20:00	Serious Injury	Dark	Dry	101	Car	Car		S	W
11	18-Apr	2007	Wed	18:45	Minor Injury	Dark	Dry	101	Car	Car	Car	N	W,E
12	21-May	2007	Mon	16:10	Serious Injury	Day	Dry	101	Car	Car		S	W
13	14-Jun	2007	Thu	17:35	Serious Injury	Dark	Wet	101	Van	Car		N	W
14	20-Aug	2007	Mon	18:55	Minor Injury	Dark	Dry	101	Car	Car		S	W

From the site inspection (Figure C.6(b)) it is evident that on the north approach, the drivers' attention is drawn through this intersection to the T-intersection beyond. Both Give Way signs are partly obscured: on the north by a pole and on the south by tree foliage. Non-standard centre of road markings on all 4 approaches look like roundabout splitter islands. The Give Way lines are worn.

**Figure C.6(b) – Intersection used in practical example 6**


**Assessment:** The crashes with vehicles on the second half of the major road suggest some drivers may think this is a roundabout, misled by the highly visible centre markings. On the north approach there is a low level, fully mountable roundabout at the previous intersection. However, the markings are only 2 years old. Alternatively, some drivers may have their attention drawn beyond the intersection by the T-intersection to the south. Direction 2 being west may be because most traffic on the major road approaches from the east.

**Treatment:** Immediate – install larger Give Way signs in more prominent positions, duplicate them on the right side of the road, change markings to standard centreline and holding line, install a Give Way Sign Ahead sign on both minor approaches. In the near future works program include a roundabout or on both minor approaches build a left kerb outstand and angled centre island (which sits across drivers' line of sight along the road) and install a pair of Give Way signs on these new features (decide which after an economic appraisal of both options).

### **C.7 Practical Example 7: Economic Appraisal**

#### **C.7.1 Example 7A: (based on Ogden 1996)**

Consider the installation of a roundabout in a local street discussed previously in Appendix C 4. Assume there is data on crashes, including crash type or DCA code and that the crash costs by crash-type are as shown in Appendix A. The following parameters apply:

- capital cost: \$240 000
- change in vehicle operating cost: assumed zero
- current crash rate: average of one adjacent approaches crash per year
- assumed effect of roundabout on crashes: 70% reduction
- appraisal period: 20 years
- discount rate: 4% per annum.

#### **The appraisal**

It is first assumed that there will be no change in the traffic flow through the intersection over the appraisal period. If this were not so, there would be a need to make some assumptions about what the likely future annual crash rate would be in the do nothing case (i.e. if the crash problem was not treated). However, as it is in a local street it could be reasonably assumed that if there is a history of one adjacent-approaches crash every year this will continue in the future in the do nothing case.

Therefore, in the 'do nothing' case, there is an annual crash cost of \$93 440 for intersection crashes (Table 5.4). The roundabout is expected to eliminate 70% of these crashes (Appendix E). It is assumed that there will be no other effects of the roundabout, i.e. that it will not introduce crash types which are not there at present. If this were not the case, there would be a need to estimate the additional effects. Therefore, the annual benefit of the roundabout is expected to be \$65 400.

Using a discount rate of 4% per annum, it is calculated (or obtained from discount tables) that the present worth of an annual sum of \$1 per year over 20 years is \$13.59. Therefore, multiplying the annual benefit value above by 13.59, the net present benefit of the project is \$888 800.

As the installation cost of the roundabout is \$240 000, the NPV is \$648 800 (i.e. \$888 800 – \$240 000) and the BCR is 3.7 (i.e. \$888 800 ÷ \$240 000).

#### **Sensitivity testing**

Assume range of crash reductions between 50% and 80%. In this case, keeping all other assumptions the same, the annual benefit of the roundabout project is between \$46 700 (at 50% reduction in crashes) and \$74 800 (at 80%) per year and the net present benefit of the project is \$634 700 (low estimate) to \$1 016 500 (high estimate). As the installation cost of the roundabout is \$240 000, the NPV is in the range of \$394 700 to \$776 500 and the BCR is in the range 2.6 (i.e. \$634 700 ÷ \$240 000) to 4.2 (i.e. \$1 016 500 ÷ \$240 000).

### C.7.2 Example 7B (based on Andreassen 1992a, p.5)

This example refers to the post-installation evaluation of a traffic signal installation program. New traffic signals were installed at 41 intersections. Figure C.7.2 shows an example of a traffic signal installed as a countermeasure to intersection crashes.

**Figure C.7.2 – Example of a recent traffic signal installation**



Crash data were analysed for 2 years before and 2 years after the installation at each site. The only significant changes in crash types were a reduction of adjacent-approaches crashes DCA code from 6.54 per site per year to 1.88, and an increase in right-turn-into oncoming-vehicle crashes (DCA 202) from 0.71 per site per year to 1.82. To evaluate the program the following assumptions are made:

- capital cost: \$170 000 per intersection
- operating cost: \$10 000 per intersection per year
- appraisal period: 10 years
- discount rate: 7% per annum.

#### **The appraisal**

It is assumed that the same level of crashes would occur each year for the next 5 years if the signals were not installed and that the crash rate experienced over 2 years would continue unchanged over 5 years.

Based on Appendix A, the average cost of a crash type 101 is \$93 440 and that for crash type 202 is \$92 482. The annual benefit of the program per intersection is:

the improved difference in annual crash frequency for intersection crashes (6.54 – 1.88)  
multiplied by the average cost per intersection crash (\$93 440

minus

the worsened difference in annual crash frequency for right turn into oncoming vehicle crashes  
(1.82 – 0.71) multiplied by the average cost per DCA 202 crash (\$92 482)  
= \$332 775 (per intersection per year).

The net annual benefit is less than this, as there is an annual operating cost of \$10 000. It is \$322 775. Using a discount rate of 7% per annum, it is calculated (or obtained from discount tables) that the present worth of an annual sum of \$1 per year over 10 years is \$7.02.

Therefore, multiplying the net annual benefit (\$322 775) by 7.02, the net present benefit of the signalisation project is \$2 265 883.

As the installation cost of the signals at each site was \$170 000, the NPV is \$2 095 883 (\$2 265 883 – \$170 000) and the BCR is 13.3 (i.e. \$2 265 883 ÷ \$170 000).

Note that the benefit has been taken as the net annual return from the investment (i.e. safety benefits minus operating costs) and the cost as the initial investment (installation cost). If the costs had been defined as the outlay by the road agency, as is sometimes done, this would have included the annual signal operating cost of \$10 000. In this case the benefit would be \$2 336 083 (7.02 x \$332 775) and the costs would be \$240 200 (\$170 000 + (7.02 x \$10 000)). This would give an NPV of \$2 095 883 and a BCR of 9.7 (i.e. \$2 336 083 ÷ \$240 200).

Note that the NPV is identical whichever way costs and benefits are defined, whereas the BCR will change.

### **C.8 Practical Example 8: Monitoring**

A narrow, two-lane wooden bridge in poor condition was replaced with a wider bridge. As part of the project the road was reconstructed a short distance in each direction. The south approach is straight, but the construction on the north end finished half way around a curve, signed at a 25 km/h advisory speed. The curve and speed warning was retained after the bridge was replaced. Figure C.8 shows an image of the reconstructed bridge.

**Figure C.8 – Looking north to the reconstructed bridge and curve**



**Table C.8 – Abridged factor matrix**

DCA code <sup>1</sup>	Key direction (to)	Number of crashes each year					Total this combination of DCA and key direction	Direction of other vehicle				Surface		Light condition			
		2002	2003	2004	2005	2006		To north	To east	To south	To west	Dry	Wet	Dawn	Daylight	Dusk	Dark
603	N					1	1	1				1			1		
607	N			1			1					1			1		
803 Off curve	N			1	2	6	9					7	2		2	1	6
804 Off curve	S					1	1						1				1
Totals				2	2	8	12	1				9	3		4	1	7

From the crash data and the factor matrix it is evident that drivers were failing to safely negotiate the curve after the bridge and running off the road. The crash data shows 5 of the DCA 803 crashes were on Saturday nights.

From the site inspection it is evident that the curve now has a change of radius half way. Near the bridge it is faster than 25 km/h, then it tightens to 25 km/h. The slower section has no edgelines. Approaching from the south the curve looks faster.

**Assessment:** This example illustrates how improving the approach to a substandard curve has lessened drivers' expectation that the road ahead is of poor alignment. The improved bridge alignment encourages higher speed into the tight curves whereas previously the bridge acted as a traffic calming device. There is nothing to suggest the curve tightens and so the 25 km/h advisory speed sign loses its credibility. If the design had been road safety audited, the potential problems could have been avoided. In the absence of an audit, this illustrates the importance of monitoring the effects of projects, especially on adjacent sections of road.

**Treatment:** Short term: improve the warning and delineation for the curves, including prominent warning that it tightens after the curve starts. Extend the guard fence. Consider lighting the curve. Longer term: reconstruct the whole curve and nearby sections so that they have a consistent design speed and consistent markings and delineation.

## **Appendix D: Detailed Case Study**

In Appendix D, a case study is used to illustrate how to apply each of the steps in the investigation and treatment process, as described in this document. While it is based on a real example, some circumstances and data have been altered for the purposes of presentation.

### ***D.1 Step-by-step Process in the Investigation and Treatment Process***

#### **D.1.1 Background**

A fatal head-on crash occurs on a curve on an urban arterial road in mid-2007 (on High Street between the Golf Club intersection and Craig Street (Figure D.1.3). A southbound car crossed the centreline. As part of the investigation of the fatal crash, state crash records are examined. They show that on this section of road, for the previous 10 years, only 2 other crashes have been reported, both run-off-the-road southbound. There are common factors in the 3 crashes:

- all involved loss of control
- all left their lane on a curve
- all problem movements were southbound.

There have been only 3 crashes in 10 years. Is this really a problem location or is it just typical of urban crash patterns and nothing more than random events, albeit with a severe consequence in the latest crash? It is decided to conduct a fuller investigation.

#### **D.1.2 Deciding which road sections and intersections are to be included**

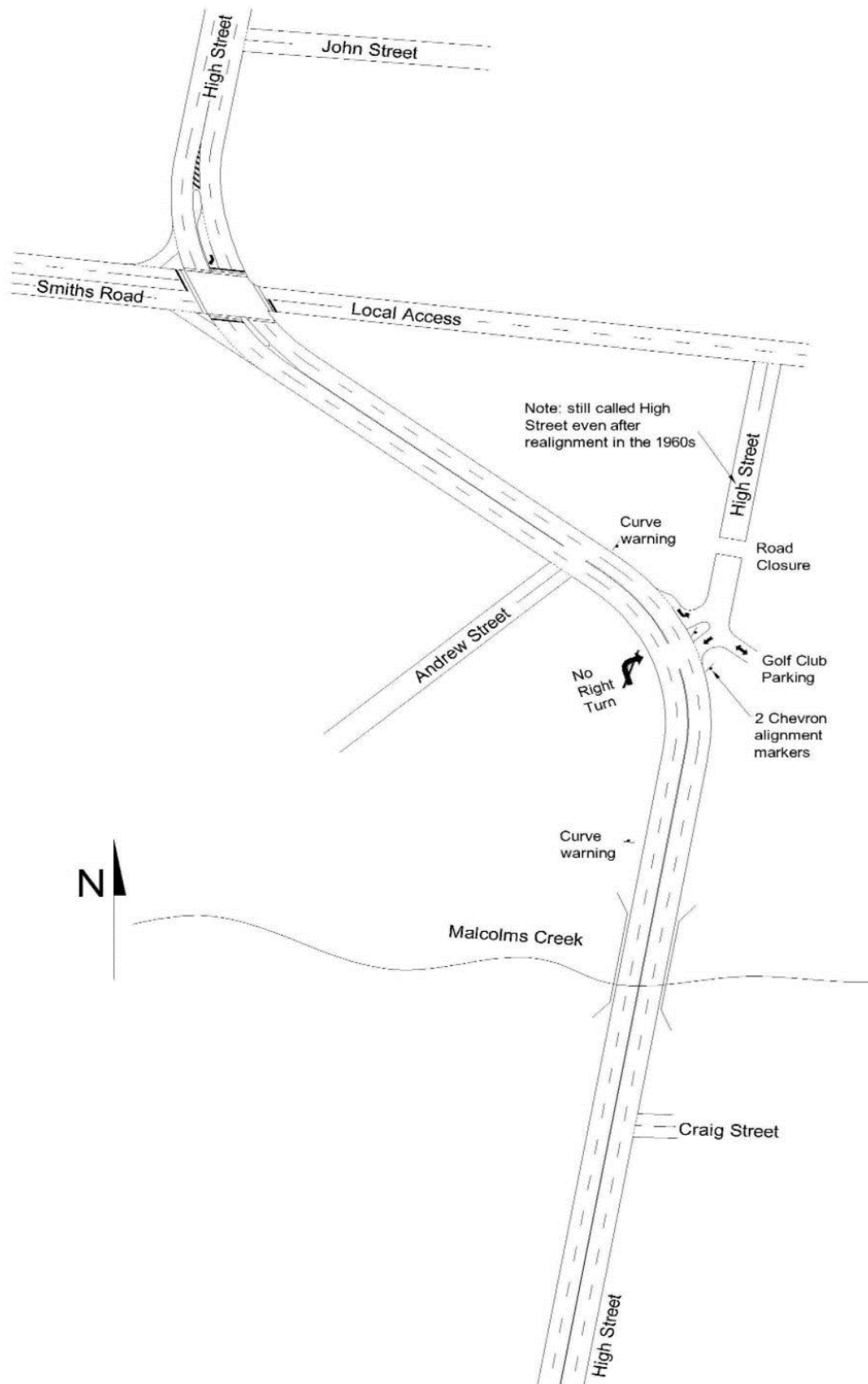
In the state crash records, the road section in which the fatal crash occurred is 200 m long, between 2 adjacent intersections. But it is only one part of a longer curve. The curves were built in the late 1960s to realign High Street and make it continuous. It is decided to look at the complete reverse curve and approaches. This includes an arterial road intersection within the reverse curve (Figure D.1.3).

As soon as the crash information is collected for the complete section of road, it is discovered that there have been over 40 crashes in the previous 5 years, including 12 out-of-control and 8 head-on. It is locally termed a 'blackspot', hidden by the segregation of crash records into individual road lengths and intersections. This shows the importance of looking at whole lengths which have consistent characteristics. It is decided the crash investigation will examine the whole length.

#### **D.1.3 Deciding on the time period**

Traffic signals were installed at the intersection to the north in the late 1980s. This road and other similar arterial roads were marked into 4 traffic lanes in the early 1990s. In the late 1990s the southern curve was treated with longitudinal grooving. Within the past 3 years a nearby local street has been closed and a left turn deceleration lane installed into it, as part of a golf club expansion. However, at least 3 years' crash data are required, so those recent changes will need to be kept in mind but should not restrict the time period. It is decided to look at the previous 5 years' data, a period in which there were no other changes.

Figure D.1.3 Case study site plan (not to scale)



## D.2 Obtaining all the Relevant Information

The relevant information includes the crash data from the state crash records and the traffic volumes. Anecdotal information from residents can be helpful, although judgement is required before it is used as a basis for decisions (or, equally, dismissed as not relevant). Information about the physical features of the road will be critical in the assessment.

The traffic volumes are:

- High Street: 24 000 vpd
- Smiths Road: 13 000 vpd.

There are no recent turning counts at the arterial road intersection. The current speed limit is 70 km/h. The crash information in the state crash records is set out in Table D.2(a) and Table D.2(b)). It is grouped by intersection and road section, using the numbers in the route plan as shown in Figure D.2.

**Table D.2(a) – Case study crashes at intersections**

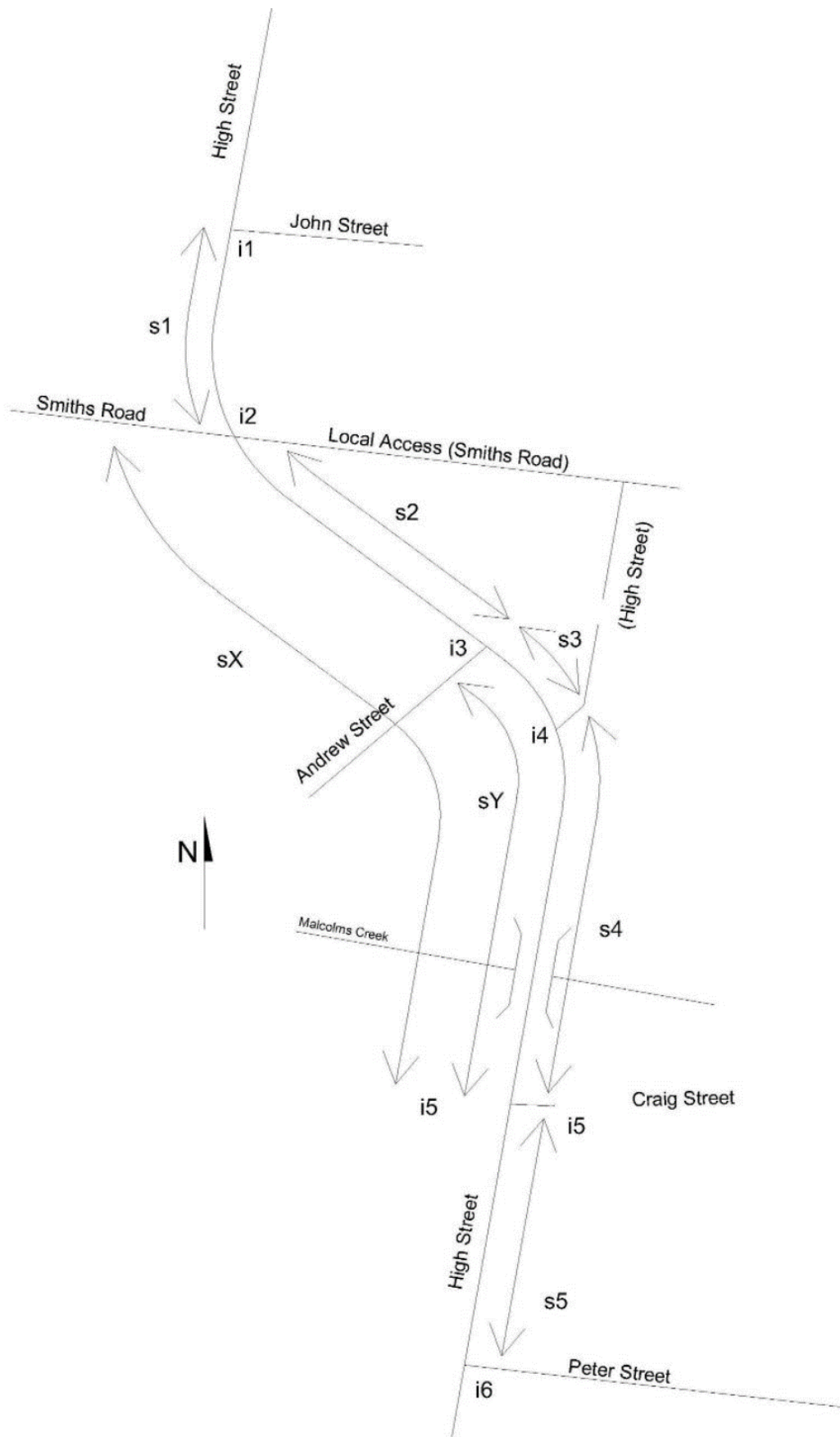
Crash number	Road location	Date: day – month	Date: year	Day of week	Time of day	Severity	Light condition	Road condition	DCA code (crash-type)	Object 1	Object 2	Object 3	Direction 1	Direction 2 (&3)
21	s1	15-01	2004	Thu	08:00	NI5	Day	Dry	703	Car	Sign		N	
22	s1	03-09	2004	Fri	11:30	MT3	Day	Dry	003	Bus	Ped		S	
23	s1	02-11	2004	Tue	07:00	INT4	Day	Wet	603	Car	Car		N	N
24	s1	17-04	2005	Sun	13:10	NI5	Day	Dry	307	Car	Car		N	N
25	s1	14-01	2005	Fri	22:45	HA2	Dark	Wet	201	Car	Car		N	S
26	s1	18-06	2005	Tue	14:20	HA2	Day	Wet	703	Car	Car	Fence	N	S
27	s1	22-03	2006	Tue	14:20	HA2	Day	Wet	603	Car	Car	Ped	N	N
28	s2	30-03	2002	Sat	13:00	NI5	Day	Wet	201	Car	Car		N	E
29	s2	23-08	2003	Sat	07:15	NI5	Day	Wet	703	Car			S	
30	s2	21-10	2003	Tue	19:40	HA2	Dark	Dry	201	Car	Car		NE	S
31	s2	07-02	2004	Sat	11:30	NI5	Day	Dry	406	Car	Car		N	W
32	s2	25-06	2004	Fri	01:00	HA2	Dark	Wet	804	Car	Tree		N	
33	s2	05-10	2004	Tue	18:00	NI5	Dusk	Wet	307	Unknown	Car	Pole	S	S
34	s2	28-05	2006	Sat	05:15	HA2	Dark	Wet	201	M/cyc	nk		N	S
35	sX	27-10	2004	Wed	17:30	NI5	Day	Wet	301	Car	Car		S	S
36	sX	15-03	2005	Tue	20:30	NI5	Dark	Dry	201	Car	Car	Car	S	N,S
37	s3	28-02	2003	Fri	09:30	INT4	Day	Wet	201	Truck	Car	Car	S	N,S
38	s4	03-10	2003	Fri	01:20	NI5	Dark	Wet	801	Car			SE	
39	s4	04-12	2005	Sun	18:10	HA2	Day	Dry	803	Car	Car	Gdrail	S	N
40	sY	09-06	2004	Wed	13:30	NT5	Day	Wet	201	Car	Car	Car	SE	N,S
41	s5	02-02	2005	Wed	10:45	NI5	Day	Wet	202	Car	Car		nk	nk
42	s5	08-06	2005	Wed	16:20	HA2	Day	Dry	003	Car	Ped		S	
43	s5	25-04	2006	Mon	22:30	INT4	Dark	Dry	303	Car	Car		S	S

**Table D.2(b) – Case study crashes between intersections**

Crash number	Road location	Date: day – month	Date: year	Day of week	Time of day	Severity	Light condition	Road condition	DCA code (crash-type)	Object 1	Object 2	Direction 1	Direction 2
1	i1	22-02	2003	Sun	19:20	NI5	Dusk	Dry	703	Car	Hydrant	N	
2	i1	23-11	2004	Tue	14:45	NI5	Day	Dry	202	Car	Car	N	S
3	i1	12-09	2005	Mon	17:40	MT3	Day	Wet	201	Car	Car	N	S
4	i2	13-02	2003	Thu	08:30	INT4	Day	Wet	302	Car	Car	E	E
5	i2	11-03	2003	Tue	08:20	MT3	Day	Dry	302	Car	Car	N	N
6	i2	11-08	2003	Mon	08:20	INT4	Day	Dry	302	Minibus	Car	NW	NW
7	i2	30-10	2004	Sat	01:30	NI5	Dark	Dry	301	Car	Car	S	S
8	i2	16-05	2004	Sun	10:45	MT3	Day	Dry	202	Car	Car	S	N
9	i2	15-06	2004	Tue	15:30	MT3	Day	Dry	308	Car	B/cyc	E	E
10	i2	02-08	2004	Mon	18:15	INT4	Dark	Wet	705	M/cyc		SE	
11	i2	15-03	2005	Tue	16:30	NI5	Day	Wet	202	Car	Car	N	S
12	i2	30-09	2005	Fri	00:30	NI5	Dark	Dry	804	Car	Signals	S	
13	i2	01-05	2006	Mon	09:30	NI5	Day	Dry	302	Truck	Car	E	E
14	i2	19-12	2006	Tue	06:30	NI5	Day	Dry	303	Car	Car	N	N
15	i2	21-04	2006	Fri	13:50	INT4	Day	Dry	202	Car	Car	SW	N
16	i2	30-08	2006	Wed	00:35	INT4	Dark	Dry	804	Car	Signals	S	
17	i2	22-10	2007	Mon	17:50	MT3	Dusk	Dry	705	M/cyc		E	
18	i2	01-12	2007	Sat	23:50	HA2	Dark	Wet	803	Car	Signals	N	
19	i3	12-Jun	2006	Mon	20:30	NI5	Dark	Wet	703	Car	Post	N	
20	i3	27-Apr	2007	Fri	05:15	K1	Dark	Wet	703	Car	Tree	SE	

- Road location: see the plan; i = intersection, s = between intersections
- DCA code: see Figure 3.1
- Object: (vehicle, person or object) number relates to direction number; nk = not known
- Direction: the direction the vehicle or person was travelling in when the collision occurred (and before making any turn involved in the collision).

Figure D.2 – Case study route plan showing road section and intersection numbers



### **D.2.1 Data discrepancies**

The information in Table D.2(a) and Table D.2(b) is a direct tabulation of the state crash record information. Note that some of the information requires interpretation:

- Direction 1 and 2 are the direction the vehicle was travelling in. Some directions are recorded as SE (south-east) while others are S (south). By looking at the plan of the road, common-sense shows these are the same direction. However, crash number 15 has a direction SW. This appears to be wrongly recorded at the site (i.e. it is the direction after a turn was commenced, rather than before). It should be coded S.
- For one crash, the direction of travel is not known. This crash cannot be included in the collision diagram unless the original police report form is obtained (and even then it may not be possible).
- Crashes no. 35, 36 and 40 were coded not using adjacent intersection names. To determine the location, the original police report form needs to be examined.
- The plan of the road shows that there are 2 intersections of Smiths Road with High Street, as the old bypassed road has not had a change of name. There is also an intersection of High Street with High Street. In these circumstances, care is needed in interpreting the state crash records (e.g. look at chainage information, type of intersection control, type of crash, or obtain the police report form).

### **D.3 Constructing a Factor Matrix and Identifying Common Factors and Clustering of Crashes**

An examination of the factor matrix applicable to the case study shows that:

- A high number of off-travel-path crashes (DCA 701-5 and 801-5) occurred on a wet road.
- An unusually high number of northbound loss-of-control crashes (DCA 701-5 and 801-5) occurred on Sunday.

During construction of the factor matrix it became apparent that:

- DCA 201 (head-on) crashes principally occurred on a dry road at night or on a wet road in daylight.

### **D.4 Drawing a Collision Diagram and Identifying Clusters of Crash types at Locations**

The collision diagram which does not show all the road features, as a separate plan (a crash factor matrix) has been prepared showing intersection controls, lane lines, islands, etc. and this would be included with any crash investigation report. An examination of the factor matrix shows that:

- Off-travel-path crashes (DCA 701–705 and 801–805) and head-on crashes (DCA 201) predominate around the southern curve, principally for southbound vehicles.
- North of the signalised intersection (i.e. the northern curve) northbound vehicles are going off their travel path (DCA 701–705 and 801–805) or crossing the centreline (DCA 201).
- At the signalised intersection, there is no significant clustering by crash types, although there are some crash types which have more than one crash: off-travel-path (DCA 701–705 and 801–805), right-turn-into-oncoming-traffic (DCA 202) and rear-end-into-left-turn (DCA 302) on 2 approaches.

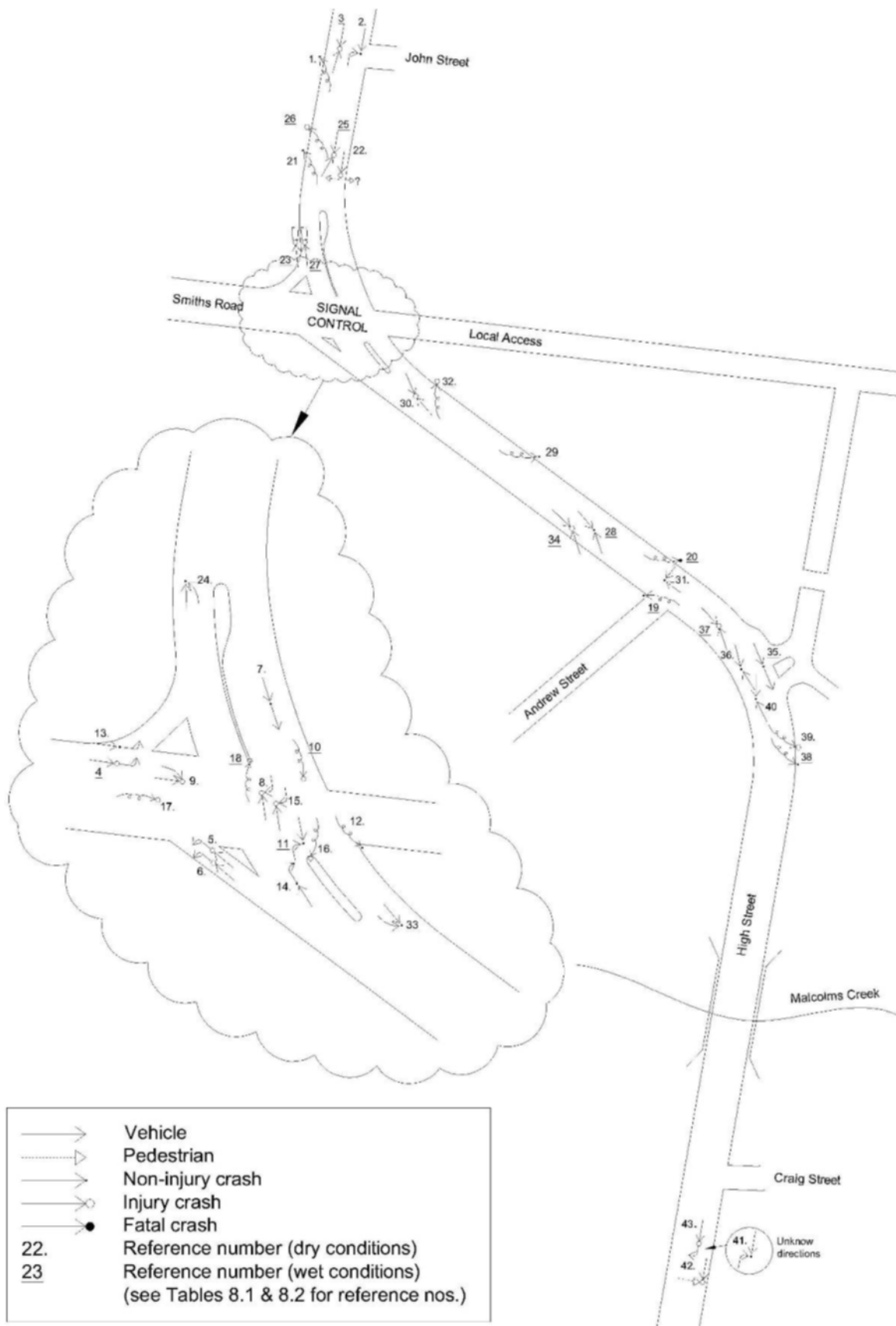
- Looking at crashes involving travel along High Street, 18 out of 34 crashes north of the creek bridge occurred in wet weather.

**Table D.4 – Case study – Factor matrix**

DCA code <sup>1</sup>	Key direction (to)	Number of crashes each year						Direction of other vehicle				Type of road users					Surface		Light condition				Day of week*						
		2002	2003	2004	2005	2006	Total	To north	To east	To south	To west	Car or similar	Van, light truck	Truck	Bus	Motorcycle	Bicycle	Pedestrian	Dry	Wet	Dawn	Daylight	Dusk	Dark	Weekday	Saturday	Sunday	Most common day	
201	N	1	1	1	1	1	5		1	4					1			1	4		2		3	4	1			-	
201	S		1	1	1		3	3										1	2		2		1	2			1	-	
701 -5 and 801 -5	N	1		2	2	1	6			1				7						2	4		2	1	3	1		5	SUN
701 -5 and 801 -5	S		3	1	2	1	7	1						7			1			3	4		2		5	5	2		-
202	N		1		1		2	2						4						2			2		1		1	-	
302	N	2					2	2						3			1			2					2			-	
302	E	1			1		2		2					3		1			1	1		2			2			-	
603	N			1		1	2	2						4						2		2			2			-	
Totals		5	6	6	8	4	29	10	3	5				44		2	1	2		12	17		16	1	12	19	3	7	

Note: A copy of an example blank factor matrix form can be found in Appendix B. The last columns of this blank form can be used for a variety of factors that might influence safety at the location being assessed, including issues such as time of day, day of week, severity etc. In this case, day of week was selected as a relevant factor, but for other situations, different variables may be more appropriate.

Figure D.4 – Case study collision diagram



## **D.5 Summarising the Factors Identified from the Crash Listings, Factor Matrix and Collision Diagram**

### **D.5.1 Intersections**

#### **John Street**

Of the 3 crashes, one was in the wet. The other 2 involve northbound vehicles.

#### **Smiths Road**

There were 15 crashes recorded. Factors include:

- 9 crashes in the daytime
- 11 crashes in dry conditions
- 6 involved southbound vehicles in the first instance, 5 northbound and 4 eastbound
- 5 were off-travel-path, 3 involved right-turn-into-oncoming-traffic (mix of directions), 4 were rear-end-left-turn (2 at each of the slip lanes).

The predominant factors were southbound traffic, left turn slip lanes and loss of control.

#### **Andrew Street**

There were 2 crashes, both in the dark and in wet conditions. Both were off-travel-path type, rather than involving intersection conflicts, so they have been included in consideration of the reverse curve section between Smiths Road and Craig Street (see below).

### **D.5.2 Road sections**

#### **John Street to Smiths Road**

There have been 7 crashes. Common factors include:

- 6 crashes in the daytime
- 5 crashes in wet conditions
- 6 involved northbound vehicles in the first instance
- one head-on, one side-swipe, one pedestrian, 2 off-travel-path and 2 struck a stopped vehicle (crash or broken down) mid-block.

The predominant factors are northbound traffic, wet road surface, parking and not keeping in one lane.

#### **Smiths Road to Craig Street**

There have been 15 crashes. Common factors include:

- 7 crashes in the daytime, 7 in the dark and one at dusk
- 11 crashes in wet conditions
- 9 involved southbound vehicles in the first instance and 6 northbound
- 6 involved loss of control and off-the-carriageway and 6.

The predominant factors are wet conditions, head-on crashes and vehicles leaving the carriageway.

### **Craig Street to Peter Street**

There have been 3 crashes. Common factors include:

- 2 crashes in the daytime
- 2 crashes in dry conditions
- 2 involved southbound vehicles in the first instance (the third one is unknown).

There is no common crash pattern; the predominant factor is southbound vehicles.

### **D.5.3 Summary of factors**

Common factors include:

- A high number of off-path crashes (DCA 701–5 and 801–5) occurred on a wet road.
- An unusually high number of northbound off-travel-path crashes (DCA 701–5 and 801–5) occurred on Sunday.
- DCA 201 (head-on) crashes principally occurred on a dry road at night or on a wet road in daylight.
- Off-path crashes (DCA 701–705 and 801–805) and head-on crashes (DCA 201) predominate around the southern curve, principally for southbound vehicles.
- North of the signalised intersection (i.e. the northern curve) northbound vehicles are losing control or running off the carriageway (DCA 701–705 and 801–805) or crossing the centreline (DCA 201).
- At the signalised intersection, there is no significant clustering of crash types, although there are some crash types which have more than one crash: off travel path (DCA 701–705 and 801–805), right turn into oncoming traffic (DCA 202) and rear end into left turn (DCA 302) on 2 approaches.
- 18 out of 34 crashes involving travel along High Street north of the creek bridge occurred in wet weather.

Armed with this summary (in a preliminary report), the crash listing, the factor matrix and the collision diagram, the crash investigation team can now inspect the site. An example of a preliminary report for a different site (produced prior to a site inspection) can be found in Appendix C.

### **D.6 Inspecting the Site**

An inspection of the case study site in daylight and at night-time resulted in the following observations:

- Observations from driving the site
- There are 2 substandard curves, with inadequate warning and delineation
- Trees obscure sections of the curving alignment in both directions. Trees obscure traffic signals and warning signs southbound as shown in Figure D.6.

**Figure D.6 – Vegetation obstructing signal on the southbound approach curve**

- There is poor alignment of traffic lanes in both directions on the north curve:
  - Northbound, the alignment on the south approach to Smiths Road runs traffic in the left lane into the right lane on the departure side and runs traffic in the right lane into the median on the departure.
  - Southbound, the curve begins tight, slackens through Smiths Road, then tightens again. On the departure from Smiths Road, the left kerb at the end of the bus bay is aligned so that it protrudes into the left lane travel path: it is at the tight part of the curve, and it has been struck often. The bus bay is partly on the left-hand curve, so there is poor kerb definition around the curve.
- There is very poor visibility between traffic on the north approach and traffic activity within the eastern half of the Smiths Road intersection (e.g. signal displays, pedestrians on the road).
- The alignment through the south curve is uniform, but tight (advisory 50 km/h):
  - Northbound, the curve warning sign is small and too close to the curve. There is no delineation around the curve. The RRPMS on the centreline are not picked up by headlights due to the tight left curve and the orientation of the RRPMS.
  - Southbound, the single curve warning sign on the left is too close to the curve (and is the first curve warning southbound). Driver attention is focused on the tight curve and the warning sign may be missed. The outer kerb alignment is interrupted by the left turn deceleration lane into the closed section of High Street. There are 2 CAMs (chevron alignment markers) on the outside of the curve. They are too few, too small and they are too low down (lost in the foliage). The guardrail south of the curve is close to the kerb, making the left lane seem narrow.

### D.6.2 Observations from inspecting the site on foot

- Northbound, there is no warning of the curve and delineation consists of the lane line, RRPMS and kerbs. On the approach a (worn out) crossroad warning sign gives misleading information. The left turn lane into Smiths Road runs in a direct alignment off the left kerb. Staying on High Street requires a right curving movement.
- Southbound, there is no warning of the curve, the signals or the intersection. There is a severe visibility problem on the north approach. In the left lane in particular, there is insufficient sight distance to the east part of the intersection, because the road curves left and the properties on the left (east) side block the view. In addition, the street tree outside the second house from the corner petrol station obscures visibility to the signals. A pedestrian considering crossing High Street from the north-east corner of the intersection has only about 50 m (3 seconds of travel) sight distance to any southbound traffic. This is grossly inadequate for safety. The wattles on the south-east corner block visibility to the first curve warning sign. They hang out over the road.
- Other pedestrian issues: there are no pram crossings across Smiths Road on the west side of the intersection; the pram crossing on the north-east corner (for crossing Smiths Road) is too far around the corner to expect left turning motorists to give way; on the south-west corner, the pram crossings do not line up for the shortest crossing distance over the slip lane, and a redundant pram crossing encourages pedestrians to cross Smiths Road to the west of the intersection.
- On the eastbound approach, a street tree completely blocks visibility to the primary signal lanterns.

#### The south curve

- There is no lane widening on the curve. The lane widths are minimum for a straight road, but inadequate for a curve (12.2 m between lips of channel, for 4 lanes). Larger vehicles are unable to stay within a single lane and the road is undivided.
- There is longitudinal grooving around the south curve.
- Northbound, the curve warning sign (too close to the curve) is the minimum size and its reflectorisation is poor. A large wattle in the parkland on the west side obscures the alignment of the road. A large gum tree beyond it also partly obscures the alignment.
- Southbound, many vehicles were observed cutting the curve and driving outside their lane as shown in Figure D.6.2 below. The 2 CAMs on the outside of the curve have Class II reflective sheeting instead of Class 1. They start too late and end too soon (they do not provide worthwhile curve delineation).
- There is W-beam guard fence on the outside (east side) of the curve, to restrain errant southbound vehicles. This guard fence is a hazard, for example, it has been struck several times (not repaired), starts too far around the curve, has no spacer blocks, and is too close to the kerb; its northern end treatment is rigid and is located part way around the curve where it can be struck by an errant vehicle; beside the end treatment there is an unprotected rigid wooden electricity pole; the south end treatment is rigid.

**Figure D.6.2 – Inadequate lane width for southbound traffic on the south curve****Other observations**

- There are rigid electricity poles close to the carriageway on the splitter island on the south-west corner of Smiths Road (on the outside of the curve, northbound) and on the east side of the road, just north of the south curve.
- There is no separate right turn lane for traffic from the south at Smiths Road, despite this being the only entry from the south to the golf club car parking. It is on a curve and is likely to increase the risk of rear-end crashes. The northbound slip lane enters Smiths Road at an angle of 40°, which encourages speed.
- The eastbound slip lane in Smiths Road has its Give Way sign too high and the repeater sign on the left is too far around (after the petrol station driveway). The holding line position results in a conflict between left turners and any northbound vehicle in High Street which is travelling into the petrol station.
- Some sections of High Street appear to have a polished surface.

**D.6.3 Observed driver behaviour**

- Southbound through the south curve, trucks and buses could not keep within the lane width. Numerous smaller vehicles were observed cutting the curve and not keeping in their lanes.
- Northbound through the signalised intersection, some drivers in the left lane drifted across into the right lane, due to the poor alignment of the lane markings.
- In the left turn slip lane from south to west, some drivers used excessive speed and had to brake quickly when a conflicting car appeared.

#### **D.6.4 Confirm speed limit**

The appropriateness of the prevailing speed limit needs to be considered (refer to *Austrroads Guide to Road Safety Part 3: Safe Speed*). If required, a full assessment should be undertaken to determine the appropriate speed limit.

#### **D.6.5 Discussion**

Some of the observed safety deficiencies at the site appear not to be a contributing cause in any of the reported crashes. For example:

- There is very poor visibility north up High Street for a pedestrian standing on the north-east corner at Smiths Road.
- A street tree on the west approach in Smiths Road blocks visibility to the primary signal lanterns.

For the crash investigator, how should these other safety hazards be dealt with? The answer is that this requires road safety engineering judgement. If the problem really is potentially serious (as the above 2 examples are), then it should be included in the list of problems and remedial treatments. Bear in mind that this may be the only time that safety problems at this location are thoroughly investigated. And it may well be that low cost, yet effective, treatments can be included (e.g. signs or removal of a tree). They could be included in the report as other safety problems warranting treatment.

#### **D.7 Selecting the Countermeasures**

The reported crashes typically provide the best information about the main problems to be solved. The site inspection provided insights into possible causes of some crashes. Another aspect of the problem is user behaviour issues noted on-site. Some of this behaviour (e.g. crossing the centreline on curves) is likely to be a factor in reported crashes (e.g. head-on crashes). The task now is to deal with those physical features of the road which are leading to crashes or to potentially unsafe behaviour. Firstly, it is apparent that there is no pattern to the 3 crashes south of Craig Street and these will not be considered further here.

##### **D.7.1 Loss of control and head-on crashes**

The reverse curves are substandard and vary in safe driving speed. One factor in the high number of loss of control crashes and head-on crashes is that people are driving too fast for the conditions or are misjudging the alignment. The south curve is tighter than the north curve. Possible solutions include:

- provide warning which is large enough and early enough
- install duplicate reverse curve signs on both approaches and repeater curve signs half way
- review the speed limit
- delineate both curves using chevron alignment markers (CAMs) (one curve has substandard CAMs)
- improve lane lining and delineation of lines (RRPMs)
- align RRPMs so headlights pick them up in time.

Of the 34 mid-block crashes, 18 occurred in wet weather, suggesting that the skid resistance of the road surface required investigation, possibly testing. Eight of the 13 loss-of-control crashes occurred at night. The lighting appeared adequate and the pattern of lanterns was not misleading. It is recommended that reliance be placed on warning and delineation improvements (outlined above).

The lanes are only 3.05 m wide (adequate on a straight urban road) but are not widened on the curves. Large vehicles are unable to stay in their lane. If drivers make errors, there is no room for correction within a lane. Over most of the length the road is undivided, and vehicles cross the centreline. Widen the lanes on the curves and physically separate opposing traffic.

Through Smiths Road (the north curve), there is poor alignment in both directions. Realign the lane lines and edgelines (include RRPMS) in both directions, to provide smooth alignments.

Trees block visibility to signs (southbound) and the general alignment (both directions) for the south curve. Remove or prune trees regularly to restore adequate visibility.

#### **D.7.2 Fixed object crashes**

Cars have run into parked vehicles, northbound, north of Smiths Road. Install permanent no stopping restrictions on the west side, north from Smiths Road.

Trees and poles on the east side, south of Smiths Road have been hit in 3 crashes. The trees block visibility to the alignment and signs. Two poles are very close to the roadway. Remove the trees and relocate the poles back from the kerb.

Two vehicles have struck the guard fence, on the east side at the south curve. The inspection showed the guard fence to have several hazardous aspects and was not shielding an electricity pole where it started. It was too close to the narrow lanes. Reconstruct the guard fence to current standards and shield the pole (note that this particular pole has not been struck but hit-pole crashes have occurred through this section).

Signals have been struck at the Smiths Road intersection. Countermeasures (above) to improve the road surface, delineation and lane alignment should address this problem.

#### **D.7.3 Other intersection crashes**

On the north approach to Smiths Road, there has only been one rear-end crash and one out-of-control-on-carriageway crash, but the site inspection identified a severe visibility obstruction to the traffic signals and pedestrians, caused by trees in the properties on the east side and by a street tree. Remove one street tree before the curve and 2 between there and the signals. Take steps to widen the road reservation to achieve adequate visibility (possible medium-term project).

The 4 rear-end left-turn crashes at the 2 left-turn slip lanes are likely to be caused by the alignment which permits high speed turns and results in last minute braking. Reshape the slip lanes to a 70–90° intersection angle with the road they enter.

The 2 right-turn-into-oncoming-traffic crashes on the north approach may have involved visibility being blocked by an oncoming right turner (there is no oncoming right-turn lane). On the south approach there was a rear-end right-turn crash. Construct a separate right-turn lane on the south approach.

#### **D.7.4 Other issues**

The site inspection identified other matters which need to be addressed, especially where they have a high potential for injury crashes, or they are cheap to solve.

On the west approach in Smiths Road, a street tree close to the intersection blocks the primary signal lanterns. Remove the tree.

Access to the golf club is difficult from the south and requires vehicles to U-turn at the signals where there is no separate right turn lane. Include alternatives in the design.

In the next section a design will be prepared, incorporating the countermeasures proposed here.

### ***D.8 Designing a Safe Remedial Treatment***

The individual countermeasures need to be incorporated into a safe remedial treatment. They should not cause any new problems in the way they are added to the existing layout.

In this case, 2 options will be developed, because the option of widening the road to provide physical separation of opposing traffic and wider lanes is relatively expensive (Figure D.8(b)). Thus, an option involving works generally within existing kerbs has been developed as a short-term option which can be implemented quicker, but which will have an impact on road capacity (Figure D.8(a)).

In the lower cost option, the separation of traffic has been achieved by reducing northbound traffic to one lane. This could be done in both directions, but there can be increased crash costs with merging traffic to one lane on an urban road with residential driveways. The designers considered it difficult to find a safe location for a southbound merge.

Both options include a northbound right turn lane to the golf club and clubhouse. As soon as the designs commenced it became obvious that this access was a real problem. The previous road closure in old High Street (to protect local residents from clubhouse traffic) severely limits options for low-cost safe access to the clubhouse. This emphasises the importance of taking a broad road safety view of proposals like road closures and developments adjacent to arterial roads – and of having the proposals road safety audited.

Both options retain the traffic signals at Smiths Road. An alternative could be a roundabout, involving road widening on the south-west corner. The need for pedestrian signals would need to be investigated in association with a roundabout.

Both options ban right turns into Andrew Street. Although there have been no reported crashes involving this turn, the designers consider the risk may increase. Safer alternative access is available via Smiths Road.

The new preliminary designs will need to be road safety audited, to ensure they are safe and do not introduce any new safety problems.

Figure D.8(a) – Lower cost case study treatment option (drawing not to scale)

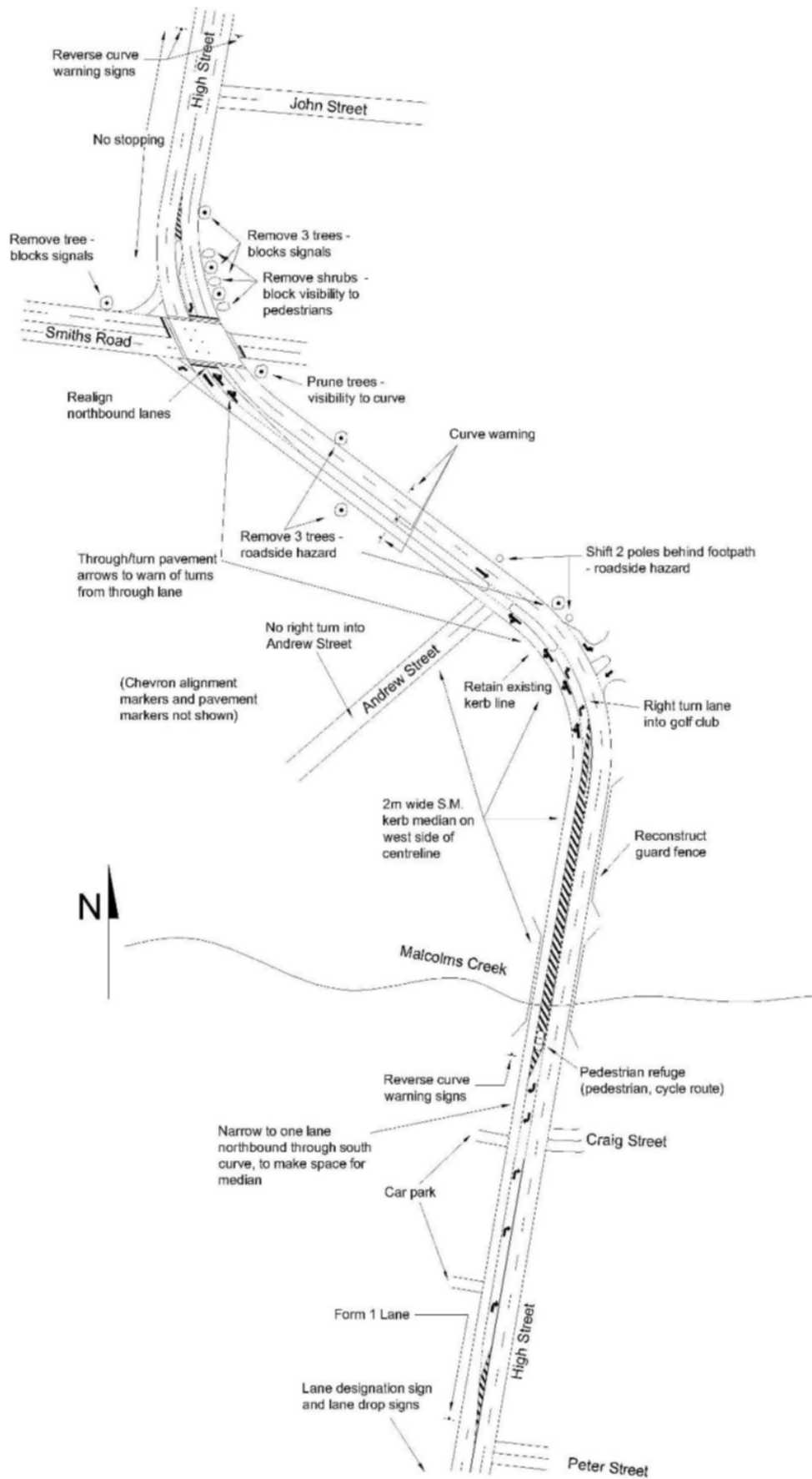
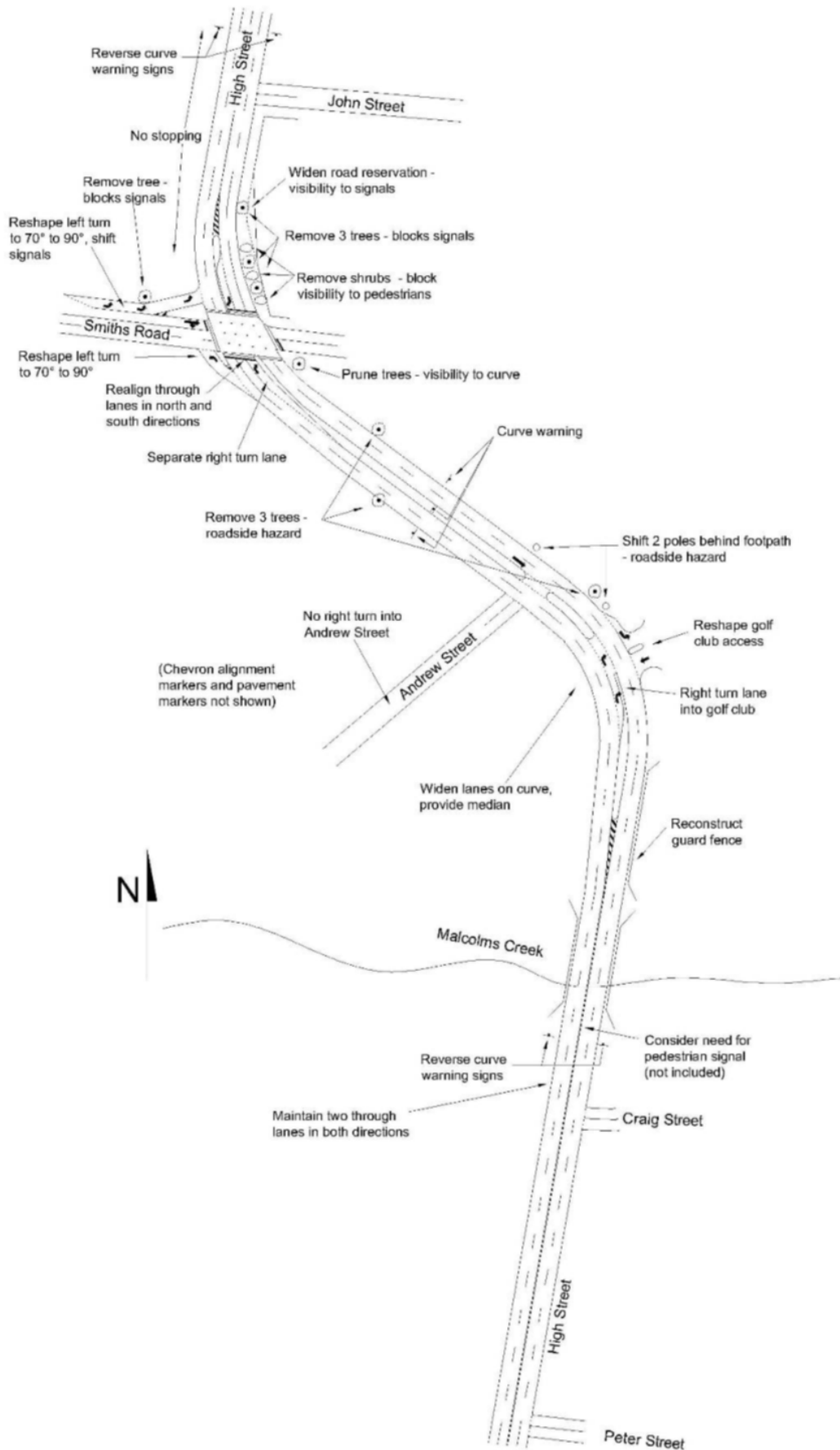


Figure D.8(b) – Higher cost case study treatment (drawing not to scale)



### D.9 Economic Appraisal

The options in Figure D.8(a) and Figure D.8(b) above involve the implementation costs shown in Table D.9(a) below, estimated by the road agency's designers. Note that these costs are provided for the purpose of this case study only. Estimated costs of treatments should be obtained from the relevant jurisdiction.

**Table D.9(a) – Implementation costs for the case study options (A\$)**

Item	Cost option (lower cost) \$	Cost option (higher cost) \$
Curve warning signs (8). Reverse curve on approaches and single curve in between	2 500	2 500
Chevron alignment markers (CAMs) (14) – both directions on both curves	3 500	3 500
Replace/realign RRPMS	1 500	1 500
Re-surface the road to restore appropriate level of skid resistance	150 000	150 000
Physically separate opposing traffic with a kerbed median	90 000	150 000
Widen the lanes on the south curve	–	350 000
Realign the lane lines and edgelines at Smiths Rd (with RRPMS) in north or both directions, to provide smooth alignments	1 000 (to north)	1 500 (both ways)
Tree removal: 3 south of John Street; 1 west approach in Smiths Rd.; 3 south of Smiths Rd.; prune 4 others	5 000	5 000
No Stopping restrictions on the west side, north from Smiths Road	500	500
Relocate 2 poles back from the kerb, east side between the curves	25 000	25 000
Reconstruct the guard fence	35 000	35 000
Widen the road reservation to achieve adequate visibility, east side north of Smiths Rd	–	120 000
Reshape the 2 slip lanes to 70–90 degree intersection angle with the road they enter	–	40 000
Construct a separate right turn lane on the south approach to Smiths Rd; realign lanes	–	55 000
Total	314 000	939 500

The expected crash reductions for the 2 options in Figure D.8(a) and Figure D.8(b) are set out in Table D.9(b) below. It should be noted that:

- The case study site is in an Australian state, so that the values in Table 5.1.2(d) apply.
- The crash costs in Table 5.1.2(d) already include factoring for severity; thus, the severity is not separately considered at this stage; it is just the number of crashes for the different crash types.
- The crashes south of Craig Street are not included, as the scheme is not likely to address the causes of those crashes.

- It is assumed that a DCA 603 crash has the same costs as a DCA 601 crash in Appendix A.
- It is expected that the northbound merge in Option 1 (Figure D.8(a)) will result in an increase in crashes at that location, though of a lower severity than those occurring on the curves.

**Table D.9(b) – Annual crash reduction savings for the case study options (A\$)**

Crash type	\$ Cost / crash (metro)	No. of crashes per year	Likely crash reduction (–) or increase (+)			
			Option 1 (lower cost)		Option 2 (higher cost)	
			%	\$ / year	%	\$ / year
001–003	164 600	0.2	–30	–9 900	–30	–9 900
703–704	116 200	1.2	–20	–27 900	–40	–55 800
705	84 400	0.4	–20	–6 750	–20	–6 750
801–802	102 700	0.2	–10	–2 050	–20	–4 100
803–804	137 600	1.0	–20	–27 500	–40	–55 000
201	178 300	1.6	–90	–256 750	–90	–256 750
202–206	77 300	0.8	–30	–18 550	–30	–18 550
301–303	38 800	1.4	–10	–5 450	–40	–21 750
305–307	60 600	0.4	20	–4 850	–40	–9 700
• existing	60 600	0.5 say	+100	+30 300	0	0
• new northbound merge						
308–309	54 200	0.2	0	0	0	0
407	54 900	0.2	–20	–2 200	–20	–2 200
601 (603)	55 000	0.4	–50	–11 000	–50	–11 000
Total				–342 600		–451 500

With the construction costs and crash reduction benefits estimated, an economic appraisal can be made. The objectives in this appraisal are to:

- decide whether the proposed treatment options are beneficial (benefits are greater than costs)
- establish the value of the benefits
- decide which one of the options gives the greater benefits.

It has been assumed that the traffic volumes remain the same over the appraisal period. The lower cost option involves a reduction in northbound traffic capacity. At this stage it has been calculated (by separate calculations not included here) that there will not be any significant delays (i.e. costs) associated with this capacity reduction. If congestion was to occur, an assessment of treatment options should take this into account.

Also note that these 2 options are not the only options. As the crash reduction benefits of the separate elements of each option can be estimated, some parts of the treatment could be deleted (or added) and the effect on crashes recalculated. However, this can only be done within a process whereby sound road safety engineering judgement is applied: taking elements of a treatment out without understanding their impact on the effectiveness of other elements, can lead to wasting money on an ineffective treatment. Note also that a roundabout could be considered, to replace the signalised intersection. Its impact on pedestrian movements and access to the golf club would need to be considered.

An appraisal period of 5 years has been selected, as one option involves a reduction in capacity which may render it an interim treatment.

**Table D.9(c) – Economic appraisal of case study options (A\$)**

Item	Option 1	Option 2
Implementation cost (Build now = present worth of costs)	\$314 000	\$939 500
Benefits per year	\$342 600	\$451 500
Appraisal period for benefits	5 years	5 years
Present worth of benefits (4% discount rate)	\$1 524 600	\$2 009 200
Present worth of benefits (7% discount rate)	\$1 404 700	\$1 851 200
BCR: benefit/cost ratio (4% discount rate) BCR: benefit/cost ratio (7% discount rate)	4.9 4.5	2.1 2.0
NPV: net present value (4% discount rate) NPV: net present value (7% discount rate)	\$1 210 600 \$1 090 700	\$1 069 700 \$911 700

This appraisal shows both options would be beneficial. Both options have very similar NPVs. The lower cost option has higher BCRs. Assuming that the northbound roadway has adequate capacity, the lower cost option is regarded as having the greater benefit. A recommendation would therefore be made to include Option 1 (Table D.9(c) above) for funding consideration within a works program.

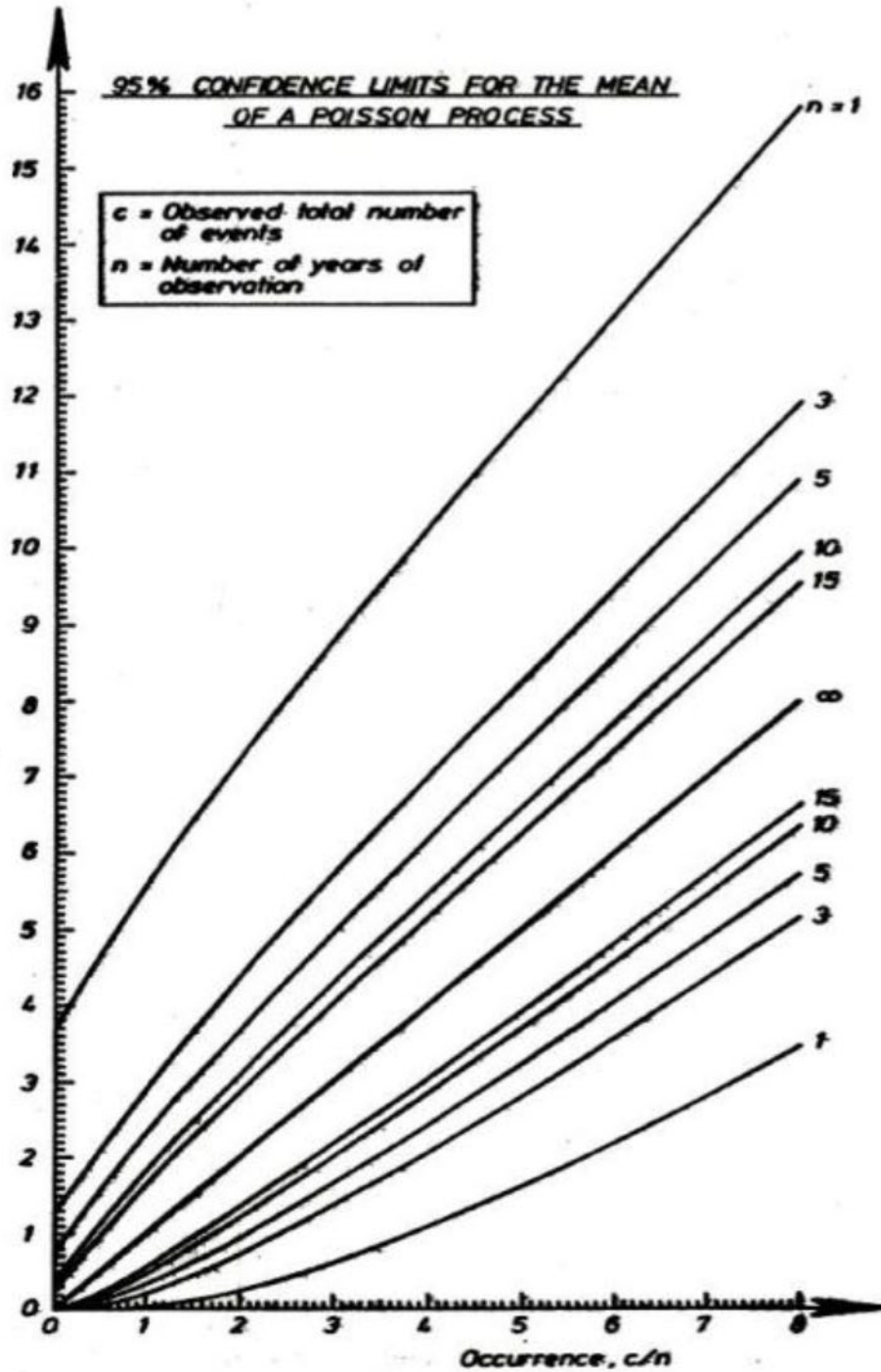
## **Appendix E: Crash Modification Factors**

(Crash Reduction Factors in Queensland)

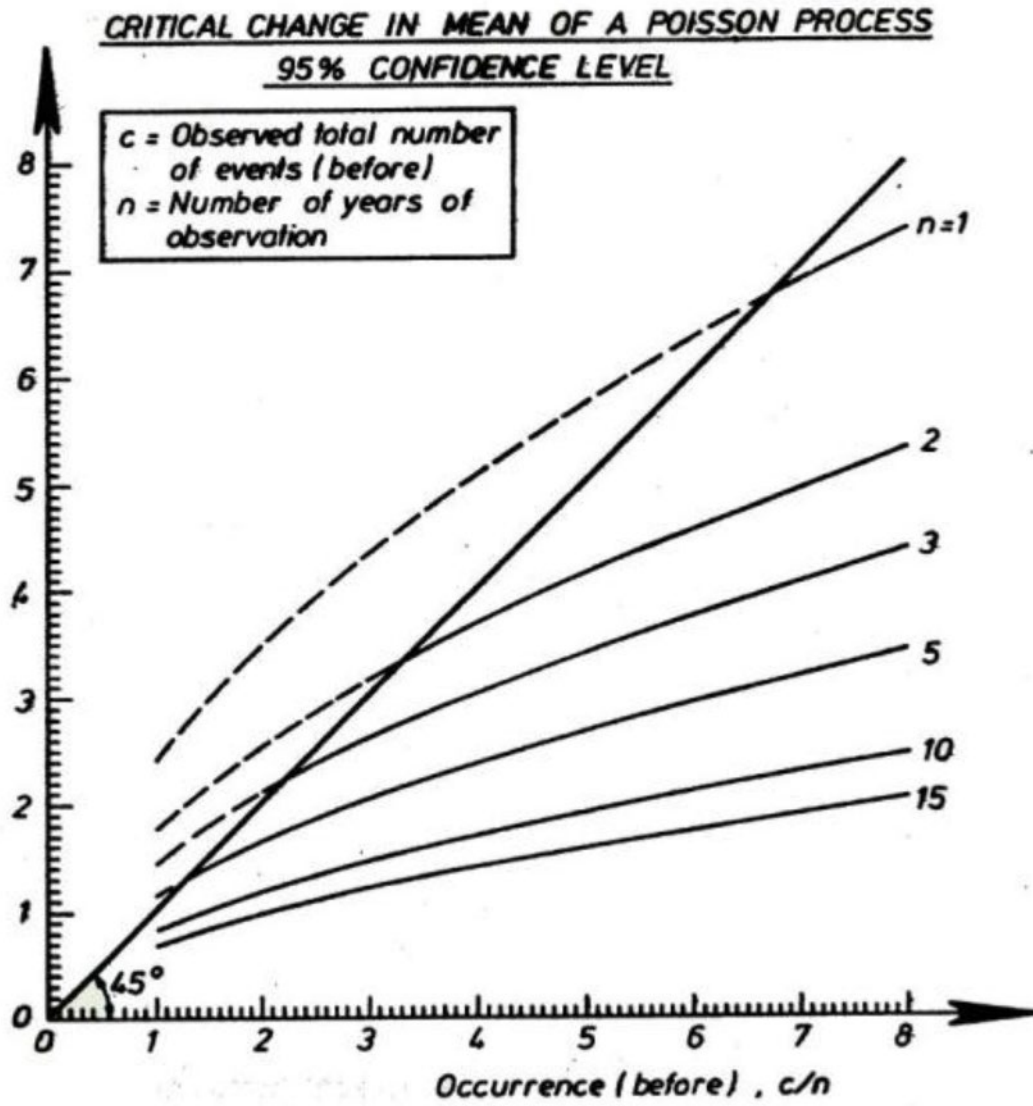
Refer to [Queensland Crash Reduction Factors](#).

### Appendix F: Confidence Limits and Changes in Critical Mean

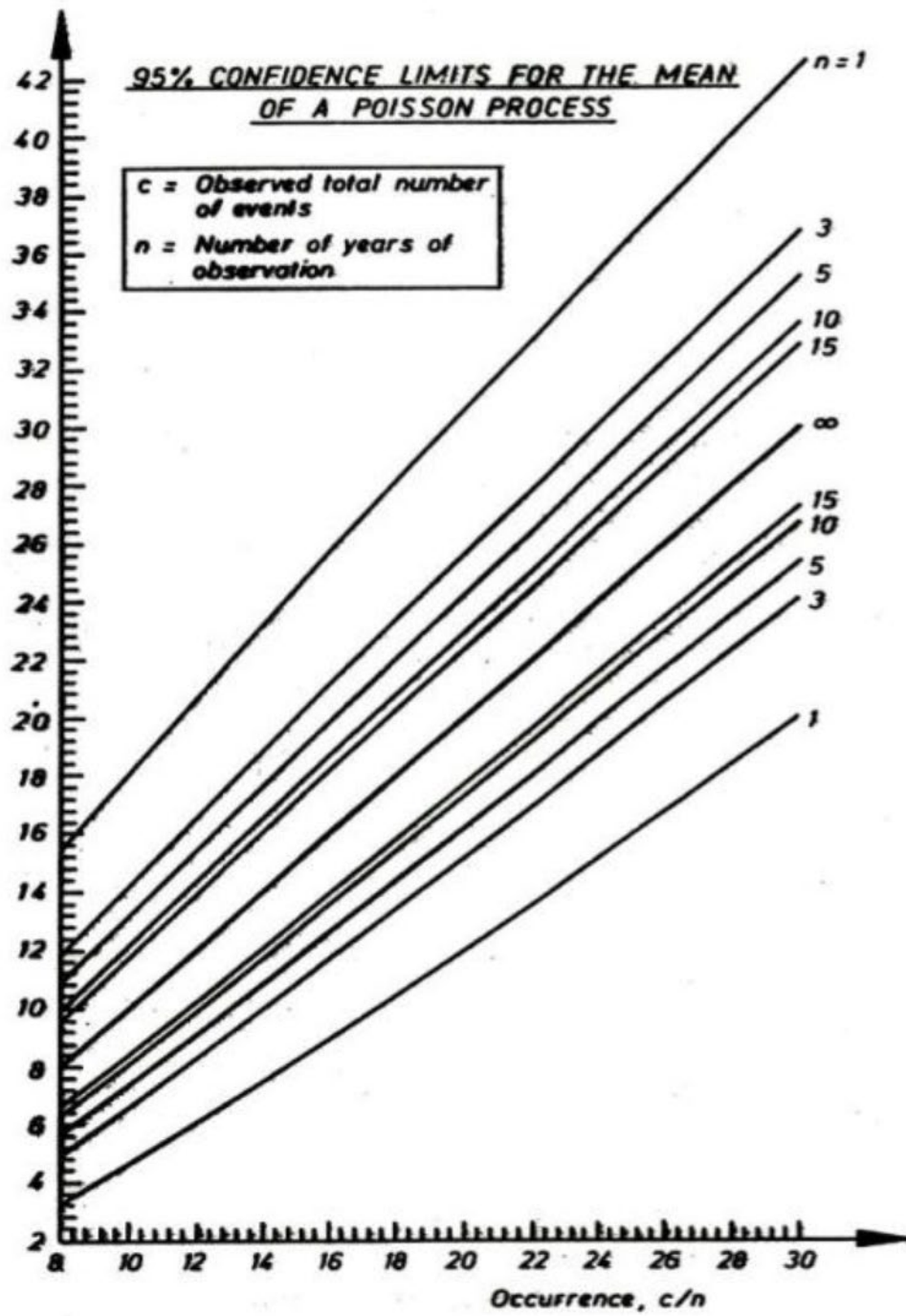
See Appendix C.2 for an illustration of how to use these graphs.



Source: Nicholson (1987).

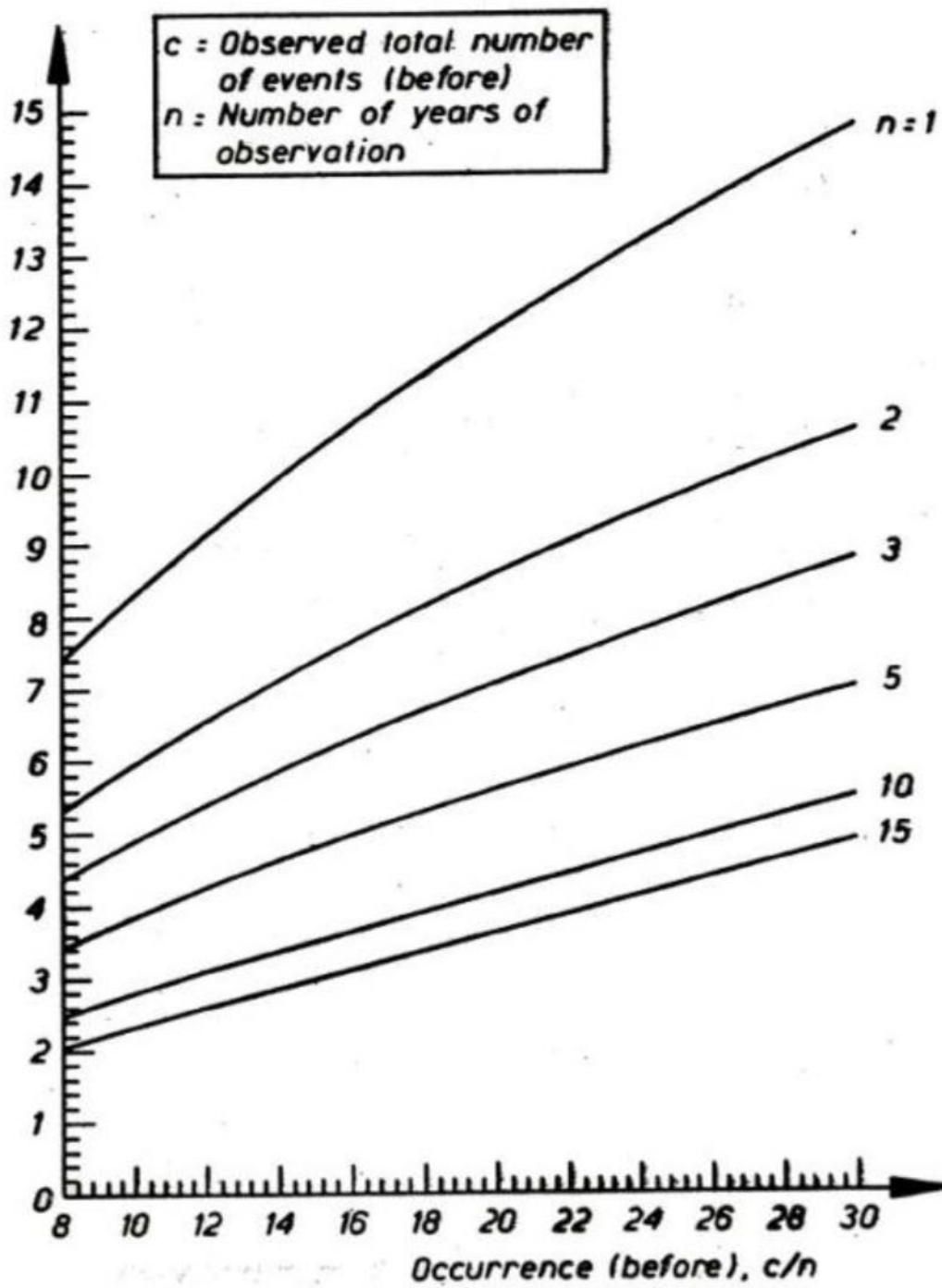


Source: Nicholson (1987).



Source: Nicholson (1987).

**CRITICAL CHANGE IN MEAN OF A POISSON PROCESS**  
**95% CONFIDENCE LEVEL**



Source: Nicholson (1987).

## **Appendix G: Monitoring Techniques and Allowing for Regression to the mean**

### ***G.1 Monitoring techniques***

This appendix provides guidance on monitoring and evaluating safety improvement projects, and considering the effects of the regression-to-the-mean phenomenon with regard to crash rates.

#### **G.1.1 Experimental design**

Monitoring aims to measure what is actually happening now and, in an evaluation phase, comparing that with what is expected would happen if a treatment had not been introduced. There are several experimental design challenges in doing this, including the following:

- There may be changes in the road environment, such as a speed limit, traffic flow, abutting land uses, or traffic control (other than the safety-related change the effect of which is to be monitored). All of these are possible at a site over a 3-5 year time period, and virtually certain over an area or route. It is impossible to conduct a rigorous scientific study where every possible influence is controlled.
- Because crashes are rare and randomly occurring events, there will be fluctuations year by year which have nothing to do with the treatment being analysed. Data for short time periods (say one year) are therefore highly unreliable. These random year-by-year fluctuations, while not necessarily biasing the result of a monitoring exercise, introduce variability which must be accounted for in the statistical analysis. A particular problem is that of regression-to-the-mean (Appendix G.2).
- It is necessary to monitor all significant factors which could possibly affect the outcome, otherwise the outcome may be wrongly attributed to the treatment. If the variation in the treatment (e.g. a speed limit) varies systematically with another variable (e.g. design standard), it may not be possible to isolate the effects of one from the other. However, if only one is measured, it is likely that all of the change will be attributed to it.
- As a variation on the previous point, if the two variables which are systematically related are in fact both measured, then it will not be possible to reliably isolate their independent effects. This is particularly a problem if multiple linear regression techniques are used, since these require that the various independent variables are not correlated one with another.
- Statistical correlation does not necessarily imply logical correlation. For example, Haight (1981) quotes a case where the law giving pedestrians the right of way over vehicles was considerably strengthened in 1977 and the number of pedestrian deaths dropped from 365 in 1977 to 268 in 1983. However, the new law was not enforced and thus had no effect on behaviour, so the improvement in the pedestrian situation could not have been a result of the change in the law and must have been due to some other factor(s). This underlines the importance of establishing a true link between the treatment being monitored and the change in the performance measure.
- Seasonal factors must be taken into account. Some factors which may affect road safety vary in a systematic way throughout the day (e.g. natural light, street lighting) or throughout the year (rain, hours of daylight, perhaps traffic flow). The selection of factors such as control sites and before and after periods must take these variations into account. It would be incorrect to compare the summer (before) crash record with the winter (after) crash record if one was trying to assess the effect of skid-resistant pavements, for example.

- Crash reporting levels may change over time and there may be inconsistencies in the crash data which need to be considered. For example, the definitions attached to specific pieces of data (e.g. severity) may change over time, or the requirement to report crashes (e.g. property damage only crashes) may be changed. The analyst needs to be aware of these changes and correct for them, since they can severely impact upon the analysis, e.g. in before and after studies.

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There may be a long-term trend in crash occurrence; changes over time in the number or rate of crashes at a site may merely reflect global trends. For this reason, it is usually necessary to use some form of control group and compare crashes at the test site with those at the control site (Section 7.2).

It is necessary to take these types of factors explicitly into account in the evaluation of the effect of a road safety treatment or program. There are four ways in which this can be done:

- controlled experimentation, in which all other factors are held constant except the factor whose effect is being investigated. This approach is rarely if ever applicable in road safety engineering because in the real world it is not possible to hold everything constant. It will not be discussed further
- before and after studies
- comparisons using control sites
- time trend comparisons. This approach is also rarely if ever applicable in road safety engineering and it will not be discussed further.

#### **G.1.1.1 Before and after studies**

This is the simplest method of monitoring and evaluation and involves comparison of the crash record at the location before and after the treatment. It is the least satisfactory method because it does not include control of extraneous factors such as those discussed above. For example, through the 1980s several countries experienced a very substantial reduction in total casualty crashes. If a treatment installed in the middle of the decade was evaluated using, say, 3–5 year before and after periods, it would quite possibly have shown a significant reduction in crashes in the after period compared with the before period. However, in reality, this may have merely reflected nationwide trends and had very little to do with the conditions at the site.

The method involves:

- determining in advance the relevant objectives (e.g. crash types intended to be affected) and the corresponding evaluation criteria (e.g. crash frequency, crash rate)
- monitoring the site or area to obtain numerical values of these criteria before the treatment and again after the treatment
- comparing the before and after results
- considering whether there are other plausible explanations for the changes and correcting for them if possible.

It is usual in a before and after study to rely on pre-existing data for the before period. It would be very rare that implementation was delayed so that adequate before data for a location could be collected. This underlines the need for systematic, ongoing data collection, so that the effect of changes in the system can be monitored routinely.

It is important to distinguish crashes by type and perhaps by time of day (e.g. when considering a lighting scheme) or by weather conditions (e.g. when considering a skid resistant pavement treatment), etc. It is often helpful to prepare collision diagrams for the site or area before and after the treatment, as there may be new or relocated crash patterns evident. If sample surveys are undertaken (e.g. to obtain a measure of traffic flow turning volumes), the observation period should ideally cover several days to gain a representative sample.

The statistical analysis of the data should be carefully undertaken, having regard to the accuracy of the data. It will often be helpful to consider more than just the change in crashes expressed, say, as annual average crash frequency of the particular crash type. It may also be useful to consider changes in the 85 percentile values, the variance, skew, etc.

Monitoring of the location should commence immediately after implementation (to detect any unexpected crash or operational problems). For before and after comparisons to be statistically valid, a reasonable period of time must elapse to enable a sufficiently large sample to be obtained (Ogden 1996, p.463). Three years is generally regarded as a reasonable period for trends to be established and a large enough data set to be obtained. Nicholson (1987) has recommended five years from the viewpoint of statistical confidence.

Using this simple before and after comparison without taking account of trends or external changes is not recommended as it is likely to lead to erroneous conclusions

#### **G.1.1.2 Comparisons using control sites**

This major drawback with the simple before and after approach can be overcome through the use of control sites. There are two variations of this method, the first using control groups which are randomly determined, and the second using selected comparison groups.

This method is of more relevance in road safety engineering. It involves a before and after study as discussed in the previous section but the results for the before and after periods at the treated location are compared with the results at control sites. The process involves:

- determining in advance the relevant objectives (e.g. crash types intended to be affected) and the corresponding evaluation criteria (e.g. crash frequency, crash rate)
- identifying a control site or (preferably) a set of control sites where no remedial works have been or are intended to be introduced
- monitoring both the treated site and the control site(s) to obtain numerical values of these criteria before the treatment and again after the treatment
- comparing the before and after results at both the treated and control sites
- considering whether there are other plausible explanations for the changes, and correcting for them if possible.

Selection of the control sites is of key importance. Ideally they would be randomly selected.

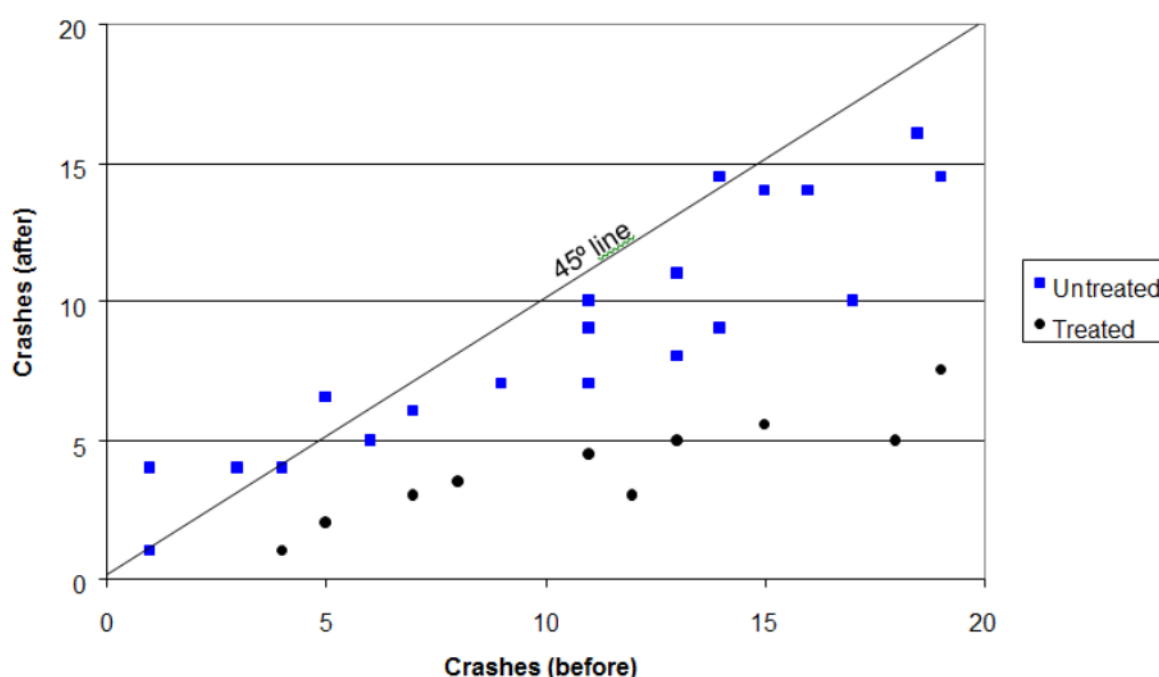
However, this is rarely possible unless a large number of control sites can be identified and a random selection made from these (Andreassen 1989, p.34). The control sites should satisfy the following criteria (Benekohal & Hashmi 1992; Council et al. 1980; Institution of Highways and Transportation 1990; Ward & Allsop 1982). These should:

- be similar to the treated sites in general characteristics (e.g. network configuration, geometric standard, land use, socio-economic characteristics, enforcement practices, etc.)

- have the same or similar traffic flows
- not be affected by the treatment at the test site
- be geographically close (however, be aware that using adjacent or nearby sites as control sites leads to bias in the evaluation results (Maher 1987))
- not be treated in any way themselves for the period of the before and after study
- have crash records and other data (if applicable) which are consistent in both collection criteria and coding covering the period of the study.

The before and after periods for both the treated location and the control sites must be the same (although it is not necessary that the common before period be the same as the common after period).

In addition to the statistical analysis, a graphical presentation of treated and control sites (as shown below) can be helpful.



Source: Adapted from County Surveyors' Society (1991).

If there was no change in the number of crashes (or whatever criterion might be used) between the before and after periods, all points would lie on a 45 degree line passing through the origin. The extent to which there is a change in crashes in the after period is indicated by the departure from the 45 degree line. If there is a noticeable tendency for points representing the treated locations to be well below the 45 degree line compared with the control sites, the treatments are having a positive effect.

## G.2 Regression-to-the-mean

Over a period of years, if there are no changes in the physical or traffic characteristics at a site, crashes at that site per unit of time (e.g. annually) will tend to fluctuate (due to the random nature of crash occurrence) about a mean value. Because sites are commonly selected for treatment on the basis of their ranking in the numbers of crashes compared with all other sites, there is a high possibility that sites will be chosen when their crash count is higher than the long term average.

Wright and Boyle (1987) assert that regression-to-the-mean can overstate the beneficial effect of a treatment by 5 to 30%. To the extent that knowledge about the safety effects of treatments is built up from the results of these sorts of studies, there is (unless corrected for) a tendency to overstate the effectiveness of road and traffic engineering treatments. This is sometimes called 'bias by selection' (Hauer 1980). There is a responsibility for the analyst to separate the real gains from the treatment from the changes due to regression-to-the-mean.

The problem can be substantially minimised by increasing the number of years of data used in the site selection process (Nicholson 1987). However, this does not solve the problem entirely, nor is it always expedient to wait for several years before conducting an evaluation exercise.

To correct for regression-to-the-mean, the essence of the task is to attempt to estimate the true underlying crash rate. One approach is described below. It involves adjusting the data to correct for biases, using assumptions about the statistical distribution of crashes year by year (Abbess, Jarrett & Wright 1981).

Crash data must be assembled for all sites similar to the site under study, for the same time period. Then, using the full data base, the mean number of crashes  $a$  and the variance of crashes  $\text{var}(a)$  is calculated. The regression-to-the-mean effect,  $R$  (in per cent), is then given by:

$$R = \left[ \frac{n(S_o + S)}{S(n_o + n)} \right] \times 100$$

where

$S$  = the number of crashes observed at the site during a period of  $n$  years,

$S_o = a^2 / (\text{var}(a) - a)$

$n_o = a / (\text{var}(a) - a)$

$S_o$  and  $n_o$  are the estimates of the parameters of the statistical distribution showing the underlying true crash rates, i.e. the probability distribution of the crash rate before any data become available. This assumes that a site with a given crash history should behave in the same way as the set of all similar sites with the same crash history.

Prolonging the before and after periods will decrease the regression-to-the-mean effect, but not remove it altogether (Nicholson 1988). On the other hand, these longer periods enlarge the influence of general trends in crashes on the results of a study (Elvik 1997).

### **G.2.1 A worked example of correction for regression-to-the-mean (from Ogden 1996, p 458)**

Suppose there is a site where there have been 90 crashes over the previous 5 years (an average of 18 crashes per year). The site has been treated, and in the following period, it has shown an average of 14 crashes per year.

To correct for regression-to-the-mean, data is needed for sites which are, as far as possible, similar to the site under study. Data for these sites is used to estimate the parameters of the statistical distribution of crashes at the test site.

Suppose that over the previous 5 years, the number of crashes at the comparison sites had been 15, 15, 16, 17 and 19 crashes per year. This produces a mean ( $a$ ) of 16.4 crashes per year and a variance  $\text{var}(a)$  of 2.80.

Thus, the values for entry in the above equations are:

- $n = 5$  (years)
- $S = 90$  (crashes)
- $S_o = -19.78$
- $n_o = -1.21$ .

This gives a value for R of 0.09. That is, it would be expected that in the after period, crashes at the test site, even if nothing was done, would reduce by 9%, i.e. to 16.38 per year. It is this value of 16.38 which must then be compared with the actual after performance of 14 crashes per year to determine whether there has been a significant change in the crash frequency.

From Appendix F, it can be seen that with  $c/n = 16.38$  and  $n = 5$ , the critical change in the mean is 5.0, i.e. any number of crashes up to five above or five below the observed mean of 16.38 would be regarded as not occurring by chance. The occurrence of 14 crashes (i.e. 2.38 fewer on average) per year after is thus very likely to be the result of chance, rather than due to the treatment.

## Part 2: Supplementary Technical Guidance

### 1 Introduction

This part of the document comprises supplementary technical information for practitioners regarding Wide Centreline Treatments (WCLT) and Audio Tactile Line Marking (ATLM) covered in the *Queensland Guide to Road Safety Part 2: Safer Roads*. The guidance in this document should only be applied in conjunction with the primary guidance as indicated in each section.

While both these treatments are also considered as traffic control devices, they are primarily Safe System supporting road safety countermeasures that are most suited to reducing the likelihood of high-speed lane departure crashes. However, ATLM and WCLT are known to be effective at mitigating the likelihood of lane departures in a wide number of applications, depending on the configuration. This includes both run-off-road as well as head-on crashes.

### 2 Wide Centreline Treatments (WCLT)

Primary guidance for the design of a Wide Centerline Treatment is contained in the department's *Road Planning and Design Manual 2<sup>nd</sup> Edition*, Volume 3, Part 3.

Wide centre lines are a widening of the centre line markings to provide increased lateral separation between opposing directions of travel. This increased separation improves safety by reducing head-on crash risk. Wide centrelines should only be deployed as a complete Wide Centreline Treatment (WCLT).

A WCLT is a system comprising of widened painted centre line marking with edge lines AND audio-tactile line marking (ATLM) supplementing the painted line marking. Retro-reflective Raised Pavement Markers (RRPMs) must also be installed adjacent to line marking.

WCLTs should be installed on all undivided rural roads, especially in high-speed environments.

### 3 Audio Tactile Line Marking (ATLM)

Primary guidance for ATLM is contained in the *Queensland Manual of Uniform Traffic Control Devices* (Queensland MUTCD) Part 2: *Traffic Control Devices for General Use*.

ATLM comprises a series of raised ribs spaced at regular intervals in association with longitudinal line markings. They enhance painted line marking by providing audible and tactile feedback to errant vehicles departing their lane(s) of travel. ATLM is typically used to supplement longitudinal line marking (such as edge lines and barrier lines) and is also mandatory component of a Wide Centreline Treatment (WCLT).

Although the audible feedback generated by audio-tactile line markings can usually be heard inside passenger vehicles, it is harder to hear in large vehicles and is often not easy to hear in heavy vehicle. As such, ATLM alone should not be relied upon, to provide adequate audible warning to heavy vehicle drivers departing lane. Note that this consideration is not as applicable to the vibration component of ATLM feedback.

### **3.1 Application of ATLM in Queensland**

The requirements in this section reflect the default requirements for the application of ATLM in Queensland. Where ATLM is not being installed or has been excluded (including for the exception cases described in the sections below), this will comprise a design departure or exception and require to be documented accordingly.

- In all instances where deployed, edge line ATLM and centre line ATLM shall be used together in combination, except where the conventional line marking is not required / deployed.
- Audio Tactile Line Marking (ATLM) shall be installed to supplement longitudinal linemarking on all undivided roads outside built up-areas, with sealed shoulder greater than 0.5 metres.
- Undivided roads outside built up areas with AADT greater than 4000 vehicles per day should have a wide centre line and ATLM supplementing longitudinal line marking.
- ATLM may still be installed where width of the sealed roadside shoulder is less than 0.5 metres (with adequate pavement support) outside the existing edge line. It is acknowledged that the effectiveness of ATLM is expected to diminish with narrower shoulder widths, however it will still provide more benefit to safety than painted linemarking alone.

Note: The primary guidance gives the practitioner options for configuration of ATLM that includes both on the line as well as adjacent or offset from the painted linemarking to suit space constraints.

### **3.2 Limitations on the use of ATLM**

ATLM is designed to be installed as a continuous system and not as a 'spot' treatment or with frequent breaks.

However, the following are examples of applications where ATLM may be excluded in limited sections:

- On or adjacent to centre lines and edge lines of winding route sections where motorcycle use is elevated (such as on known recreational motorcycle routes), or
- On edge lines where left-turn auxiliary lanes are provided at intersections on a curve due to the potential for confusing delineation, or
- On edge lines where left-turn auxiliary lanes are provided at intersections on a curve due to the potential for confusing delineation, or
- On edge lines of roads with a sealed shoulder narrower than 0.5 m in width. ATLM may still be installed on these roads if deemed appropriate by a site specific investigation, and
- New ATLM should generally not be installed where pavement resealing works are expected or programmed to occur within one year.

### **3.3 Noise Considerations**

The noise generated by vehicles traversing ATLM must be considered when selecting locations for installation.

ATLM may be excluded when within 200 m of residential dwellings AND there is a risk that vehicles will frequently traverse the ATLM.

Such scenarios include, but are not limited to:

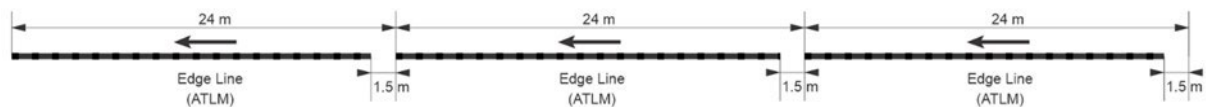
- On the inside of curves of radii less than 450 m. The likelihood will vary depending on speed zone, lane width, use of lane widening and design vehicle, or
- Where there is a left turn deceleration lane or other higher speed exit into driveways or access roads servicing significant traffic generating developments (ie service centres), or
- Where the number of access points along the road exceeds 20 per km, or
- There is an evidenced history of existing noise complaints from other noise sensitive developments, or
- Where ATLM is excluded for noise considerations, a site-specific assessment shall be completed to evaluate if the potential adverse noise impacts outweigh the compromise to safety benefits.

### 3.4 Provision for Cyclists

On known cyclist routes in Queensland, (such as on a declared Principal Cycle Network), road authorities shall provide the following gaps in edge line ATLM for cyclists as below.

- At longitudinal roadside objects (such as bridge rail, guard rail and culverts), ATLM should be excluded between the 10 m prior to and 10 m immediately following the object where the effective sealed shoulder width is < 1 m,
- A 1.5 m long gap in the ATLM spaced every 24 m (inclusive of the 1.5 m gap) as shown in the figure below.

**Figure 3.4 – Longitudinal placement of gaps in ATLM for people riding bicycles**



NOTE: Width provisions do not include the width of the ATLM.

## Part 3: Driver fatigue – Guidelines for road-based driver fatigue in rural areas

### 1 Introduction

Fatigue is recognised as one of the 'Fatal Five' and is one of the leading factors contributing to road crashes on Queensland roads. In Queensland between 2015 and 2019, 4.6% of all reported casualty crashes were fatigue-related, with 11.8% of fatal crashes and 6.7% of hospitalisation crashes being fatigue-related.

If fatigued drivers are given a warning before their vehicles run off the carriageway, corrective action could be possible. Further, drivers need to be able to recognise the onset of fatigue and to be encouraged to take rest breaks before continuing their driving.

The best way to combat driver fatigue is for drivers not to become fatigued or to stop driving once onset of fatigue occurs.

Transport and Main Roads has used fatigue messages and campaigns to educate the motoring public of the dangers of driving while fatigued in order to reduce the incidence of fatigue-related crashes.

Despite education campaigns, people continue to drive while fatigued, seriously increasing their risk of being involved in a crash.

#### 1.1 Queensland Specific fatigue countermeasures

Road based countermeasures that are specifically targeted at reducing fatigue-related crashes are as follows:

- roadside signs
- driver reviver program
- wide centre lines
- audio-tactile edge lines, and
- rest areas and associated signing.

Guidance for wide-centrelines and audio-tactile line marking is contained in Part 2 of this document. These treatments are no longer considered only applicable to fatigue related crashes.

The remaining countermeasures are addressed in the following sections.

##### 1.1.1 Roadside Signs

A number of roadside signs are used to warn road users of presence of fatigue zones or otherwise as part of a fatigue zone management plan. Trivia signs, for example, may be deployed as part of a fatigue management plan to encourage drivers to exercise their mind. Practitioners are advised to check the [Traffic Control \(TC\) signs](#) database for the latest TC sign diagrams.

##### 1.1.2 Driver Reviver Program

Queensland's [driver reviver sites](#) are supported by a dedicated group of volunteers from a wide variety of community organisations and are set up at rest areas to supply free tea or coffee for travellers.

A suite of roadside signs is available for signing driver reviver sites. Hinged signs requiring manual operation are not preferred. Practitioners are advised to check the [Traffic Control \(TC\) signs](#) database for the latest TC sign diagrams.

### 1.1.3 Rest Areas and associated Signage

Rest areas play an important role in fatigue management for both general motorists and heavy vehicle drivers as they provide places for drivers to take rest breaks; however, in order to encourage drivers to use them, it is necessary to ensure that sufficiently attractive and suitably-equipped stopping places are provided, particularly in areas where fatigue-related crashes are known to be a problem.

The frequency of use of a rest area depends on many factors, including its location along a route, the features and facilities that it provides, and personal safety and comfort. Drivers should normally expect to find the following features at a rest area:

- sheltered tables and seats
- potable water
- rubbish bins, and
- toilets.

### 1.1.4 Guidance on the provision of rest areas

The following Transport and Main Roads documents provide guidance for the provision of rest areas in Queensland:

- *Road Planning and Design Manual 2nd Edition, Volume 3, Part 6B: Roadside Environment.*

### 1.1.5 Signing of rest areas

Signing of rest areas is a positive way to increase their use; however, to be effective, signs need to be conspicuous and placed at locations that give motorists sufficient notice of the facilities ahead.

Guidance for signage is set out in the Queensland *Manual of Uniform Traffic Control Devices* (Queensland MUTCD) Part 6: *Service and Tourist Signs*.

**Figure 1.1.5 – Rest area signing**



When associated with fatigue, signing for rest areas can include fatigue safety messages. The messages have been designed to alert motorists of the danger of driving while fatigued. Examples of approved fatigue (service) signs and their typical placements are described following.

To minimise their use by motorists and tourist traffic, signs for heavy vehicle rest areas should not show the facilities available. These additional users may restrict the space available for trucks and create unnecessary disturbance to resting truck drivers.

### **1.1.6 Advance signing**

The first advance service sign is generally located 2 to 10 kilometres in advance of the rest area to give drivers sufficient time to decide on a course of action and indicates the type of facility available and the distance ahead. It also contains a fatigue-related safety message, to maximise the effectiveness of these signs, and rumble strips should be used in advance of these signs to better alert the drivers.

When the first advance service sign is placed 10 kilometres or more in advance of the rest area, it is desirable to place additional advance service signs (using different fatigue messages) in advance of the rest area (for example, at 20 km, 10 km and 5 km).

A second advance service sign is generally placed 300 metres to 2 kilometres in advance of the rest area and indicates the type of facility available and its location (for example, '2 km ON RIGHT'). These signs (for example, G7-1-4) are described in Part 1 and Part 6 of the Queensland MUTCD and the TC Signs database.

### **1.1.7 Position sign**

The position service sign is placed at, and opposite to, the rest area entrance. This sign indicates the type of facility provided as in the advance signings. These signs (for example, G7-3-1 (L or R)) are also described in the Queensland MUTCD.

### **1.1.8 Next Service Sign**

This sign is normally placed on the departure from the rest area to inform motorists of the distance to the next rest area in either direction. This sign may also be placed just before the entrance or turn-off to a rest area to inform motorists of the distance from the next rest area to help them decide whether to stop now or later.

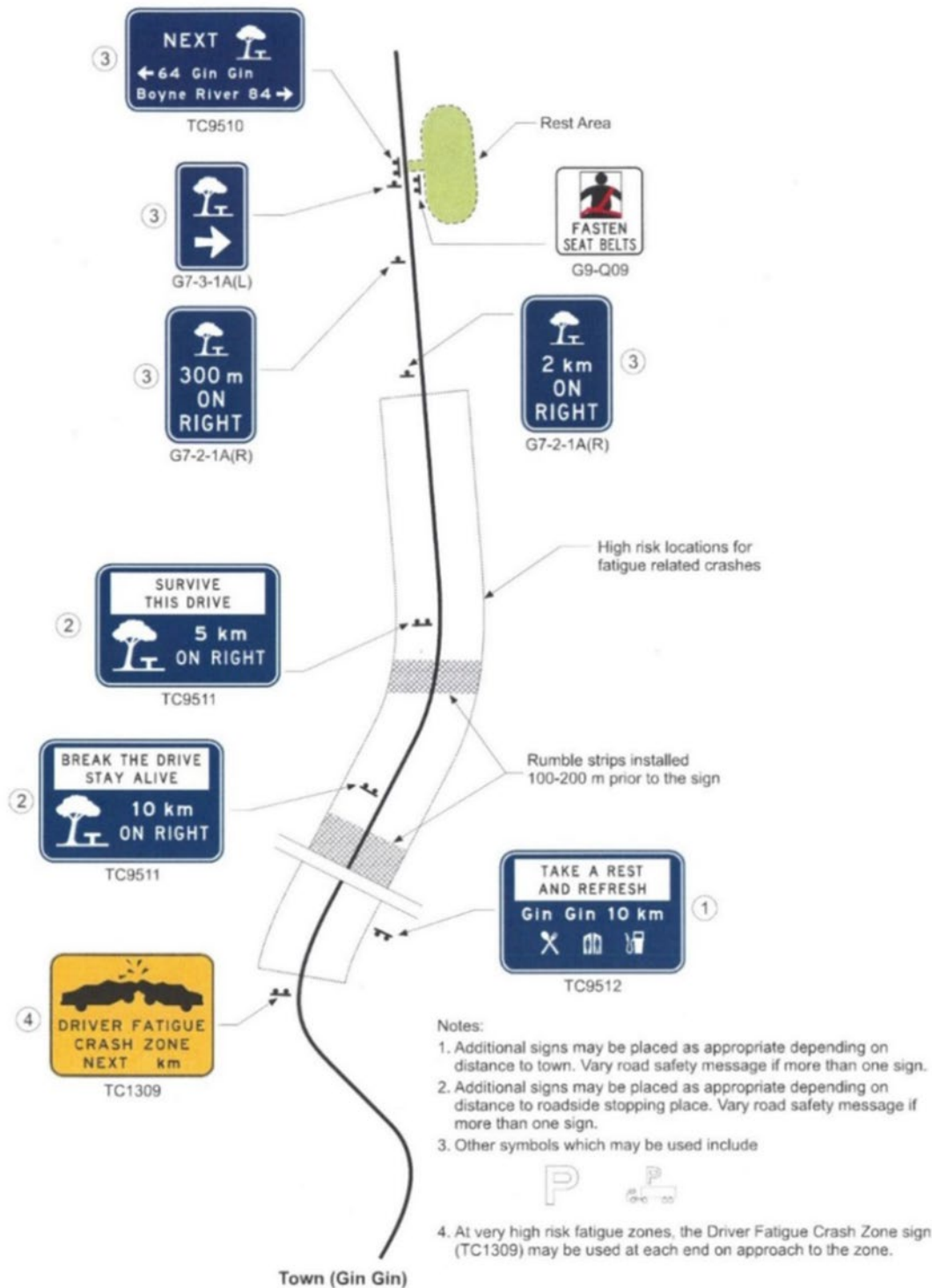
### **1.1.9 Fasten seat belts sign**

The 'Fasten Seat Belts' sign (G9-Q09) should be placed adjacent to the exit points of all rest areas.

### **1.1.10 Fatigue signing layout**

The figure below shows a typical signing layout for a rest area.

Figure 1.1.10 – Fatigue signing layout



### 1.1.11 High Risk crash zones

At very high-risk driver fatigue zones where there has been a large number of fatigue-related crashes, the 'DRIVER FATIGUE / CRASH ZONE / NEXT x km' sign may be used to alert motorists about the seriousness of driver fatigue. This sign should be erected at each approach to the fatigue zone and be located about 200 m to 300 m before the first advance rest area sign. See TC Signs database for sign design details.

Ensure that this sign is only used at very high-risk fatigue zones as its overuse could erode its effectiveness.

## **Part 4: Local Government and Community Road Safety**

### **1 Convex Mirrors**

#### **1.1 Introduction**

This section provides guidance on the use and installation of convex mirrors functioning as a traffic safety device on Queensland roads. This section is not relevant to convex mirrors when used for parking stations and parking areas.

The purpose of the convex mirror is to indicate to the road user the presence or absence of a moving or stationary vehicle and/or pedestrian.

The convex shape of the mirror results in distortion of the image, speed and distance of any object. The degree of distortion depends on the radius of curvature and size of the convex mirror – the larger the radius of curvature, the less the distortion and vice versa.

#### **1.2 Considerations**

Consideration of mirror shape is essential to ensure the road user has adequate time in a particular situation to understand and interpret the information provided by the convex mirror.

The image appears to be smaller, further away and travelling at a slower speed in a mirror with a smaller radius of curvature. A convex mirror with a small radius of curvature could potentially provide too much detail in a small area, which will hamper a road user's ability to discriminate detail.

The larger the radius of curvature, the less the distortion of the oncoming vehicle. Larger diameter mirrors are more easily seen by road users. These large diameter mirrors also provide a larger field of view, enabling the oncoming traffic to be seen more clearly than would be the case if smaller mirrors were used.

In addition to distortion effects, the image of a vehicle in a convex mirror appears to be on the wrong side of the road due to the 'mirror image' effect, where left appears to be right and vice versa. This 'mirror image' effect can result in road users misinterpreting the images. This can be potentially dangerous, especially in the case of vehicles approaching the intersection from a one-way street. This is seen as a serious limitation.

Consideration should also be given to potential problems resulting from headlight glare at night and the effect of glare from the sun, particularly at dawn and dusk.

Dark blue, black and other dark colours are difficult to detect in these mirrors in the early morning or late afternoon as these colours appear to be absorbed by the road surface.

#### **1.3 Road Safety Inspection**

A road safety inspection should be conducted prior to a decision to install a convex mirror on a Queensland road. Considering the problems inherent in the design and use of convex mirrors, the road safety inspection must indicate that the solution provides both safety and traffic management benefits.

The road safety inspection outcomes and consequent decision to install the convex mirror must be fully documented in accordance with Australian Standard AS/NZS ISO 3100 *Risk Management*.

## **1.4 Limitations on Queensland Roads**

Convex mirrors should not be installed:

- on Queensland roads where alternative traffic management measures or engineering measures, such as improvements to sight distance and road realignment, are available in the short term
- within the carriageway, including shoulders, islands and medians
- to enhance pedestrian crossing movements (in this instance, other solutions should be considered, such as relocation of the crossing point or the provision of strategically-located pedestrian refuges), and
- without appropriate signs.

Convex mirrors may be used on Queensland roads as an interim measure until appropriate traffic management / engineering solutions are implemented.

## **1.5 Legal Issues**

When considering the installation of convex mirrors, a risk assessment shall be carried out in accordance with Australian Standard AS/NZS ISO 31000 Risk Management, the purpose of which is to document that the benefits of installing a convex mirror provide a safer solution than doing nothing. To ensure the department is not compromised in the event of a crash, the following three-step process shall be adopted:

- use and documentation of road safety inspection procedure to assess the road safety benefits relative to the risk of crash(es) in installing a convex mirror at a particular location
- make a decision based on the assessment of the road safety benefits and the risk of crash(es) arising from the installation
- take all necessary steps to ensure safe and proper installation, operation and use of the mirror; for example, if the installing road authority is aware of some potential danger arising from a road user's reliance on a convex mirror at a particular location, failure to provide adequate warning of the deficiency of the mirror could increase the level of risk carried by the road authority at that location, and
- where property owners or developers believe that a convex mirror on the Queensland road will assist safe access from concealed private driveways or private roads, they should approach the road authority for approval.

Convex mirrors should be installed and maintained by the road authority responsible for the care and control of the particular road. See Section 12.1.7 of Part 3.

To ensure safe installation and community acceptance, each convex mirror proposal on a state-controlled road should be in accordance with this section. Local and regional councils should seek advice from the local Traffic Advisory Committee prior to considering installation.

Road authorities are advised that all necessary precautions should be taken to securely install a convex mirror at the appropriate location and height to ensure safety of all road users, including pedestrians, and to prevent vandalism. See Section 12.1.6.4 of Part 3.

Convex mirrors shall be regularly inspected by the road authority to ensure that the mirror is adequately maintained, in a serviceable condition, and that the mirror is correctly aligned and not damaged.

Adequate records of these inspections are required.

## **1.6 Installation**

### **1.6.1 Criteria for use**

Convex mirrors are not for general use. They should only be installed as a traffic safety device in situations where lateral visibility / sight distance is critical but considered severely limited and there are no other immediate viable options available, such as turn restrictions, where alternative routes are available.

Convex mirrors should only be used in low-volume and low-speed road environments. They should only be used to determine the presence of road users and not to be used for judging speed or distance.

The following conditions should generally apply:

- 85th percentile speed on the road(s) is 60 km/h or less, and
- traffic volume on the road(s) is less than 300 vehicles / peak 3-hour period.

### **1.6.2 Typical uses**

Convex mirrors may be installed at the following locations where the lateral visibility / sight distance is critical, but considered to be limited:

- obscured T-junctions
- concealed driveways
- acute bends of a narrow road, such as hairpin bends in mountain passes
- parking areas with acute exit driveways, and/or
- approaches to skewed railway level crossings.

### **1.6.3 Types and selection of convex mirrors**

Convex mirrors must be suitable for outdoor use. They should be very durable, vandal-resistant, require nil or low minimal maintenance, and be of weatherproof material and construction.

Acrylic, highly-polished stainless steel or polycarbonate convex mirrors should be used.

The acceptable sizes are 600, 800, 1000 and 1200 mm diameter or rectangular size 600 mm x 450 mm.

While field trials may be necessary to determine the preferred range of curvature and size for a particular use, generally convex mirrors with diameters of 800 mm and 1000 mm are appropriate for installation on Queensland roads.

### **1.6.4 Mounting Details**

Convex mirrors must be securely mounted to a pole, wall or other suitable high point to deter vandalism. Appropriate signs shall be used in conjunction.

The convex mirror shall be fitted with a visor at its top. This will reduce the accumulation of dust on the mirror surface. The fitting of a brightly-coloured protective outer band (target board) will assist in improving the conspicuity of the mirror, which could be of assistance to road users who do not visit the area regularly.

The convex mirror should be installed at a location that provides the best view of the road and the oncoming vehicles concerned. It may be necessary to use 2 mirrors when one mirror does not give a complete view of the road scene.

### **1.6.5 Funding**

The road authority undertaking the installation and maintenance of convex mirrors is responsible for funding.

Where the installation of a convex mirror on a Queensland road is requested by the property owner or developer, the road authority may require the property owner or developer to contribute to the installation and ongoing maintenance of the mirror.

## **2 Guideline on domestic waste collection on state-controlled roads**

### **2.1 Introduction**

The purpose of this section is to provide guidance to local governments for implementation of domestic waste collection schemes using wheelie bins on state-controlled rural roads in Queensland.

Throughout Queensland, local governments have introduced domestic waste collection services using wheelie bins. This has resulted in wheelie bins being placed on, or adjacent to, state-controlled and local government roads.

The major concern in relation to these collection services is the potential conflict in high-speed environments between the constantly stopping collection vehicles and other road users.

Waste collection, particularly on roads with a high-speed limit and high traffic volume, can have adverse effects on road safety due to the speed differential between road users and collection vehicles – this can also have the following flow-on effects:

- inadequate pull-over width on road shoulders for waste collection vehicles, resulting in roads being partially blocked – this is especially hazardous where the road alignment is poor or in adverse weather conditions: there is a potential hazard when a collection vehicle stops in a no overtaking zone and the lane is not wide enough for following vehicles to pass without crossing the barrier lines
- waste collection vehicles constantly stopping and starting and obscuring vision of other drivers
- the presence of wheelie bins as potential roadside obstructions / hazards, and
- unsealed shoulders that may become unstable in wet conditions for waste collection vehicles to travel.

### **2.2 Considerations**

#### **2.2.1 Role of local government**

Local government has a duty of care to road users to manage associated risks. Any third party employed to provide the domestic waste collection service has the same duty of care.

To ensure the collection system is not introducing any unnecessary risks, local government should conduct a risk assessment, in accordance with AS/NZS ISO 31000 *Risk Management*, of the waste collection method and route (new or existing), taking into consideration the type / size of waste collection vehicles to be used and factors affecting the route – for example, road width and local environmental conditions – and nominate mitigation factors to reduce these risks.

### 2.2.2 Wheelie bin placement

Driveways are likely to provide a relatively flat and stable area for waste collection vehicles to pull off the carriageway, either completely or by straddling the carriageway. Driveways are also less likely to be susceptible to instability in poor weather conditions. Areas where vehicles can pull over may need to be provided where there is insufficient hard shoulder and poor visibility. As such, information provided to residents for wheelie bin placement, issued by local government, should include that wheelie bins be placed on driveways on collection days only.

Where possible, the wheelie bin should be placed on the departure side of the driveway with adjacent property wheelie bins grouped together to give waste collection vehicles space to manoeuvre and possibly pull off the carriageway: therefore, the driveway effectively becomes the pick-up area.

**Figure 2.2.2 – Wheelie bin placement on residential driveway**



### 2.2.3 Waste collection vehicle operation

During waste collection activity, waste collection vehicles are to be manoeuvred out of the traffic flow, that is, on the hard shoulder or as far away from the through traffic lane as practicable (example image below).

**Figure 2.2.3(a) – Waste collection activity**



During the collection activity, the wheelie bin should be replaced on the ground in an upright position (example image below) or at least off the carriageway with the lid closed so that the wheelie bin does not become a hazard for other road users.

**Figure 2.2.3(b) – Wheelie bin following collection**



#### **2.2.4 Time of collection**

To minimise conflict with other road users, early morning daylight collections or a time that avoids the heaviest traffic flows on a route should be considered when scheduling domestic waste collection services.

### 2.2.5 Road rule exemptions

The *Transport Operations (Road Use Management – Road Rules) Regulation 2009* made under the TORUM Act (‘the Road Rules Regulation’) contains a provision that specifically deals with the operation of waste collection vehicles on roads. Section 313A exempts the driver of a waste collection vehicle from a number of listed provisions of the Road Rules Regulation on certain conditions.

### 2.2.6 Signing of waste collection vehicles

In addition to the requirement for vehicles with a GMV of 12 tonnes or more to have Rear Marker Plates (National Heavy Vehicle Regulator, National Heavy Vehicle Inspection Manual), waste collection vehicles should display a sign both on the front and rear of the vehicle stating ‘Vehicle Frequently Stopping’ (image below is an example only). Refer to the department’s TC Signs database.

**Figure 2.2.6 – Signing of waste collection vehicle (example only)**



