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Road Safety Note 8

IDENTIFYING AND TREATING CRASH SITES

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Ministry of Physical Infrastructure and Transport
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FINAL (REVISED)

ROAD SAFETY NOTE 8

IDENTIFYING AND TREATING CRASH SITES

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List of Abbreviations

BCA	:	Benefit Cost Analysis
BCR	:	Benefit/Cost Ratio
CMF	:	Crash Modification Factor
DCC	:	Descriptive Crash Code
DFID	:	Department for International Development
DoR	:	Department of Roads
DoTM	:	Department of Transport Management
GoN	:	Government of Nepal
WB	:	World Bank
MAAPS	:	Microcomputer Accident Analysis Package System
NIRTTP	:	Nepal India Regional Trade and Transport Project
NPV	:	Net Present Value
NRCDS	:	Nepal Road Crash Database System
NRSC	:	National Road Safety Council
RAIMS	:	Road Accident Information Management System
RTU	:	Research and Training Unit
SI	:	Severity Index
SRCTIP	:	Strategic Road Connectivity and Trade Improvement Project

1 INTRODUCTION

1.1 Background

A crash even though is a random event, there are locations where its occurrences are concentrated rather than evenly distributing along the road sections or the network. In this regard, a hotspot (blackspot) can be an individual site, a length of road, an area of the road network, or locations across the road network which have a common hazardous feature and/or crash type. It is a location with a high number of historic crashes, and location specific infrastructural treatments can be provided at these locations to decrease the number of crashes and its concentration at that particular location. This can be defined as the treating of crash sites or hotspot (blackspot) locations. But for this purpose, analysis of previous crash history, whether at points on the road, on routes, or across areas, is vital.

Crash risk is the product of three elements: probability, exposure and severity (AustRoad, 2015) and treatment of crash locations is just one but an important and probably the most cost-effective element among many road safety strategies addressing those three elements. It should be noted that only certain level of reduction in road crashes is possible through hotspot treatment programs. The safety system approach has to be incorporated and implemented covering all the aspects of road safety to tackle with the devastating effect of road safety on society.

This guideline provides a clear process to identify high risk locations, analyze the risk at these locations, select appropriate countermeasures, prioritize the countermeasures, and monitor and evaluate the outcomes from these efforts.

1.2 Definition of Terms

There is no clear definition of road crash and injury available in the country. As per Nepal police “Road Traffic Fatality or Fatal Accident” is an accident resulting in the death of one or more persons. The persons killed may be drivers and passengers of vehicles, or cyclists and pedestrians and killed immediately or dying within the period of 30 days as a result of an injury crash.

As per proposed Road Safety Bill 2080, the term "road crash" refers to a situation in which vehicles collide while in motion on the road. It can also refer to an incident where a moving vehicle collides with a stationary one, pedestrians, domestic animals, wildlife, or when passengers or cargo fall from a moving vehicle. Additionally, it encompasses any other event that leads to an uncontrolled situation, often due to mechanical failure or other factors, resulting in rollovers or overturns.

1.3 Organization of the Report

This guide includes four chapters as:

Chapter 1: Introduction

Chapter 2: Road Crash Data Collection

Chapter 3: Identify Crash Locations and Clusters

Chapter 4: Preliminary Crash Analysis

Chapter 5: Develop Remedial Measures

Chapter 6: Economic Analysis

Chapter 7: Detailed Design and Implementation

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Appendices

2 ROAD CRASH DATA COLLECTION

2.1 Crash Data Collection System

As previously emphasized, obtaining high-quality crash data is crucial for safety analysis, identifying effective countermeasures, and monitoring and evaluating safety initiatives. In Nepal, the responsibility for collecting road crash data primarily falls on the Nepal Police. Therefore, road crash data records collected during crash investigation by Nepal police will be the primary source of information. Historically, paper-based methods were employed for maintaining road crash data records within various levels of traffic police administration (see Appendix A). Regrettably, these paper-based crash record forms were not consistently completed nationwide. Furthermore, there were variations in the crash data recording formats among different jurisdictions, with some incidents only being reported through daily police incident reports.

As a result, it is imperative to urgently enhance the capacity of the police force to systematically gather quality crash data across the entire country in a timely manner. This is essential for promoting data-driven decision-making in road safety interventions.

2.2 Technology used for Crash Data Collection

Before 1995, precise recording of crash locations and comprehensive crash data were major challenges, hindering the process of crash investigation and remedial efforts. The introduction of the Microcomputer Accident Analysis Package System (MAAPS) in 1995 marked the first step in creating a crash database, utilizing an advanced data storage and analysis system. Initially, MAAPS covered the areas of Kathmandu, Lalitpur, and the Naubise-Mugling section of the Prithvi Highway.

Unfortunately, Nepal faced difficulties in maintaining this system for various reasons, including uncertainties in institutional, legal, and funding frameworks. Following the collapse of MAAPS, the collection of crash data was limited to filling out crash report forms that were developed during the same period with the assistance of Department of International Development (DFID) experts. In terms of data storage, the Nepal Police continued to maintain aggregated crash data records within its computer system. However,

the collection of crash data remained inconsistent, and there were doubts regarding the coverage of all crashes.

The necessity for a Crash Database System became evident during the Road Safety Support Project period funded by World Bank (WB). In 2016, the Nepal Road Crash Database System (NRCDS) was developed through a study funded by the project. This initiative recommended several measures to be taken prior to initiating the collection of crash data. In addition to creating a straightforward system for collecting and storing crash data for use by the Nepal Police and/or the National Road Safety Council (NRSC), the study provided various recommendations for ensuring the sustained operation and maintenance of the system. Regrettably, despite these efforts, the NRCDS did not see continuous use and was never implemented due to a lack of ownership and support.

In 2019, the Department of Transport Management (DoTM) under the Ministry of Physical Infrastructure and Transport (MoPIT), with the support of the Nepal India Regional Trade and Transport Project (NIRTTP), in collaboration with Nepal Police, initiated the development and piloting of a web-based Road Accident Information Management System (RA-IMS). This initiative was rolled out in the Kathmandu Valley and along the Kathmandu-Birgunj Road corridor.

However, the proper functioning of RAIMS came to a halt following the closure of NIRTTP due to several significant reasons, with the primary ones being unresolved ownership and funding issues. These persistent challenges, coupled with a lack of strong leadership and commitments, resulted in a shortage of funds for the continued technical and logistical support to the Nepal Police. This, in turn, led to the collapse of the system although during the pilot period of RAIMS, over 24,000 crash data records were reported and collected.

Currently, there is an ongoing WB funded loan project known as the "Project Management Consultancy for Road Safety Management" under the Strategic Road Connectivity and Trade Improvement Project (SRCTIP). One of the components of this project is to provide technical support for the nationwide rollout of the Road Accident Information Management System (RAIMS). This is the replacement of paper-based road accident form used by traffic police with the information technology-based system for collecting, verifying, storing and

disseminating road crash data. The mobile application of RAIMS has special feature of capturing the geographic location and photographs of the sites.

2.3 Crash Coding

Nepal currently lacks a comprehensive Road Crash Database System. The data collected and published by the Nepal Police is presented in an aggregated report format, which is not suitable for in-depth safety analysis. The data is gathered using an outdated crash report form introduced in 1996, which lacks clear instructions for its use, supporting documentation, and procedures for data collection and retention.

To conduct meaningful safety analysis, it is crucial to transform the raw data collected on the crash report form into organized groups of relevant and useful information. Crashes with similar characteristics should be grouped under a code, known as Descriptive Crash Codes (DCC). These DCC groups, combined with location information, create clusters that can be analyzed by road safety experts. This analysis allows for the identification of specific crash patterns and contributing factors, which are essential for practitioners to develop effective road safety strategies.

All road crash data exhibits patterns that provide insights into behaviors, road conditions, road design, and vehicle-related issues contributing to the crashes. Many types of crashes have well-established remedial solutions to reduce both the frequency and severity of crashes. The proposed Descriptive Crash Code (DCC) system (Draft report on Development of Nepal Road Crash Database System, 2016), as outlined in appendix B, is designed to bring consistency to the identification of crash types in Nepal. By implementing this system, it will be easier to categorize and analyze crash data effectively, ultimately aiding in the development of targeted road safety measures.

3 IDENTIFY CRASH LOCATIONS AND CLUSTERS

3.1 Defining Locations

The initial and most crucial stage in the crash treatment process involves pinpointing areas with a significant frequency of crashes, known as crash clusters. Various methods can be employed to address these crash clusters.

Single Site: Single site treatment focuses on addressing individual locations, such as intersections, curves, or short road segments, where crash incidents are concentrated. According to the proposed Public Road Act of 2079, a "blackspot (hotspot)" is defined as a location where a minimum of five road crashes have occurred in the past three years or where at least five fatalities have resulted from road crashes within a three-year period. The term also encompasses road segments that are at least one hundred meters in length and have experienced such crashes. The definition of the term "Blackspot (hotspot)" is not universal and varies from one country to another. Therefore, it is important for Nepal to establish a clear and specific definition of "Blackspot (hotspot)" within its own context.

Route action: Under route action, safety treatments are implemented across an entire road segment with a history of consistently poor crash records.

Mass action: In mass action, standardized safety treatments are implemented across all locations that exhibit similar crash characteristics.

Area action: It involves the application of safety treatments across a designated area with an overall history of poor crash records.

3.2 Criteria for Selecting Locations

Typically, "Blackspots (also known as hotspots these days)" refer to individual sites with a history of poor crash records, such as intersections, short road sections, and junctions. However, this concept can be expanded to include road segments with an unusually high number of crashes (route action) and entire areas (area action).

To undertake a blackspot improvement program, it is essential to identify these blackspots based on available crash data spanning from 3 to 5 years, considering various types of roads. It is important to note that only casualty crashes, which involve injuries or fatalities to one or more persons, should be considered when identifying blackspots. Property damage-only crashes tend to be underreported and are typically not included in this analysis.

Blackspot identification can be carried out through various methods, including cluster analysis, spatial analysis, grid analysis, and corridor analysis. However, the availability of a crash data management system or a road safety management system is crucial for these processes. These methods are all aimed at pinpointing road sections with a high frequency of crashes. The choice of the specific method to use depends on the availability of locational information and the particular network under consideration.

3.3 Prioritization of Blackspot for Treatment

In cases where resource constraints prevent the rectification of all identified blackspots in a single financial year, the road safety implementing agency can plan the blackspot improvement program in multiple stages based on prioritization. The prioritization process can be carried out using severity indices, as described below, to determine which blackspots should be addressed first.

At a blackspot site, there may be various crashes with different levels of severity. To prioritize blackspots, severity values can be assigned to each type of crash, and a severity index can be calculated. This approach allows for the identification of sites with more severe crashes. Blackspots with higher severity indices should be given priority for treatment, with prioritization typically carried out in descending order of severity index for these sites, ahead of other crash locations. Below are the assigned severity values for different type of crashes:

Fatal crashes: 10

Serious Injury Crashes: 6

Minor Injury Crashes: 2

3.4 Worked Out Example for Prioritization

Table 3-1, provided below, displays the 17 crash clusters identified as blackspots within the Bharatpur municipality of Chitwan district. The severity index was calculated by assigning severity values to the different crash types, as explained in section 3.3.

$$Severity\ index\ (SI) = \sum_i n_i \times SV_i) \quad \ldots (3.1)$$

Where,

n_i = number of persons with severity 'i'

SV_i = Severity value for the severity 'i'

i = Fatal or Serious or Minor

For example:

Crash Case 1:

Location: Bharatpur Municipality, Ward number 1, Bageshwori

Number of Crashes = 1

Severity of Person involved

Fatal = 0,

Serious = 5,

Minor = 2

As explained in section 3.3, severity values are:

Fatal crashes: 10

Serious Injury Crashes: 6

Minor Injury Crashes: 2

$$Severity\ index\ (SI) = \sum_i n_i \times SV_i)$$
$$= 0 \times 10 + 1 \times 5 + 6 \times 2$$

Therefore,

Severity index (SI) = 17

Table 3-1 Worked out example for severity index

S.No.	District - Chitawan			Total number of crashes	Person involved with Severity Level			Severity Index
	City	Ward No.	Place		Fatal	Serious	Minor	
1	Bharatpur	1	Bageshwori	1	0	1	6	17
2	Bharatpur	1	Pokhara Buspark	1	0	0	1	2
3	Bharatpur	1	Ramnagar	1	0	0	1	2
4	Bharatpur	3	Shahidchowk	2	0	0	7	14
5	Bharatpur	9	Bikashchowk	1	0	1	1	7
6	Bharatpur	9	Gondrang Chauki	1	0	1	0	5
7	Bharatpur	9	Milanchowk	1	1	1	0	15
8	Bharatpur	9		1	1	0	0	10
9	Bharatpur	10	Airport	2	1	1	0	15
10	Bharatpur	10	Bhatbhateni Oralo	1	0	0	1	2
11	Bharatpur	10	Bypass road	1	0	2	1	12
12	Bharatpur	11	Bhojad, Kati fatory	1	0	0	1	2
13	Bharatpur	11	Jagritichowk	1	0	0	2	4
14	Bharatpur	12	Tikauli Jungle	4	1	5	0	35
15	Bharatpur	16	Shivaghat Chowk	1	0	1	1	7
16	Bharatpur	18	Basantachowk	1	0	1	0	5
17	Bharatpur	29	Kerabari	1	0	0	0	0

Once the severity index is determined, it can be reorganized in descending order, as demonstrated in Table 3-2, to establish a prioritized list of blackspots. Blackspots with higher severity indices should be addressed as an immediate priority, while others can be scheduled for treatment in later stages, depending on the availability of resources.

According to Table 3-2, Severity index is the highest (35) for the crash at Bharatpur Metropolitan city war no 12, Tikauli jungle. The order of priority for this crash site need to be of the first priority.

Table 3-2 Blackspot treatment order of priority

S.No.	District - Chitawan			Total number of crashes	Person involved with Severity Level			Severity Index	Treatment Priority
	City	Ward No.	Place		Fatal	Serious	Minor		
14	Bharatpur	12	Tikauli Jungle	4	1	5	0	35	1
1	Bharatpur	1	Bageshwori	1	0	1	6	17	2
7	Bharatpur	9	Milanchowk	1	1	1	0	15	3
9	Bharatpur	10	Airport	2	1	1	0	15	3
4	Bharatpur	3	Shahidchowk	2	0	0	7	14	4
11	Bharatpur	10	Bypass road	1	0	2	1	12	5
8	Bharatpur	9		1	1	0	0	10	6
5	Bharatpur	9	Bikashchowk	1	0	1	1	7	7
15	Bharatpur	16	Shivaghat Chowk	1	0	1	1	7	7
6	Bharatpur	9	Gondrang Chauki	1	0	1	0	5	8
16	Bharatpur	18	Basantachowk	1	0	1	0	5	8
13	Bharatpur	11	Jagritichowk	1	0	0	2	4	9
2	Bharatpur	1	Pokhara Buspark	1	0	0	1	2	10
3	Bharatpur	1	Ramnagar	1	0	0	1	2	10
10	Bharatpur	10	Bhatbhateni Oralo	1	0	0	1	2	10
12	Bharatpur	11	Bhojad, Kati fatory	1	0	0	1	2	10
17	Bharatpur	29	Kerabari	1	0	0	0	0	11

4 PRELIMINARY CRASH ANALYSIS

4.1 Preliminary Crash Analysis

Following the selection of prioritized sites, the subsequent stage involves examining whether there is a discernible crash pattern at these locations. An analysis of crash summaries for each site can be compiled, encompassing information such as crash type, severity, victim characteristics, involved vehicle types, and time of occurrence. The primary aim of this process is to detect patterns in the crashes that may aid in identifying contributing factors. An illustration of a summary report can be found in Table 4-1.

Table 4-1 Example of summary analysis

Chitwan Khaireni 1 Tarkarichowk					
CrashNo.	1	2	3	4	5
Date	31/05/2077	18/07/2077	26/07/2077	29/10/2077	28/11/2077
Vehicle 1	Truck	Truck	Truck	Motorcycle	Mini bus
Vehicle 2	Truck	Motorcycle	Motorcycle	Truck	Motorcycle
Vehicle3					Truck
No.of vehicle	2	2	2	2	3
Severity	Minor Injury	Serious Injury	Fatal	Fatal	Serious
No. of Casualties	4	1	1	2	2
Time	03:30	18:00	06:40	01:35	17:00
Weather					
Description	Rear end collision	Head on Collision	Head on collision	Rear End collision	Head of collision of mini bus and motorcycle and later truck hit by motorcycle
Cause				Truck hit by motorcyclist	

4.2 Site Investigation

Inspecting the crash site is a crucial step in assessing causative factors that may not be evident through crash data analysis alone. However, it is advisable to conduct these site visits after the initial analysis of crash data. Bringing crash reports and analysis to the site can provide better insight and ensure that the findings align with the actual field conditions. The reasons for conducting site inspections are as follows:

a. To accurately assess the road conditions and other site-related factors that may be relevant.
b. To experience the challenges faced by road users

Ideally, the field team should explore the site by walking, driving, and possibly cycling through it during both daytime and night time conditions. This comprehensive approach helps in understanding the difficulties road users encounter. Taking photographs with date and time stamps from various angles and capturing videos during day and night conditions can be valuable for reviewing the site's conditions back at the office.

Local residents and witnesses may provide essential information, as they may have observed the crashes. Engaging with traffic police and road agency engineers to gather their insights about the crash situation can be enlightening. Discussing the initial diagnosis with these stakeholders can help reach a consensus on remedial measures. The factors to consider during site inspection are listed in Table 4-2. These factors are essential for a comprehensive evaluation of the crash site.

Personal safety measures, such as wearing reflective vests and staying attentive to traffic movement, are essential for those working at the site. Additionally, ensuring public safety by avoiding actions like parking on the road, obstructing traffic, or blocking the visibility of other road users is equally important. These precautions help maintain a safe and secure environment during site inspections and contribute to overall road safety.

It may be necessary to carry out following additional studies and surveys to confirm analysis result and to determine and design appropriate remedial measures.

- Classified traffic counts at mid blocks/intersections (turning movement count)
- Pedestrian counts along and across the road
- Pedestrian road crossing behavior
- Sight distances
- Spot speeds
- Conflicts

Table 4-2 Site inspection checklist

S.No.	Elements	Details
1	Road Cross Section	Lane width, shoulder width, side drains, kerbs, footpaths
2	Road Geometry	Curves, Gradients, Extrawidening, Superelevation
3	Road Surface	Type, Drainage, Friction
4	Sight Distance	Visibility through traffic, road side traffic, pedestrians, parked cars, trees etc.
5	Intersection	Type, layout, geometry
6	Signs and Markings	Type, condition, legibility, conspicuity, credibility
7	Traffic Signals	Type, visibility, timing
8	Lighting	Type, positioning, effectiveness
9	Traffic	Motorized and non-motorized traffic volume, actual speed, speed limit
10	Parking	On street, off street, bus stops/stands, taxi stands
11	Pedestrians	Volume, age, facilities provided, travel direction
12	Roadside Objects	Poles, posts, trees, side slopes, other roadside hazards
13	Road Environment	Land use, presence of road side amenities, development, schools
14	Crash Related Evidences	Skid marks, broken glasses, damaged road and road furniture
15	Other Human Factors	Driver/pedestrian travel paths, collision diagram

4.3 Conflict Studies

Conflicts refer to situations where a collision could occur if one or more road users fail to take timely actions to prevent such incidents. Conflict studies primarily involve observing the dynamics of traffic, including pedestrians, at the location of a potential collision, with the aim of identifying potential conflicts or close calls between different traffic movements. This approach can be especially valuable at intersections when collision diagrams are unavailable in crash records. While not a completely objective method for assessing crashes, a brief observation over just a few hours, can yield valuable insights into the challenges faced by road users.

4.4 Identify Crash Cause and Severity Factors

After analyzing crash data and conducting on-site inspections, the subsequent phase involves identifying the root causes of the crashes, effectively diagnosing the issues at each identified blackspot location. The conclusions drawn from this process should be based on sound reasoning, as they directly relate the countermeasures that need to be recommended. The primary goal of this task is to pinpoint the contributing factors that influence the crashes, which, when addressed, can potentially alter the future safety landscape.

5 DEVELOP REMEDIAL MEASURES

5.1 Introduction

The selection of countermeasures should align with the specific crash types identified during the diagnosis phase and be applicable to the underlying causes. There may be several alternative countermeasures available, either for individual use or in combination. Choosing the appropriate countermeasures necessitates road safety engineering expertise and a sound understanding of the factors contributing to crashes. At a minimum, the selected countermeasures should achieve one of the following objectives:

- Eliminate the root causes of conflicts leading to the issue.
- Enhance the existing conditions.
- Lower vehicle speeds to reduce the risk and severity of crashes.

5.2 Crash Modification Factors (CMF)

Crash Modification Factors (CMFs) serve as an estimation of the impact of a specific countermeasure. In simpler terms, they quantify the relative alteration in crash frequency resulting from a modification in a particular condition and can be mathematically expressed as follows in Equation (5.1):

$$CMF = \frac{Expected\ average\ crash\ frequency\ with\ condition\ 'b'}{Expected\ average\ cra\quad frequency\ with\ condition\ 'a'} \quad \ldots (5.1)$$

CMF values less than 1.00 signify that the alternative treatment reduces the estimated average crash frequency compared to the base condition. Conversely, CMF values greater than 1.00 indicate that the alternative treatment increases the estimated average crash frequency in comparison to the base condition.

For example:

If CMF = 0.90, the expected percent change is 100% × (1.00 - 0.90) = 10%, indicating a 10% reduction in the expected average crash frequency.

If CMF = 1.2, the expected percent change is 100% × (1.00 - 1.2) = -20%, indicating a 20% increase in the expected average crash frequency.

Reliable information on CMFs can be found in various literature sources. Appendix C provides one such reference that covers various treatment options as Nepal does not have its own CMFs.

When multiple treatments are applied at the same crash site, the most common technique used is the application of equation below.

$$CMF_t = CMF_1 \times CMF_2 \times \ldots\ldots \quad \ldots (5.2)$$

Where

CMF_t = Total crash modification

CMF_i = individual crash reduction for treatment 'i'

5.3 Countermeasures Selection and Design

Based on road safety engineering expertise and informed judgment, the selection of a single solution or a combination of solutions should be made. Subsequently, the impact of the proposed treatment can be assessed using Crash Modification Factors (CMFs). This evaluation allows for a more accurate determination of the treatment's effectiveness in improving road safety.

To simplify the process, and in situations where reliable data on CMFs are unavailable, Appendix D offers information on the most frequently occurring crash types, potential contributing factors, and suggested engineering treatments (countermeasures). This resource can assist in making informed decisions when addressing road safety concerns.

6 ECONOMIC ANALYSIS

6.1 Introduction

In scenarios where multiple schemes or solutions are available and there is a budget constraint, it becomes essential to prioritize and select cost-effective solutions. Making efficient use of available resources and funds is crucial for achieving the best possible outcomes while managing budget limitations. A common approach for ranking schemes based on cost-effectiveness involves conducting a Benefit Cost Analysis (BCA). BCA utilizes monetary values to assess and compare the total benefits with the total costs of a particular countermeasure.

6.2 Cost of Crashes and Remedial Treatment

Crash cost is important component of BCA. The benefits of safety improvements are estimated by placing economic value on crashes and applying this to reduction of crashes. The crash cost (economic value of crash) therefore includes social cost of crashes, the value of property damage, medical and ambulance costs, insurance and administration cost, lost output costs, police costs, human costs related with pain and suffering resulted by death and injury. The crash cost can generally be calculated using both human capital and the willingness to pay approach. Though the crash costs can be determined for different level of severity i.e., fatal, serious injury, minor injury, a single average cost for all injury crashes is sufficient for the purpose of prioritizing actions for reduction of crash frequency.

6.3 Calculating Cost and Benefits

The important parameters for estimating benefits and costs of countermeasures are treatment life, costs, benefits and the discount rate.

The term "treatment life" refers to the duration during which a specific safety improvement or countermeasure will continue to provide safety benefits before necessitating significant rehabilitation or replacement. The actual treatment life can vary based on several factors, including:

- The type and scope of the project.
- Local climate conditions that may cause infrastructure to deteriorate.

- Traffic volume, which can contribute to infrastructure wear and tear, or growth that leads to congestion and necessitates infrastructure changes.
- Compliance with local standards and the availability of resources for infrastructure replacement.
- The level and regularity of maintenance efforts.

In projects involving multiple treatments, such as network or national blackspot (hotspot) programs, the service life applied is typically that of the longest-lived component among the treatments. Accurate information about the expected life of a countermeasure is essential for making informed decisions about fund allocation, with the goal of achieving the most cost-effective outcomes in terms of reducing injuries and crashes.

The total countermeasure costs encompass various components, which include:

1) Implementation Costs: These are the costs incurred during the initial phase of a project as it is designed and constructed. They cover expenses related to installation, materials, and labor required for each countermeasure. The specific costs can vary depending on factors such as the type of road environment, traffic volumes, local conditions, labor costs, and the availability of materials.
2) Annual Maintenance Costs: This includes routine and periodic maintenance expenses associated with the countermeasure. The level and regularity of maintenance are contingent on the nature of the countermeasure or, in cases involving multiple treatments, the combination of countermeasures.
3) Operating Costs: Operating costs may involve ongoing expenses like electricity supply, which are incurred to keep the countermeasure functioning as intended. These costs can vary based on the operational requirements of the specific countermeasure.

Accurate assessment and consideration of these cost components are essential for evaluating the overall financial implications of implementing and maintaining a countermeasure and for making informed decisions in road safety projects.
The benefits of a safety countermeasure refer to the savings in road crash costs that are anticipated to occur as a result of its implementation. These savings result from either a

decrease in the number of crashes or a reduction in the severity of crashes. Unlike the cost, which is typically incurred during the project's design and construction phase, often within one or possibly two years, the benefits are accrued over the project period.

These benefits are quantified in terms of monetary savings resulting from the reduction or prevention of casualties, which include fatalities and injuries, over a specified number of years. Therefore, the benefits represent the long-term advantages and positive outcomes that can be realized from the improved safety brought about by the countermeasure.

In any economic analysis, it is crucial to establish a specific base year from which all future costs and benefits can be evaluated. This is necessary to accurately account for the time value of money. The base year serves as the reference point to which all monetary values associated with the impacts (both benefits and costs) of a treatment are discounted.

The discount rate is employed to convert future benefits and costs into present values. The choice of the discount rate can exert a significant influence on the attractiveness and selection of projects, particularly when the benefits and costs materialize later in the treatment's lifespan. A higher discount rate diminishes the worth of benefits and costs occurring in the later stages of the treatment's life, thereby favoring projects where the benefits are realized early in the project timeline.

The equations used for the economic analysis are given below

1) Net Present Value (NPV)

$$NPV = Benefit\ (or\ Cost) \times Discount\ Factor \quad \ldots (6.1)$$

$$Discount\ Factor = \frac{1}{(1+r)^n} \quad \ldots (6.2)$$

Where r = discount rate and n = number of year from base year

2) Benefit Cost Ratio (BCR)

It is defined as the present value of benefits (net operating and maintenance costs) divided by the present value of implementation costs and is given by

$$BCR = \frac{PV(B-OC)}{PV(IC)} \quad \ldots (6.3)$$

Where

PV = Present value

B = All benefits

OC = Treatment operation and maintenance costs

IC = Treatment implementation costs

6.4 Ranking the Treatment

Following the economic analysis, it is essential to prioritize the schemes to determine which one should be implemented to achieve the maximum benefit, particularly in terms of reducing fatal and serious injury crash outcomes, within the available budget.

Two key metrics are used to assess and rank the schemes:

- Net Present Value (NPV): NPV offers insights into the total welfare gain over the treatment's lifespan. It quantifies the net social benefit derived from the project.
- Benefit/Cost Ratio (BCR): BCR reveals the relationship between the present value of benefits and the implementation costs of a project. It helps assess the efficiency and viability of the project.

The NPV method is particularly applicable when there is a budget constraint, and the goal is to select the most valuable set of projects. It's important to note that the benefit/cost ratio itself should not be used to rank alternatives. Instead, the ranking should involve a comparison of all alternatives with a BCR greater than 1, signifying that the benefits outweigh the costs.

In general, NPV is the preferred criterion as it provides an estimate of the absolute magnitude of the treatment's net social benefit. The Table 6-1 below offers guidance on when to use the different criteria in decision-making processes.

Table 6-1 Decision criteria

Criterion			
Budget	Decision context	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 nagative NPV	No rule exists
Constrained budget	Accept-reject decision	Select project such that NPVof project set is maximised subject to budget constraint	Rank by BCR until budget is exhausted or BCR cut-off reached
	Option selection	Highest NPC subject to budget constraint	No rule exists

(Source: Austroad, 2005b)

7 DETAILED DESIGN AND IMPLEMENTATION

7.1 Detailed Design

Preparing detailed design drawings for recommended remedial measures at a specific site is advisable, and at times, it may be necessary to engage experts from various sectors. When finalizing these designs, it is crucial to have a clear understanding of road user actions, ensuring safe and easy vehicle maneuvers, and identifying any hazards to road users during both day and night.

Conducting a site trial provides a better understanding of implementation feasibility, especially in urban scenarios. This trial serves as a demonstration case for stakeholders, offering an opportunity to evaluate the proposed design. During the implementation of the devised scheme, it might be necessary to conduct a publicity campaign to effectively communicate the purpose of the design. This campaign should also educate the public on how to safely navigate the roads during and after the implementation of the scheme.

7.2 Monitoring and Evaluation

The safety measures undertaken at the site may be new to the site environment and hence its performance should be closely monitored which will enable to know about its cost effectiveness. This will also form the basis of road safety engineering. Evaluation is not so simple and easy as each crash was caused by multiple reasons and there was not theoretically sound technique to prove that particular counter measure has prevented the crashes. But it will certainly give the indications of improvement so as to prescribe counter measures for certain type of crashes. For the measurement of cost effectiveness of safety measures, it is also needed to consider the public acceptability of the measures adopted. Therefore, the countermeasures should clearly fulfill certain objectives in terms of crash/severity reductions and should have clear logical linkages between the causes and treatments.

It is always good to monitor the implementation of scheme closely for few days to weeks. Road users will take some time to adjust themselves in the new road environment and there might also be some crashes. Therefore, there may be need of change in design due to serious

problems. The targeted interventions may reduce some targeted type of crashes and not all the crashes thereby creating the topic of public criticism which should be responded on time.

The fundamental way of measuring effectiveness is to conduct before-after study. There are complications in this kind of study due to extraneous factors (change in weather, traffic pattern, vehicle composition, enforcement), randomness of crash occurrence, regression to the mean effect, unavailability of crash data during and just after implementation of the schedule to changed traffic behavior during and just after construction time, inclusion of multiple measures (which is often a case) in a single implementation scheme like providing signage along with geometric improvement. Generally, three years crash data (both before and after) are used conducting before-after study. The variables for comparison generally include traffic speeds, conflicts, pedestrians using crossings, road users' perception, red light violations etc.

7.3 Statistical Analysis

There are number of statistical tests that can be used to compare the safety performance in before-after study. Paired t test and Chi squared test being the most common ones. It can compare the before and after data of treated sites with same kind of data of untreated sites (controlled sites) and hence shows the difference of two data sets.

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APPENDIX A: POLICE CRASH RECORD FORM

TRAFFIC POLICE OF NEPAL

ROAD ACCIDENT REPORT

1. Report No.		2. Computer No.	
3. Police Station		4. District	

5. No. of Vehicles Involved		9. Accident Severity	10. Day 11. Month 12. Year
6. No. of Driver Casualties		1. Fatal	Date
7. No of Passenger Casualties		2. Serious	13. Day of Week
8. No. of Pedestrian Casualties		3. Minor	14. Time (24 hours) Hour Minute
		4. Damage	

15. Junction Type 1. Not at junction 2. + 3. T 4. ⊥ 5. Y 6. ○ 7. Other	16. Traffic Control 1. None 2. Centreline 3. Ped Crossing 4. Police 5. Traffic Signals 6. Stop Sign 7. Give Way Sign 8. Other	17. Collision Type 1. Head On 2. Rear End 3. Right Angle 4. Side Swipe 5. Overturned Vehicle 6. Hit Object in Road 7. Hit Object off Road 8. Hit Parked Vehicle 9. Hit Pedestrian 10. Hit Animal 11. Other	18. Movement 1. 1 Way Street 2. 2 Way Street 19. Weather 1. Fair 2. Rain 3. Fog 4. Smoke/Dust	

20. Light 1. Daylight 2. Night (Unlit) 3. Night (Lit)	21. Road Character 1. Straight + Flat 2. Curve only 3. Incline only 4. Curve + Incline 5. Bridge (Name of River)	22. Surface Type 1. Asphalt 2. Gravel 3. Earth	23. Road Condition 1. Good 2. Damaged	24. Surface Condition 1. Dry 2. Wet 3. Muddy 4. Flooded	25. Roadworks 1. Yes 2. No	26. Hit & Run 1. Yes 2. No

Name of City / Town	Office use	XY Map No.	Route	Node Map
Location	Urban/ Rural	X =	Km	Node 1
Location ..... km from ..... (Town/Village) towards ..... (Town/Village)	Town/ Village	Y =	100m	Node 2

Accident Location Sketch

Show site in relation to prominent landmarks such as bridges or Km posts. Mark distances to the landmarks.

Collision Diagram Sketch

Mark the position and direction of each vehicle and details of the road layout at the site of the accident.

Police description of accident	Witnesses (Name, Age, Address, Signature)
	Reporting Officer Name Rank
	Reviewing Officer Name Rank
	Action Taken / Recommendation

VEHICLE 1

38. Vehicle Registration No. |_|_|_|_|_|_|_|

Owner's Name & Address

Third Party Insurance ☐ Yes ☐ No

Make

39. Vehicle Type
1. Bicycle
2. Rickshaw
3. Motor Cycle
4. Autorickshaw
5. Car .....
6. Pick up
7. Mini Bus
8. Bus
9. Truck
10. Other

40. Vehicle Maneuver
1. Right Turn
2. Left Turn
3. 'U' Turn
4. Cross Traffic
5. Merging
6. Diverging
7. Overtaking
8. Going Ahead
9. Reversing
10. Sudden Start
11. Sudden Stop
12. Parked (off) Road
13. Parked (on) Road
14. Other .....

41. Loading
1. Legally Loaded
2. Overloaded
3. Insecure Load
4. Protruding Load
5. Other Improper Load

42. Vehicle Defect
1. None
2. Brakes
3. Steering
4. Tyres
5. Lights
6. Multiple
7. Other

43. Vehicle Damage
1. None
2. Front
3. Rear
4. Right
5. Left
6. Roof
7. Multiple
8. Other .....

44. Ownership
1. Government
2. Corporation
3. Diplomatic
4. Private/ Personal
5. Public
6. Police
7. Army

DRIVER 1

Driver's Name

Driver's Address

45. Licence Number |_|_|_|_|_|_|_|_|

46. Place of Issue

47. Licence Type
1. Full Licence
2. Provisional Licence
3. Probationary
4. Unlicenced

48. Driver Sex **49. Age**

50. Driver Injury
1. Fatal
2. Serious
3. Minor
4. Uninjured

51. Driver Error
1. None
2. Fatigued/Asleep
3. Inattentive
4. Too Fast
5. Too Close
6. No Signal
7. Bad Overtaking
8. Bad Turning
9. Other .....

52. Alcohol
1. Not Suspected
2. Suspected

53. Seat belt/Helmet in use
1. Yes
2. No

VEHICLE 2

38. Vehicle Registration No. |_|_|_|_|_|_|_|

Owner's Name & Address

Third Party Insurance ☐ Yes ☐ No

Make

39. Vehicle Type
1. Bicycle
2. Rickshaw
3. Motor Cycle
4. Autorickshaw
5. Car .....
6. Pick up
7. Mini Bus
8. Bus
9. Truck
10. Other

40. Vehicle Maneuver
1. Right Turn
2. Left Turn
3. 'U' Turn
4. Cross Traffic
5. Merging
6. Diverging
7. Overtaking
8. Going Ahead
9. Reversing
10. Sudden Start
11. Sudden Stop
12. Parked (off) Road
13. Parked (on) Road
14. Other .....

41. Loading
1. Legally Loaded
2. Overloaded
3. Insecure Load
4. Protruding Load
5. Other Improper Load

42. Vehicle Defect
1. None
2. Brakes
3. Steering
4. Tyres
5. Lights
6. Multiple
7. Other

43. Vehicle Damage
1. None
2. Front
3. Rear
4. Right
5. Left
6. Roof
7. Multiple
8. Other .....

44. Ownership
1. Government
2. Corporation
3. Diplomatic
4. Private/ Personal
5. Public
6. Police
7. Army

DRIVER 2

Driver's Name

Driver's Address

45. Licence Number |_|_|_|_|_|_|_|_|

46. Place of Issue

47. Licence Type
1. Full Licence
2. Provisional Licence
3. Probationary
4. Unlicenced

48. Driver Sex **49. Age**

50. Driver Injury
1. Fatal
2. Serious
3. Minor
4. Uninjured

51. Driver Error
1. None
2. Fatigued/Asleep
3. Inattentive
4. Too Fast
5. Too Close
6. No Signal
7. Bad Overtaking
8. Bad Turning
9. Other .....

52. Alcohol
1. Not Suspected
2. Suspected

53. Seat belt/Helmet in use
1. Yes
2. No

Passenger Casualties

Complete tables using codes from bottom panel

Name & Address	54. Veh. No	55. Sex	56. Age	57. Injury	58. Position	59. Action	60. Belts/ Helmets
1							
2							
3							
4							

Pedestrian Casualties

Name & Address	61. Sex	62. Age	63. Injury	64. Location	65. Action	66. Alcohol
1						
2						
3						

57./63. Passenger Injury
1. Fatal
2. Serious
3. Minor

58. Passenger Position
1. Front Seat
2. Rear Seat
3. M/cycle Passenger
4. Bus Passenger
5. Outside-Sitting
6. Outside-Standing

59. Passenger Action
1. None
2. Boarding
3. Alighting
4. Falling
5. Other

60. Seat Belt/ Helmet In Use
1. Yes
2. No

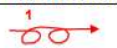
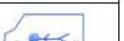
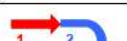
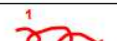
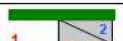
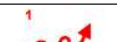
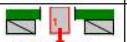
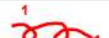
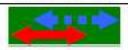
66. Alcohol
1. Not Suspected
2. Suspected

64. Pedestrian Location
1. On Pedestrian Crossing
2. Within 50m Ped. Crossing
3. On Central Refuge
4. In Road Centre not in 1-3
5. On Footpath/Verge

65. Pedestrian Action
1. None
2. Crossing Road
3. Walking along Road
4. Walking along Edge
5. Playing on Road
6. On Footpath

APPENDIX B: PROPOSED DESCRIPTIVE CRASH CODES (DCC) FOR NEPAL

Annex no: 15.6 A, **DCC (Descriptive Crash Codes)** **DCC Nepal**

	0 Hit Pedestrian	1 From opposing directions	2 From one direction	3 From adjacent directions	4 From one direction side by side	5 Overtaking	6 Out of Control On/Off Road	7 Hit Object On Road	8 Maneuver	9 Passenger & Misc.
0	Near Side 00	Thru-Thru 10	Thru-Thru 20	Thru-Thru 30	Lane S/S 40	O/T-H/On 50	 O/C Thru 60	Hit Park/V 70	Leave Park 80	 Fell In/Veh 90
1	Veh.left 01	Right-Thru 11	 Thru-Right 21	Thru-Right 31	Lane/C Rht 41	P/O-R/End 51	 O/C Right 61	 Hit Door 71	Parking 81	Fell Off Top 91
2	Veh.Right 02	Left-Thru 12	Thru-Left 22	Thru-Left 32	Lane/C Left 42	O/T-R/E.O/T 5:	 O/C Left 62	Hit D/Park 72	Parked Vehs. only 82	Off Side/Back 92
3	Far Side 03	Right-Right 13		Right-Thru 33	S/S R-R 43	O/T-Cut In 53	Off-Thru 63	Hit/Perm. 73	 Leaving Driveway 83	Out Off Back 93
4	Playing Working Lying On Road 04	Right-Left 14		Right-Right 34	S/S L-L 44	O/T-Right 54	 Off-Right 64	Roadworks 74	Leaving Footpath 84	
5	With Traffic 05	Left-Left 15		Left-Right 35		O/Control 55	Off-Left 65	Temp.Obj. 75	Reversing in Traffic 85	
6	Face Traffic 06	UTurn-Thru 16	UTurn-Thru 26	Left-Thru 36		O/T-UTurn 56	Off/T-Hit/O 66	Hit Crash or Breakdown 76	Reversing into Fix Obj. 85	Runaway Veh. 96
7	Driveway 07			Right-Left 37			Off/R-Hit/O 67	Hit Animal 77		Hit Train 97
8	 On Path 08			Left-Left 38			Off/L-Hit/O 68	Load 78		Hit Rail X-ing 98
9	Boarding or Alighting 09	Other 19	Other 29	Other 39	Other 49	Other 59	Other 69	Other 79	Other 89	Other 99

APPENDIX C: TREATMENT OPTIONS – SINGLE VEHICLE ROAD CRASH

Likely Contributory Factors	Possible Counter Measures	
• Excessive speed not matching the road environment • Driver fatigue • Poor lighting/ Dark conditions • Road alignment is unclear • High speeds on curves • Restricted forward visibility for the actual approach speed • Narrow carriageway width after a long wide section • Sharp sag or crest curve • Incorrect super elevation • Tree / pole / bridge parapet / other hazard is too close to the edge of the road and is poorly marked • Objects closer to road not visible in dark conditions	Speed limiting measures	• Install vertical speed calming measures[2] - rumble strips, bar markings, speed breakers, speed tables, etc., with traffic signs, as appropriate. • Provide speed limit signs and initiate speed enforcement (supported by wide campaigns). • Install warning signs along with Advisory Speed Limit, as per IRC:67. • Install Chevron sign or delineator posts, as per the stipulated spacing depending on the radii. • Consider applying speed limits.
	Improve signing[3]	• Ensure that all traffic islands, medians conform to the requisite road signs and markings as per relevant IRC Codes/ Standard • Install hazard markers on obstructions close to the edge of the road and / or paint the obstruction with black and yellow stripes. • Install clearly visible junction warning signs before all junctions.
	Improve road markings[4]	• Mark centre and edge lines. • Apply hatch markings in advance of medians and traffic islands to guide the drivers through the lane. • Mark STOP lines or Give Way lines at all junctions; Where 'Stop' road markings are provided, it shall be supported with a 'STOP' sign.
	Improve visibility	• Remove bushes, trees, advertising boards/ hoardings,if they are obstructing visibility. • Consider installing street lighting if the site is located in urban area or even in the case

Likely Contributory Factors	Possible Counter Measures	
• Steep gradient • Potholes or depressions in road surface • Road surface is slippery when wet • Slippery road surface due to debris on the road • Ponding of water on the road • Attempt to avoid collision • Traffic island that is difficult to see • Forward visibility is hampered due to the parked vehicles, in particular on the inside edge of carriageway on the curves		of the site having a history of night time crashes. • Remove the median plantation at (1) those curves which obscure the forward visibility while negotiating the curve and (2) at least 20 m on either side of median openings. • Anti-glare measures can be installed on the paved road medians based on road environment, to reduce headlight glare from opposite traffic as per relevant codes for 4/6 lanes highways. Anti-glare screen shall be highlighted with retro-reflective tape for achieving enhanced visibility during night and adverse weather conditions.
	Soften the roadside environment	• Remove roadside obstacles or move them further back from the road. • Consider installing crash barrier/crash attenuators[5] with retro-reflective tape for visibilityat night and adverse weather condition. • Consider re-forming embankments and cuttings to make the side slopes less steep.
	Improve the geometry	• Eliminate sharp changes in alignment - realign the road completely - use transition curves. • Ease gradient; Correct the gradient in locations where horizontal bend comes after a crest in the vertical gradient[6]. • Provide extra widening at curves as per IRC standards. • Correct the super elevation, if found faulty.
	Improve the road surface	• Rectify potholes and repair damaged edges. • Improve drainage if water ponding is a cause of crashes or pothole formation. • Improve skid resistance, especially if there is a high incidence of wet weather crashes.
	For crashes involving parked vehicles	• Consider parking regulations; consider removing on-street parking on locations where the crashes involving parked vehicles are high. • Consider conversion of angled parking to parallel parking • Consider increasing the clearance between the parking bays and through traffic lanes.
		• If many of the crashes are at night, consider provision of street lighting. • Enforce 'No Parking' on carriageway edge in multi-lane highways.

APPENDIX C: TREATMENT OPTIONS –PEDESTRIAN ROAD CRASHES

Likely Contributory Factors	Possible Counter Measures	
• Lack of footway/footpath. • Available Footway/footpath in poor condition. • Footway/Footpath is obstructed with encroachments (temporary shops, parked vehicles). • Narrow road. • Poor visibility for pedestrians. • Poor visibility for drivers. • Wide carriageway to cross. • Excessive speeds • Heavy traffic volumes - few gaps in which to cross.	Improve facilities for pedestrians walking along the road Improve facilities for pedestrians crossing the road	• Provide raised footpaths, wherever possible. The kerb height shall not bemore than 150 mm high in raised footpaths. • Provide wide at-grade walkways on the edge of the carriageway[7] . • Consider providing Speed Tables at junction approaches in urban areas[8] . • Consider ribbed bar marking for edge line to discourage vehicles to encroach the shoulder portion of the road. • Provide controlled or uncontrolled pedestrian zebra crossing, as appropriate[9] . • Erect clearly visible advance warning signs for pedestrian crossings. • Construct pedestrian refuge (with barrier kerbs or with over-runnable kerbs) to enable pedestrians to cross wide roads in two stages.

Likely Contributory Factors	Possible Counter Measures	
• No crossing facilities or clear places to cross. • Dark conditions – pedestrians not visible to the vehicular traffic. • Children playing in the road.	Speed limiting measures Improve visibility	• Construct Foot Over Bridge (FoB)[10] or Pedestrian subway[11], or PUP where this is justified by the volume of pedestrians and traffic. • If pedestrian crashes are occurring at a signal-controlled intersection, consider provision of pedestrian signals and an exclusive pedestrian phase. • Speed limit signs. • Implement speed limiting measures. • Prohibit parking which obstructs visibility. • Removal of sight-limiting obstacles. • Where there is on-street parking, construct a build-out to improve visibility for pedestrians. • Consider street lighting (especially of crossing sites) if site is in an urban area. • Re-site bus stops so that buses do not obstruct visibility.

APPENDIX C: TREATMENT OPTIONS –VEHICLES TRAVELLING IN SAME DIRECTION

Likely Contributory Factors	Possible Counter Measures	
• Lack of lane markings • Lack of lane discipline • Confusion over which lane to be in • Lanes are too narrow	Improvement of road markings/ signs	• Provide lane markings and centerlines • Mark lane direction arrows where appropriate • Mark no-overtaking zones • Improve visibility, markings and signs in U-Turns

Likely Contributory Factors	Possible Counter Measures	
• Dangerous overtaking • Careless driving - following too closely • Vehicle ahead stops suddenly (bus, taxi, auto) • Stopped vehicle sets off suddenly • Excessive speed • Dangerous U-turn • Contra flow: Wrong-way driving along a travel lane in a direction opposing the legal flow of traffic on a divided highway	Improvement of road markings/ signs	• Provide warning signs • Provide advance direction signs for junctions (consider overhead signs in multi-lane carriageways)
	Improvement of road facilities	• Provide extra widening on curves • Prohibit gaps in median to prevent hazardous U-turns • Provide bus bays where possible • To avoid contra flow, reposition median opening in the divided carriageway or provide service road upto the nearest safe crossing location to other carriageway
	Speed limiting measures	• Speed limit signs • Construction of speed limiting measures such as speed breakers or rumble strips • Active police enforcement

APPENDIX C: TREATMENT OPTIONS – INTERSECTION CRASHES

Likely Contributory Factors	Possible Counter Measures
"Hit from side" - vehicle from side road overshoots the stop/give way line and hits a vehicle on the main road	• If a cross-road, consider altering it to a staggered junction • If a skewed junction consider re-aligning the minor road so that it joins the major road at a right angle • Reshape the junction layout to include a right turn protected lane wherever possible with all safety elements • Ensure adequate warning signs/advance direction signs on the side road • Ensure there is a clearly visible Give Way or STOP sign • Install a splitter island in the side road • If a lot of the crashes are at night consider installing / improving street lighting • Consider installation of rumble strips or other traffic calming measures in the side road • If the junction is signal-controlled, improve the visibility of the signals (additional signal heads, overhead signals, backing boards). Consider provide vehicle actuated signal control. Moderate the cycle time according to the actual traffic volume

Likely Contributory Factors	Possible Counter Measures
"Hit from side" - vehicle from side road hits a vehicle on the main road after restarting from the stop / give way line	• Improve visibility at the stop/give way line by clearing obstructions • If a skew junction, consider re-aligning the minor road so that it joins the major road at a right angle • Consider installing traffic signals, if visibility cannot be improved • Consider installing traffic signals or roundabout if the volume of traffic warrants[12]
"Hit from side" - vehicle turning out of main road is hit by oncoming vehicle	• Clear any obstructions to visibility for vehicles waiting to turn right out of main road • Consider providing protected turning lane • If the junction is signal-controlled consider provision of a fully-controlled right turn phase
"Hit from rear" - vehicle going ahead is hit by a following vehicle	• Improve the warning signs/advance direction signs • If more rashes are observed due to wet weather , check skid resistance and drainage • At signal-controlled junctions check stopping sight distance to "tail of queue", and duration • on amber signal - improve the visibility of the signals and consider provision of overhead signals
"Hit from rear" - vehicle turning out of main road is hit by a following vehicle	• Improve the warning signs/advance direction signs • Provide protected right/left turn turning lane • Consider prohibiting the right turn if it can be catered for more safely at an another junction
"Hit from side" - vehicle in the roundabout is hit by an entering vehicle	• Improve the warning signs/advance direction signs • Provide Give Way signs and markings at the entries to the roundabout • Remove any obstructions to visibility close to the give way lines • Consider altering the geometry of the approaches arms so as to encourage slower speeds (increased deflection)
"Hit object on road" or "Ran off road" - vehicle entering the roundabout loses control	• Improve the warning signs/advance direction signs • Put Turn Left and Chevron signs on the centre island opposite each entry • Provide Give Way signs and markings at the entries to the roundabout • Consider altering the geometry of the approach arms so as to encourage slower speeds (increased deflection) • If there are a lot of wet weather crashes, check skid resistance and drainage • Consider installing rumble strips or other traffic calming measures on the approaches

Likely Contributory Factors	Possible Counter Measures	
• Excessive speeds - loss of control • Inadequate overtaking sight distance • Short straight road section between consecutive curves • Steep gradient with slow heavy traffic • Slow traffic uses centre of road • Vehicles "cut the corner" at bends • Poor forward visibility • Vehicle swerves to avoid pothole • Vehicle swerves to avoid bad edge • No centerline • Narrow road	Improve control	• Mark no overtaking zones and consider installing no overtaking signs • Supplement markings with reflective studs • Use "ladder" hatch markings on centerline to create a painted median - and reinforce the markings with rumble strips • Install warning signs (e.g., for bends, junctions, narrow roads) • Install delineator posts on the centre line of sharp horizontal curves • Install speed limit signs and provide active police enforcement • If there is a median, consider: improving the signing/marking, widening of the median or provision of a median barrier • Providerumble strips/raised bar marking along the centre line
	Improve the road surface	• Patch potholes • Repair damaged edges
	Improve the alignment	• Improve sight distances by improving geometry or/and by clearing bushes or obstructions • Increase the number of sections with opportunity for safe overtaking • Construct overtaking/climbing lanes
	Upgrade the road	• Consider widening the lanes and/or shoulders (but note that excessive width might encourage dangerous overtaking) • Upgrade the road to a dual carriageway

Likely Contributory Factors	Possible Counter Measures
• Excessive speed • Poor visibility • Careless overtaking • Inattention by driver • Failure of crossing control system • Crossing may be narrower than approach roads	• Install speed reducing measures (in the form of rumble strips, road humps, etc.) on the approaches. • Improve visibility of the crossing and light signals associated with it. • If the crossing is unmanned, improve the visibility along the rail track on the approach to the crossing. • Upgrade the signing and marking so that no-one can be in doubt that they are approaching a crossing - consider using "countdown posts". • Discourage overtaking by means of signs, markings or delineator posts. • Consider provision of street lighting. • Consult the railway authority about changing the control system (unmanned to manned or automatic). • Consult the railway authority about widening the crossing if it is narrower than the approach roads. • Consider replacing the crossing with an over bridge or under pass.

APPENDIX D: MODIFICATION FACTORS (FOR SAMPLE ONLY)

Table D-1: Crash modification factors of various countermeasures for intersection crashes

Treatment type	Description and DCA code								
	Adjacent approach 101–109	Head-on 201	Opposing turns 202–206	Rear end 301-304	Lane change 305–307	Parallel lanes-turning 308, 309	Vehicle hits ped 001–003	Loss of control, L or R turns 706, 707	Hit parked/ parking vehicle 601, 401, 402
Roundabout	0.3			1.2			0.4		
New traffic signals (no turn arrows)	0.3		1.9				0.7		
New traffic signals (with turn arrows)	0.3		0.55				0.7		
Remodel signals	0.7		0.6				0.7		
Grade separation	0.0		0.5			0.8	0.3	0.5	
Improve sight lines	0.7		0.7				0.7	0.8	
Street closure (one leg of cross-intersection)	0.5		0.5				0.5	0.9	
Street closure (close stem of T)	0.0		0.0				0.5	0.0	
High skid resistance surfacing				0.6				0.9	
Stagger cross-intersection (right-left)	0.5		0.5	1.3	1.1				
Improve/reinforce priority (e.g. add a control sign)	0.7								
Prohibit right turns			0.5			0.5		0.5	
Ban left or U-turns			Note 1	0.5		0.5		0.5	
Improve lighting							0.7		
Traffic islands on approaches		0.8	0.8	0.8				0.9	0.9
Indented right turn island			0.7	0.6				0.8	0.8
Painted turn lane			0.8	0.8					0.8
Ban parking adjacent to intersection	0.9			0.8	0.8		0.7		0.5
Extend median through intersection	0.0	0.0	0.0				0.5		
Reduce radius on left turn slip lane				0.5					
Protected left turn lane in crossing street				0.9					

Table D-2: Crash modification factors of various countermeasures for non-intersection crashes (by collision type)

Treatment type	Description and DCA code					
	Head-on 201	Opposing turns 202–206	Rear end 301–304	Lane change 305–307	Vehicle hits pedestrian 001–003	Hit parked/ parking vehicle 601, 401, 402
Median on existing carriageway	0.1				0.5	
Pedestrian refuge					0.55	
Pedestrian (zebra) crossing					0.6	
Kerb blisters	0.9				0.9	0.5
Pedestrian overpass					0.15	
Pedestrian signals					0.3	
Pedestrian crossing lighting					0.4	
Improved route lighting					0.7	
Clearway, parking bans			0.8		0.7	0.5
Indented right turn island		0.7	0.6			
Painted turn lanes		0.8	0.8			
Roadside hazards – remove	Note 1					
Roadside hazards – guard fence						
Wire rope safety barrier – roadside						
Wire rope safety barrier – median	0.05					
High skid resistance surfacing			0.6			
Seal shoulders	0.6					
Advisory speed signs on curves	0.7					
Delineation						
Edgelines						
Audio-tactile edgelines						
Reconstruct superelevation on curve	0.5					
Climbing/overtaking lanes	0.7 Note 2			1.1		
Signs (railway level crossing)						
Flashing lights (railway level crossing)						
Barriers or gates (railway level crossing)						
Bridge or overpass (railway level crossing)						
Frangible posts, poles						

Table D-3: Crash modification factors of various countermeasures for non-intersection crashes (by crash location)

Treatment type	Description and DCA code						
	On straight			On curve			Hit train 903
	Off road 701–702	Off road, hit object 703, 704	Loss of control, on road 705	Off road 801, 802	Off road, hit object 803, 804	Loss of control on road 805	
Median on existing carriageway							
Pedestrian refuge							
Pedestrian (zebra) crossing							
Kerb blisters							
Pedestrian overpass							
Pedestrian signals							
Pedestrian crossing lighting							
Improved route lighting							
Clearway, parking bans							
Indented right turn island							
Painted turn lanes							
Roadside hazards- remove	1.8	0.2		1.8	0.2		
Roadside hazards – guard fence	0.7	0.7	1.3	0.7	0.7	1.3	
Wire rope safety barrier – roadside	0.15	0.1		0.15	0.1		
Wire rope safety barrier – median							
High skid resistance surfacing	0.9	0.9	0.9	0.9	0.0	0.9	
Seal shoulders	0.6	0.6	0.6	0.6	0.6	0.6	
Advisory speed signs on curves				0.7	0.7	0.7	
Delineation	0.85	0.85	0.85	0.85	0.85	0.85	
Edgelines	0.7	0.7		0.7	0.7		
Audio-tactile edgelines							
Reconstruct superelevation on curve				0.5	0.5	0.5	
Climbing/overtaking lanes							
Signs (railway level crossing)							0.85
Flashing lights (railway level crossing)							0.5
Barriers or gates (railway level crossing)							0.2
Bridge or overpass (railway level crossing)							0.0