Technical Guide for the Application of Road Safety Inspections in Latin America and the Caribbean

Transport Division

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ABBREVIATIONS

BASt	Federal Highway Research Institute – Germany
CFPV	*Road Prevention Fund Corporation – Colombia*
FHWA	Federal Highway Administration - Estados Unidos
iRAP	*International Road Assessment Program*
ISO	*International Organization for Standardization*
RSA	Road Safety Audit
RSI	Road Safety Inspection
PAHO	Pan-American Health Organization
PIARC	*World Road Association*
RIPCORD	*Road Infrastructure Safety Protection* *Core-Research and Deveolopment for Road Safety in Europe*
RISMET	*Road Infrastructure Safety Management Evaluation Tools*
SEETO	*South East Europe Transport Observatory*
Sétra	*Service d'études sur les transports les routes et leurs aménagements*
SWOV	*Institute for Road Safety Research* - Países Bajos
UNISDR	*United Nations Office for Disaster and Risk Reduction*
WHO	World Health Organization

CONTENT

PREFACE

To contribute to addressing the road safety crisis in the world, responsible for the deaths of 154,089 people in 2013, it is essential to direct efforts towards the operation of safe road infrastructure. From the total number of deaths, 113,083 occurred in Latin America and the Caribbean alone (WHO - 2015), which is equivalent to 12% of transit related deaths worldwide.

To ensure that the road network is truly safe, in both urban and rural settings, there are two tools which have proven effective instruments for identifying potential road hazards and eliminating the risks of road incidents. These tools are Road Safety Audits (RSA) and Road Safety Inspections (RSI).

Faced with the lack of road safety in Latin America and the Caribbean and taking into account the potential of RSA and RSI to achieve a reduction in traffic incidents, the IADB considers it necessary to structure two complementary guides for the systematic application of these processes.

The Road Safety Audit Guide - RSA, is applied to new projects, particularly in the planning, design and construction phases and in the reconstruction of existing roads. On the other hand, this Road Safety Inspection Guide is used for active roads. The two techniques employ similar processes, are carried out by expert personnel and test the safety level of the road infrastructure.

Therefore, the objective of a RSA is to improve road safety before roads are built or rebuilt. RSIs also contribute to road safety by identifying existing hazards; they can be carried out periodically for an entire road network or to sections of the road. The difference between the two techniques lies mainly in that the RSIs are based on a detailed field inspection and the RSAs are based on design blueprints.

This guide seeks to standardize the procedures for the application of RSIs, so that they are uniform and serve as a basis for the improvement of road infrastructure. This can be achieved through the guide's dissemination in governments, those responsible for the operation of roads and professionals related to road safety in Latin American and Caribbean countries. In addition, the guide seeks to establish the principles and guidelines to identify existing hazards, the potential risks of associated incidents and to provide recommended intervention measures.

1 INTRODUCTION

Road Safety Inspections are a systematic method of well-known efficacy for the identification of existing hazards in a road network or on an active road. Such inspections contribute to improving the safety performance on existing roads and promoting the operation of safer highways and urban roads in Latin American and Caribbean countries.

This technique, as in the case of RSAs, is used in many countries. However, the most encouraging examples are found in the United Kingdom, Denmark, Germany, Norway, Australia, New Zealand and the United States[1], where the process was associated with encouraging statistics.

According to research conducted by Rune Elvik (Norwegian Center for Transport Research, 2006), RSIs and their associated interventions, resulted in significant reductions in traffic incidents where victims such as the following can be expected:

* Traffic sign correction: 5% - 10% reduction of incidents with victims.
* Addition of safety or containment barriers along slopes: 40% - 50% reduction in damage caused by incidents due to vehicles swerving off the road.
* Treatments on barrier ends: 0% - 10% in the reduction of injuries by impact against end-of-the-road barriers.
* Temporary recovery-free areas: 10% - 40% reduction in damage due to vehicle overturn.
* Obstacle removal: 5% reduction of incidents with injuries
* Installation of light poles with breakaway systems: 25% - 75% reduction of incidents with impact injuries against posts.
* Transferable road slopes: 5% - 25% reduction of incidents with victims due to overturns.

Due to the advantages of the application of the RSI and the improvement in road safety as a result of their implementation, the IADB concluded there is a need to develop a guide for the implementation of this tool on active roads in Latin America and the Caribbean countries, allowing for standardizing procedures and exchanging lessons learned.

1.1 Purpose of this Guide

To provide Latin American and Caribbean government agencies in charge of the operation and management of road infrastructure with procedural and conceptual guidelines for the implementation of RSIs.

RSIs are defined as the systematic revision of an existing urban road, in order to identify potential hazards for different users and propose corrective measures (Adapted from Elvik R, 2006).

1 RIPCORD-ISEREST "Road Safety Inspections: best practice and implementation plan". 2017

1.2 Scope of this Guide

This technical guide for the implementation of road safety inspections was developed based on international experience, knowledge of the consultancy in charge and the developments achieved in the region and is applicable to both urban and rural active roads.

This guide includes a theoretical section made up of an applicable conceptual framework, which contains detailed information on road safety criteria and risk theory. Following the conceptual framework, the guide identifies the steps required for the development of the RSIs, the profiles of those responsible, the checklists and evaluation methods for the implementation of intervention measures. Finally, the guide concludes with a practical section with examples of inspections on rural and urban roads.

1.3 Target Audience

The RSI Guide is intended for inspection team members, professionals, road safety technicians and those related to the operation of urban and rural roads. Likewise, it is important that this guide is available to road infrastructure designers and builders, so that they may incorporate risk factors commonly found in the stages of operation by RSIs.

This guide should also be familiar to those contractors who are in charge of RSI implementation and who are responsible for the formulation of road safety programs and plans.

1.4 Organization of the Guide

The guide consists of three chapters, which are described below:

The first chapter contains the introductory section, in which the purpose and scope of the guide is described and the target audience is identified.

The second chapter brings together all the theoretical principles that underpin the application of the RSI. It begins with the concepts and principles of a safe system and discusses road safety strategies such as Sustainable Security, Vision Zero and Forgiving Roads. All of these strategies, in addition to being examples of how road safety is managed, establish principles that should become practical measures that protect the lives of users over any other consideration. The guide continues with the presentation of road safety criteria that must be taken into account in a road inspection; which includes a guide for best practices as obtained from experience in the international implementation of RSIs, a compendium of risk factors for different attributes of road infrastructure and a catalog of intervention measures based on findings detected in the exercise of the RSI. The guide concludes with guidelines and directions for the application of risk theory in the inspection of roads, which can measure the potential for road incidents and guide the prioritization of intervention measures.

The third chapter includes the RSI guide, which consists of five sections. The first section presents the definition, essential elements, objectives, benefits, needs, intervening parties and types of projects subject to inspection. The second section includes the steps that must be followed in the application of inspections, from the development of an RSI program, to the monitoring and evaluation of the measures implemented. The composition and profile of the inspection team is defined in the third section, as well as the responsibilities of the group members. This section also includes guidelines for the establishment of a regular inspection program. The fourth section contains checklists for urban and rural roads. The fifth section explains the methodological process for following up the implementation of the recommendations in the RSI report. Finally, the guide concludes with the presentation of practical examples of previous RSI, which are included as an annex.

2

THEORETICAL PRINCIPLES FOR THE IMPLEMENTATION OF AN RSI

This chapter includes a series of theoretical principles that serve as the basis for the implementation of RSIs as well as a guide for the inspection team on road safety criteria that should govern the process of identifying different elements of road infrastructure, to optimize safety for all drivers.

The chapter begins by describing how a safe road system should always prioritize the protection of life. It proceeds with road safety criteria for the different attributes of road infrastructure in order to guide the inspection, and closes with a catalog of intervention measures.

2.1 PRINCIPLES OF SAFE ROADS AND THEIR ENVIRONMENT

It is important that whoever orders, hires or carries out a road safety inspection understands the concepts and principles of a safe system. It is also crucial that the system places human life above any other consideration and adopts said principles when they are applicable to active roads.

Comparing the road safety initiatives of different countries, three international strategies stand out. These strategies are part of the Netherlands Sustainable Mobility policy, the Zero Vision of Sweden and The Forgiving Roads approach, and they are used to respond to the risks of traffic related incidents with victims in a road network.

The strategies are discussed in more detail in the IADB guide for the application of RSA in Latin American and Caribbean countries.

2.1.1 Sustainable Safety

This vision focuses on preventing serious traffic incidents or at least reducing the risk of serious injuries. Towards this end, road systems must be tailored to the needs of users and, therefore, their physical vulnerability must be taken into account as well as the fact that users make mistakes and do not always comply with rules.

First the road, the environment and the vehicle must be adapted to the capabilities of the users and must offer assistance and protection. Second, information and education should prepare users for their role in transit and their behavior should be monitored (SWOV, 2013).

In the case of RSIs, and because the roads are already built, the recommended interventions should include the predictability of user behavior through the provision of a recognizable road, the provision of obstacle-free side areas and the implementation of systems of vehicle containment.

2.1.2 Vision Zero

Vision Zero is an aspirational project with the hope of reducing road fatalities and injuries to zero. It is composed of several basic elements, each of which impacts road safety. These elements relate to ethics (no person should die or be injured for life), human capacity and tolerance (transport systems should be designed taking into account biological tolerance against external violence), responsibility (designers are responsible for system safety in the same way users are responsible for complying with the rules) and the understanding that these factors operate both in tandem and independently

Similarly, because RSIs are carried out on active roads, this strategy ensures that interventions take into account the level of human tolerance to external impacts.

2.1.3 Forgiving Roads

A forgiving road is defined as a road designed or constructed in such a way that it interferes with or impedes driving errors and avoids or mitigates the negative consequences of such errors. This is achieved by allowing the driver to regain control, stop or return to the road without damage or injury.

This strategy is directly related to inspections of working roads, since the recommendations should prioritize the construction of forgiving lateral areas with the elimination, relocation, shielding or demarcation of dangerous objects.

2.2 ROAD SAFETY CRITERIA FOR THE APPLICATION OF RSIs

This section contains the main road safety criteria that the inspection team should consider in the application of the RSI. These criteria are presented as guidelines and should not replace the knowledge or experience of the inspection group.

These criteria include a guide to best practices, a description of the risk factors for the elements of the road infrastructure, the typical deficiencies that are found as a result of inspection processes and a catalog of intervention measures to address these deficiencies.

2.2.1 Infrastructure

Consistency of the Geometric Design of a Road

The consistency of design is related to the uniformity of the geometric characteristics of a road, which influences the speed, comfort and safety of users.

The less variable the parameters (radii of curvature, length of straight road, widths, slopes, types of intersections and others), the better the traffic conditions.

There are several procedures to detect points of inconsistency that lead to incidents including:

* The operating speed profile: determining the operating speed of each of the elements that make up the section under study and representing them in a graph that illustrates their variation. Significant changes indicate consistency problems.
* The alignment indexes: Numerical representations of the geometric characteristics of the road, which allow comparisons between different sections and establish ranges for safer designs.
* Driver attention: How much concentration is required to safely navigate a road? High levels of concentration are required when roads have consistency problems, and this can result in greater fatigue and risk of loss.
* Others, including combinations of the above.

Pavement Surface

Pavement is designed, constructed and maintained to provide the user with a comfortable and safe driving surface. A critical factor in road safety is pavement friction, especially when roads are wet. Proper friction allows for better control of the vehicle and the ability to stop quickly in case of a critical maneuver.

Friction is calculated with the coefficient of the friction of the pavement. Friction can be impacted by factors such as temperature, time of year, pavement condition, humidity, vehicle speed, braking action, tire properties and others. In rainy conditions, if adequate drainage is not available, a critical condition known as hydroplaning occurs when there is a sufficiently deep layer of water (measured in mm) between the tire and the pave-

ment. This causes the tire to lose contact with the bearing surface and, therefore, the driver to lose control of the vehicle.

Speed Reducers

These elements are used to control speed without becoming an additional danger. A road speed reducer is a variation in the longitudinal profile of pavement, designed to create a slight oscillation in a vehicle that crosses over it at low speed and an abrupt and concerning sensation for vehicles that cross it at high speeds. There are several types of speed reducers used in different countries according to country regulations and the area in which they are located. These include rumble strips, parabolic, circular, trapezoidal and cushion-type bumps, and lines drawn in different patterns on the pavement. All of these speed reducers work to mitigate speed in sites with limits of more than 60 km/h.

A speed reducer must be properly demarcated with reflective paint, to increase visibility. Visibility can also be improved with vertical warning signaling and where possible, an illuminated area.

Berms

The surface of berms can be paved or treated with stabilized soils. Berms have several functions such as allowing evasive maneuvers, granting space to stop a vehicle in case of emergencies, facilitating traffic in special situations, facilitating traffic for diversions, facilitating traffic for emergency vehicles, serving as turn lanes, space for pedestrian traffic or as a cycle path when the operating speed is less than 60km/h.

There are several factors that determine the functionality and safety of berms, including: structural resistance, width and continuity, the cross slope, the side joint, the surface, the contrast with the road surface and demarcations.

Each country has its own regulations regarding berm widths, and berms of different sizes can be safe. The International Road Assessment Program (iRAP) recommends a berm with a width of 2.4 m on each side of the road for ideal safety conditions

Rumble strips

Rumble strips are positioned perpendicular to the flow of traffic to create a noise that alerts drivers in places where it is necessary to reduce speed or be particularly. Rumble strips are used when changes in the conditions of the road or its surroundings are approaching, for example: sharp curves, entrances to towns on rural roads, proximity to toll stations, school zones, end of road with mandatory stop and other circumstances that may not be immediately perceived by the driver.

To prevent users from driving off the road, some countries use rumble strips, also known as alert strips, which are road safety features that modify the road surface on the side or central road markings creating a noise as the user drifts out of their lane or onto the side of the road. Rumble strips are most often used on straight roads or roads with a history of past incidents due to run-off-road collisions. Such collisions are most often caused by micro sleep or distracted driving.

Vertical Signaling

The main function of vertical signals is to communicate. These signals allow users to be aware of road regulations, they provide warning of hazards and they give information regarding routes and services. To comply with its function, each signal must be visible and legible, both day and night, by all users in all situations on the road. Vertical signals should be located in places with good visibility, allowing for adequate reaction times and safe maneuvers; they should be of an adequate size and letter type, and feature short captions, symbols and retro-reflective shapes.

The visibility of a signal depends on its condition and location, the materials it is made of, the surroundings and possible distractions at the signal location, the maintenance and condition of the vehicle's windshield, the cleanliness of the signal and the user's vision. At night, certain additional considerations must be taken, such as retro-reflectivity, the condition of vehicle lights and general lighting in the area.

Proper vertical signals provide the following benefits: prevention, orientation, increased user satisfaction during the driving experience, reduction of traffic related incidents and a better corporate image of those responsible for the operation of the road.

Demarcation (Horizontal Signaling)

As in the case of vertical signaling, the main function of demarcation is to communicate regulations, channel traffic, provide warnings about hazards and provide information. Road markings act as a complement to vertical signals.

Uniformity in dimensions, design, symbols, characters, colors, frequency of use, circumstances in which it is used and type of materials used are important in horizontal signaling.

In order to guarantee the visibility of horizontal signals at night and in the hours of darkness, the materials used must be made reflective through the use of glass microspheres, reflective tape or other materials that guarantee visibility at night. In this case, the road safety auditor must ensure that the demarcation is visible at night, so that the minimum retro reflectivity standards in each country or in international standards, are met.

Delineators

Delineators are retro-reflective devices of different shapes, colors and sizes. They are installed on the surface of the road, beyond the edges of the road or in the vehicular containment systems and can be located on the side of the road or to mark the middle line.

The main function of the delineator is to capture the driver's attention, so that he or she can perceive the road characteristics ahead of time in order to maneuver safely.

Vehicle Containment Systems

Vehicle containment systems are devices that are installed on the margins of a road. Their purpose is to retain and redirect vehicles that run off the road to limit damage and injury, both for occupants and for the other road users and people or objects nearby.

Collision with a vehicle containment system constitutes an alternative incident to the one that would take place in the absence of this mechanism and with more predictable, less serious consequences. However, this does not mean that the occupants of the vehicle are without risk. The barriers and their terminals also constitute an obstacle in the margins of the road and should only be placed there when their absence would result in greater risk in the event of an incident.

The installation of a vehicle containment system must be properly designed. It should take into account the type of traffic and users on the road in question. Aspects to consider are, for example: the presence of motorcyclists, the amount of heavy or light weight vehicles and other factors according to the geometry and the type of incidents on the road.

Lighting

Road lighting allows road users to travel as safely and comfortably as possible during the night. Proper lighting must be continuous and uniform so that the driver can distinguish in detail the road in front of him/her and their surroundings. He or she should have sufficient time to carry out preventive maneuvers in any situation that puts him/her at risk of an incident, and to distinguish traffic signs. Pedestrians and other vulnerable road users must also be able to distinguish street crossing signs, vehicles and obstacles. To implement this type of lighting, several factors must be taken into account. In addition to considering the economic and aesthetic aspects of the illuminated road, a study of installation and maintenance costs should be conducted.

2.2.2 Vehicles

As a fundamental principle, RSI's should consider all project users. In that sense, the inspection team must be clear about the differences between the types of vehicles and users expected in the area.

Generally speaking, there are three types of vehicles: motorized vehicles (trucks, buses, cars and motorcycles or similar), human-powered vehicles (pedestrians, cyclists, wheelchairs) and animal-powered vehicles.

Motor vehicles include two categories, heavy vehicles and light vehicles. For each of these types of vehicles there are differences in the operation and geometric design of the road.

The category of heavy vehicles includes cargo vehicles and passenger busses. Table 1 lists the particular elements of interaction between heavy vehicles and the road, and the geometric design that must be taken into account for these vehicles.

Table 1 Considerations for the Operation of Heavy Vehicles

OPERATION OF HEAVY VEHICLES

Road-vehicle Interaction	Geometric Design
Weight, length, width	Lane width
Side stability, overturn thresholds	Maximum and minimum slopes
Turning radius	Visibility distance
Widening	Design of intersections
Rear widening	Widening
Breaking distance	Pavement
Elevation of driver's vision	Bridges or artwork
Acceleration characteristics	Gauge
Rear overhang	Escape ramps
Parking	Stop areas
Special lanes	Rest areas
Length of acceleration lanes	Parking zones
Limitation of sign visibility (place signs on both sides)	Special lanes
Super heavy and oversized loads	Acceleration lanes
Transportation of dangerous loads	

The considerations for the geometric design according to light vehicles are summarized in Table 2.

Table 2 Considerations for the Operation of Light Vehicles

OPERATION OF LIGHT VEHICLES

Geometric Design
Geometric design
Width of lanes and berms
Visibility distance
Breaking distance
Slopes
Acceleration lanes
Horizontal curves
Intersection design
Ramps
Containment systems
Signaling
Road surface conditions

There are differences for human and animal powered vehicles in both the geometric design and the operation. The risk for these vulnerable users differs according to the vehicles with which they interact in the traffic system. Table 3 lists the main measures to mitigate the risk of pedestrian and cyclist incidents.

Table 3 Infrastructure for Pedestrian and Cyclists

INFRASTRUCTURE FOR VULNERABLE USERS

Pedestrians	Cyclists
Pedestrian ways	Bicycle lanes
Sidewalks	Gates of physical barriers
Crossings: zebra, pelican, traffic light	Bicycle bridges
Refuge islands	Shared space
Gates or physical barriers	
Pedestrian bridges or walkways	

In some Latin American countries the population uses horse, mules or oxen-powered cars for personal transport, transport of small loads or recycling in the same space of mixed traffic. An RSI should consider the following considerations:

Table 4 Operation of Animal-Powered Vehicles

OPERATION OF ANIMAL-POWERED VEHICLES

Animal-powered vehicles	Presence of other animal species
Is it allowed?	Livestock crossing
Assigned lane	Livestock containment fence
Night visibility	Livestock farmyard
Volume of vehicles	Crossing for non-domestic species or fauna
Signaling	Signaling
Crossing priorities	Crossing priorities

2.2.3 Human Factor

The human factor is an essential element in the operation of traffic systems. To meet certain mobilization needs, people are tasked with driving vehicles, participating as passengers or traveling on foot, bicycle or other means.

Hence, it is important that road safety inspectors understand the differences between drivers, different driving tasks, know how users receive and prioritize information, understand the concepts of expectations, reaction time and display process and needs of users for good communication.

The differences between drivers can be measured through driving skills according to experience, control activities, channeling and navigation, lack of attention, distraction, fatigue, sleep, lack of expertise, physical deficiency or use of medication, alcohol or narcotics.

Expectations are associated with all aspects of the road: speed, layout, profile, geometric design, signaling and others. These factors depend on regional or local culture, collective experience, level of training and road conditions, its characteristics and signaling.

In order to achieve good communication with the driver, message display must be eye-catching (large and bright with bold text) or stand out and be legible, understandable and credible.

There is a close relationship between the infrastructure and the user. The main objective is for the infrastructure to serve the human well so that they do not make errors while driving. Some factors that favor a better human-infrastructure relationship are:

Consistency of Operating Speeds:

The consistency of operating speeds along a road is one of the criteria for evaluating the consistency of geometric design. The consistency of geometric design is the degree of consistency between the behavior of the road and the expectations of the driver. The driver's expectations can be divided into two types.

* *A priori* expectations: Expectations based on previous experiences driving on other roads. To meet these expectations, there must be a direct relationship between the type of road, the geometry of the road and its elements.
* *Ad hoc* experience: Experience derived from the driver's perception of the characteristics of the itinerary as he/she travels. As a driver travels along a stretch of road, he/she expects that, in the following distance, the road behaves in a similar way.

In order to evaluate the consistency of a road, the most relevant variable is the speed of operation, which can be estimated from statistical models that are directly related to the geometry of the road.

Workload

With the development of intelligent transport systems, the analysis of workload as one of the elements that impacts users is more and more relevant. There is a need to assess whether the systems that are implemented in road infrastructure really help the driver in his/her task or if, on the contrary, they only increase the workload and require drivers to process excess information.

The workload can be defined as the effort required by humans to complete a task. Mental workload and driver performance are directly related. Subjective methods can be implemented to assess workloads, as well as more precise measurements. It is necessary to take this factor into account before implementing innovative systems to be certain that they facilitate the driver's ease of use rather than creating a distraction.

Readability of a Road

The readability of a road is the degree to which the elements of the road contribute to simplify the driver's expectations, prevent the occurrence of incidents or reduce their consequences.

Roads with good readability forecast their direction several hundred meters in advance. Generally, curved roads in which successive sections are hidden by a change in ground level or a very tight curve, have poor readability.

Self-Explanatory Roads

The concept of self-explanatory roads originated in the Netherlands and refers to roads that naturally encourage the driver to adopt the behavior compatible with the design and function of the road. Self-explanatory roads should allow the user to distinguish between different types of roads, maintain consistency along the route, and encourage the driver to trust their instincts. The goal is to use the simplicity and consistency of the design to reduce driver stress and driver error.

Pedestrians

On average, 27% of the deaths that occur in Latin America and the Caribbean in traffic related incidents are pedestrians. 34% of the total deaths, the highest percentage, occurs in the sub region of Mesoamerica (PAHO, 2015).

The RSI inspection team must be clear about the principles of road safety for pedestrians, which will allow for a better assessment of the environment and the quality and safety of the facilities used to travel on foot. In this regard, the recommendations of the Federal Highway Administration (FHWA) of the United States[2] shown below are acceptable.

In general, three fundamental principles of pedestrian safety are identified:

A Walking as a Mode of Transport

A large percentage of the population in Latin American countries travel by foot. Foot travel carries people to work, study, make purchases or for recreational activities. Traveling on foot is also an important element of connection between different modes of transport.

This human activity is subject to very high risk, including the possibility of traffic related incidents where a pedestrian is struck by a vehicle. That is why it is necessary to accommodate pedestrians safely, and provide access and mobility in the different transport facilities. In urban areas, pedestrians are the main priority in the design of public infrastructure.

Walking is also impacted by physical barriers that pedestrians encounter along the road, such as unprotected crosswalks, lack of sidewalks, poor quality of walking surfaces, obstacles on sidewalks and crossings, lack of crossings and vehicles traveling at a high rate of speed.

B Pedestrian Characteristics

There are a number of considerations that distinguish different types of pedestrians. These include: walking speed, spatial needs, mobility, vision, cognitive abilities, crossing options and waiting times. Infrastructure for pedestrian mobility must be designed to accommodate for senior citizens, people with mobility problems and children, among others. Infrastructure for a typical population should account for a significant portion of pedestrians with these characteristics.

2 FHWA. Pedestrian Road Safety Audit Guidelines and Prompt Lists. USA. 2007.

C **Factors that Contribute to Pedestrian Traffic Incidents**

When an RSI is performed, the inspection team must be aware of the factors that contribute to

pedestrians being involved in road incidents, both with drivers and other pedestrians. Dangerous driver' behaviors include disrespect for the right of way, driving too fast, distraction, and others. Dangerous pedestrian behaviors include but are not limited to: inappropriate crossing, not respecting the right of vehicles and invading the road. Most of these behaviors are codified and are part of police reports on traffic incidents.

It is also important that the inspection team understands the places where pedestrian incidents have occurred or could occur, when the vehicles turn, back up, when the driver violates the intersection or at the access points to properties and other facilities.

When analyzing pedestrian safety, the road safety inspectors should consider that the design of a project corresponds to the typical behavior of pedestrians and not how the designer thinks pedestrians should behave.

Cyclists

As in the case of pedestrians, the inspection team must be clear about the principles of road safety for cyclists, which requires a full assessment of the environment and the quality and safety of the i nfrastructure on which bicycle trips are made. The recommendations of FHWA[3] regarding cyclists are captured below.

A **The Bicycle as a Mode of Transport**

Nowadays, bicycles have a wide variety of uses ranging from recreation, transport for children to and from school, and to the workplace. The use of bicycles has grown significantly in recent years and investment in road infrastructure improvements to accommodate cyclists has also increased. Infrastructure for cyclists must ensure safety and must be integrated into transport systems.

B **Characteristics of Cyclists**

It is important that the inspection team understands the range of skills and qualities of both the bicycle and rider that impact their interaction with relevant infrastructure. These include space, length, stability, speed, deceleration and breaking.

C **Factors that Contribute to Cycling Incidents**

When conducting an RSI, the inspection team should be aware of the factors that contribute to cycling incidents, such as: location (urban area, intersections), project design aspects, speed, user behavior and others. These factors should correspond to the common behavior of cyclists, which is captured in Table 7.

3 FHWA. Bicycle Road Safety Audit Guidelines and Prompt Lists. Washington. USA. 2012.

2.3 BEST PRACTICE GUIDE FOR THE APPLICATION OF ROAD SAFETY INSPECTIONS

A study conducted by Rune Elvik in 2006, commissioned by the Norwegian Institute of Transport Economics - TøI, as part of the European Road Infrastructure Safety Protection - Core-Research and Development for Road Safety in Europe (RIPCORD-ISEREST) program, which studied the Road Safety Inspection practice in eight European countries, recommends taking into account the following guidelines for the application of RSI´s, which are the result of lessons learned. These can be useful in Latin American and Caribbean countries. The guidelines for best practices regarding the RSIs proposed by the referred study are the following:

I The quality of the traffic signals, including any needed repairs, if they are placed correctly and if they are legible in the dark.

II Inspections must be standardized and designed to ensure that all included elements are covered and evaluated objectively. The development of checklists may be helpful towards this end.

III The list of items that should be included in the RSI's (checklists) should include those that are recognized as important. The following elements must be included in all RSIs:

- A The quality of the traffic signals, including any needed repairs, if they are placed correctly and if they are legible in the dark.
- B The quality of the demarcation, particularly whether the markings are visible and compatible with the traffic signs.
- C Road surface quality, in particular its friction and uniformity.
- D Visible distances and the presence of permanent or temporary obstacles that prevent timely observation of the road or other users.
- E The presence of traffic hazards near the road such as trees, exposed rocks, drainage pipes, posts, columns, walls, etc.
- F Aspects of traffic operation, particularly if users adjust their speed sufficiently to local conditions.

IV A standardized evaluation should be completed for each item included in the inspection, addressing the following categories:

- A The item represents a traffic hazard that must be addressed immediately. A specific solution must then be proposed.
- B The item is not in perfect condition, but no short-term action is necessary to correct it. Long-term observation is recommended.
- C The item is in good condition.

V Findings and proposals for inspection safety measures should be reported through standardized reports.

VI Inspectors must be formally certified for their work. They should meet regularly to exchange experiences and ensure uniform application of safety standards in inspections.

VII There should be a follow up inspection after some time to verify whether the proposed measures were applied or not. The appropriate time for follow up will be determined by the inspection team and the client, taking into account the type of measures proposed and the resources available.

With regard to the selection of inspection routes, there are advantages to each of the two approaches currently being used: (i) only inspect those routes that are known to have a problems; or (ii) inspect them all. Both approaches make sense and the choice will depend on whether the road managers have enough resources to inspect and treat all the roads.

During an initial stage, it may be appropriate to select roads with a poor safety record for inspection. However, as more experience is gained, RSIs can increasingly be used as a preventive tool and extended to roads that do not have a poor safety record (Rune Elvik, 2006).

2.3.1 Risk Factors to be Considered in an RSI

Table 5 summarizes the main risk factors that must be addressed in an RSI, ordered according to the different attributes of the road infrastructure. Table 6 lists the factors that should be considered in the inspection of pedestrian crossings and Table 7 refers to cyclist routes. These factors are incorporated into the checklists in section 3.5.

Table 5: Risk Factors that an RSI Should Address

RISK FACTORS TO BE CONSIDERED IN AN RSI

Functionality

- Appropriate functionality for traffic volumes
- Separation of vulnerable road users
- Speed limit
- Environmental impact
- Access to properties

Cross-Section

- Platform width for the traffic volume
- Lane widths
- Berm widths
- Drainage conditions
- Separation of vulnerable road users

Alignments

- Consistency of alignments with curves
- Distance and visibility restrictions
- Horizontal alignment at intersections

Intersections

- Type of intersection (traffic consistency)
- Appropriate for traffic volumes
- Access visibility
- Visibility in turns
- Vertical signals
- Traffic lights
- Demarcation
- Pedestrian crossings
- Access to properties
- Cyclists
- Traffic light visibility
- Lighting

Road Section

- Dangerous areas
- Speed limit signals
- Visibility distance for turns
- Stopping distance
- Use of rumble strips
- Drainage elements

Vulnerable Road Users

- Needs of users with reduced mobility
- Pedestrian's needs
- Cyclist's needs
- Motorcyclist's needs

Transit Operation

- Speed
- Transit volume
- Transit composition
- Heavy vehicle volume
- Motorcycle volume
- Volume of cyclists
- Pedestrian volume

Signaling

- Signaling and proper demarcation, complete at intersections and in road sections

Lighting

- Road lighting
- Surrounding lights
- Glare at night
- Glare from sunlight
- Intersection lighting
- Users

Pavement

- Surface features
- Surface condition
- Pavement drainage

Bridges

- Alignment near bridges
- Visibility distance at the top of bridge curves
- Intersections near bridges
- Containment and safety barriers
- Facilities for pedestrians and cyclists

Lateral Zone

- Untreated obstacles
  - Ditch profile
  - Unsafe drainage elements
  - Posts, trees, walls
  - Defenses or barriers
- Capacity and relevance of existing treatments
- Consistencies of existing vehicle containment systems

Table 6: Risk Factors that an RSI Should Address Regarding Pedestrians

RISK FACTORS TO BE CONSIDERED IN AN RSI REGARDING PEDESTRIANS

Location
Road alignment
Consistency between the width of the road and type of passage
Interaction with parking lots
Coordination with public transport stops
Coordination with the routes desired by pedestrians
Sidewalk consistency
Distance to other pedestrian crossings
Distance to stop line
Distance to the intersection
Distance to traffic ligh

Visibility Distance
Visibility of adult pedestrians
Visibility of child pedestrians
Visibility of people in wheelchairs
Parked vehicles blocking visibility
Drainage conditions
Separation of vulnerable users

Accessibility
Presence of ramps on the curbs
Slope of the ramps on the curbs
Sidewalk height
Sidewalk width
Parked vehicles obstructing access to the crosswalk
Permanent obstacles obstructing access to crosswalks

Signaling
Day and night visibility of demarcation
Contrast between the demarcation of the pedestrian crossing and the pavement
Length, spacing and direction of demarcation
Visibility of crosswalk signs
Traffic light visibility
Day and night pedestrian demarcation phases
Separation of vulnerable users
Coordination between the pedestrian crossing and the location of the traffic light
Visibility of the stop line

Lighting
Night visibility
Visibility of pedestrians at sunrise and sunset

Transit
Speed
Truck percentage
Motorcycle percentage

Table 7: Risk Factors that an RSI Should Address Regarding Bike Lanes

RISK FACTORS TO BE CONSIDERED IN AN RSI REGARDING BIKE LANES

Cross Section	Track Section	Road Surface	Intersections and Access	Parking Stops	Signaling
There are sidewalks on both sides	Critical width for cyclists	Surface quality	Clarity in cyclist priority	Legality of parking and stops on both sides of the road	Clarity in demarcation
	Speed limit compatible with the design	Drainage quality	Approximate speed of cars	Distances of the cyclist's circulation line to parked vehicles	Signaling and demarcation generate awareness of cyclist's presence
		Drainage covered with covers and grilles	Access visibility	Visibility reduction	
		Grille placement and visibility	Visibility to turn		
		Intersections	Visibility at the intersection		
			Location of the stop line		

Transit Operation	Safety	Lighting	Behavior	Travel Experience	Transition between Systems
Cleanliness of the road	Enough width space for the cyclist regarding cars and buses	Road lighting status	Driveway or sidewalk use	Presence of views or positive landscapes	Visibility
Vegetation that blocks visibility	Safety perception		Compliance with the rules	Narrow passages	Transition at intersections
State of signals			Conflicts with pedestrians		Demarcation
					Start and end of the bike lane

Continued to Table Risk factors to be addressed by an RSI of bicycle routes

RISK FACTORS TO BE CONSIDERED IN AN RSI REGARDING BIKE LANES

Cross-Section

- There are bike lanes on both sides
- There are sidewalks on one or both sides

Track Section

- Critical width for cyclists
- Speed limit compatible with the design

Road Surface

- Surface quality
- Drainage quality
- Drainage covered with covers and grilles
- Grille placement and visibility
- Intersections

Intersections and Access

- Clarity in cyclist priority
- Approach speed of cars
- Access visibility
- Visibility to turn
- Visibility at the intersection
- Phase for cyclists at the traffic light
- Anticipated stop line for cyclists
- Geometry, roundabout demarcation

Parking Stops

- Parking and stops on both sides of the road
- Parking blocking the bike lane

Signaling

- Clear demarcation
- Longitudinal demarcation of the bike lane
- Demarcation through the intersection

Transit Operation

- Cleanliness of bike lanes
- Vegetation that blocks visibility
- State of signals

Safety

- Enough width space for the cyclist regarding cars and buses
- Safety perception

Lighting

- Road lighting status

Behavior

- Use according to purposes
- Compliance with circulation direction
- Sidewalk circulation
- Conflicts with cars
- Conflicts with pedestrians

Travel Experience

- Presence of views or positive landscapes
- Narrow passages

Transition Between Systems

- Visibility
- Transition Widths
- Appropriate speeds
- Signaling and demarcation

Continued to Table Risk factors to be addressed by an RSI of bicycle routes

RISK FACTORS TO BE CONSIDERED IN AN RSI REGARDING BIKE LANES

Cross-Section

- Compliance with safety standards

Track Section

- Maximum slope
- Access to the bike lanes
- Continuity
- Pedestrian Volumes
- Car access to properties
- Safety barriers to separate mixed traffic

Road Surface

- Surface quality
- Drainage quality
- Drains covered with covers and grilles
- Grille placement and visibility
- Height of curbs at the intersection and at the access points

Intersections and Accesses

- Clarity in cyclist priority
- Car speed at intersections
- Speed of cyclists
- Visibility at access points
- Visibility to turn
- Visibility at the intersection
- Phase for cyclists at the traffic light
- Geometry, roundabout demarcation

Parking Stops

- Parking and stops on bike lanes
- Visibility obstacles at access points or at the intersection

Signaling

- Clarity in the demarcation
- Demarcation and signaling of the bike lane
  Demarcación y señalización de la ciclorruta
- Intersection demarcation
- Demarcation of the roundabouts

Transit Operation

- Cleanliness of bike lane
- Vegetation that blocks visibility
- State of signals

Safety

- Perception of network safety
- Lighting

Bridges and Underpasses

- Slope at crossing
- Slope with respect to the track
- Width and height of the bike lane
- Visibility in access and intersection
- Underground passage lighting
- Drainage in the underpass

Behavior

- Use according to purposes
- Use of the bike lane on the bridge
- Sidewalk Circulation
- Conflicts between cyclists in different directions
- Conflicts with pedestrians
- Conflicts with cars at the intersection and at access point

Travel Experience

- Presence of views or positive landscapes
- Narrow passages

Transition Between Systems

- Visibility
- Slopes at intersections
- Barrier and protective defenses
- Signaling and demarcation

2.3.2 Typical Deficiencies that Affect Road Safety

This section presents some typical deficiencies in road infrastructure which may impact the safety of the users of a road in operation. It serves as a guide for those who perform RSIs, but does not replace the detailed examination that should be performed by the inspection team on the conditions of the road under inspection.

Table 8 Typical Deficiencies that Affect Road Safety

Element	Typical Deficiencies	Risk
Road Function	Incongruity between the intended function of the road and the operation of high traffic volumes	Conflicts with vulnerable users, especially with pedestrians, at risk of being struck by a vehicle in a traffic related incident
	Nonconformity of current use with mixed traffic (passing through population centers)	
	Absence of protected crosswalks	
	Speed limits not coherent with the presence of pedestrians in certain sections of the road	
Cross-Section	Two-lane roads per direction of movement without divider	Vehicle – vehicles conflict with potential risk of traffic incidents due to head-on collision
		Vehicle - Vehicle conflict - vehicle with potential risk of traffic incidents due to head-on collision
	Two-lane roads, one per direction, with insecure lane width	Lateral collisions due to overtaking restriction, which worsens when heavy vehicles are present
	Drainage system elements that produce sudden changes in width	Traffic incidents due to collisions with fixed objects
Alignments	Restrictions on visibility distance, insufficient stopping distance and poor orientation for drivers, which may be caused by sharp curves, curved ridges or vegetation	Vehicle -Vehicle conflicts - vehicle with potential risk of traffic incidents due to head-on collisions Traffic incidents can also occur by driving off the road at curves
	With regard to horizontal alignment, the most frequent deficiencies are: inconsistency in radius sequences with high-speed differentials, use of small radii in sections with high speed and sudden alignment changes without transition. This should be measured by analyzing the geometric design blueprints or the topographic data	

Element	Typical Deficiencies	Risk
Intersections	Lack of adequate information to each user to make safe decisions	Vehicle conflicts - vehicle with potential risk of incidents due to side collisions
	Poorly designed intersections that induce high-risk decisions or misunderstandings of rights of way (some Y-intersections)	Vehicle - pedestrian conflict with potential risk of road traffic incidents
	Obstructed by vegetation or difficult to detect obstacles	
	Lack of controlled left turn lanes	
	The intersection is not easily recognizable or there is not enough visibility	
	Lack of access control	
	Lack of visibility at the intersection	
	Insufficient space for maneuvering	
	Traffic light visibility problems	
	Absence of safe crosswalks	
Vertical Signals	Lack of signals	Traffic incidents due to misinterpretation or absence of the regulation or prevention that the signals must provide
	Incomplete signaling	
	Inconsistent signaling	
	Illegible signals	
Demarcation	Lack of clarity in road markings	Traffic incidents due to misinterpretation or absence of the regulation or prevention that the demarcation must provide
	Poor night visibility of demarcations	
	Inconsistency between demarcation and vertical signals	
Vulnerable Users	Pedestrians crossing traffic without protection	Vehicle - pedestrian conflict with potential risk of road traffic incidents.
	Longitudinal traffic of pedestrians along the road or very close to it	Vehicle - cyclists conflict with potential risk of incidents due to side or drag crashes
	Circulation of cyclists with mixed traffic	
Lateral Zone	Obstacles in the untreated lateral area	Traffic incidents by collision with fixed object
	Ends of barriers freely exposed to traffic	
	Absence of an adequate transition between the railings of the bridges and the adjacent vehicle restraint barriers	
	Semi-rigid defenses, discontinuous or with aggressive or non-folding ends	

Source: SEETO. *Road Safety Inspection Guideline. Belgrade*, Serbia. 2012.

2.3.3 iRAP Program

An important reference for the identification of risk factors in a road in operation is provided by the international iRAP (International Road Assessment Program).

The iRAP [4] program works in conjunction with governmental and non-governmental organizations with the objective of:

* Inspecting high-risk roads and developing the Star Rating and Investment Plans for Safer Roads.
* Providing training, technology and support in order to sustain capacity development at national, regional and local levels.
* Tracking road safety performance so that donor agencies can assess the benefits of their investments.

Star rating implies an inspection of the elements of the road infrastructure that are known to have an impact on the likelihood of a collision and its level of severity. The rating ranges between 1 and 5 stars according to the level of security on a given road.

The safest [5] (4 and 5 stars) roads have appropriate safety elements for current traffic speeds. Elements of the road infrastructure in a safe road could include the separation of traffic in opposite directions by a wide divider, adequate demarcation and proper intersection design, wide lanes and sealed (paved) berms, hazard-free road edges and facilities for cyclists and pedestrians, such as roads and crossings designed for them.

Less secure roads [6] (1 and 2 stars) do not have appropriate road safety elements for traffic operation speeds. iRAP analysis shows that these are often single-lane roads with relatively high speed limits, with frequent curves and intersections, narrow lanes, unsealed berms, poor demarcations, hidden intersections, and side hazards to roads that are not properly protected, such as trees, posts and steep embankments near the edge of the road. On such roads it is very likely that they do not have adequate facilities for cyclists and pedestrians.

Risk Factors

Table 9 shows the attributes of the road infrastructure that, according to the iRAP road inspection methodology, can become risk factors if they are not designed, built and operated in compliance with the standards that make them safe for all users.

4 iRAP. Star Rating for Safer Roads.

5 Ídem.

Table 9 Risk Factors for Different Users According to the Type of Incident

Type of Incident	Risk Factors
Vehicle Occupants	
Incidents caused by driving off the road	Lane width Curvature Curve quality Demarcation Rumble strips on berms Road conditions Slope Adheence Object in the lateral zone Distance to object Width of paved berm Operating speed Influence of external flows Road Divider
Head-on-turn crash	Number of lanes Slope Adherence Speed differential Divisor type Operating speed Influence of external flows Road Divider
Incidents at intersections	Type of intersection Intersection quality Slope Lighting Adherence Channeling Visibility distance Speed management Operating speed Influence of external flows
Incidents in access to properties	Property access point Service routes Type of divisor Operating speed Influence of external flows

Type of Incident	Risk Factors
Motorcyclists	
Incidents caused by driving off the road	Lane width Curvature Curve quality Demarcation Rumble strips on berms Road conditions Slope Adherence Object in the lateral zone Distance to object Width of paved berm Operating speed Influence of external flows Road Divider
Head-on collision caused by loss of control	Lane width Curvature Curve quality Demarcation Rumble strips on berms Road conditions Slope Adherence Type of divisor Operating speed Influence of external flows Road Divider
Head-on-turn crash	Number of lanes Slope Adherence Speed differential Divisor type Operating speed Influence of external flows Road Divider
Incidents at intersections	Type of intersection Intersection quality Slope Lighting Adherence Channeling

Incidents at intersections	Visibility distance Speed management Operating speed Influence of external flows

Type of Incident	**Risk Factors**
Access to properties	Property access point Service routes Type of divisor Property access point Operating speed Influence of external flows
Incidents traveling along the road	Facilities for motorcyclists
Cyclists	
Incidents caused by driving off the road	Lane width Curvature Curve quality Demarcation Lighting Road conditions Slope Adherence Object in the lateral zone Distance to object Operating speed Influence of external flows
Incidents traveling along the road	Facilities for cyclists Curvature Curve quality Visibility distance Lane width Demarcation Slope Road conditions Speed management Rumble strips on berm Vehicle parking Adherence Lighting Operating speed Influence of external flows

Type of Incident	Risk Factors
Incidents at intersections	Type of intersection Intersection quality Property access point Adherence Facilities for cyclists Lighting Visibility distance Channeling the intersection Speed management Pedestrian crossing Access to properties Operating speed Influence of external flows
Pedestrians	
Incidents walking along the road	Sidewalk Curvature Curve quality Visibility distance Lane width Demarcation Slope Road conditions Speed management Vehicle parking Rumble strips in berms Lighting Operating speed Influence of external flows

Incidents crossing the road	Number of lanes (each side of the road) Type of separator (each side of the road) Pedestrian crossing (each side of the road) Quality of crosswalks Type of intersection Intersection quality Pedestrian fences or railings Adherence Lighting Visibility distance Vehicle parking Speed management School zone Crosswalk Operating speed Influence of external flows

Source: iRap. Methodology Fact Sheet # 6 – Star Rating Score equations. 2014.

2.3.4 Measures for the Management and Control of Traffic Incidents Risks for All Users

The following table shows some guidelines for the management of findings that are frequently detected as a result of RSIs.

Table 10 Procedure of Findings According to Inspected Road Elements

Finding/Problem	Potential Incidents	Affected Users	Procedure
		Function of the Road	
Variety of mixed transit in longitudinal settlements, with slow traffic flows and non-motorized users	Striking pedestrians Collisions with cyclists Lateral collisions Head on collisions with barriers	Pedestrians, cyclists and motorcyclists	Access control Separate berms and barriers Separate lanes
Mixed functions, national roads that cut across settlements	Striking pedestrians and collisions with cyclists	Local population and commerce	Construction of relief roads Construction of road systems outside urban areas Construction of express roads
Use of roads and distribution routes by non-motorized users	Striking pedestrians and collisions with cyclists	Non-motorized users, especially children	Demarcation Separate paths for pedestrians and cyclists Sidewalk construction Construction of paved berms, for roads with operating speeds of less than 60 km/h
High traffic speed and volumes for the safety of non-motorized users	All types of incidents, especially head-on collisions, lateral collisions and rear-end crashes	All types of users due to the rapid movement of traffic	Traffic calming measures
Dangerous sections of roads (two-lane roads with paved berms, four-lane roads not separated)	Head on collision Lateral collision	Road exits Vehicle occupants	Design of the straight section as part of the design phase Lane division with barriers Road reconstruction towards a safe straight section
Uncontrolled crossings in the divisor	Head on collision Lateral collision	Trucks, buses, cars and motorcyclists	U-turn demarcation Elimination of the crossing Provision of acceleration and deceleration lanes Construction of a return
Unpaved roads, without divisor	Head on collision Lateral collision	Occupants of trucks, buses, cars and motorcyclists	Central barrier Central green zone divisor

Finding/Problem	Potential Incidents	Affected Users	Procedure
Alignments			
The course of the road is not predictable to drivers	Head on collision Lateral collision Rear end collision	Occupants of trucks, buses, cars and motorcyclists	Provide sufficient visibility distances
Inconsistency in alignments, combination of small radius curves with large radius curves	Head on collisions Rear end collisions	Occupants of trucks, buses, cars and motorcyclists	Signaling Barrier installation Curve reconstruction
Hidden curves after the peaks or slopes	Head on collisions Rear end collisions	Occupants of trucks, buses, cars and motorcyclists	Signaling Curve reconstruction
Poor visibility in the vicinity of the bridges	Head on collisions Rear end collisions	Occupants of trucks, buses, cars and motorcyclists	Signaling Curve reconstruction
Lack of cants	Loss of vehicle control Head on collisions Collisions on the outside of the curve		Early warning signs Signaling Installation of fenders Guarantee a constant condition Barrier installation Improved traction Rebuild the cant Remove sharp curves
Poor horizontal and vertical curvature: A single narrow curve between a series of long curves A horizontal curve after a ridge A horizontal curve in a long descent or ascent A slope change in a horizontal curve A sharp curve at the bottom of a long descent	Loss of control of the vehicle Overturn Head on collision	All users	Signaling Rumble strips Barriers Improved visibility Curvature improvement

Intersections

Finding/Problem	Potential Incidents	Affected Users	Procedure
Diagonal intersection	Lateral collision Head on collision Collisions with pedestrians Collisions involving cyclists	Occupants of trucks, buses, cars and motorcyclists Vulnerable users	Clearly define priorities and connect secondary roads perpendicular to the main one Decrease intersection width
Faults in small roundabouts: Unobstructed view of the other accesses to the roundabout Pedestrians and other vulnerable user needs not considered	Lateral collisions Collisions with pedestrians Collisions involving cyclists	Occupants of trucks, buses, cars and motorcyclists Vulnerable users	The roundabout island must have a raised, hill-shaped surface Entry islands should be used for crosswalks and cyclists when necessary
Insufficient deflection through the roundabout	Lateral collisions Overturn		Provide islands - mini roundabout Increase the size of the central island Increase the size of entry islands Stagger access roads Realign the access roads
Poor visibility at T-type intersections	Lateral collisions Rear end collisions	All users	Increase visual obstruction in the access of the minor road Provide warning signs at all access points Remove visual obstruction at the intersection Mark lanes through the intersection Increase the access width of the secondary road Apply a speed limit at the intersection Provide a central shelter for turning traffic Expand the main road locally Provide signal crossing Provide roundabout Realign lanes

Finding/Problem	Potential Incidents	Affected Users	Procedure
Poor visibility of crossings	Lateral collision Rear end collision	All users	Improve signaling Improve T type intersection Improve staggering Change intersection
Insufficient acceleration and deceleration lane length	Lateral collision Rear end collision	All users	Divergent transitions to the left side Auxiliary lanes on the left side Fusion of transitions to the left side
Dangerous turn maneuvers	Lateral collision Rear end collision	All users	Turn signaling and demarcation Traffic lights Construction of a roundabout Channelization islands in the minor pathway
	Vulnerable Users		
Closed contact of high-speed traffic and heavy vehicles with vulnerable users	Collisions with pedestrians Collisions involving cyclists Collisions involving motorcyclists	All users	Border marks Adequate crossing facilities Relocation of bus stops Curbs and barriers Calming traffic Separate pedestrian trails Separate bike lanes
Pedestrian conflicts at rural intersections	Collisions with pedestrians Run over by cyclists	All users, especially pedestrians	Install pedestrian defenses and central pedestrian shelters Central pedestrian shelter on minor roads in unmarked crossing Zebra crossing, with or without central pedestrian shelter Traffic lights to control movements at the intersection
Conflicts of cyclists at intersections	Cyclist collisions Collisions between pedestrians and cyclists	All users, especially cyclists	Separation of cyclists from motorized traffic Modify the intersection design giving priority to the cyclist Traffic light at intersection
Absence of ramps at curbs	Collisions with pedestrians	Collisions with pedestrians	Use of ramps in transitions from roads to sidewalks Adding tactile paving for the blind

Finding/Problem	Potential Incidents	Affected Users	Procedure
Absence of refuge islands	Collisions with pedestrians Lateral collisions	All users, especially pedestrians	Demarked dividers Raised dividers Shelter islands
Pedestrian conflicts in urban intersections	Collisions with pedestrians Lateral collisions	All users, especially pedestrians	Signaling and demarcation Physical separation
Pedestrian conflicts in rural intersections	Collisions with pedestrians Collisions involving cyclists and other non-motorized vehicles Lateral collisions Head on collisions	All users, especially non-motorized users	Physical separation
Obstructions for pedestrians	Incidents involving pedestrians	All pedestrians, especially those with reduced mobility	Trail and obstacle-free sidewalks
Parking near intersections	Collisions with pedestrians Lateral collisions	All users, especially pedestrians	Demarcation Install curb extensions
Unmarked crosswalks	Collisions with pedestrians Lateral collisions	All users, especially pedestrians	Signaling and demarcation traffic calming measures Install curb extensions
Crossings with traffic lights without pedestrian crossings	Trampling Lateral collisions	All users, especially pedestrians	Installation of pedestrian crossings
Work areas on sidewalks	Death of blind pedestrians	All pedestrians, especially those with vision limitations	

Finding/Problem	Potential Incidents	Affected Users	Procedure
Signaling and Demarcation			
The signals at the intersection do not clearly indicate the right of way	Lateral collisions Head on collisions	All users	Improved vertical and horizontal signaling
Unmarked traffic and turn lanes	Lateral collisions	All users	Early preventative signaling Intersection demarcation Intersection signaling Break the visibility distance at the intersection Staggering of the minor roads
Signal Proliferation	Lateral collisions Head on collisions	All users	Simplify signaling Improve signaling consistency
Lateral Zone			
Unshielded embankments	Collision with pedestrians Overturning Collisions against fixed objects	All users	Signs, demarcation, rumble strips Safety barrier in front of the edge of the embankment Expand the berm Smooth out slopes
Deep lateral drain	Collision with pedestrians Exiting the lane	All users	Signs, demarcation, rumble strips Safety barrier in front of the canal Grids on the canal Transferable slopes Canal relocation
Deep ditches and manhole covers	Diving off the road Overturn	Vulnerable users Occupants of trucks, buses, cars and motorcycles	Signaling and demarcation Rumble strips Semi-rigid barriers Place pipes or grids Remove dangerous manhole covers
Dangerous berms	Collision with pedestrians Collisions with cyclists Lateral impacts Rear end collision	All users	Signaling and demarcation Maintenance of berms Relocation of dangerous objects Shielding dangerous objects

Finding/Problem	Potential Incidents	Affected Users	Procedure
End of railings in bridges, exposed to vehicular traffic	Overturn Collision against fixed objects		Installation of semi-rigid barriers with proper transition to the bridge rail
Sharp ends of metal defenses	Overturn Collision with fixed objects	Drivers and vehicle occupants	Lower and deflect the end of the barrier Installation of shock absorbers
Un-delineated curves	Overturn Collision with fixed objects		Installation of liners Rumble strips Information panels and signals
Un-forgiving lateral areas	Overturn Collision against fixed objects	Drivers and vehicle occupants	Removal of obstacles in the free zone Rumble strips on the edge of the berm Berm Enlargement Installation of liners Flatten slopes Safety barriers

3

GUIDE FOR THE APPLICATION OF ROAD SAFETY INSPECTIONS

3.1 INTRODUCTION TO ROAD SAFETY INSPECTIONS

Road Safety Inspections are one of the tools used for the management of road safety in infrastructure that differs in some ways from other tools, such as an RSI, the identification and solution of incident concentration points and the diagnosis of road safety from in-depth analysis of traffic incident police reports. For this reason and in order to clarify its scope and distinct features, as well as to establish why these concepts are relevant to interested parties, this chapter presents the concepts that frame RSI.

3.1.1 RSI Definition

RSIs emerged in the United Kingdom and were included in the later stages of development before the opening of a road.[7] The definition of an RSI varies internationally according to the scope of activities, the types of incidents that initiate an inspection and its dependence on maintenance routines. Some countries call RSIs road safety reviews while others call them road safety audits for existing roads.[8]

Starting with the RIPCORD-iSEREST Project which utilized the understanding of RSIs in European countries and PIARC (World Road Association) findings to clarify the concept, the following definition was adopted.

"Road Safety Inspection is a proactive tool developed through an on-site systematic and regular review process, of a section or the whole road, by a trained independent team, with expertise in road safety, in order to identify dangerous aspects, deficiencies or weaknesses likely to trigger a traffic incident, propose action measures and monitor their implementation."

Inspection Team Independence

To ensure the objectivity and transparency of the process, the members of the inspection team must be an independent group with no relation to the design, nor the operation of the road subject to inspection. Likewise, the inspection team must have absolute independence from the client or contractor so that their opinions and decisions are objective, without any bias that may influence their findings.

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7 RISMET. Recommendations for the development and application of evaluation tools for road safety infrastructure management in the EU. EU. 2011.

8 Idem.

Essential Elements during an RSI

Several concepts are referenced in the definition and should be highlighted and taken into account by those who contract and develop RSIs. These elements are described below.

RSIs as a Systematic Process

RSIs are carried out by developing a methodical and organized process that involves the development and documentation of a series of planned, sequential stages. It includes previous planning work, followed by a field visit that culminates in the analysis of the findings and recommended interventions.

Knowledge, Training and Experience of the Inspection Team

The team that will perform the road safety inspection must have experience and knowledge in the fields of road safety, geometric road design, traffic engineering, user behavior, lateral zone design, safe drainage systems, vehicular containment systems and others. The RSI contracting party must verify the suitability of the inspection team. Team members must also have training and skills in the visual inspection of road networks.

Site Inspection

I The inspection must be carried out by means of a site visit, traveling the road both day and night, in both directions, both walking and in a vehicle, and as many times as necessary. This does not imply that panoramic video cameras installed in the vehicle, photographic records, and aids such as Google Earth or ortho-photos cannot be used. However, direct visual observation, corroborated and complemented with video and photographic evidence is optimal.

Additionally, and without limitation, the following personal and technical equipment can be used:

- I Maps, blueprints or any information about the road.
- II Water level to verify the perpendicular fall and elevation, especially around curves.
- III Measuring tape/measuring wheel.
- IV Digital camera (for images or video).
- V GPS.
- VI Spray paint to mark specific points.
- VII Some form of voice recording.
- VIII Paper and pencil.
- IX Stopwatch to record vehicle speed, hurdles and traffic flows.
- X Optical distance measurement tool.
- XI Point-and-shoot pistol with a grip handle (speed gun).
- XII Checklist.
- XIII Vest/protection: To use during inspection so that inspectors are visible to road users.
- XIV Yellow flash light and flash torches for inspections at night.
- XV Clothing suitable for weather conditions, boots.
- XVI It is recommended to have a cover letter, in case the police or pedestrians request it.

3.1.2 RSI Objectives

According to the definition referenced above, RSIs have the following objectives:

* Identify hazards that have the potential to cause traffic incidents.
* Propose treatment measures for risk control.
* Monitor the implementation of the treatment measures adopted.

3.1.3 RSI Benefits

Important benefits of RSIs:

* Reduction in the potential risk of traffic incidents as a result of the identification and analysis of existing dangerous conditions.
* Identification of possible road safety concerns for all road users.

In support of the statements above, the Rune Elvik Road Safety Measures[9] Manual notes that "An evaluation of the road safety inspection conducted in 300 high incident rate sites in New York reported an incident reduction between 20% and 40% (FHWA, 9 Rune Elvik. The Handbook of Road Safety Measures - Second Edition. Institute of Transport Economics. Oslo, Norway. 2009. 2006).

3.1.4 Types of RSI Liable Projects

In general, any road in operation, whether urban or rural, can undergo a road safety inspection process. It all depends on the needs of the authorities responsible for the administration of urban and rural roads, which must develop a prioritized inspection plan, taking into account factors such as the importance and role of the road, location, traffic volume or traffic incidents with reference to global norms. At this point it is necessary to clarify that in order to conduct an RSI it is not essential to have records or specific road incident data. However, these records are very useful.

Neither the inspections nor the audits study factors relevant to tunnel safety. Therefore, tunnel audits and inspections require other types of specialists in vulnerability and emergency treatment in risk situations.

9 Rune Elvik. The Handbook of Road Safety Measures - Second Edition. Institute of Transport Economics. Oslo, Noruega. 2009.

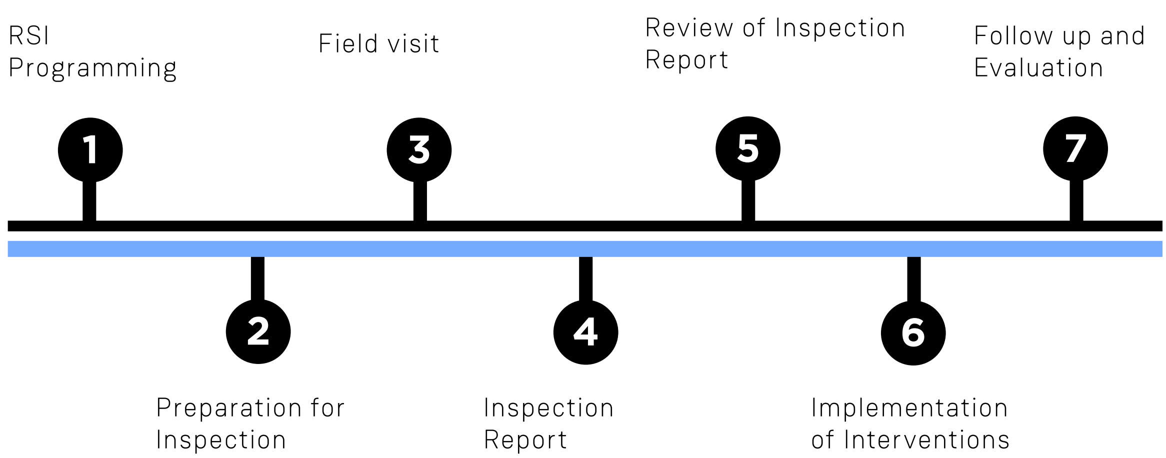
3.2 METHODS FOR THE DEVELOPMENT OF ROAD SAFETY INSPECTIONS

One of the main characteristics of an RSI is that it corresponds to an organized, systematic, methodical, documented and confidential process. Accordingly, this chapter discusses the methodology commonly used to develop RSIs and indicates the steps to be followed by inspection team members.

It is common practice that RSIs are developed through the execution of seven planned, sequential steps, so that their application has a logical order and, at the same time, exercises control over activities. Although the formal RSI process is defined by phases 2, 3 and 4, the other phases include the activities to be carried out by the person responsible for the road, to ensure the application of the recommendations of the inspection report, which makes the process an integral part of a road safety infrastructure management plan. Additionally, this process allows feedback from the inspection group on the effectiveness of the measures that can be included in the lessons learned.

The steps that make up the RSI are shown in Figure 1, described below.

Figure 1 Process step for conducting an RSI



3.2.1 Programming and Requesting an RSI

In this step, the entity responsible for the administration and operation of the roads, whether urban or rural, must establish a road safety inspection plan for the relevant road network. This plan must be prioritized, and can respond to compliance with a regular inspection program or address new situations arising on a specific section of a road. Within the execution of the inspection plan, an agenda for the RSI is prepared for the chosen road.

Programming should consider the factors shown in Table 11.

Table 11 RSI
Programming

Programming
Exact identification of the road (name, mileage, nomenclature)
Length of the road section where the RSI will be applied
Period in which the RSI will take place
Documentation needed for the RSI
Mechanisms for coordination between the inspection team and the contracting entity
Communication channels between the inspection team and the contracting entity
Safety and protection measures for the inspection team as they travel along the road

3.2.2 Preparation for the Inspection

This RSI step takes place during the phase prior to the field visit. There should be enough time to prepare for the inspection, which is the basis for the report which includes the RSI findings. This preparatory phase includes the collection of all the necessary data on the road and the preparation of the logistics necessary to carry out the field work, following safety protocols and protection of personnel and with all the required support elements to guarantee the work's completion and quality.

Table 12 Information Required and Minimum Logistics Recommended for an RSI

PREPARATION FOR THE RSI FIELD VISIT

Type of Road	Transport Conditions	Road Condition	Minimum Logistic Requirements
Type: urban, interurban, highway	Transit volumes	Consistency of alignments with curves	Vehicle equipped with video cameras
Function	Composition of vehicular traffic	Visibility distance	Reflective vests
Vulnerable users	Composition of non-motorized transit		Safety boots
Through cities and population centers	Transit growth patterns		Sunscreen and caps or helmets
Locations generating travel	Public transportation routes		Tape measure and levels to measure slopes
School zones			Chronometer
			Photo and video camera
			Maps
			Checklists
			GPS
			Speed control radars

3.3.3 Field Visit

The field visit is perhaps the most important phase of the RSI. Along with the analysis of the information collected, this phase is the basis for the inspection report and the presentation of intervention recommendations.

The purpose of the field work or inspection visit is to identify the dangers and potential risks of traffic incidents for all users of the road in operation. These risks and dangers could relate to infrastructure, environment, signaling, demarcation and all elements and road characteristics that can affect road safety performance and threaten the integrity of users, especially the most vulnerable.

To facilitate the field visit, the road must be divided into sections of homogeneous geometry, so it will be necessary to know details about the plant (horizontal curves), the profile (vertical curves) and the cross-section (road width, berms, separator, clear zone).

Table 13 Factors to Consider During a Field Visit for an RSI Field Inspection

FIELD VISIT

What to inspect?	When?	How?	Who?
Environment Type of area (urban or rural) Land use Activities in urban areas (residential, commercial, industrial) Transit generating centers Access to properties	During daytime	Divide the track into sections with homogeneous geometry	The whole inspection team
Transit Traffic density Operating speed Volume of vulnerable users and travel generating centers	During nighttime	Drive a vehicle	Capture user ratings on site
Condition of Infrastructure User visibility of road elements Visibility among users Legibility of track elements, easy decoding Possibility of regaining control of a vehicle Consistency of road characteristics in relation to the cited criteria Identification of deficiencies with the help of the checklist	Under normal traffic conditions	Walk the road in both directions	Consider risk perceptions by those responsible of traffic surveillance and control
	In favorable weather conditions	Check lateral zones	The opinion of technicians in charge of the road maintenance, as well as the transit agents, is useful to understand the activity in the area
		Examine trajectories and user's fields of vision	
		Travel the route twice	
		Use checklists	
		Use video and photographic records	
		Locate findings through GPS, if possible	

3.3.4 Inspection Report

The next phase of the inspection process corresponds to the preparation of a complete report on the results of the RSI. The content of a model inspection report, based on common RSI practice is shown in Table 14.

Table 14 Contents of the RSI Report

RSI REPORT

Introduction

Introduction
Description of the inspected road Name of the road Location Function Ground uses General characteristics
Inspection Team Names and professions of team members
Inspection Process Start and end date Field visit dates Conditions during the visit Support elements used (checklist, video, photography, GPS) Scope
Ratings of Results Methods used for risk rating and prioritization

Results of the RSI Inspection

Carried out Activities	Findings	Recommendations
Background	**Road Safety Problems** Findings are described as a result of the inspection. They are organized by topic and refer to the inspection carried out. They also refer to nomenclatures, kilometers and geographic coordinates	For each finding we must indicate the nature of each to address it. Each recommendation must receive a rating that indicates the priority level to eliminate the danger, which is also associated with the incident risk level. This prioritization is the responsibility of the inspection team.
Gathered information Connection of the information, sources, state and usefulness Questionnaires and inquiries	**Damage Potential** indings or found risks must be accompanied by potential risks and the corresponding rating.	
Process Description of the activities carried out	**Evidences** Attach photographic evidence and references to the corresponding blueprints	

3.3.5 Presentation and Review of the Inspection Report

It is recommended that during the development of the RSI process, the results are presented to the entity that ordered the inspection, through a meeting where all parties participate. This meeting is an opportunity to examine the findings, the evidence establishing risks to user safety and to obtain feedback from those responsible for the administration and operation of the road.

Once the client receives the report, a review of the report must be conducted by the entity that requested the inspection, which should result in an action plan to manage and control the hazards and risks identified.

Table 15 shows the activities that should be completed by the client in the review of the RSI report.

Table 15
Review of the RSI Report

Review of the RSI Report
Examination of the findings and their rationale from the point of view of road safety
Review of the recommendation for the management of findings and risk control
Prioritization plan review
Well-argued presentation of findings, recommendations and priorities that are considered questionable
Schedule a new visit, if needed
Decision to formulate and execute an action plan to implement the recommendations

If and when the application of RSIs is conducted through a methodical, organized and documented process, the client must provide an appropriate response to each section of the inspection report. The client must indicate in its action plan which recommendations will be implemented, as well as the measures that cannot be implemented and the reason for the rejection (budget, legislation, technique, etc.).

3.3.6 Implementation of Recommended Interventions

After reviewing, discussing and approving the recommendations for the management of hazards that impact road safety, the client or the person in charge of the administration and operation of the inspected road must proceed to formulate an action plan to implement the solutions.

Table 16 lists the guidelines for the formulation of the remedial action plan.

Table 16 Guidelines for the Formulation of a Remedial Action Plan

Action Plan Guidelines
Classification of measures according to impact on road safety
Prioritization of interventions according to risk level
Estimation of intervention costs
Planning and execution schedule of interventions with activity managers
Monitoring, control and follow up method

3.3.7 Follow Up and Evaluation

It should not be allowed that RSI processes are isolated. It is essential that the treatment measures adopted as a result of the results of the RSI undergo monitoring, control and follow up methods that allow for measuring efficacy.

This method must monitor the characteristics of the road incident rate before and after the measure is applied, confirm that the measures adopted are executed in accordance with the recommended road safety specifications and follow up on the planning of roadworks, verifying that the schedules are met.

3.3 PROFILE AND RESPONSIBILITIES OF THE ROAD SAFETY INSPECTION TEAM

This section provides guidelines on the inspection team's composition, profile and responsibilities. Ideally, the requirements to be a road safety inspector at its different levels (leader and auxiliary) are defined by a competent governmental authority, for example country level training programs where these are available. The participation of engineering and architecture university departments, as well as professional associations of engineers and architects should also be considered.

3.3.1 Members of Inspection Team

On the basis of international experience, an inspection team must consist of at least two members, and one must act as team leader. Entities such as PIARC recommend that the inspection have several members in order tofacilitate the distribution of tasks and the exchange of opinions (PIARC, 2007). However, in small projects the RSI can be done by a single person. Road safety professionals can be part of the inspection team as apprentices and technical experts when necessary.

Inspection Team Leader

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Inspection Team Leader

is The team leader is a professional and a leading member of the inspection team. This figure must meet the requirements indicated in Table 17 to direct both the RSI and the inspection team.

Auxiliary Inspector

is the auxiliary inspector is another member of the inspection team. This figure must have professional training meeting the requirements indicated in Table 17, and is responsible for specific tasks and duties in the RSI.

Apprentice Road Safety Inspectors

Apprentice road safety inspectors are professionals who are still part of the training process to become a road safety inspector. This individual should attend the inspection only as an observer.

Expert Technician

The expert technician, without being an auditor or inspector, is requested for consultation on a technical concept.

Social Area Expert

The social area expert is a psychologist, sociologist or anthropologist who supports the engineering team. The professional background and area of expertise should be selected according to the needs of each project and the location.

3.3.2 Profile and Responsibilities of the Inspection Team

Based on international experience, Table 17 presents the profile, the minimum experience required, and the responsibilities of each member of the inspection team.

These requirements should be used as a reference for contracting and performing RSIs. These requirements emphasize proven experience of the members of the inspection team, which is essential to ensure inspection quality.

Table 17 Profile and Responsibilities of the Inspection Team

Position	Academic Profile	Experience	Responsibility
Lead Inspector	Professional training and registration in Civil Engineering of roads that includes training in the design, construction and maintenance of road infrastructure Knowledge in Road Safety Engineering Training course in RSA or RSI Training course and other activities related to topics such as: road signaling, road containment systems design, lateral zone design, calm traffic measurement design, etc.	7 years of professional experience Demonstrates leadership skills in the direction of projects Specific experience in road design, road reconstruction techniques and engineering, traffic management and traffic signaling Has participated in no less than 5 RSI or RSA, 3 of which must correspond to road or urban projects according to the type of project that is contracted	Agree on the object and scope of the RSI Define the make-up of the inspection team Direct and carry out the RSI Manage the RSI process Intervene in the development of all stages of the inspection Analyze information required for the RSI Define checklists Organize and direct the field visit Prepare and sign the RSI report Make presentation on the RSI Verify that equipment and personal protection elements necessary to perform the RSI are available
Assistant Inspector	Professional training in Civil and Road Engineering, and other similar professions Knowledge in Road Safety Engineering Training course in Road Safety Inspections or Audits	5 years of professional experience Has participated in at least one RSI or RSA	Intervene in the RSI data collection and analysis process Participate in the preparation of checklists Participate in the field visit Complete checklists Make photographic and video records as proof of the hazards identified Intervene in the elaboration of the RSI report Participate in the presentation of the inspection report
Apprentice Road Safety Inspectors	Professional training in Civil and Road Engineering, or similar professions Knowledge in Road Safety Engineering	1 year of professional experience Has received training in road safety issues	Participates as an observer of the inspection process
Social Area Expert	Professional training and registration in disciplines such as Anthropology, Sociology or Psychology Experience in human factor analysis and project impact in communities	3 years of experience in project management with communities Experience in road project social impact analysis	Determine the possible impacts of the project on the surrounding communities Determine human factors that could affect road safety in the construction work design Prepare risk analysis reports of situations that may arise with the communities and their respective mitigation measures

3.4 ROAD SAFETY INSPECTIONS REGULAR PROGRAM

The development of RSIs must follow the execution of a road safety assessment as much as possible. This development must be duly funded, both to conduct the RSI and to implement the remedial measures.

3.4.1 RSI Frequency

Although budgetary limitations may present an obstacle to performing regular RSIs, those responsible for the management and operation of the roads must ensure that inspections, due to their systematic nature, are carried out regularly and periodically, according to the type of road elements. This is necessary in order to permanently assess the safety of all users of the road network.

In deciding to conduct an RSI and how often to do so, it should be taken into account that there are elements of the road infrastructure that change more frequently than others, such as the condition of the pavement surface, signaling, demarcation and lighting. There are attributes of the roads that should be inspected regularly, such as intersections, access control, pedestrian areas, cycle paths the lateral zone and others.

3.4.2 Selection of Roads to be Inspected

International practice establishes criteria for the selection of roads that must be subjected to an inspection process, for example [10]:

Road Sections

Criteria to select specific road sections to inspect:

* When a concentration of incidents is observed in that section, especially with various types of structures.
* When there is evidence or other information about problems in the section.
* When there are road safety deficiencies, potential hazards or the same type of incidents along the section

Road Systems

In regards to road systems, prioritization analysis must ensure that safety inspections are carried out on those roads in which corrective measures will provide the greatest benefits in terms of road safety.

There are several methods used for this classification, and the recommended observation periods are between three and five years.

10 *Federal Ministry for Transport, Innovation and Technology. ROAD SAFETY INSPECTION (RSI): Manual for Conducting RSI. Austria, Vienna. 2014.*

Road Classification by Traffic Volume

If a single category of roads is considered, an RSI must first be implemented on roads with the highest traffic volume.

Classification According to Road Incident Density

Classification proceeds by dividing the number of road incidents in a section by the length of the section. The RSI must be completed first in the sections with the highest density of traffic incidents.

Classification according to Road Incident Rate

Classification proceeds by multiplying the road safety incident rate related to the volume times in the section under study. The RSI must first address the sections with the highest road incident rate.

3.5 RSI CHECKLISTS

In the same way that checklists are used for road safety audits, checklists are designed for road safety inspections. These are not mandatory, but are a useful tool to review aspects of road infrastructure or human behavior, which can become dangerous.

For inspections, checklists are even more useful, so a detailed field review is essential in these types of studies. Keeping a list of points or questions that must be asked to evaluate or conduct tests that facilitate a proper decision when it is time to carry out the risk assessment or to propose mitigation measures, is the way to guarantee that all the elements that can affect road safety are included, covered and objectively evaluated.

Forgetting to observe any aspect that could present danger in the field visit may require a new visit, a time extension and an increase in costs for the inspection team.

Inspections should be standardized and designed so that they can be systematic procedures. For this reason, the development of checklists can be of great value. However, it should be noted that using a checklist does not replace the experience, knowledge, or good judgment of the auditors and that such checklists do not constitute the fundamental work needed to perform an RSI. Checklists are a support measure for auditors to objectively determine the basis for their assessments and decisions.

In RSIs, direct observation of the operation of a road helps to detect environmental, socio-cultural, infrastructure, vehicle and pedestrian traffic variables, user behavior, the way in which they take risks, incident close-calls, relationship with speed and other aspects that must be evaluated.

The risk factors described in section 1.3 of this guide are the basis for the preparation of checklists, which include functional aspects of the road surface, the environment, the operation, signaling, visibility, lighting, accessibility, traffic control, circulation factors for comfort and safety in cross-sections, surface for vehicles and for pedestrians, the interrelation and conditions between the different users of the infrastructure to share common areas, etc. The list can be supplemented with the risk factors considered by the iRAP Program described in Table 9 for the different users according to the type of incident. Each of these raise questions when planning a road safety inspection process.

On rural roads the fundamental characteristics that qualify a road as safe are more related to the potential dangers for the users of motor vehicles, including the presence of pedestrians. On the other hand, on urban roads it is the vehicle that constitutes a danger to the pedestrian's mobility and that conceptual difference modifies the form of the checklist, the questions to ask and subsequent analysis. and the same factors influence the behaviors of the users, where user experience and number of users impact the potential danger.

Each RSI case is unique and has variables that depend on the object and site characteristics. Therefore, the auditors, coordinated by the lead auditor, must adapt checklists for each site, and this step is part of the preparatory phase of that inspection to include the elements that are considered important, distribute the work and assign responsibilities.

The use of standard checklists is helpful, but the experience of the group is critical to their ultimate utility.

As base lists for road safety inspections, those recommended by international guides in the countries that apply them systematically, can be used and adapted to the specific case, study and modify them, codify concerns or need for evidence in the most relevant aspects, define the level of detail for direct observations and relate them to photos or videos that should be taken during the inspection.

It is advisable to make a general list of factors to consider first during the evaluation and then decide which checklists can be used as the basis for their adaptation.

The following are general checklists that may be useful for preparing detailed lists for each inspection.

3.5.1 Checklist for Road Safety Inspections in Rural Roads

General Aspects

1	**Functionality of the road**: type of road, road hierarchy, design parameters, general characteristics, special characteristics of the road, special characteristics during construction
2	**Verification of previous recommendations:** recommendations in the final design stage, in the pre-opening stage and in previous inspections, interaction of functional aspects
3	**Transit:** review of current trip generators compared to design, land use, current volumes, priority conflicts, day and night operation, legibility for drivers, exchangers, cross-links, turns
4	**Transport:** type of loads, type of passengers, origin, destination, use of the road for current transport
5	**Vehicles:** types of vehicles in circulation, compliance with conditions for allowed and not allowed vehicles, current volumes, traffic composition
6	**Operating speeds:** homogeneous speed sections, speed reduction at special sites, day and night speeds, problematic speeds, abrupt speed changes, speed limit signaling
7	**Environmental conditions:** behaviors in normal and adverse , climatological, geophysical, topographic situations
8	**Incident rate:** databases and sites of concentration of road incidents
9	**Preventive and control measures:** highway police, awareness campaigns, messages and prevention program
10	**User behavior:** traffic control sanctions, dispute and conflict resolution, acceptance of control measures, degrees of conformity/nonconformity
11	**Temporary closures:** scheduled, unscheduled, detours, administrative actions

Geometry of the Road

12	**Cross-section:** lane operation, special lanes, cross-section changes
13	**Berms:** temporary use of berms, widths, obstacles, lateral slope, transferability
14	**Ditches:** drainage, transferability
15	**Medians or central dividers:** widths, obstacles, transferability, glare, unevenness
16	**Curbs:** height, rounded borders, transferability
17	**Sewers:** visibility, lateral location, head height, decks, transferability
18	**Bridges and pontoons:** width, day and night visibility, special signaling, railings, crosswalks, front and rear protection, transition elements
19	**Lateral zone:** lateral obstacles, transferability, user protection areas
20	**Lateral obstacles:** trees, posts, stones, objects that can be impacted, transferable elements
21	**Lateral slopes:** separation, inclination, transferability, ditch, rock fall

22	**Accesses:** road interchanges, access to properties, turnarounds, acceleration and deceleration lanes, visibility, driver legibility, functionality, operability, operating speeds, ascent/descent ramps, intersections, junction areas, islets, waiting times
23	**Roundabouts:** radios, operating speeds, visibility, incorporations, exits, ring lanes, special signaling, pedestrian traffic
24	**Road surface:** type, current state for vehicular traffic, damage caused by construction, general and special characteristics, zoning, vehicle - surface interaction (friction), surface drainage, waterlogging, surface uniformity, damage, color of the surface, action of speed reducers, berms and rumble strips

Road Furniture

25	**Bus stops:** location and operation, lateral separation, special signaling, shelter areas, capacity, structure, protection system, passenger ascent/descent zone
26	**Tolls:** location, types, booths, speeds, special signaling, protection for collectors, shelters, islets, impact attenuators, queue length, electronic tolls
27	**Redirection and containment elements:** types, location, height, work area, dynamic deflection, rigidity, installation, embedment, length, terminals, transition elements, anchors, discontinuities, day and night visibility, uniformity, impacts, maintenance status
28	**Impact attenuators:** location, containment level, type, homogeneity, work area, installation, visibility, special signaling, operating status, traffic hazards, visibility obstructions, maintenance
29	**Emergency or braking ramps:** location, type, special signaling, visibility, maneuverability, vehicle entry, length, roadbed condition, recovery area
30	**Temporary traffic lights:** location, installation, visibility, special temporary signaling, operability, phase operation, cycles, posts, forecasts for operation and temporary operability
31	**Services:** gas stations, restaurants, garages, location, special signaling, vehicle entry/ exit
32	**Speed bumps:** traffic calming measures, rumble strips, highlights, justification, functionality, temporary speed bumps
33	**Lighting:** visibility of road works and traffic restrictions during day and night, need for temporary lighting, type of lighting, school zones, pedestrian paths, intersection areas, crossings, bridge areas, high-risk sectors
34	**Emergency vehicles:** location of headquarters, alarms, calls, special access, facilities for crossing, turnarounds, location of emergency centers, travel times

Signaling

35	**Vertical signs:** size, shapes, colors, pictograms, messages, location, height, daytime visibility, night reflectivity, consistency with demarcation, relevance to existing signs, maintenance
36	**Demarcation:** central and lateral lines, width, day and night visibility, stop lines, parking lots, channelization, shelters, uniformity, symbols, characters, colors, frequency of use, circumstances in which they are used, types of materials used, consistency with vertical signaling, use of temporary demarcation where necessary
37	**Auxiliary traffic controllers:** workwear, location where they are needed, training,location, functions, stop and go signs, whistles, day and night visibility, hours of operation
38	**Traffic delineators and separators:** location, location on the road, sizes, shapes, lengths, types, visibility, proximity, warnings, user considerations, parking lots, breakdowns
39	**Elevated traffic signs:** message, posts, location

40	**Variable message signals:** location, messages, day and night visibility
41	**Signs for pedestrians, cyclists, motorcyclists**

Users Segregation

42	**Motorcycle lane:** lane separation, signaling, speeds, crossings, turns, widths, use of shared areas, lane separation, track edges or obstacles in drainage works, protection in redirection and containment barriers, slippery surfaces
43	**Bicycle lanes:** segregation, safe access during construction, continuity, special signaling for cyclists and vehicle drivers, location, crossings, turns, widths, uses of shared areas, user facilities, areas of incorporation, slopes, road geometry, upward ramps/downward, bridges or overpasses
44	**Pedestrians:** mobility during construction, predominant groups, access for the elderly and disabled, pedestrian volumes, pedestrian network, pedestrian paths, shelter areas, fences, walkways, level crossings, pedestrian bridges, protection elements, surface conditions, railings, special signaling for drivers and pedestrians, inclusive mobility, ramps, stairs, ascent/descent of vehicles, intersection crossings, pedestrian traffic light phases, continuity, access to buildings, effects on road density, conflicts with other road users, shared spaces with cyclists, situations and danger risks.
45	**Non-motorized vehicles:** type, use lanes, operability, expected volumes, operating speeds, interaction with other vehicles, special signaling
46	**Animals:** presence, type of animal, fences, railings, special signaling, stockyard, control measures, wildlife passes, location, visibility, special provisions
47	**Segregation elements:** type, length, height, location, installation, visibility, comprehension, continuity, vehicle access/exit

Special Zones

48	**School zones:** special signaling, drop-off and pick-up zones, parking lots, shelters, pedestrian paths, user protection system, speed bumps
49	**Urban passages:** maximum allowed speed, special signaling, pedestrian paths, crosswalks, vulnerable users, street furnishing, crossings, turns, vehicle entry and exit, parking areas, speed bumps
50	**Intersections:** warnings, location, type, special signs, visibility, merging and exit, maneuverability, turns, crossings, evenness, unevenness, upwards and downwards ramps, road geometry, speeds, users allowed/not allowed, user protection
51	**Other:** non-designed elements, day and night travel assessments

3.5.2 Checklists for Urban Road Safety Inspections

General Aspects	
1	**Progress of road project development:** proposed objectives and their compliance, justification and current operation, future plans, road function, project context, road hierarchy
2	**Verification of previous recommendations:** previous audits, recommendations in the design stage, previous inspections, interaction of functional aspects
3	**Mobility:** accessibility, impacts on each type of user, temporary mobility, future mobility, routes
4	**Surrounding infrastructure:** impact, contributions, mobility on the existing road network, activities that take place in the context, connection of the new road with previous road
5	**Incidents:** records of incidents in the area, incident analysis, causes, sites or sectors of incident concentration, previous mitigation measures
6	**Transit:** trip generators, future land use, design volumes, priority conflicts, day and night operation, driver legibility, overpassing, crossings, turns, special mass transit lanes, peak and off-peak times
7	**Transportation:** transportation systems, type of loads, type of passengers, origins, destinations, use of the road for transportation, special loading/unloading schedules, freight transportation routes, special school routes
8	**Vehicles:** type of vehicle, vehicles allowed/not allowed, acceptable dimensions, traffic impact, accessibility impacts, vehicle composition
9	**Operating speeds:** consistency with the road hierarchy, sections of homogeneous speeds, problematic speeds, sudden changes in speed, speed signs
10	**Environmental conditions:** climatological, geophysical, topographic
11	**User behavior:** vulnerable population, effectiveness of special signaling measures, spaces, social services, concentration sites, acceptance of control measures
12	**Control measures:** police action and citizen behavior brigades
13	**Institutional coordination:** institutional responsibilities, evaluation criteria and evaluation of the operation of the infrastructure

Urban Space	
14	**Urban conception:** pedestrian/vehicle relationship, public/private transportation, connections with other means and roadway corridors in the surrounding areas, compatibility with future land use
15	**Urban space elements installed:** pedestrian protection elements, stops, parking spots, parking lots, street vendors, billboards, public service infrastructure, safety in access to garages and public places
16	**Passenger mobility:** transfers between modes of transportation, physical andoperational compatibility of modes of transportation in the area, stations, travel continuity, effects on other types of users
17	**Tree planting:** garden treatment, green areas built, landscaping, proximity to the area of vehicular flow, trees as obstacles in pedestrian areas, flowerpots
18	**Pedestrian surfaces:** shape, type, continuity, current status, construction defects, tactile paving, platform access ramps, curbs, drainage areas

19	**Pedestrians:** mobility, predominant groups, volumes, pedestrian network, pedestrian paths, shelter areas, fences, walkways, level crossings, pedestrian bridges, protection elements, surface conditions, railings, special signs for drivers and pedestrians, inclusive mobility, ramps, stairs, ascent/descent of vehicles, intersection crossings, pedestrian traffic light phases, continuity, building access, road density impacts, conflicts with other road users, shared spaces with cyclists, hazardous situations and effects

Geometry of the Road

20	**Horizontal alignment:** curvature, minimum radii, degrees of curvature, deflection angles, cants, curve visibility, vehicle instability, visibility
21	**Vertical alignment:** maximum and minimum slopes, visibility, curve length,outline losses
22	**Cross-section:** lanes, special lanes, lane widths, pumping, gauge widening, rear gauge widening, cross-section changes
23	**Berms:** widths, obstacles, lateral slope, transferability
24	**Ditches:** widths, depth, side slopes, berm ditch, crossing ditch, obstacles, transferability
25	**Medians or central dividers:** widths, obstacles, transferability, glare, unevenness
26	**Curbs:** height, rounded borders, transferability
27	**Sewers:** lateral location, head height, decks, transferability
28	**Bridges and pontoons:** widths, day and night visibility, special signs, railings, crosswalks, front and rear protection, transition elements
29	**Lateral obstacles:** trees, posts, stones, objects prone to collision, transferable elements
30	**Access points:** road exchangers, access to properties, turnarounds, accelerationand deceleration lanes, visibility, driver legibility, functionality, operability, operating speeds, upwards/downwards ramps, crossings, junction areas, islets
31	**Roundabouts:** radii, operating speeds, visibility, merging, exits, ring road, special signs, pedestrian traffic
32	**Surface:** type, general and special characteristics, zoning, vehicle-surface interaction (friction), surface drainage, waterlogging, surface uniformity, damage, surface color, speed bumps, berms and rumble strips.

Road Furniture

33	**Bus stops:** location and operation, lateral separation, special signaling, shelter areas, capacity, structure, protection system, passenger ascent/descent zone
34	**Urban tolls:** location, types, booths, speeds, special signaling, protection for collectors, shelters, islets, impact attenuators
35	**Redirection and containment elements:** types, location, height, work area, dynamic deflection, rigidity, installation, embedment, length, terminals, transition elements, anchors, discontinuity, day and night visibility, uniformity
36	**Runaway truck ramps:** location, containment level, type, homogeneity, work area, installation, visibility, special signaling, operating status
37	**Traffic lights:** location, installation, visibility, special signaling, operability, phase operation, cycles, posts
38	**Facilities:** gas stations, restaurants, garages, location, special signaling, vehicle entry/exit

37	**Traffic lights:** location, installation, visibility, special signaling, operability, phase operation, cycles, posts
38	**Facilities:** gas stations, restaurants, garages, location, special signaling, vehicle, entry/exit
39	**Traffic calming devices:** traffic calming devices, rumble strips, speed humps and bumps.functionality
40	**Lighting:** need, type of lighting, school zones, pedestrian paths, intersection zones, population crossings, bridge areas, high risk sectors
41	**Emergency vehicles:** location of headquarters, alarms, calls, special access, passing, turnarounds, location service centers, travel times

Vehicle Area Signaling

42	**Vertical signs:** size, shapes, colors, pictograms, messages, location, height, daytime visibility, night reflectivity, demarcation consistency
43	**Demarcation:** central and lateral lines, line widths, day and night visibility, bus stop lines, parking, channeling lines, shelters, uniformity, symbols, characters, colors, frequency of use, circumstances in which they are used, types of materials used, consistency with vertical signs
44	**Road studs:** location, type, size, delineation, spacing, demarcation, color, day and night visibility, transferability
45	**Elevated signs:** messages, posts, location
46	**Variable message signs:** location, messages, day and night visibility
47	**Signs for pedestrians, cyclists, motorcyclists**

User Segregation

48	**Motorways:** lane separation, signaling, speeds, crossings, turns, widths, shared space use, lane separation, road edges or drainage obstacles, protection in redirection and containment barriers, slippery surfaces
49	**Bicycle lanes:** segregation, continuity, special signs for cyclists and vehicle drivers, location, crossings, widths, use of shared areas, user facilities, merging areas, slopes, track geometry, upward/downward ramps, bridges or overpasses
50	**Non-motorized vehicles:** type, lanes, operability, expected volumes, operating speeds, interaction with other vehicles, special signaling
51	**Segregation elements:** type, length, height, location, installation, visibility, comprehension, continuity, vehicle entry/exit

Special Zones

52	**School zones:** special signaling, pick-up zones/drop-off zones, parking lots, shelters, pedestrian paths, user protection system, speed bumps
53	**Intersections:** location, type, volumes, design for future needs, variation of hourly, daily, occasional traffic flow, special signaling, visibility, merging/vehicle exits, maneuverability, turns, crossings, even situations, uneven situations, upward/downward ramp, road geometry, speed, users allowed/not allowed, user protection system, surface condition, cant, pumping, drainage, gauges
54	**Other:** non-designed elements, day and night travel assessments

3.5.3 Client Verification Checklist

Detailed List for Client Verification

Project:
Inspector:
Date:

Question		Comments
1	Have all road users been considered?	
2	Have vulnerable users been taken into account?	
3	Have all vehicles on the road been considered?	
4	Have traffic volumes been considered?	
5	Has the vehicle composition been considered?	
6	Have travel generator sites been taken into account?	
7	Was a day tour conducted?	
8	Was a night tour conducted?	
9	If needed, has the consistency of the design been reviewed?	
10	Have the lateral areas of the road been reviewed?	
11	Has the contact surface been reviewed?	
12	Have potentially dangerous obstacles been detected?	
13	Are there any concerns about the environment of the road?	
14	Have intersections been reviewed?	
15	Have vertical signs been reviewed?	
16	Has the road demarcation been reviewed?	
17	Have the temporary signs been reviewed?	
18	Has the traffic light system been reviewed?	
19	Has the risk factor been calculated for each unsafe aspect?	

20	Have the factors contributing to overall risk been reviewed?
21	Have the redirection and containment elements of the road been reviewed?
22	Is there evidence to support the findings?
23	Have recommendations on the findings been made?
24	Has a monitoring stage been conducted?

3.6 EVALUATION OF ITERVENTION MEASURES AS A RESULT AS A RESULT OF AN RSI

As in the application of risk theory, the methodology for monitoring the implementation of the intervention measures adopted as a result of the recommendations of the road safety audit or inspection processes is applicable to both. The purpose of this methodology is to quantitatively and qualitatively evaluate the results of the actions taken with respect to the implementation of the recommendations to mitigate incident risks identified by road safety inspections. The evaluation method is composed of three steps as indicated in Figure 2:

Figure 2 Steps to Evaluate the Implementation of the Recommendations of the RSI Report

1. Clasification of the findings check
2. Individual assessment of interventions
3. Assessment of the set of interventions by parameter

The classification of findings includes the classification and organization of the interventions recommended by the RSI report in the categories according to the risk factors found called check parameters.

The individual assessment of each of the recommendations is based on four criteria or variables: 1) progress of implementation, 2) time of implementation, 3) complexity and 4) approximate cost of implementation, according to previously established evaluation criteria. The measurement of each criteria is obtained from interviews with those responsible for the project, from the field visits carried out and from the experience of the evaluation team. The results obtained are recorded in an individual valuation matrix for each criteria evaluated.

For the evaluation of the intervention set, measurements of effectiveness and efficiency, complexity and cost are used for the interventions performed in each parameter check and for the total project audited in absolute and relative terms. The effectiveness is established in terms of the level of implementation of the recommendations of the RSI, rated as one of three categories: total, partial and null. Efficiency is defined based on compliance with the estimated deadline for the implementation of the RSI recommendations as "Yes" or "No". Complexity is divided into three categories: low, medium and high and the cost is measured in three categories: low, medium and high. The evaluation should take into account that not all recommendations must be implemented. To establish compliance rates for the set of interventions, a matrix is developed to reflect each check parameter for each evaluation criteria. The analysis is made from the absolute variations that correspond to the total number of interventions in each category or the relative variations that are calculated by dividing the total number of interventions for each column, over the total number of interventions in each parameter.

A detailed development of this methodology, accompanied by a practical example is presented in this guide.

4 BIBLIOGRAPHY

FEDERAL MINISTRY FOR TRANSPORT, INNOVATION AND TECHNOLOGY. ROAD SAFETY INSPECTIONS (RSI): Manual for Conducting RSI. Vienna, Austria. 2014.

FEDERAL HIGHWAY ADMINISTRATION GEOMETRIC DESIGN LABORATORY. IHSDM Roadway Model. Washington D.C, USA. 2001.

INTERNATIONAL CIVIL AVIATION ORGANIZATION- ICAO. Safety Management Manual (SSM). Montreal, Canada. Second Edition- 2019.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION- ISO. ISO/IEC 31010, Risk Management- Risk assessment techniques. 2009.

INSTITUTE OF INTERNAL AUDITORS. IIA Position Paper: The Role of Internal Auditing in Enterprise-Wise Risk Management. 2009.

PANAMERICAN HEALTH ORGANIZATION. Report on Status of Road Safety in the Region of the Americas. Washington D.C, USA. 2015.

RUNE ELVIK. The Handbook of Road Safety Measures- Second Edition. Institute of Transport Economics. Oslo, Norway. 2009.

RUNE ELVIK. Road Safety Inspections: Safety Effects and Best Practice Guidelines. Institute of Transport Economics. Oslo, Norway. 2006.

SEETO. Road Safety Inspection Guideline. Belgrade, Serbia. 2009.

SWEDISH TRANSPORT ADMINISTRATION. Analysis of Road Safety Trends, 2013. Management by Objectives for Road Safety Work towards the 2020 Interim Targets. Borlänge, Switzerland. 2014.

SWOV. Functionality and Homogeneity. Leidschendam, the Netherlands. 2010.

SWOV. Sustainable Safety: Principles, Misconceptions, and Relations with Other Visions, the Netherlands. 2013.

SWOV. Predictability by recognizable road design. Leidschendam, the Netherlands. 2012.

Swedish Road Administration. Safe Traffic: Vision Zero on the Move. Borlänge, Switzerland.

UNISDR. Terminology on Reduction of Disaster Risk. 2009.

WORLD HEALTH ORGANIZATION. Global Status Report on Road Safety. Geneva, Switzerland. 2015.

5

ANNEXES

5.1 ANNEX 1

TERMS OF REFERENCE FOR THE CONTRACTING OF AN RSI

Note to the reader: the text [in square brackets] must be completed with the specific information in each case.

5.1.1 Background

Circumstances such as the growth of the road network, the increase or diversity of the car park (small vehicles share the road with large vehicles), the increase of the age difference of drivers, economic restrictions on the construction of roads, the economic development of countries and technological progress can all contribute to an increase in traffic incidents.

The occurrence of traffic incidents has traditionally been related to vehicle failure, human factors, or roads and the environment. Different factors are involved in the occurrence of a traffic incident, the vehicle (mechanical failures), the driver (human errors), or the road and the environment. These elements could act individually or together to cause a traffic incident.

Before 1960, roads around the world were built and designed with no consideration for the protection of users, nor their physical and psychological limitations. Between 1960 and 1970, construction and operation of roads that considered how to mitigate the severity and consequences of an incident began. Since the 1970s, countries that made the largest investments in road infrastructure took interest in building and operating roads with higher safety standards and highlighted the need to prevent collisions, rather than mitigate them. Despite this progress, road infrastructure projects with low safety standards are still designed and built in developing countries, due to multiple factors.

Infrastructure projects that are designed and built with limited road safety criteria are prone to the generation of critical road incident points or sections that are identified over time. Carrying out studies that identify and analyze the most critical incident sites represents a reactive measure to treat road safety problems, based on events that have already caused human injuries or losses. It is often identified that these critical sectors were generated by safety defects not analyzed in the design of road projects.

In order to develop a methodology that would prevent incidents rather than react to them, the Road Safety Audits began in England in 1987 with the intention to design infrastructure projects that would detect the deficiencies or potential security problems on paper before the construction of the projects. Therefore, errors can be corrected by modifying the plans, instead of implementing corrective measures in a structure that has already been built. It is clear that it is more cost effective for countries and for society in general, if road safety problems are detected and solved before the construction of a road.

The need to carry out Road Safety Inspections for existing road infrastructure projects has been recommended for a long time. The main international organizations concerned with road safety recommend them as a measure that generates an important cost-benefit relationship for road pro-

jects. Due to the declaration of the Decade of Action for Road Safety 2011 - 2020, the United Nations presented a World Action Plan, which is highlighted in section 2.2.-Initiatives that give results, the design of safer roads and the requirement of independent audits on road safety for new construction projects. In pillar 2 "Safer transit and mobility routes", six priority activities are defined, one of which highlights the need to promote the creation of new, safe infrastructure, which set better safety standards for new designs and road investment.

[Background information of the country where the RSI will be carried out should be mentioned. Data on the condition of the transport sector, challenges regarding the history of traffic incidents, existing policies and programs to mitigate the problem, the context and relevance of the project for the country and present some experiences or expectations (as the case may be) of RSIs in the country.]

5.1.2 Justification

[This section should include a brief description of the project and the need to carry out the proposed RSI. Context, statistics (if applicable), the type of RSI that is required and other relevant information should also be included.]

5.1.3 Objectives

General Objective

Carry out an RSI in the road project [Project name (describe the project))], between location, [settlement or kilometer] and second location, [settlement or kilometer], n order to identify risk factors of traffic related incident involving different road users *[(people with reduced mobility, pedestrians, cyclists, motorcyclists, public transport users and vehicle occupants or those who apply to the specific project)]* and based on this, present general recommendations for improving the safety of the road project.

Specific Objectives

* Identify elements of road infrastructure that constitute potential dangers for road users.
* Analizar el comportamiento histórico de la siniestralidad vial presentada en el proyecto vial en estudio, de acuerdo con la información disponible.
* Analyze the historical behavior of traffic related incidents presented in the road project under study, according to the information available.
* Identify the conditions of potential risks and road safety in the geometric design, drainage works, lateral zones, visibility, speeds, horizontal and vertical signaling, vehicle containment systems, traffic calming measures, etc.
* (If applicable) Review previous RSIs carried out in the project and verify the actions taken.

5.1.4 Scope

A Define the reasons why the road safety inspection is being carried out.

B Description of the road (location, starting point and end point, length, number of lanes, number of lanes per road, number of regulated intersections (stops, traffic lights, overpasses, etc.), type of terrain, type of vehicles , importance of the road, TPD, pavement, planned or under construction, etc.)

C Details of the activity to be carried out

  Planning of the RSI

  Execution of the RSI

  Report of the RSI

D Details of existing or missing information

Detailed plans

Traffic and incident information

Vertical/horizontal signaling

E Confidentiality

F Deliverables

G Deadline

5.1.5 Methodology

The methodology for developing the RSI includes the description of the techniques that will be used to carry out the work, based on the Technical Guide for the Application of Road Safety Inspections in Latin American and the Caribbean countries, published by the Inter-American Bank Development - IADB and to consider the methods and procedures that will be used for the development of the work, which will allow for the fulfillment of planned objectives.

The methodology for the evaluation of each proposal will be a fundamental part of the overall plan and the relevance of the proposed methods and the innovation, consistency and robustness of the same should be evaluated.

The methodology must include at least:

* Basic conceptual elements.
* Techniques that will contribute to the desired outcome.
* Methods and techniques to be used by the contractor.
* Activities or tasks to be carried out that comply with those outlined in these terms of reference.

For the development of the activities of the RSI the proponent must consider the following points at a minimum:

* Meeting with the contracting entity to sign the start of the study and present the Work Plan which should include the schedule of activities with the estimated times.
* Description of the secondary information collection necessary for the development of the RSI, based on what is established in the Technical Guide for the Application of Road Safety Inspections published by the Inter-American Bank of Development - IADB. To fulfill this task, the inspector must prepare a diagnostic report with the information collected.
* Description of the field visit. Depending on the type of project to be inspected, information can be taken through videos, photographs, measurements of the road, etc.
* Intermediate meetings with the contracting party to present the diagnosis of the findings and the risk analysis.
* Prepare a report that highlights the road safety recommendations applicable to the roads studied, in accordance with international technical standards for the construction and operation of safe roads.
* Make a presentation of the RSI report, during the final meeting with the contractor, in which the recommendations presented are substantiated.

[The proponent must accurately describe the tasks and main activities that will be executed and define their sequence and articulation. In addition, it must describe the products and results that are expected to be achieved, which will allow for the general objective and the specific objectives of the service to be hired. It should be taken into account that activities and tasks must be described specifically for each project.]

5.1.6 Key Personnel in an RSI

In the composition, profiles definition and responsibilities of the inspection team, the provisions of section 2.3 of the Technical Guide for the Application of Road Safety Inspections in Countries of Latin America and the Caribbean, published by the Inter-American Bank of Development - IADB, should be considered.

The profiles and responsibilities of the inspection team are those included in section 3.3.2 of the Technical Guide for the Application of Road Safety Inspections in Countries of Latin America and the Caribbean, published by the Inter-American Development Bank - IADB, as detailed below:

In general and according to international experience, an inspection team must consist of at least two members, one of these must act as team leader. Entities such as PIARC recommend that the inspection team be plural, which facilitates the distribution of tasks and especially the exchange of opinions (PIARC, 2007). However, in small projects the RSI can be carried out by a single person. Road safety professionals can be part of the inspection team in the role of trainees and technical experts when necessary.

Inspection Team Leader

[Indicate the applicable requirements as recommended in section 3.2 of the IADB RSI Guide.]

Auxiliary Inspector

[Indicate the applicable requirements as recommended in section 3.2 of the IADB RSI Guide.]

Trainee Road Safety Inspectors

[Indicate the applicable requirements as recommended in section 3.2 of the IADB RSI Guide.]

Expert Technician

[Indicate the applicable requirements as recommended in section 3.2 of the IADB RSI Guide.]

5.1.7 Profile and Responsibilities of the Inspection Team

[Based on international experience, Table 18 shows the profile, the minimum experience required and the responsibilities of each member of the inspection team.

These requirements should be taken as a reference for contracting and performing RSIs. Among these requirements, proven experience of the members of the inspection team is particularly important, which is essential to ensure the quality of inspections.]

Table 18 Profile and Responsibilities of the Inspection Team

Position	Academic Profile	Experience	Responsibility
Lead Inspector	Professional training in civil engineering, road engineering or other similar profession, which includes training in the design, construction and maintenance of road infrastructure Knowledge of road safety engineering Training courses in RSI or RSA Training course and other activities related to: road signaling, road containment system design, design of lateral zones, design of traffic calming measures, etc.	Seven years of professional experience Leadership and project management skills Specific experience in road design, road reconstruction techniques and engineering and traffic management and signaling Participation in no less than five RSI or RSA, three of which must correspond to open road or urban projects according to the type of project that is contracted	Agree on the object and scope of the RSI Define the composition of the inspection team Direct and carry out the RSI Manage the RSI process Intervene in the development of all stages of the inspection Analyze the information required in the RSI Define checklists Organize and direct the field visit Prepare the RSI report Present the RSI Verify that personal protection elements and equipment to perform the RSI are made available
Auxiliary Inspector	Professional training in civil engineering, roads engineering or other similar professions Knowledge in road safety engineering Training course in Road Safety Inspections or Audits	Five years of professional experience Participation in at least one RSI or RSA	Participate in the collection and analysis of information for the RSI Participate in preparing checklists Participate in the field visit Fill out checklists Take photographic and video records as proof of the hazards encountered Participate in the preparation of the RSI report Participate in the presentation of the inspection report

5.1.8 Products and Reports to be Delivered

The inspection team must submit the following reports or products:

Report 1: A work plan and schedule of activities that includes estimated deadlines.

Report 2: Data collection of information and diagnosis gathered during the field visit.

Report 3: Identification, analysis and proposals for mitigation and risk management.

Report 4: Final inspection report that includes the findings and recommendations.

[*In short-term projects, reports 3 and 4 can be presented together.****]***

These reports must have all the information required and should be duly substantiated and presented so that they can be clearly understood. The reports must clearly present the following: the manuals or standards applied, design drawings of the recommendations, incident statistics (if applicable), and comparisons with international best practice cases.

5.1.9 Terms of the Contract

[*The tasks carried out by the team performing the RSI do not depend on the length of a road and, therefore, a value per kilometer of route is not established. However, it does depend on the number of homogeneous sections that the road has, so that each one must perform studies, measurements and analysis to determine road safety conditions. The costs and schedule for conducting Road Safety Inspections should be analyzed according to the characteristics of each country, the geographical location of the project, the number of people who will perform the inspection, fees, the equipment that would be used, the elements of personal protection and vehicles, among others.****]***

5.1.10 Resources and Facilities

[*For the development of the RSI, consider the availability of the contracting party to provide the inspection team with resources such as: office, vehicle for field visits, project plans, meeting room, etc.****]***

5.1.11 Payment Method

[*The contracting entity must specify the costs which constitute the payment of the proponent, the currency in which the payment will be made, how the fees will be calculated, form and payment milestones (it is recommended to use the reports and deliverables indicated above), based on which the consultant will prepare his proposal and will be indicated in this section. In each proposal, the payment conditions and percentages must be established: advance payment (%), partial payment (%) and final payment (%).****]***

5.1.12 Selection and Evaluation Criteria

The following aspects should be considered in the evaluation of proposals:

A **Experience:**

Specific experience of the leading inspector in road safety inspections.

General experience of the leading inspector in road engineering works.

Specific experience of the auxiliary inspector in road safety inspections.

General experience of the auxiliary inspector in road engineering works.

Note: Specific experience in performing RSA or RSI should be assessed through prior contracts or through billing analysis. This should include the number of Road Safety Inspection contracts completed and experiences in the region, country or locality.

B **Quality** of the methodology and the proposed work plan.

C **Qualifications** of the lead auditor (inspector).

D **Value** of the proposal.

Weights may be established to evaluate these factors, so the distribution of points on each factor should be objectively defined, with the understanding that proposals that do not meet the minimum requirements established in these terms of reference should not be considered. As an example, the following weights are proposed, based on a total of 100 points:

* Quality of the methodology and proposed work plan: Between 0 and 10 points.
* Qualifications of the leading auditor (inspector) between 10 and 20 points.
* Experience: Between 30 and 40 points.
* Value of the proposal: Between 30 and 40 points.

5.2 ANNEX 2

PRACTICAL EXAMPLE OF AN RSI

In order to inform a practical way in which the concepts, criteria and process of the RSI are applied, this annex presents an example of an RSI report.

5.2.1 Introduction

The road is 86 km long on wavy, mountainous and steep terrain. It is a high-order road that connects sectors of great agricultural and industrial potential, with average daily traffic exceeding 8,000 vehicles/day, on a single road.

It is paved in its entirety. Currently, extension work and studies are being carried out to build a second road.

Scope

The RSI covered the total length of the road and was carried out in both directions. All potentially dangerous road elements were reviewed.

Objectives

For this study the following objectives were established:

General Objective

To carry out a road safety inspection of the transportation corridor, for a total length of 86 km, for the identification of the potential incident risks and to propose general recommendations that contribute to the reduction of road incidents.

Specific Objectives

* Review the geometric specifications of the road, signaling, the environment and operating conditions of the road, from the point of view of road safety.
* Identify the factors that may constitute a risk for road users.
* Formulate general recommendations (related to the road) that contribute to the prevention of the occurrence of road incidents or to minimize negative effects.

Project Description

A **Basic aspects of location** The route extends between p. k. 0 + 000 to p. k. 85 + 600

B **Special road conditions**

I The first section runs through a primarily rural area, with pedestrians and some populated areas on the edge of the road.

II This is a road with significant geological and topographic stability difficulties, with frequent landslides that require constant road work.

III According to the type of terrain it can be classified by sections in wavy, mountainous and steep terrain. Its topography is relatively rocky during the first 25 kilometers, then it changes to steep until km 70 and then it moves from wavy to flat topography.

IV In regards to the cross and longitudinal slopes of the road, there are sectors of strong inclination that influence the operating speed according to the direction of travel.

V The surface can be classified as good, paved in its entirety with asphalt mix except for the sectors with rigid pavements in tunnels and some short sections that are paved with cobblestones.

VI Most of the road has two lanes, with three-lane ascent/descent sections and some crossings at intersections that have a road division and four lanes.

VII The width of the road and the berms are not constant, specifically due to bridges, where lateral visibility is reduced. The berms are also not constant in tunnels or in the sections with a third lane.

VIII Since it is a road without a central separator, there is risk of frontal and lateral collision through the intersection zones between lanes. Head-on collision becomes more dangerous at speeds greater than 60 km/h and with poor visibility, characteristics that are frequently found on the road.

IX Side collisions are mainly caused by the perpendicular merging of vehicles, when there are no acceleration and deceleration lanes which can become obstacles for vehicles that come at speeds greater than 60 km/h and that do not have sufficient visibility or stopping distance to avoid collisions, a situation that is critical on the road due to the large number of uncontrolled accesses.

X There are population crossings that directly affect traffic and vehicle operation speed, for which special sign sites should be considered.

XI The road does not have free or forgiving areas for the eventual lateral exit of vehicles.

XII The operating speed was measured by the route manager in 39 stations located along the road and in both directions of traffic flow.

XIII Speed bumps are used in populated areas and with pedestrian flow, which can be detected in the map delivered by the road manager. These places were considered as special areas where speed reduction measures and their corresponding transition zones should be placed.

5.2.2 Inspection Activities

For the development of the RSI the following stages were completed:

* Inspection planning
* Execution of the inspection
* Inspection report

These stages were developed according to the following activities:

Preliminary activities

A **First Meeting**

A previous meeting was held with representatives of the road administrators. The lead inspector explained what is and is not an inspection, the basic principles, the operational form and the work of the inspection group. In this meeting, the scope of the RSI was defined, the communication channels, the documents to be delivered by the person in charge of the road and the execution plan were addressed as well as a few other minor topics.

B **Receipt and Subsequent Review of Existing Road Information**

The following information was received:

I Record of detailed plans of the existing road with horizontal geometric information.

II Traffic and incident records of the road.

* Elements and traffic conditions, traffic volumes, vehicle composition, users, periods, days and hours of maximum demand.
* Road incident information and identification of critical incident sites.

III Record of vertical signs, with speed limits.

IV Register of road access points.

Road Recognition

A visit to the road was made, in which day and night tours were conducted.

To begin the inspection process, the inspection team met with the road administration's work groups, the work plan was adjusted and teamwork dynamics were defined.

The inspection group traveled the route in its entirety, stopping at the sites where photographs and field measurements were taken to serve as evidence of the inspection.

Measurements of the height and characteristics of some safety barriers (metal fenders) installed were made and recorded. Visual information was complemented with the recognition and measurement of existing elements that affect road safety. Vehicle operations were observed in detail during incorporation and exit maneuvers and while crossing through towns or urban areas. An analysis of the sites that register high incident rates was performed, according to the statistics provided for the study.

Information Analysis

With the information provided and the information obtained during the field visit, the geometric and sign designs contained in the plans were reviewed, to analyze incident rates in the last two years.

The information was evaluated taking into account a checklist based on the following inspection criteria:

* Standards for compliance with geometric design standards.
* Visibility and operability of all geometric elements.
* Need for additional signaling or modification of the current signs.
* Current state of the road surface.
* Signs and road adjustments taking all users into account: cyclists, motorcyclists and pedestrians.
* Concordance between traffic conditions and traffic signs
* Road influence in the continuity of the adjacent road network and identification of the safety needs of all road users, pedestrians, passengers and drivers.
* For the analysis of the geometric design, compliance with standards and requirements established in the following documents was taken into account:
    * The geometric design manual for roads.
    * The road marking manual.
    * American Association of State Highway and Transportation Officials - Aashto (2001).
    * Roadside Design Guide. Washington, USA Federal Highway Administration (2001). IHSDM Roadway Model.

Checklists

To carry out the inspection, the checklist was used in order to verify the inspection criteria, to ensure that no aspect was overlooked.

Information Processing

At this stage the following activities were carried out:

* Review of geometric characteristics and compliance with design standards.
* Processing of speeds measured to obtain the operating speed profiles.
* Analysis of the consistency of geometric design.
* Detailed inventory of road signaling, demarcation and review of compliance with standards.
* Inventory of road elements that may represent a potential danger to users.
* Determination of critical incident sites.
* Incident rate analysis and determination of threat levels, vulnerability and incident risk.

Preparation of the RSI Report

This document registers the procedures followed, inspection findings and results. Also, general recommendations are made.

RSI Final Presentation

Results will be presented to the audited company. Inspectors will comply with the principle of confidentiality at all times.

5.2.3 Description of the Findings

The following tables show a description of RSI findings, classified by subjects.

Table 19
Description of Findings

ROAD SAFETY INSPECTION	DAY	MONTH	YEAR

ROAD: Population A – Population B
ROUTE: Number 1 A
TYPE: First order
LONGITUDE: 86 km

DESCRIPTION OF FINDINGS AND RISKS

1 Analysis Of Accesses

A Accesses to service stations

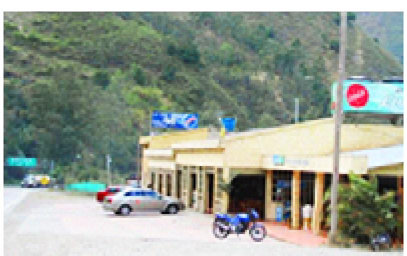
Exits to service stations do not have deceleration and merging lanes; there is a cross-linking of vehicles, which generates a high risk of lateral collision; drivers use the surrounding areas as parking spaces which prevents adequate visibility for vehicles entering and leaving, blocking passage and forcing road users to suddenly decrease the speed of operation. In some cases they are located in curves where there is little visibility to enter the road again which does not comply with the regulations in force for the construction of accesses.

B Accesses to car washes

These businesses are located on the side of the road, and do not have adequate safe exits or entry accesses. They have insufficient parking areas, and there is a high concentration of people working in the area. This creates increased risk for vehicles that normally circulate along the road, because car washes reduce the width of the berms and visibility, which is unsafe for pedestrians.

C Accesses to business by the side of the road

Most restaurants, workshops, etc. do not have acceleration and deceleration lanes, generating risk of lateral and rear end collisions, which encourages vehicles to park in berms and gutters or invade the traffic lane. This also encourages vehicles passing through to invade the opposite lane to overtake those who are parked, and in the opposite direction generates left turn stopping. The risk is increased by the pedestrian crossing or by their longitudinal transit, some businesses have a parking area, but do not have safe crossing or shelters for vulnerable users.



D Other accesses

Along the route, a series of potentially dangerous accesses to properties and homes were observed, which, in addition to not having merging lanes, are located in places with low curve visibility and followed by a countercurve. Also, there is inadequate construction of rigid ditches with curbs, in some cases perpendicular to the road, which can cause a vehicle to be forced off the road. Another additional risk caused by indiscriminately located access points is crash guard discontinuity (to allow access to the premises) which affects the anchor that allows containment and redirection of vehicles in the event of a possible collision. The risk identified on p. k. 19 + 250 is of critical importance, because there is a merge and a cross-linking in a sector with a 9.96% slope, which increases the speed of vehicles that are descending.

Next, specific information on some accesses to properties which represent a greater risk:

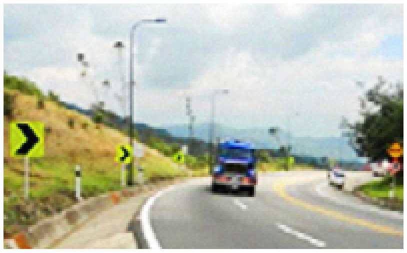
2 Design Consistency

A Dangerous road curves

The road has 152 horizontal curves which limit the operating speed to less than 60 km/h and among these, 15 curves that limit the specific speed to 40 km/h. The combination of degree of curvature greater than 100º and small radii can be observed in five curves which can be dangerous when driving at higher speeds than allowed. In the p. k. 29 there is an area of dangerous curves, some with no visibility. It was also observed that the crash guards have no continuity and that there is no link between flexible guards and rigid barriers (in this case New Jersey type). They do not work as a containment system.

B **Curves without gauge widening**

In the p. k. 9 + 000, the lack of gauge widening in curves creates an overlap of the vehicles over the demarcation lines and the invasion of the opposite lane or the berm, as can be seen in the photographs.



p. k. 4+480

p. k. 9+000

3 Signaling

A **Lack of information**

Informational road signs available do not describe all destinations, for example, there are no signs indicating the exit to a specific town.

B **Maintenance of signals**

In the p. k. 3 + 120, deteriorated signs and non-pruned trees are observed, which decreases visibility in vertical signs, preventing driver legibility.

C

Functionality of signals

In signs located in the intersection on p. k. 6 + 000, there is a sign which indicates an approaching roundabout. However, the intersection is not a roundabout.

D

Location of signals

The guide sign is installed over the intersection. The sign should be placed repeatedly and previously, since there is a left turn without a deceleration lane, which causes drivers to read the sign in an untimely manner, being forced to break in the lane they are circulating in, which generates queues. Additionally, the exit is in the middle of a horizontal curve, a situation that restricts driver visibility and generates high risk.

E

Safety devices

There are no devices to warn about oncoming obstacles, nor the demarcation of approaching a road bifurcation.

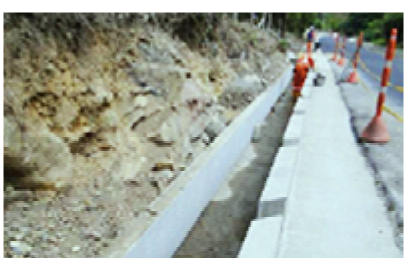
F Location of signals

A sign indicates a dangerous curve to the right, but is located in the middle of the horizontal curve to the right and then comes the countercurve to the left. In this particular case, the inter-tangency must be reviewed to determine if the curve-countercurve signaling applies

4 Sites Of Potential Incidents

A Ditches

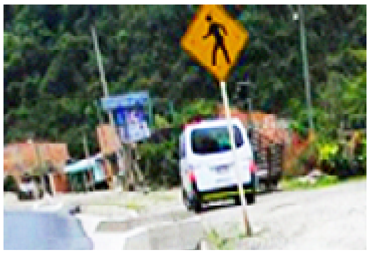
Triangular ditches with lateral slopes between 30% and 40% were found located next to narrow berms that forced vehicles to stop so as not to be exposed to risk by the ditch, as can be seen in the photographs. This parking practice, in addition to affecting the pavement structure, by reducing the contact area between the tire and the surface, can cause vehicles to overturn.



On p. k. 45+000 there were 75cm long depth canals next to the road, with 30 cm curbs and water passage slots. The width of the berm is 80 cm. These curbs become an obstacle, so when they are hit, they produce overturn. If more hydraulic section is needed, then the ditch can be covered with a grid so that it can be crossed over safely.

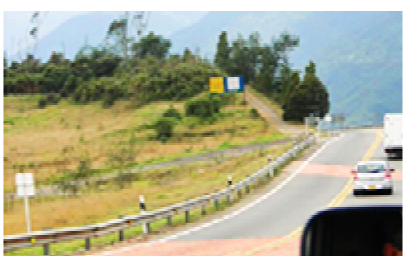
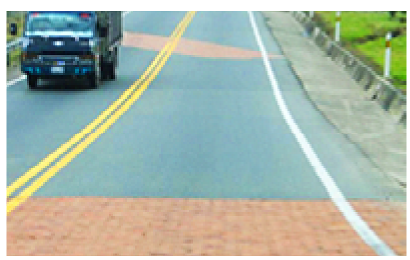
B Ditch ramp

Due to the large number of residential and commercial properties adjacent to the road and old roads, a wide variety of ditch ramps have been built, which are challenging for vehicles that circulate along the road. The aggressiveness of the ditch ramps is greater the closer they are to traffic lanes.



C Road surface differences

At several points along the road, cobbled red pavement is used due to geological instability that constantly deforms the surface. This causes vehicles to suddenly slow down due to the change of regularity of the surface, becoming a virtual speed reducer, which also reduces the possibility of frontal crashes. However, rear end collisions can increase due to sudden breaking. There are prevention signs that alert drivers of this situation.

D

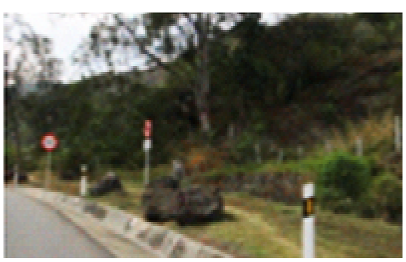
Trees

In the lateral zone of the right of way there are leafy trees with diameters greater than 10 cm. They can constitute dangerous obstacles for the occupants of vehicles out of control, with potential risk of incidents due to collisions with fixed objects. In sectors with operation speeds that exceed 60 km/h, the probability of impact due to swerving off the road increases and, consequently, the greater severity of collisions against fixed objects. These trees must be removed, replaced or protected with safety barriers, in order to eliminate the possibility of collision with a tree or at least minimize the magnitude of such an incident.

E

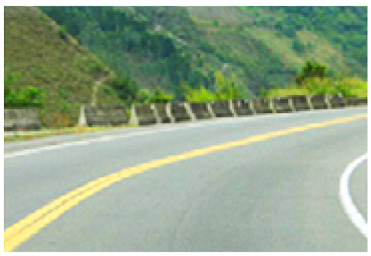
Stones

There are large rocks on the right of way and within the 9.0 m strip of the lateral zone, which constitute dangerous objects that can collide with out of control vehicles creating a high risk of incident due to collision with a fixed object. Removal is recommended. Road obstructions constitute hazards that should be removed whenever possible; however, when they cannot be removed, their presence should be made known to users.



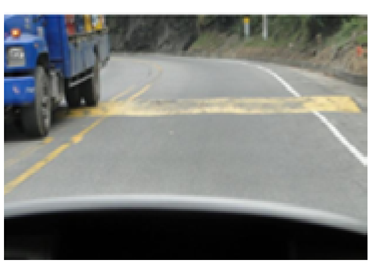
F Walls

At several points at the edge of the road, very short barriers have been installed mimicking barriers known as New Jersey. They do not function as redirection systems, nor containment because they are not interlocked and thus, are not working under tension. Their presence as lateral guidelines is potentially dangerous, since if they become fixed objects close to the road which, if struck from the front or from the side, can cause serious incidents. In some cases, behind these barriers there are negative slopes with deep inclination, where barriers and vehicles can be dragged, increasing the severity in case of a vehicle swerving off the road in those sections.



G Speed bumps

The placement of speed bumps, intended to reduce speed, must be accompanied by adequate signs which include, in addition to vertical signs, an increase in speed-bump visibility using paint and lighting, if possible.

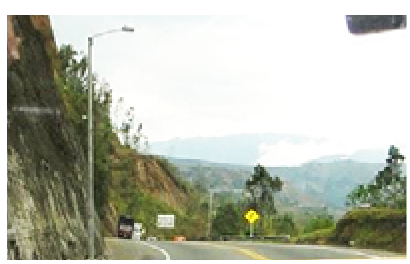


H Manhole cover obstructions

There are frequent manhole covers that protrude more than 10 cm above the berms and are very close to the road surface, which constitutes a hazard. It is recommended that these manholes are relocated further away from the road or are redesigned to make them transferable to avoid overturns in case of impact. In these cases, the use of grilles that cover the gap generated by the sewer construction is recommended.

I Poles near the road

In the p. k. 5 + 900 there is a lighting pole near the cutting slope that reduces the amplitude and visibility of the curve and becomes a dangerous object for the occupants of vehicles leaving the road.



Information poles over the berms may become dangerous objects for the occupants of a vehicle if they are sticking out of the road. This causes a high risk of collision with a fixed object.

J Metallic rails or safety barriers

In several points of the track there are metallic rails that have not been designed, or placed technically to function as redirection and containment systems. Metallic beams are semi-flexible elements that do not work for frontal impact stop, but their effectiveness is based on mechanical tension which absorbs part of the kinetic energy of the vehicles that impact them.

Many sites are observed in which there is no continuity and, on the contrary, there is interruption in the transmission of efforts which makes them inoperative because they lose functionality. Very short lengths fail to develop the necessary distances for anchoring which must be a minimum of eight (8) posts and 64 bolts to dissipate the required stress in case of impact.

Many containment barriers have the possibility of hooking, so they have been placed with overlaps contrary to the direction of traffic or because they do not have the necessary separators to provide the working width.

Most of these metallic barriers do not have suitable terminals, because they use a fish tail. This element has been reevaluated in many parts of the world, because they generate the so-called knife or "spearhead" effect when introduced in the front part of the vehicles and penetrate, in some cases, to the passenger compartment, which compromises their safety.

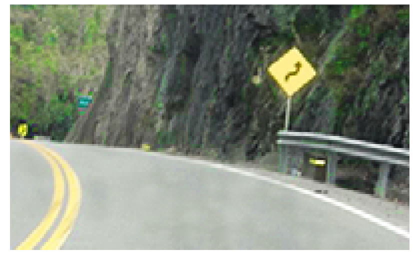
Also, there is no use of transition elements for rigidity change or energy transfer between different containment systems. For example, when transitioning from walls to metallic rails, or between these and bridge railings. Each element acts in isolation with the consequent danger of impacting the transition zone.

There is a metallic barrier at 0.75m height (p. k. 5+280) without a proper working area, since the first eight poles are anchoring poles. This may be to direct the flow and not to contain it, since there is a low chance of exiting in this location. The need for this barrier should be reevaluated.

On p. k. 15+180 there is a very short metallic barrier. It starts on the curve and it does not provide any safety to the vehicles that may crash on this location. →

On p. k. 18+200 there is a rail without a barrier nor poles. The lateral zone is flat, with curbs that are transferable, with the exception of the manhole covers and the channeling of the waters on the starting point. It ends on a “fish tail” device, going the same direction as traffic that the spear effect can cause. Its use may be reconsidered since it may not be necessary.

On p. k. 21 +100 there is a metallic barrier that delineates the manhole cover, with a short longitude (3 bodies of 3.81 m), which does not guarantee its operation as a containment system.



In some cases it was observed that below the metallic barriers, curbs over 10 cm height were built, which prevents the normal flexibility of the barriers and may produce sudden stops with impacts to the occupants of the vehicles.

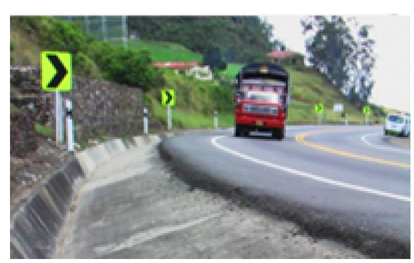
On p. k. 24+460 the curb is placed before the barrier, which prevents that vehicles heading in the wrong direction approach it. This situation recurrs on different sections of the road.

K

Slopes between the road and the berm

Due to the continuous re-paving, the height of the slope increases and the slope with the ditch becomes greater. An unevenness of 10 cm or more is dangerous for a vehicle that unexpectedly leaves its lane, especially in places with horizontal curvature where the risk of swerving off the road is increased by the centrifugal force.

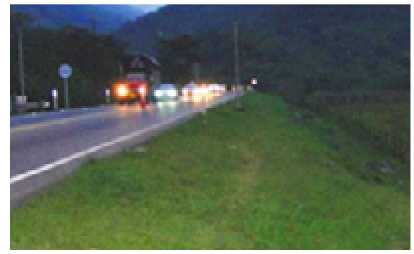
On p. k. 7+700 there is dangerous unevenness between the road and the green area (>10 cm).



L

Embankments

Most of the embankments have 2:1 slopes, which are not transferable or recoverable. If a vehicle swerves off the road it can overturn and crash against objects located on the side. It is recommended that embankment slopes greater than 3:1 and over one meter high have redirection and containment barriers.



M

Intersections

There are difficulties and delays for the turn at this intersection, due to the high vehicle volume, which constitutes a danger for users. The functionality of the intersection should be reviewed.

5.2.4 Conclusions and Recommendations

The current infrastructure has a single road with bidirectional traffic, which increases the risk of incidents due to frontal collision where a driver is driving in the wrong direction in their opposite lane, with the aggravating factor that the road has a high percentage of heavy vehicles traveling in in both directions. The road is generally in good condition, alignments have been improved, tunnels and viaducts have been built which has contributed to the expansion of the road space and the reduction of travel times for users. The road has a pleasant appearance due to the cleanliness of the circulation areas, berms and lateral areas.

During the visit, there was climatic variation on the road: In the morning there was fog, sun at noon and clear weather, and in the afternoon rain. Day and night tours were conducted, which allowed us to observe: (i) that surface drainage is acceptable because there is no waterlogging or accumulations of water that can reduce the coefficient of friction between the road and the vehicles; (ii) that there are sections of the road with very good reflectivity and lighting; and (iii) that traffic actions are presented in varying circumstances.

The functionality of the road is affected by frequent geological and geotechnical phenomena that, associated with the improvement, rehabilitation and construction works in slope protection and road works, reduce free flow mobility.

One of the main concerns for road safety is the control of entrances and exits to the road. Although the person responsible for the road has made an effort to mitigate the negative impact of the accesses, the sheer amount of accesses cannot be ignored, this amount increases the risk of incidents due to intercrossing of vehicles, lateral collisions and rear end crashes, among others.

There are more than 400 direct accesses on the road, entrances of neighboring sectors and entrances to businesses on the side of the road or at intersections with lower hierarchy roads. These accesses do not have acceleration or deceleration lanes, they are potential incident points because they are a single-lane road. By not having controlled access, they lack a secure design. Sometimes, horizontal curves are adjacent to steep slopes and have poor visibility that lead to dangerous maneuvers. The findings highlighted the accesses that present the greatest risks for the road, classified in entry or exit to service stations, car washes, quarries, businesses, population areas and for the operation of the road. Entrances on left turns are a source of concern because they require vehicles to stop in the direct flow lanes, which due to the low visibility in some sectors can contribute to rear end collisions.

As the main objective of this road is communication within a rural area, encouraging vehicles to circulate at high speed without interference from the surrounding environment. It is recommended to minimize the effect of road accesses and reduce conflicts with pedestrians by installing speed bumps. This will necessarily affect road operating speeds.

If a road with unrestricted traffic at the maximum speed is desired, then roads that separate the flows by direction and internal roads parallel to them are needed. Roads that are interconnected through overpasses or that merge into the traffic of the road through controlled accesses at previously designed intersection points. Fast roads must not have controls that force the decrease of speed, generated by the road environment, the presence of pedestrians or by the danger that may be generated in lateral areas when a vehicle leaves the road due to a human, vehicle or road error.

As a summary of the analysis of the consistency of the geometric design of the road in its entirety, the following comments are made:

* There are different traffic conditions in different sections, so it was necessary to divide the road into eight sectors where within each sector homogeneous traffic conditions are maintained.
* S ub-sectors with special characteristics related to the presence of tunnels, tolls, bridges, towns and others that affect the speeds were discarded. However, their interrelation with the rest of the road is taken into account.
* For the consistency study the method of operating speed profiles and the comparison of speed between consecutive elements was used.
* To obtain the velocity profile, different models were evaluated and the one that best adapted to the characteristics of the sector under study was applied.
* According to the results obtained, sectors located at opposite ends (sectors one and eight) do not present problems of path consistency, since they have generous geometric characteristics, with relatively large straight radii and segments.
* The most critical sectors are four and six, which are characterized by having a large number of consecutive curves, small radii and short inter-tangencies.
* 35 sites with geometric design consistency problems were identified, where there are speed reductions equal to or greater than 20 km/h.
* The main cause of inconsistency is due to small radius curves located at a short distance from the end of large radius curves. The location of small radius curves following long lines is less frequent.
* In most of the identified sites, the relationship between radii of consecutive horizontal curves is breached.
* In the identified sites, it is recommended to study the possibility of improving geometry, by increasing the radius of the horizontal curve. As a provisional measure, preventive and regulatory signaling should be installed or reinforced, so that the driver should not suddenly decelerate. The same measures should be applied to access to bridges, tunnels, urban areas, areas with faults or sinking and other elements that restrict speed.
* Most of the identified sites have been detected by the method for setting speed limits and the corresponding regulatory signaling has been arranged.
* In the access and exit of large bridges, it is difficult to improve the geometry because of the costs that this implies. In those cases the signaling must be reinforced or speed-reducing devices that do not represent a risk for the drivers should be used.

As for signaling, there are preventive, informative and regulatory vertical signals on the road, for which the following annotations stand out:

* In some signs there is an excessive number of destinations per information sign, which makes them illegible and confusing.
* The location of the signs must be reviewed to ensure functionality.
* Compliance with the technical design characteristics of the informational signs must be guaranteed in relation to the number of lines, size and shape of the arrows in accordance with what is stipulated in the Road Signaling Manual.

* Some messages in the signals do not clearly represent the geometry of the road. There are signs of narrow bridge, in almost all structures, which indicate that the width of the road is reduced even when this situation does not occur.
* There are electronic signs used in the tunnels which provide information about the conditions of speed and safety that must be followed.

During the visit, the demarcation was observed in good condition and with the colors established by the standard. The quantitative part of retro-reflectivity measures that the paint provides was not the subject of this inspection and, therefore, is not conceptualized on compliance with the minimum values to which the standards refer. During the night tour it was observed that the sectors that were already marked had good reflectivity at plain sight.

Long sections under construction were observed with work signals and others already built that were in service without demarcation or signals, which represents a danger to users. In some sections only the yellow center line was marked and the white side lines were missing.

In the sections with new asphalt that have not completed the required curing days (approximately 30), it is not possible to apply the paint as it would be absorbed in large part and its application would be lost. However, when taking into account that it is necessary to guarantee the safety of users, it is recommended to perform a pre-puncture or retroreflective demarcation of minimum thickness until the definitive demarcation is carried out.

Although the visibility of the road was improved with devices called delineator posts, the installation of studs is recommended, especially in sites such as bifurcations, islands and islets, considering the climatic conditions of fog and rain that are present on the road.

It is recommended to check the places where there are missing obstacle delineators in order to warn the driver of the proximity of a dangerous element and to assist in the channeling of vehicles when intercepting the islets.

In proximity to dangerous sites such as pedestrian zones, special zones and population passages, speed reduction devices of different types have been adopted: speed bumps, virtual bumps, logarithmic spacing lines and studs. In order to improve their visibility, good results have been achieved when installing studs in a perpendicular manner at the beginning of the different reducers and thus helping the comprehension of the message in the corresponding vertical signal. It is recommended that physical bumps should have constant maintenance with good demarcation.

To choose the most appropriate type of speed reducer, it is recommended to carry out further studies that consider the design parameters, the specific environment and the speed desired with these devices. In order to verify if those that are installed are the most suitable or if it is necessary to change them for more efficient speed reducers, for example, rumble strips that exhibit better performance and lower maintenance.

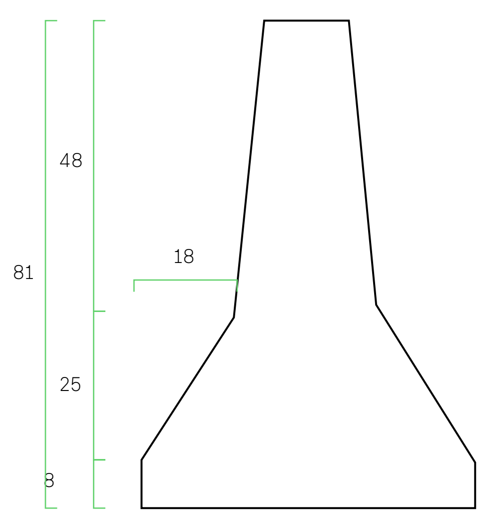
Flexible barriers that represent imminent risks for vehicle occupants, such as the following were observed:

* Inadequate development length which does not guarantee containment and redirection. According to the technical specifications they are approximately 30 m, plus the necessary anchorage lengths.
* Installation errors, which allow hitching when leaving overlaps between posts in the direction of vehicular traffic.
* Insufficient working distance for the flexibility is needed in this type of containment barriers.
* There are not enough anchoring lengths for the metal berms to act efficiently on traction.
* There is discontinuity and interruption of the road barriers, which lowers the effectiveness of this system.
* There are "fishtail" terminals, facing the driving lines, which are known to be dangerous because they can produce the so-called spear penetration effect in vehicle cabins.
* There is a reduction in the height of the beams due to pavement that have raised the level of the slope.

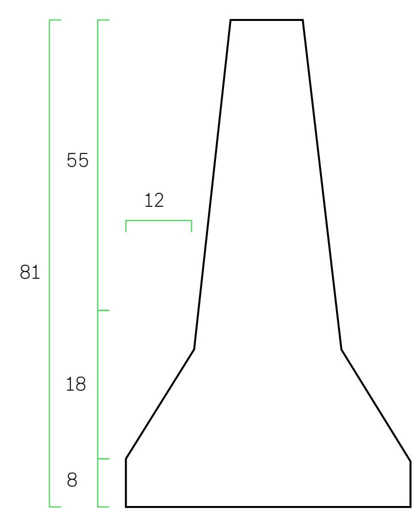
Rigid barriers used on the road mimic the well-known "New Jersey" type wall. They have smooth, completely separate prefabricated walls that do not act as a barrier.

These types of elements in lateral areas do not act as incident prevention systems. They lack the technical characteristics to constitute a containment barrier in the event that a vehicle swerves off the road. There are also dangerous curbs that can generate overturns. The impact of a vehicle against the concrete walls without mitigating the kinetic energies of the movement is decisive in the severity of the incident.

It is recommended that retaining walls or road separators carry the design of the barriers already recommended in the road safety literature, and that their placement follow a complete design that includes, in addition to the placement of sections of fenders or containment walls, the terminal elements, the placement of shock absorbers, reflectors and obstacle delineators at the beginning of the barriers. For rigid barriers it is recommended



New Jersey Barrier



Type F Barrier

Note: measures in centimeters

to carry out type F wall design with the appropriate heights and anchors so that they can contain heavy vehicles.

Installation of vehicle restraint systems is recommended to shield embankment slopes with an angle of less than 3:1 and a height greater than one meter, close to blunt objects that cannot be removed, such as bridge piles or abutments, light posts, large trees, etc. The barrier systems must be as far away from the edge of the lane as the site conditions allow, and removed at least 60 cm from the edge of the slope, in the case of embankments. The AASHTO manual (Roadside Design Guide, American Association of State Highway and Transportation Officials, 2011) presents a series of recommendations and tables for the location, length and characteristics of these containment elements.

Most of the metal restraint systems have heights of 80 cm, but there are walls where the height is less than the established one, thus failing to protect users. The existence of very low metal systems and walls can allow vehicles to pass over them, especially large vehicles, so it is recommended to check their heights after resurfacing the road.

A study is also recommended to determine the places where it is convenient to install frontal impact devices (impact absorbers), such as toll booths, at the entrance to tunnels or to avoid the collision of blunt elements against fixed non-transferable obstacles.

When making combinations of barriers, energy transfer devices and rigidity changes should be used, in order to provide security to vehicles that may impact the transition zones and that, when moving from one containment system to another, the objective of redirection and containment does not end.

A study on widenings is also recommended to determine the curves that require expansion for the safe trajectory of vehicles without invading lanes. The circulation of vehicles on demarcation lines is very frequent, especially in horizontal curves. This measure also requires a review of berms.

Lighting posts or flag-type signals that can constitute dangerous fixed obstacles due to frontal impact, should be collapsible and allow the displacement and reduction of high deceleration produced by the impact of a vehicle on a rigid element. The comments on incident rates on the road are as follows:

* The road is classified as high risk due to the incident rates per kilometer and their mortality.
* Having identified critical sites, a detailed analysis of the incidents must be carried out. This will allow for recommendations that give rise to operational improvements along the route and a decrease in the number of incidents and their severity. These recommendations can be made for the short, medium and long term, depending on the characteristics of the sites and how urgent they are.
* It is essential to carry out an evaluation that allows the effect of the measures applied to be assessed in terms of incidents. That is, a comparison between situations before and after as evidence of improvement.
* For sections with more than 10 incidents, it is recommended to follow the following methodology to determine the most convenient solution:
    * Study the conditions prevailing in the location.
    * Interview residents from places defined as critical.

* Periodically perform speed measurements and compare them with the volume and inventory of the existing traffic signs.
* Prepare incident studies that include condition and collision diagrams.
* Identify the most probable incident causes.
* Formulate solution proposals.

In conclusion, the road has a high potential for road insecurity due to its incident rates and mortality, the absence of free or forgiving areas, its large number of uncontrolled accesses, the geometric conditions of the road and traffic present, and the interaction proximity between the road and humans. The reduction of these indicators requires actions closely related to the conditions of geometry, human behavior and the state of the automotive fleet.

In the road safety inspection, dangerous elements of the lateral areas were found, some of which can be removed, others can be relocated and for the most part can be protected with redirection and containment systems that are technically designed and placed for greater effect.