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PRACTICAL GUIDE FOR ROAD SAFETY AUDITORS AND INSPECTORS

With the support of PIARC

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ROAD SAFETY AUDITORS AND INSPECTORS

IMPRESSUM

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PREFACE

After almost two decades of experience with Road Safety Audit (RSA) Worldwide, this procedure is now recognised as one of the most efficient engineering tools. RSA is a highly efficient and cost-effective engineering tool for improvement of safety on roads. It is much cheaper to identify road safety deficiencies in the process of design than later after construction is completed. RSAs are among the most cost-effective investments a Road Authority can undertake.

With its EU Directive No. 2008/96 on road infrastructure safety management, published in October 2008, the European Union (EU) made a clear decision that RSA will be mandatory for the Trans-European Road Network (TERN) in forthcoming years. This Directive contains another tool called Road Safety Inspection (RSI) on safety deficiencies of existing roads. The RSI is very similar to the process of Road Safety Audit in the pre-opening phase of newly constructed roads. RSIs are essential for the redesign and upgrading of existing roads, and these are done in many countries to give the designers insights and direction for safety improvements. Given that, the purpose of this practical guide is to provide practical guidance to those doing RSAs and RSIs, the examples of typical design deficiencies shown should be useful to both road safety inspectors and road safety auditors.

Unfortunately, there is little systematic application or acceptance of RSA at present in Low and Middle Income Countries (LMICs). RSAs that are implemented are mostly done at the insistence of IFIs funding the road projects and these are often implemented by foreign consulting companies and relate to only the 5% or so of the road network funded by IFIs. Even when such RSAs are undertaken, the resulting RSA recommendations are not always implemented by the road authorities. RSAs are usually not undertaken at all on the 95% of the network funded domestically. Some recent IFI projects have attempted to develop local capacity for RSA implementation in LMICs and have done some pilot projects but there are far too few of these.

Education and training of the road safety auditors remains the weakest point in the entire RSA chain. The reason for this is a relatively short history of RSA, lack of understanding of RSA methodology and procedures, lack of RSA literature in local languages, etc. This *Practical Guide for Road Safety Auditors and Inspectors* with visual examples of typical problems and solutions has been produced to try to overcome such constraints.

Actual traffic situations and design faults have been used to show road safety deficiencies and best international practice and proposals for improvement (treatment). The actual images used to illustrate unsafe designs are drawn mostly from road networks of Europe, Western Balkans, Caucasus and Central Asia regions. However, although the roads and traffic conditions from other regions of the world will produce different images, the underlying typical problems of design and typical solutions will be similar. Local safety auditors and inspectors in these other geographic regions can therefore still benefit from and make use of the contents of this guide. In due course, they should develop their own versions with local images relevant to road networks in their geographic areas.

Since there are many international transport routes (corridors), harmonisation of road standards and elimination of potential risks for the road users are issues of primary importance. These RSA Guidelines are based on the approach used in Road Safety Audit Manuals and apply a conventional approach to RSA/RSI based on PIARC (World Road Association) guidance. This will ensure that similar approaches are applied to RSA/RSI related improvement of road infrastructure (RSA/RSI Reports) in different parts of the World. The approach of these guidelines is to give an overview about typical deficiencies in design and in the existing roads. For a better understanding of unsafe design and its consequences, most typical crash types are dedicated to the related deficiency (see Chapter 10). Particular attention has been given to the attempt to make the RSA Guidelines user-friendly.

There are plenty of illustrations from different countries which will help users to understand common road safety deficiencies easily and to select appropriate treatments.

This document draws on the more comprehensive guidelines and manuals on Safety engineering mentioned in the acknowledgements but deliberately focuses only on these issues of direct relevance to road safety auditors/inspectors and to the road safety reports that they must prepare, including of recommendations for improvements.

ACKNOWLEDGEMENTS

This *Practical Guide for Road Safety Auditors and Inspectors* builds to a large extent on international best practice and the direct experience of the authors and draws upon detailed guidance and concepts from three sources indicated below:

1. “Towards safer roads in developing countries”, a guide for planners and engineers, developed by TRL, Ross Silcock partnership and ODA in 1991,
2. "Road Safety Audit Guideline for Safety Checks of New Road Projects", developed by World Road Association (PIARC) in 2011,
   "Road Safety Inspection Guideline for Safety Checks of Existing Roads", PIARC, 2012,
   “Catalogue of design safety problems and practical countermeasures”, PIARC, 2009 and
3. “The handbook of road safety measures”, written by Rune Elvik and Truls Vaa, in 2004.

The above three sources of documents provide much more detailed guidance on all critical aspects of safety engineering, and the authors recommend that road engineers should use these in planning and operation of roads to ensure safer road networks. We are grateful to the authors of the original documents for sharing their experience via these documents.

This document is aimed primarily at the needs of safety auditors/inspectors in LMICs and has addressed only the main issues of relevance to them and their tasks in preparing safety audit/safety inspection reports. Images and examples used in this Guide were gained within recent SEETO and TRACECA Projects.

The production of the document was coordinated by senior members of SARSA and the following specialists contributed valuable inputs and assistance in it’s development:

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Note
This document has been prepared within limited time and resources in order to offer some practical guidance to road safety auditors/inspectors as quickly as possible. When and if additional resources are available this document will be reissued in an improved version. Readers are welcome to provide comments and suggestions on how the document can be improved.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CADaS	Common Accident Data Set
CARE	Community Database on Road Accident Resulting in Death or Injury
CR	Crash Reduction
EBRD	European Bank for Reconstruction and Development
EC	Expected Cost
EFA	German Guidelines for Pedestrian Traffic
EIB	European Investment Bank
ETSC	European Transport Safety Council
EU	European Union
IBRD	International Bank for Reconstruction and Development
IFI	International Financial Institutions
IRF	International Road Federation
IRSC	International Road Safety Centre
LMIC	Low and Middle Income Countries
NGO	Non-Governmental Organization
ODA	Official development assistance
PIARC	World Road Association
PRI	La Prévention Routière Internationale
RSA	Road Safety Audit
RSI	Road Safety Inspection
RSIA	Road Safety Impact Assessment
SEETO	South East European Transport Observatory
TERN	Trans European Road Network
TL	Team Leader
TM	Team Member
TMP	Traffic Management Plan
UN	United Nations
WB	World Bank
WHO	World Health Organization

Note
In this document where feasible and in line with international practice, we have used the term "crash" instead of "accident" in recognition that these are events which can be prevented or avoided and are not just some random acts of God or luck. In a few cases, historic use of the word accident is still used (e.g. Common Accident Data Set - CADaS).

INTRODUCTION

It is a well-known fact that in almost all countries in the world road crashes are a serious social and economic problem. Different measures and programs have been developed to reduce the number of casualties on the roads. On an international level, the United Nations, World Health Organization, International financial institutions (especially WB, EIB, IBRD, EBRD, etc.) and some specialised NGOs (PIARC, IRF, ETSC, PRI, SEETO, IRSC, etc.) represent high-quality stakeholders for global road safety improvements.

In most countries, road design guidelines are applied which in most cases include road safety issues. Despite this, crashes still occur on new roads. There are several reasons for this. Firstly, design standards often contain only minimum requirements regarding road safety, and sometimes a combination of these elements can lead to unforeseen dangerous situations. Furthermore, it is not always possible to comply with the standards. Sometimes, especially in built-up areas or in steep terrain, there are conditions which make the application of the standards impossible or too costly a solution.

Several techniques and processes have been developed in the last two decades for improving road safety infrastructure. One of them is *Road Safety Audit (RSA)* and another one is *Road Safety Inspection (RSI),* which are now recognised as some of the most efficient engineering tools. With the Directive of the European Parliament and the Council no. 2008/96 on road infrastructure safety management, published in October 2008, the European Union made a decision and instruction that road infrastructure should be an essential component of efforts to improve road safety. Among other Road Safety Management tools, RSA will be mandatory for the Trans-European Road Network in the coming years, and IFIs (WB, EIB, IBRD, EBRD, etc.) are already extending the application of the Directive via their Projects. RSAs will have to be performed not only during the design process of new roads but also ahead of major rehabilitation or upgrading of existing roads to detect existing safety deficiencies.

The undertaking of RSA and RSI is vital for road safety because a formal RSA/RSI Report should identify the existing and potential road safety deficiencies and, if appropriate, make recommendations aimed at eliminating or reducing these deficiencies. With the audit process, it is possible to reduce the number and severity of traffic crashes by improving the road safety performance.

The Project team members who prepared these guidelines have worked in over 100 different countries all around the world and had an opportunity to see different road safety deficiencies on major road networks. The need for such a *Practical Guide for Road Safety Auditors and Inspectors* was identified during the observation of common road safety deficiencies in many different countries. The guide can also be used as a resource to show potential road designers the typical problems that can occur and which they can be avoided by adopting some of the solutions presented in the guide.

Therefore, although the primary aim of the *Practical Guide for Road Safety Auditors and Inspectors* is to be strong and illustrative support for previously trained and future/prospective road safety auditors and inspectors, it can also be used to guide road designers towards better, safer design. The Guide follows the PIARC (World Road Association) approach concerning the classification of identified road safety deficiencies into eight broad groups or categories:

- Road function
- Cross section
- Alignment
- Intersections
- Public and private services; service and rest areas, public transport
- Vulnerable road user needs
- Traffic signing, marking, and lighting
- Roadside features, passive safety installations, civil engineering structures

Apart from typical road safety deficiencies, this Practical guideline contains three separate chapters:

- Temporary signing and marking at Work Zones

- Accident type sketches
- Potential crash reduction via various countermeasures.

Before giving a detailed presentation of typical road safety deficiencies, it is necessary to state a few basic facts about RSA (most of which can also be applied to RSI).

➢ WHAT IS ROAD SAFETY AUDIT (RSA)?

RSA is a well-known internationally used term to describe an independent review of a project to identify road or traffic safety deficiencies. It is a formal examination of a road or a traffic project and can be regarded as part of a comprehensive quality management system. For new roads, RSA is a pro-active approach with the primary aim to identify potential safety problems as early as possible in the process of planning and design, so that decisions can be made about eliminating or reducing the problems, preferably before a scheme is implemented, or crash occur. However, it may also be a reactive approach for detecting safety deficiencies along existing roads as a start for rehabilitation.

The most common definition of RSA is: "*A formal road safety examination of the road or traffic project, or any other type of project which affects road users, carried out by an independent, qualified auditor or team of auditors who reports on the project accident potential and safety performance for all kinds of road users*", as stated in The Road Safety Audit Manual of the World Road Association (PIARC).

➢ AREAS OF APPLICATION

RSA can be undertaken on a wide range of projects varying in size, location, type, and classification. The types of projects that can be audited are categorised under the following headings:

- function in the network (International roads, Main roads, Regional and Local roads)
- traffic (motor vehicles only or mixed traffic with non-motorized or slow agricultural traffic)
- position - location (outside or inside built-up area).

RSA should be undertaken for all new designs of roads and for their major rehabilitation as well.
The RSA could be conducted as follows:

- on new roads, motorways, highways, and other road surroundings/equipment,
- before and during reconstruction and rehabilitation,
- inside and outside built-up areas.

➢ STAGES OF ROAD SAFETY AUDIT

According to international best practice (PIARC Manual), RSA should be conducted in four different stages[1]:

Stage 1: draft (or preliminary) design,
Stage 2: detailed design,
Stage 3: pre-opening of the road and
Stage 4: early operation, when the road has been in operation for some time.

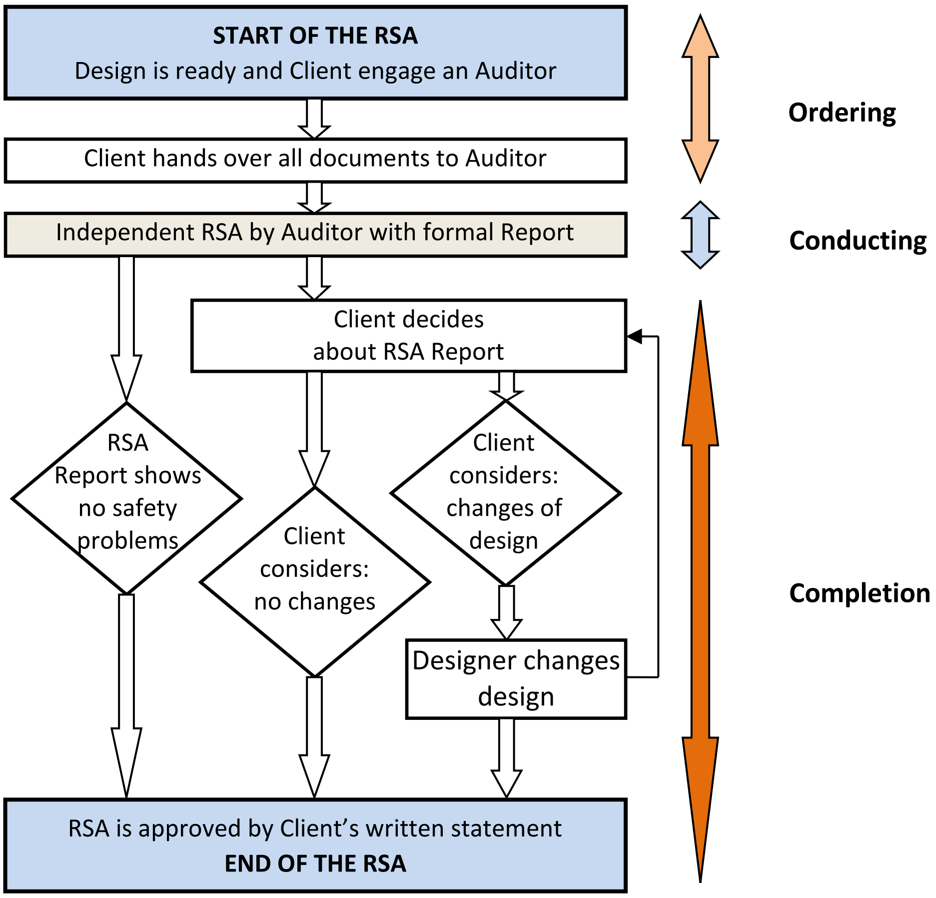
Checklists are normally used (see Chapter References) and at each stage, Road Safety Auditors should provide proposals for improvements.

➢ ROAD SAFETY AUDIT PROCESS

As a relatively new road safety procedure, RSA requires an efficient organisational structure and with clear responsibilities. The general RSA procedure will include three main phases:
1. Ordering, 2. Conducting and 3. Completion.

[1] In some countries an additional stage is introduced - Road Safety Impact Assessment (RSIA) to enable safety checks to be done at planning stage when decisions are made about the route, junction strategy, access controls, etc. before design even starts.

The following chart (Figure I1) describes the typical RSA process.



- **QUALIFICATION OF ROAD SAFETY AUDITORS**

It is essential that the auditor has extensive experience in road safety issues.

The general expectation is that RSA Team Leader (TL) should have completed relevant university education preferably with Master's degree in a relevant topic such as Traffic Engineering and have significant experience in road safety engineering (design) and/or road traffic crash investigation. Minimum requirements for RSA Team Leader should be at least five years of working experience in the field of RSA and minimum 3 RSA Reports written in the last two years. In addition to this, TL should possess a certificate of competence in road safety audits (i.e. License issued by a recognised institution). RSA Team Members (TM) should ideally hold at least a Bachelor's degree and a minimum of three years of experience in road safety engineering (design) and road traffic crash investigation or else have had at least 10 year's experience in in working on safety engineering or related traffic safety fields such as traffic policing.

Auditors should possess driving licenses and have good knowledge of Road Design Standards, Traffic Safety Law, and Law on Roads. The knowledge of other related standards is highly desirable.

To ensure the quality of the audit, auditors should undergo initial training, resulting in the award of a Certificate of Competence (CoC) and should take part in further training at least once every 3 years. The training should include site inspections of existing roads identified as having a high rate of crashes from police reports to get an understanding and picture of safety deficiencies in design. In the case where teams undertake audits, at least one member of the team, apart from the team leader, should hold a CoC. Some variations of qualifications are expected in different parts of the World due to the scarcity of adequately qualified specialists.

It is important to note, that this Practical Guide is not intended to be seen as a detailed design manual. It is just a collection of the most common types of design failures and suggested ways to overcome these.

1 ROAD FUNCTION:

1.1 ROADS WITH MIXED FUNCTION (LINEAR SETTLEMENTS)

Background and possible problems

A mixture of road functions (usage of the road as fast distributors for fast long distance motorised traffic and as a route for slow local traffic) causes one of the major road safety problems especially in Low and Medium-Income Countries (LMICs). This is a typical problem in countries where the development of linear communities along a major road can rapidly cause unsafe conditions and reduce the effectiveness of a nationally or regionally significant route as a result of the local traffic activities and needs conflicting with the through route function of the road.

In such cases, the role of the road in the road hierarchy becomes confused. While the road is passing through settlements (without the existence of by-pass), can it keep its geometry unchanged? Can it be called International/Regional/National road, or does it become a "street" for that section? This, simple planning (designing) and access control mistake of road administrations, can cause tremendous problems in road safety. Once intense development has been allowed to occur, it is then very difficult to achieve safety improvements without major reconstruction on a new alignment.

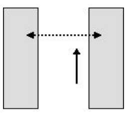
Often even when a bypass has been built, the village, over time, may extends out across to the new road. This is mainly an issue of ensuring effective access control (See Chapter 1.2).

Examples of unsafe designs

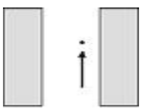
1+1 road with mixed function

2+2 road with mixed function

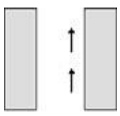
Typical accidents in accordance with CADaS:



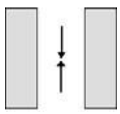
Pedestrian crossing street outside a junction



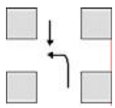
Pedestrian in the road



At least two vehicles - same direction - rear end collisions



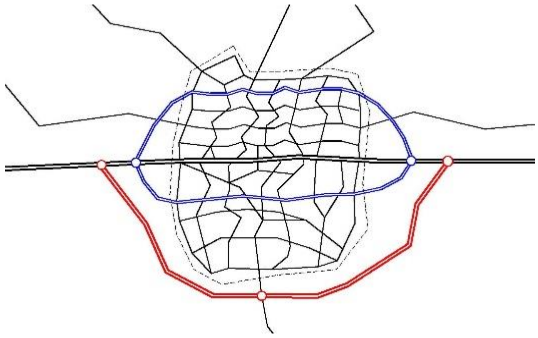
At least two vehicles - head-on collision in general



At least two vehicles - same road - opposite direction - turning left (right) in front of another vehicle

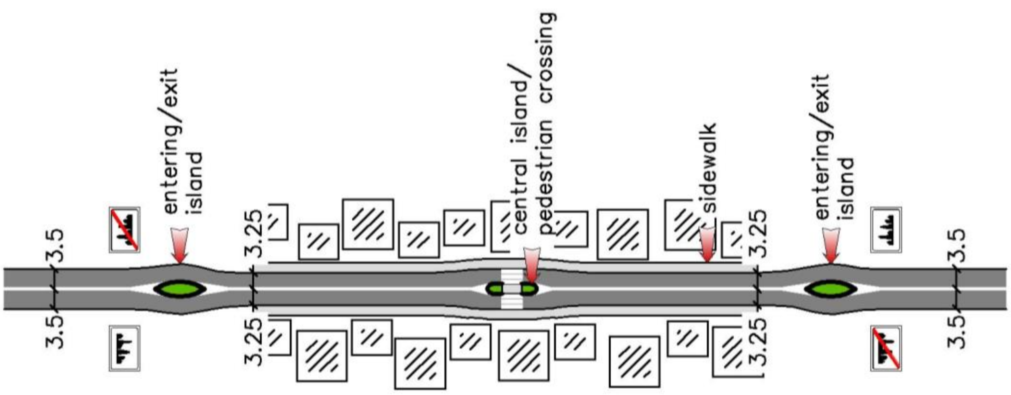
CADaS: Common Accident Data Set (EU Protocol), presented within Chapter 10.

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Separation of slow and fast traffic by small distributor roads either between the main road and house or behind those ($$-$$$) - Construction of by-pass Best but expensive solution with the high possibility that one-day a new by-pass will be needed ($$$) If building a bypass, the opportunity should be taken to downgrade the old road by narrowing it, widening footpaths etc. to deter through traffic using it. The number of connections between the bypass and the new road should be kept low.	**8 - 30 %** **16 - 33 %** (these figures include crashes on old road network and by-pass)	 Example of small distributor roads (blue) and by-pass (red) around the built-up area
2. Grade separation of long distance and local traffic - Full space separation of fast moving vehicles and local transport. Fast road with access control (grade separated intersections, acceleration/ deceleration lanes, etc.) ($$$) - Separation of pedestrians (pedestrian bridges or underpasses with ramps and no steps) ($$)	**20 - 57 %** **13 - 44 %** (including all crashes)	
3. Changing character of road (from mobility to accessibility) – so it acts as a street. The primary task is to “kill” the speed - Building of entering/exit islands or roundabouts ($$) - Narrowing of the road ($) - Implementation of different traffic calming measures ($)	**11 - 47 %** **2 - 10 %** **5 - 12 %** (including road narrowing)	 Example of speed reducing entering/exit island to/from the built-up areas

$-Small amount of investment (mostly short-term measures);
$$-Medium amount of investment (usually midterm measures);
$$$-Significant amount of investment (mostly long-term measures)

Sketches (with dimensions):



Example of road elements within the built-up areas

1.2 ACCESS CONTROL

Background and possible problems

Along interurban roads, strong access control is the basis of road safety. The precise legal regulation of developments along the road in road legislation is necessary for avoiding development of linear settlements. However, access control is also a safety issue for urban roads.

Limiting the number of access points to the road/street is usually done for two reasons. The first is to limit the number of side roads joining a major route, in order to reinforce a road hierarchy and to concentrate potentially dangerous turning movements at a single junction, which must be properly designed for such movements. The second reason is to reduce through traffic in a residential area, by making the route into and through an area tortuous and lengthy so that it deters through traffic.

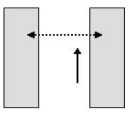
These situations should be predominantly urban, but in LMICs there can be examples of trading posts on major regional/rural routes where a number of direct access points occur at closely spaced intervals. Such locations are often become black spots, due to uncontrolled turning movements and pedestrian activity. By closing most (or all but one) of the accesses, and one of the exits, turning movements could be redirected and concentrated at single points of entry and exit where other additional measures can be applied to deal with them more safely.

Examples of unsafe designs

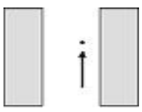
Missing access control (Route 6)

Linear settlement along interurban road

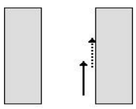
Typical accidents:



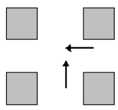
Pedestrian crossing street outside a junction



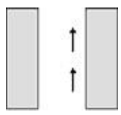
Pedestrian on the road



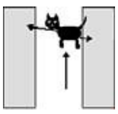
Pedestrian walking along the road



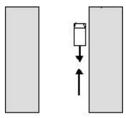
At least two vehicles - crossing (no turning) - different



At least two vehicles - same direction - rear end collisions



Single vehicle accidents with animals

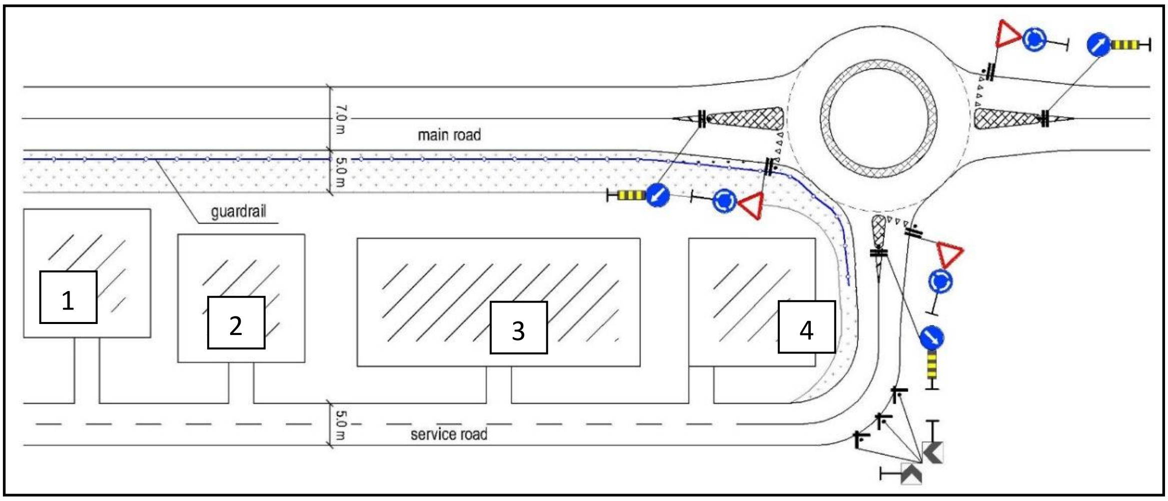


At least two vehicles - opposite direction no turning – reversing

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Closing of direct access to road and construction of parallel service road which will collect traffic and connect to the main road at only a few better-designed junctions ($$$)	**8 - 30 %**	
2. Traffic signage and traffic calming measures: - Traffic lanes narrowing on the main road ($$) - Traffic stream channelization ($$) - Pedestrian crossings with refugee islands ($) - Warning and speed limit signs (reduction in speed limit) ($)	 **15 - 37%** **15 - 37%** **3 - 21 %** **13 - 16 %**	 Access to/from buildings prevented by a wall and only allowed at a single location

Sketches (with dimensions):



Example of parallel service road and roundabout for connection to the main road

(Traffic from buildings 1,2,3,4 not permitted to join the main road directly
but is controlled via the service road and brought to a better safer junction)

1.3 EXCESSIVE SPEED

Background and possible problems

Excessive speed and driver inattention are two of the most commonly occurring contributory factors in road crashes. Because of the different demands, the auditor should clarify if the road section is inside or outside a built-up area. There is also an urgent need to give the driver the relevant information about the situation. That means the details of design, the signing (e.g. city limit sign) or other indication to show driver is entering a different type of area should give the drive a clear picture about the speed limit.

Interurban sections: Long straight road sections, can increase speed (see Chapter 2. Alignment). Reducing speed, therefore, is likely to offer substantial safety benefits. In LMICs speed limits are widely abused, especially on intercity sections, and police enforcement is not seen as frequently on the road. Self-enforcing physical measures are necessary to encourage, or force, drivers to slow down and obey speed limits. Several methods have been developed to achieve this. Self-enforcing measures, such as road geometry to discourage particular movements and speed cameras to deter speeding on intercity roads are possible and desirable treatments/measures.

Urban areas: In a residential area, where city by-passes or separation of long distance and local transport does not exist, through traffic strongly interacts and conflicts with local inhabitants and therefore should be treated in a different way. In this case, the road acts as a local street. Therefore, the concept of speed calming devices (road humps), sometimes called “sleeping policemen”, should be considered as the cheapest and most effective physical measure for speed reduction.

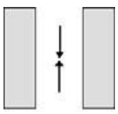
Other measures can be implemented such as chicanes, road narrowing, median island, roundabout, etc. Most of these measures should be implemented at the entrance/exit of the settlement and drivers speed be influenced by the changed condition of the road as it passes through the settlement.

Examples of unsafe designs

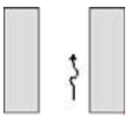
Wide carriageway and high speed

Long stretch section and high speed

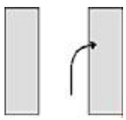
Typical accidents:



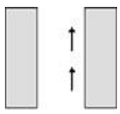
At least two vehicles - head-on collision in general



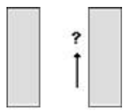
Single vehicle accidents on the road



Single vehicle accident - Leaving straight road - either side of the road



At least two vehicles - same direction - rear end collisions

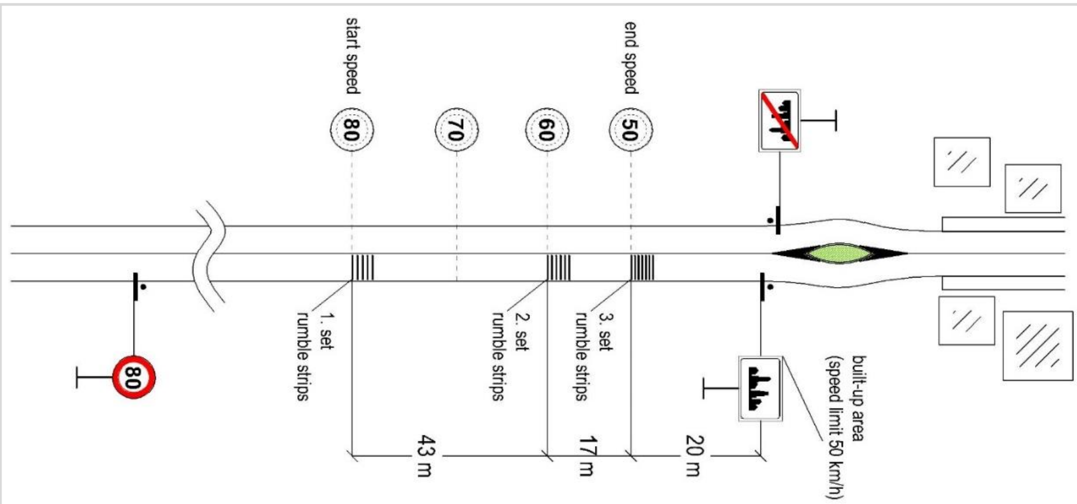


Single vehicle accidents with obstacles - others

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. On interurban road section:		 
- speed limit management (reduction in speed limits) ($)	13 – 16 %	
- lane width reduction (overtaking traffic lane from 3.75 to 3.50 m) (no costs, savings)	15 – 37 %	
- speed cameras ($)	16 – 19 %	
- variable massage signs ($$)	24 – 62 %	
- traffic police speed control (stationary speed enforcement) ($)	5 – 24 %	
- traffic police patrols (mobile forms of enforcement)	12 – 20 %	
2. Through traffic in a residential area (where no by-passes or separation of long distance and local traffic):		
- built-up areas entering islands ($$)	11 – 47 %	
- narrowing of the road ($$)	2 – 10 %	
- roundabout ($$/$$$)	14 – 47 %	
- central (refugee) island ($$)	3 – 21 %	
- rumble strips ($)	25 – 40 %	
- speed humps ($)	42 – 54 %	

Sketches (with dimensions):



Example of rumble strips on an entrance to the built-up area used for speed reduction.
(Rumble strips used to give advance warning before entry point or "gateway" to the urban area where the interurban road becomes a "street" as it passes through the settlement.
Speed reduction can be maintained by sped reduction measures at intermittent intervals on the road as it passes through the settlement.)

2 CROSS SECTION:

2.1 TYPES OF CROSS PROFILES (WIDTH OF THE ROAD)

Background and possible problems

A cross section will normally consist of the carriageway, shoulders or kerbs, drainage features, and earthwork profiles. It may also include in built-up areas facilities for pedestrians, cyclists, or other special road user groups. There is some evidence to suggest that widening lane or carriageway width or widening shoulders up to a certain extent (1 m) is beneficial in reducing certain types of crashes. However, beyond a certain point (1 m) it can have negative effects (users will start using extended width as a regular lane). Dangerous cross sections of express roads and highways are still used in. For example, a four lane road without a crash barrier or two lane road with wide hard shoulders. Drivers can sometimes misuse a road with a wide hard shoulder, as a very narrow four lane road, with disastrous results and severe crashes.

The road surface performance must ensure adequate grip for tires and should be a stable driving surface. In the case of a run-off the carriageway the shoulder must also be stable enough to keep the car in an acceptable position and to make it possible for the driver to guide the car back to the carriageway. That means the difference of bearing capacity of these adjacent areas should be taken into consideration. In several countries, for that reason, gravel stabilised, shoulders are in use as a cost-effective and functional solution. This stabilised shoulder strip is also stable enough to carry trucks. On the other hand, this kind of surface is not “attractive” as (illegal) driving space.

Cross sections, particularly on roads through built-up areas, are often not uniform or consistent. Local developments may encroach onto the carriageway because of the lack of effective planning control. In rural conditions, cross sections may be reduced at drainage structures causing sudden changes in width. Maintenance of the road in full profile affects the safety situation. If a pavement width reduces due to the lack of maintenance (water on the pavement, sand, gravel, debris, etc.) or pavement breaking at the edges effectively narrowing the road width, head on collisions or loss of control over a vehicle can occur.

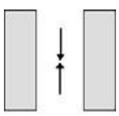
Steep side slopes, introduced for drainage purposes, do not allow a driver time/space to recover in situations where he leaves the carriageway, and thereby add to the likelihood of a crash. Open channel drains can also increase the probability that if a driver error occurs, vehicle wheels may go into the drain and cause vehicle to crash.

Examples of unsafe designs

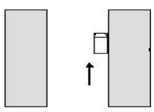
Too wide traffic lanes

1+1 road with wide (asphalted) hard shoulders

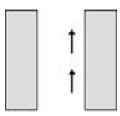
Typical accidents:



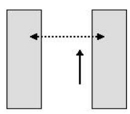
At least two vehicles - head-on collision in general



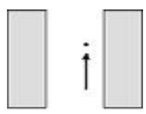
Hitting parked vehicles on the right (left) side of the road



At least two vehicles - same direction - rear end collisions



Pedestrian crossing street outside a junction

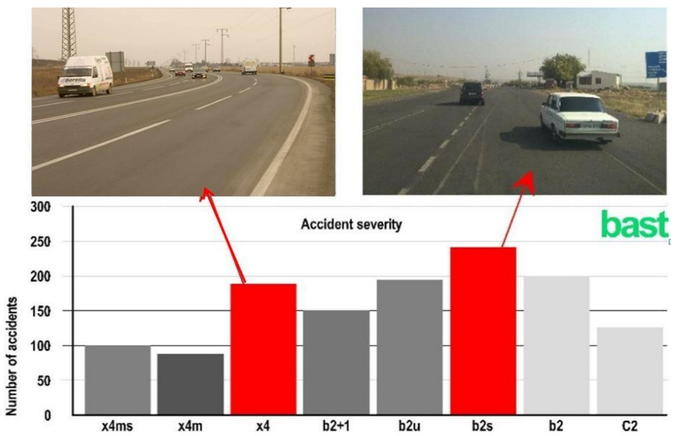


Pedestrian in the road

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Reconstruction of cross section - Changing into one of the safest solutions (motorway cross profile) ($$$) - Introducing of the 2+1 cross-section with the marked median area, where each direction periodically and alternatively is given two lanes. This gives the opportunity of safe overtaking along 40% of the road length for traffic volumes up to 20.000 vehicles per day) ($$) - New median barrier for 4-lane roads without barrier ($$)	**10 – 80 %**	
2. Road improvements (Rehabilitation) - Installation of medians ($$$) - Reducing the lane width (in built-up areas) - Improving slopes – flattening side slopes ($$) - Gravel stabilised shoulder	 **7 – 24 %** **15 – 37 %** **18 – 46 %**	 
3. Better signing and marking - Improved signing – usage of warning signs, speed limit signs and VMS. Use of high reflective and raised markings ($) - Improved markings – usage of central hatching, rumble strips, "ghost" islands, etc. ($)	**10 – 62 %** **11 – 35 %**	

Sketches (with dimensions):



X4ms = 4x (3.00 to 3.75) metre wide lanes + median + 1,5 emergency lane
X4m = 4x (3.00 to 3.75) metre wide lanes + median
X4 = 4x (3.00 to 3.75) metre wide lanes No median!
b2 = 2 x 3.50-metre wide lanes
C2 = 2x 3.25-metre wide lanes + speed limit
b2s = 2x 3.50-metre wide lanes + 2.5m emergency lane: used as four lane roads
b2+1 = 2x 3.50 metre wide lanes + an overtaking lane alternatively used (regulated by markings, plastic poles, or barriers)

Example of cross section influence on crash severity
(BASt – Federal Highway Research Institute in Germany with example of dangerous cross sections)

2.2 DRAINAGE

Background and possible problems

The safety issues of drainage can be improved in two fields:

Road surface*:* The auditor should check if the design could ensure fast and save pavement drainage. This is an urgent need to reduce the risk of aquaplaning. Critical are the so-called “transition sections”. That means in sequences of left and right horizontal curves the direction of carriageway crossfall must revolve. In fact, there will be a short area with crossfall of 0%. To ensure a sufficient drainage the long fall of the gradient should be there at least 1.5%.

Drainage provisions*:* Drainage ditches are an essential part of all roads, which are not on an embankment and must be incorporated into most highways. They are designed to take up the expected rainfall but can often be hazardous to vehicles that run off the road. Therefore, adequate attention should be paid to the safety considerations of drainage facilities when designing and upgrading highways. Unfortunately, deep and steep-sided drainage channels can result in more damage in the case of vehicles going off the road. In a case of hitting high curbstones with a sharp shape, the vehicle overturn with serious results. This requires an “error forgiving” design of such facilities. Inadequate maintenance and clearing of debris from drainage channels, especially on the uphill side of the carriageway where large volumes of solid material are often washed down into the ditch, can result in water and debris overflowing onto the carriageway. This results in the potential danger of drivers colliding with debris or aquaplaning.

In LMICs, rural roads become the main pedestrian routes between adjacent communities and the absence of pedestrian footpaths forces pedestrians to walk along the road, especially if the drainage ditch is of such type (e.g. deep U or V type) which cannot be used as a pedestrian route. Unprotected U and V type ditches present a hazard to motorised vehicles particularly motorcyclists. These types of drainage should be covered as this reduces problems for vehicles, particularly motorcyclists/bicyclists. Another possibility is to give the ditches a smooth rounded shape.

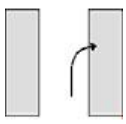
When there are culverts, there are often concrete headwalls which are rigid obstacles.

Examples of unsafe designs

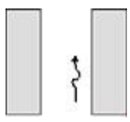
Unsafe drainage system, with headwall

Unsafe drainage system, U-Type with headwall

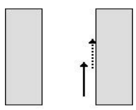
Typical accidents:



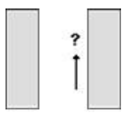
Single vehicle accident - Leaving straight road



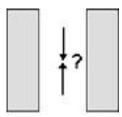
Single vehicle accidents on the road



Pedestrian walking along the road



Single vehicle accidents with obstacles - others

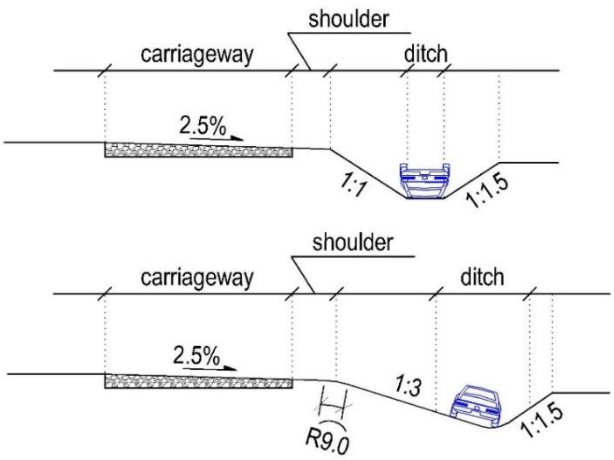


At least two vehicles - opposite direction no turning - others

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Road improvements - Improving drainage system (adding of ditches with gentler slopes; adding of the gutter) ($$$) - Adding of culverts where is necessary ($$$) - Closing of drainage system – piped drainage ($$$) - Usage of special asphalt types at dangerous locations – improving friction coefficient (bridges, etc.) ($$$)	No reliable data No reliable data No reliable data **5 – 55 %**	 
2. Usage of traffic signage and equipment - Marking of edge lines as rumble strips (along the deep ditches, in front of culverts, etc.) ($) - Usage of protective devices (guardrails, etc.) ($$)	**11 – 45 %** **41 – 52 %**	
3. Maintenance of drainage system - Cleaning of ditches ($) - Covering of drainage system ($$)	No reliable data No reliable data	

Sketches (with dimensions):



Steep sided slope increases risks and rollover

Gentle slope increases chances of recovery

Example of gentler slope of ditch and positive effect on traffic safety (preventing rolling over of vehicles)

3 ALIGNMENT:

3.1 VERTICAL AND HORIZONTAL CURVES (CONSISTENCY)

Background and possible problems

In the networks of most LMICs, there is a reasonable percentage of interurban roads with substandard designs, which are not compatible with our modern design principles. It is not possible to have a complete redesign and reconstruction of these road sections. However, in the case of rehabilitation projects it is necessary for the road administration and the auditor to identify the most risky situations and to demand the required improvements.

Safe design parameters consist of two components: Sight Component and Physical-dynamic component. These are usually connected.

Sight Component:
Unexpectedly tight horizontal curves can lead to crashes as drivers try to drive through them at too high a speed. A similar situation may occur on steep gradient where the driver is encouraged or misled (by the approach geometry which is too straight) to think that he can drive at a higher speed than is safe for that particular location. In both cases, drivers are not able to adapt their speed early enough for timely reactions. In addition, the sight distances associated with larger curve radii may also encourage the driver to overtake in unsafe conditions. Poor coordination of the horizontal and vertical alignments can result in misleading visual effects that contribute to crashes and are detrimental to the road appearance. In addition, the skid resistance of the surface should be checked in RSI.

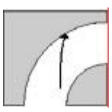
Physical-dynamic component:
- Cross section in curves: The auditor should have in mind if there is a need of widening the cross section in curves. In narrow curves with a radius smaller than 200 m there is a need to have a sufficient widening.
- Steep gradients: Highway sections in mountainous regions generally have sections with steep gradients. Redesign of those sections (by reducing the long fall) is usually impossible, and auditors should think about the alternative possibilities of introducing climbing lanes and arrester beds.
- Transition areas: For transitions, the auditor should obey two safety-related issues - drainage and the usage of spiral curves. Drainage is elaborated in Chapter 2.2. Secondly, a spiral curve can introduce the main circular curve in a natural manner. The spiral transition curve supports a smooth and safe driving manoeuvre and provides a suitable location for the superelevation.

Examples of unsafe designs

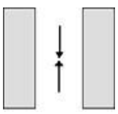
Straight section with vertical curve and sharp left curve after hill

Straight section with sharp left curve

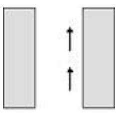
Typical accidents:



Single vehicle accident in a bend - going either side of the road

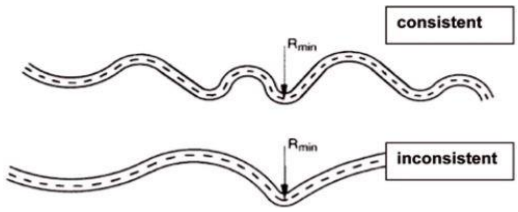


At least two vehicles - head-on collision in general

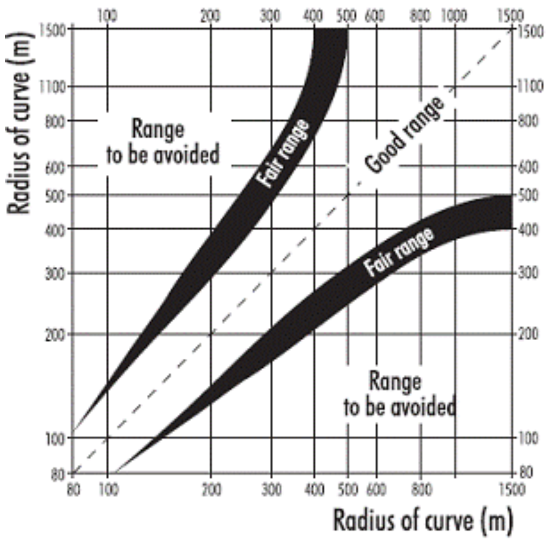


At least two vehicles - same direction - rear end collisions

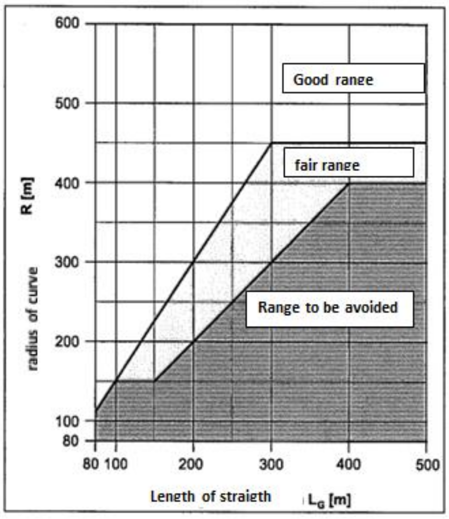
Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustration
1. Reconstruction of curves - increasing the radii of horizontal curve ($$$) - construction of transition (spiral or compound) curve with adequate skid resistance and superelevation ($$$) - reducing the gradient of vertical curve ($$$) - the consistency of alignment (horizontal and vertical curve) ($$$) - Widening of curves (if R ≤200 m) ($$) - Resurfacing of the top layer of pavement in horizontal curves (better skid resistance with a "High Frictions Surfacing Treatment") ($$) - Retexturing of pavement, e.g. with diamond grooving ($) + - if needed climbing lanes - arrester beds	 **8 – 55 %** **7 – 15 %** **5 – 38 %** **17 – 28 %** **NA** **0 – 50 %** **25-40 %** **25-40%** **NA**	 An inconsistent alignment surprises the driver 
2. Improving sight distance in curves - Forward visibility at the insides of curves (open visibility) ($$) - Removing/cutting of vegetation ($)	 **6 – 38 %** **NA**	
3. Better signing and marking - Better signing (including warning signs, chevron signs, speed reduction and overtaking prohibition signs) ($) - Better marking (including lines as a rumble strip) ($) - Usage of protective devices ($$) - Lighting ($$/$$$)	 **13 – 16 %** **11 – 45 %** **41 – 52 %** **17 – 64 %**	

Sketches (with dimensions):



The combination of radii for rural roads



Alignment chart straight/curve

3.2 SIGHT DISTANCE (VISIBILITY)

Background and possible problems

In general, the visibility offered to drivers should be sufficient to identify any necessary course of action and then to perform that action safely. A usual critical requirement is that the driver can stop safely, and this requires the understanding of speeds, reaction times and deceleration rates. Sight distance requirements are thus related to geometric design and speed controls and are inherent in all design standards. Visibility may relate to another road user, or to an object such as a road sign.

The following types of sight are taken into consideration:

a. **Stopping sight distance**–to be mandatory along the whole road section,
b. **Orientation sight distance** –this parameter is not included in every national design guideline. However, since decades is it well known, that the orientation sight has very good advantages for the road safety. In German interurban road design guidelines   it is recommended to the designer that he should have an orientation site distance in most subsections of the amount of the stopping sight + 30 %. The auditor should advise on that direction in his report.
c. **Passing sight distance** – for two-lane roads. In the most national design guidelines, there is a demand of 20% passing possibility in each direction. Nevertheless, in the most cases, this demand is not easy to ensure, e.g. because of limited sight in curves. For important highways, an additional passing lane (alternate in both directions) could be the safe and economical solution.
d. **Sight distance at junctions**

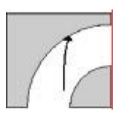
Pedestrians also need to see and be seen, and crossing movements are often concentrated at or near junctions. From human factors research, drivers need 4-6 seconds to respond to a new situation; this means 300 m ahead if the speed limit is 100 km/h or 200m for 80 km/h.
Warning and information signs may sometimes be so sited that they have poor conspicuity, and the detailing of the road may not provide sufficient additional clues as to the hazard or decision ahead.

Examples of unsafe designs

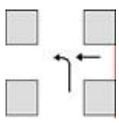
Sharp left curve + optical illusion (secondary road in curve gives perception that road is going straight)

Insufficient site distance in curve

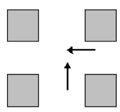
Typical accidents:



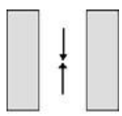
Single vehicle accidents in a bend - going either side of the road



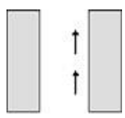
At least two vehicles - different roads - turning left (right) into traffic from the right (left) side



At least two vehicles - crossing (no turning) - different

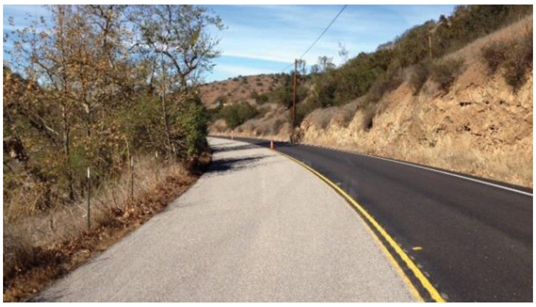
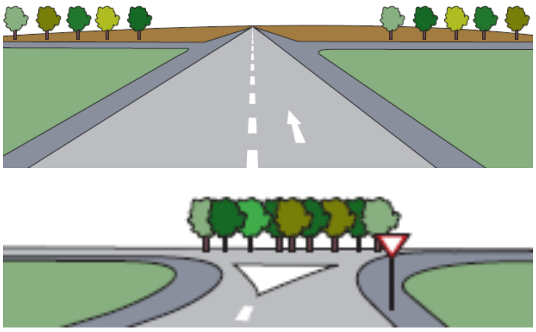


At least two vehicles - head-on collision in general

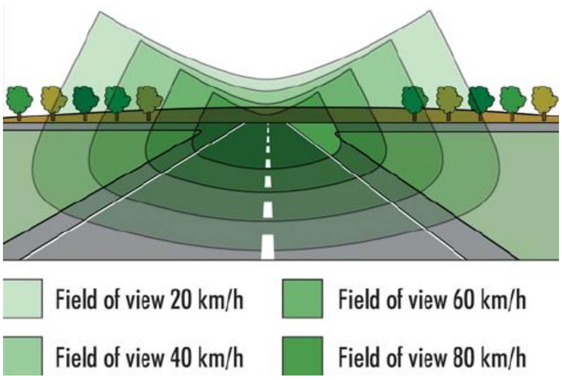


At least two vehicles - same direction - rear end collisions

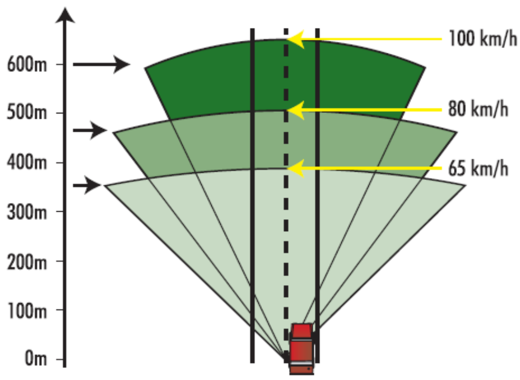
Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Reconstruction of the curve, intersection, pedestrian crossings, etc. - Improved radius and visibility ($$$)	**8 – 55 %**	 Example of improved radius of horizontal curve and visibility in curve
2. Provide sufficient sight distances for adequate driver reaction - Opening of visibility (see sketch at the end of page) ($$) - Enable proper orientation for drivers (e.g. adding of trees at secondary roads which shows that there is intersection ahead) ($) - Breaking the sightline of the driver is important to show that the road is not continuing ahead.	**20 – 38 %** **no reliable data** **no reliable data**	
3. Improved signing and marking - improved signing (usage of high-class reflectivity materials for traffic signs, adding of chevron signs in sharp and hidden curves, using of flash beacons on approach to the pedestrian crossing, etc.) ($) - improving markings (usage of reflective glass beads, usage of nonstandard markings, etc.) ($)	**10 – 33 %** **11 – 35 %**	

Sketches (with dimensions):



Example of speed and peripheral vision



Example of speed and focus point

Conclusion: The faster we drive the further we need to look ahead and vice versa in order to be able to read, understand and react in time to a hazard ahead.

4 INTERSECTIONS:

4.1 CHANNELIZATION OF TRAFFIC FLOWS

Background and possible problems

The designer and auditor should have in mind some general considerations about the road safety of intersections. Golden rules for intersections are: Every intersection must be visible early enough; Traffic regulation must be understandable from the signing and marking; The design should support traffic regulations; Good sight conditions for all users; The geometry has to ensure enough space for the relevant driving manoeuvres.

The intersection should be located in a road section with good visibility conditions. The best place is often in a sag curve of vertical alignment. The minimum visibility condition should be ensured for all legs of the intersection, but this is particularly important for the secondary legs that should give way. The design must be such that the road can easily understand how he must behave. This can be done, for example, by a channelising. In built-up areas, the needs of vulnerable road users are particularly important for road safety. Traffic islands have the added benefit of providing a refuge for pedestrians crossing the road. They also provide a convenient location for street furniture such as signs, street lighting and drainage covers

Channelization guides the driver through the conflict points, provides safe areas for him to stop while making a manoeuvre and reduces conflicts between different flows of traffic. The minimum demand regarding road safety is to have at least separate central turning lanes and traffic island in the secondary leg of the junction. A raised traffic island in the secondary leg will support the need of the give way-regulation. Turning lanes can help to reduce the risks of rear-end crashes.

For high-speed roads with a high traffic volume, road safety often can be increased by grade separation.

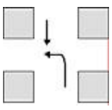
For all other roads, the auditor should bear in mind that in the event of a crash the consequences are often severe with crash and casualty severity depending on the speed of cars. Because of that, it is recommended that the legal speed in the area of the intersection should at maximum be 70 km/h.

Examples of unsafe designs

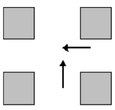
Missing channelisation in junction

Missing channelisation in junction

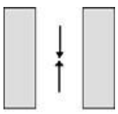
Typical accidents:



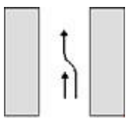
At least two vehicles - same road - opposite direction - turning left (right) in front of another vehicle



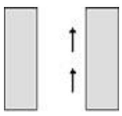
At least two vehicles - crossing (no turning) - different



At least two vehicles - head-on collision in general

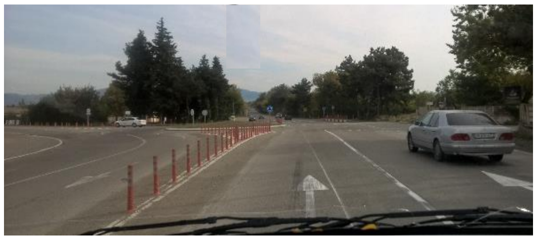


At least two vehicles - same direction - entering traffic

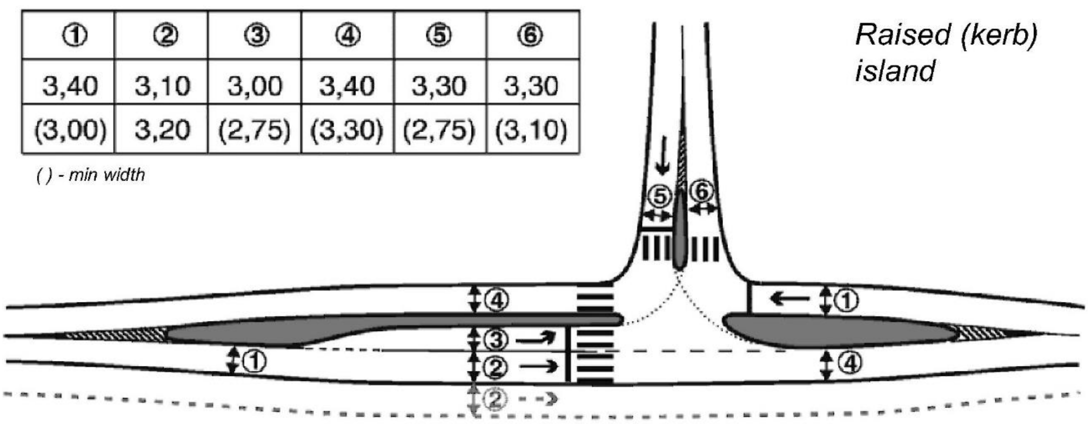


At least two vehicles - same direction - rear end collisions

Possible safe countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Construction of raised (kerb) islands - Local widening (if necessary) and clear guidance of driver with raised (kerb) islands ($$) - Narrowing of traffic lanes (if existing lines are too wide) ($$) - Additional lighting ($$) - Sufficient length for left/right turning lane ($$)	**15 – 37 %** (full channelization at crossroads)	
2. Usage of markings and traffic equipment - Clear marking of traffic lanes for better guiding of drivers ($) - Plastic markers, flex poles and other rubber elements can be used ($) - Advance information signs for lane direction ($)	**42 – 68 %** (full channelisation at crossroads)	
3. Usage of "ghost" island - Different texture of island surface could be used with edges on pavement level ($) - Markings and rumble strips for better guiding of drivers and unpleasant feeling crossing over the island ($) - Reflective studs for the delineation of lanes especially during night time condition ($)	No reliable data	 Example of "ghost" island
4. Separate left turning lanes ($) - Separate lane marked in the centre of the road to provide a safe area for turning cars	10-25%	
5. Traffic signalisation with signalised turning lanes ($$)	25-40%	

Sketches (with dimensions):



Example of channelisation of "T" junction in built-up areas
(Note the “protected” lane for turning traffic where it can wait in safety until a suitable gap appears to allow it to turn)

4.2 INTERSECTION TYPES ("Y" TYPE, ROUNDABOUTS, ETC.)

Background and possible problems

A junction is required wherever two or more roads cross or meet so that vehicles can pass through the junction in ways that are both safe and understandable for all road users. It is important that the junction is appropriate for the site and that it is defined regarding road priorities and legitimate manoeuvres.

Common junction shapes are a T-junction, X-junction and staggered junction and crossroads. If an inappropriate junction type is used at a particular site, such as a "Y" type junction, significant safety problems can occur, including high crash rates, unnecessary delay, and congestion.

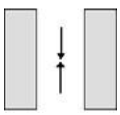
Roundabouts are a very effective form of intersection, as they require all vehicles to reduce speed as the pass through the intersection. They are particularly useful where there are large turning flows or where there is a need to reduce speeds of traffic. The most common problem preventing more widespread use of roundabouts is the lack of familiarity of drivers with the proper use of this type of traffic control. One of the road safety facts about roundabouts is that the number of minor crashes can even increase, but the number of fatalities and serious injuries will decrease due to impact angle and reduced speeds of impact. Roundabout design should be such that approaching drivers sightline straight ahead is disrupted, he should have to deviate to go around the central island and the vehicle should not be able to drive through a roundabout without slowing down.

Examples of unsafe designs

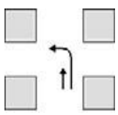
Dangerous "Y" type intersection

Dangerous "Y" type intersection

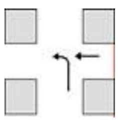
Typical accidents:



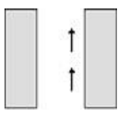
At least two vehicles - head-on collision in general



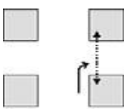
At least two vehicles - turning or crossing - same road - same direction - turning left (right)



At least two vehicles - different roads - turning left (right) into traffic from the right (left) side

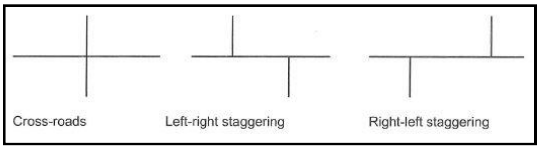


At least two vehicles - same direction - rear end collisions

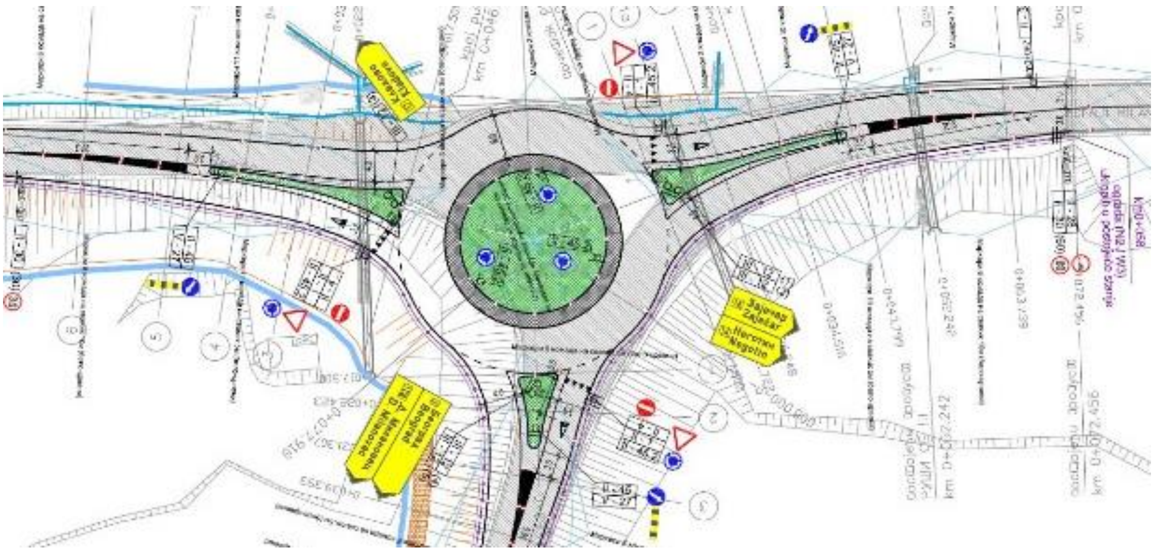


Hitting pedestrian - turning right (left)

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. For “Y” type of junction: - Full reconstruction from “Y” type into “T” ($$$) - Improving visibility ($$/$) - Improving signing and marking ($) - Adding of rumble stripes ($) - Clear prioritisation of main traffic stream by signage and markings ($) - Additional “STOP” sign for minor road approx. ($)	20 - 70 % 5 - 18 % 11 - 35 % 25 - 40 %	
2. For cross-roads with high traffic volume on minor road approach: - Full reconstruction to staggered junctions ($$$) - Adding of traffic signals ($) - Channelization of traffic flows (narrowing of traffic lanes) ($$) - Usage of "STOP" sign on minor roads ($) - Additional traffic (turning) lanes on the minor approaches ($$)	21 - 43% 25 - 35% 15 - 37% 25 - 44%	 Possible forms of junction staggering
3. For roundabouts - Channelization of traffic flows (narrowing of traffic lanes) ($$) - Adding of raised (curb) islands (pedestrian refuge islands and central island of the roundabout which should be shaped like a hill) to break sight lines of approaching traffic Bus bays should be at the exits behind the pedestrian crossing ($$). - Usage of “Give Way” signs at all approaching legs with the priority of traffic in a circle (this is still not a standard solution in some of the Post-Soviet states) ($)	15 - 37% 3 - 21% 3 - 9%	One-circle lane roundabouts are the safest and cost-effective type of junctions up to a traffic volume of 20.000 cars/day incoming vehicles per day within and outside of built-up areas as well.

Sketches (with dimensions):



Example of traffic flows channelisation on approaches to the roundabout

4.3 U-TURNS

Background and possible problems

Policies regarding the provision of gaps in medians, particularly in urban areas must balance the needs of both local and through traffic in terms of connections to local streets and enabling of U-turns. Their number should be kept to an absolute minimum, and wherever possible roundabouts overpasses/underpasses should be provided instead of allowing U-turns. The primary consideration which governs median opening (U-turns) is minimum turning path (that is, the length of median opening depends upon the width of the median and the minimum turning the path of the most massive vehicle allowed on that road). If U-turns are to be permitted they should have protected lanes from which to make the U-turn.

Road crashes tend to cluster at median gaps particularly on dual carriageways mainly due to the conflict between the slow manoeuvre of a wide turn and fast approaching vehicles (usually with high speed) from the other direction and from behind (If there is no protected lane from which to make the U turns).

There is always a conflict between serving the demands of local traffic and through traffic. The poor planning of U-turns is contrary to the interest of any wide-scale area traffic control proposals for removing through traffic from the local street system. The openings are also sometimes provided at locations where due to the horizontal and vertical geometry of the road, the movements of vehicles using the facility are not clearly visible to other road users. Where local traffic dominates, the conflict between local and through traffic gets more serious. This problem is aggravated by poor design standards used for right/left turning lanes which do not offer adequate protection to the turning vehicle.

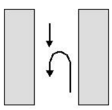
In the case of problems with unsafe U-Turns, one of the possibilities can be the construction of roundabout as a safe solution. Unsafe U-turns can be closed if there is a possibility to construct a roundabout nearby.

Examples of unsafe designs

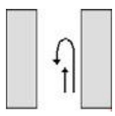
U-turn at high-speed road Danger place for U-turn

Danger place for U-turn

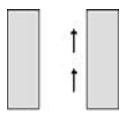
Typical accidents:



At least two vehicles - U-turn in front of the other vehicle

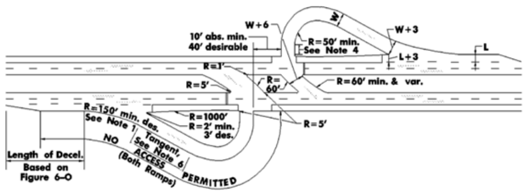
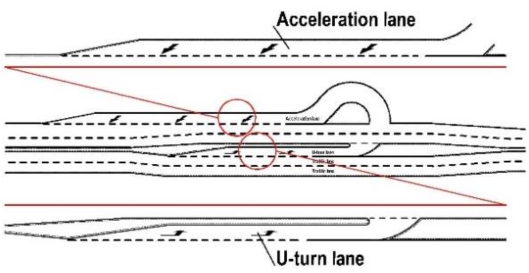


At least two vehicles - same direction - U-turn in front of the other vehicle

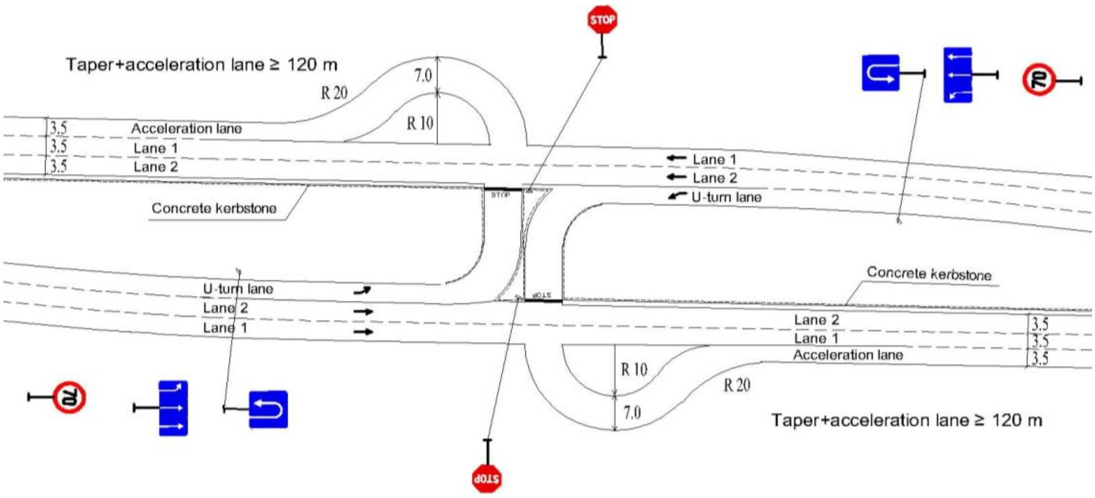


At least two vehicles - same direction - rear end collisions

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Construction of "flyover" U-turns (grade separation of traffic streams) - Changing existing U-turn into safer solution with grade separation of traffic streams ($$$)	**no reliable data**	
2. Reconstruction of cross section (U-turn) - Changing existing U-turn into safer solution ($$$) - Protected deceleration lane for turning vehicle -A short crossing of opposite carriageway at right angle to minimise exposure and then an acceleration lane to join the traffic on that carriageway	**15 – 37 %**	
3. U-turn improvements (Rehabilitation) - Widening and creation of left turning lane ($$$) - Improving U-turn radius ($$) - ITS implementation to reduce traffic speed ($$) - Additional signing and markings ($) - Where ever possible, roundabouts will offer safe U-turning manoeuvres	**4 – 27 %**	

Sketches (with dimensions):



Example of U-turn for both directions
(Note the protected lane for turning traffic to wait in safety, the short exposure when crossing and acceleration lane with hatched area to run in parallel to mainstream until merging can occur).

4.4 RAILWAY CROSSINGS

Background and possible problems

Level, crossings can be hazardous because of the crash severity when a train hits a vehicle.

In some LMICs there are still many railway crossings operated just by warning signs. For various reasons drivers do not stop and give way to trains. Sometimes the visibility/sight conditions are not suitable, the speed of car is too high or sometimes road geometry makes crossings hidden to approaching drivers. Better safety performance can be seen when there are active warning lights and/or barriers (ramps) installed. In the case of automatic or manual ramps, it is recommended that they close the whole width of road, not just half of the road because there are many cases when rail/road crashes occur while drivers are trying to cross the road illegally by zig zagging between the barriers

Sometimes are there additional road safety deficiencies in design (e.g. risks for two-wheel riders, pedestrians, etc.).

For road and railway sections with a high amount of traffic and high operating speeds, the safest solution is grade separation.

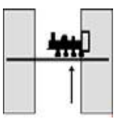
Where large numbers of pedestrians can be expected, it is recommended that special solutions be applied such as footpath crossing barriers)

Examples of unsafe designs

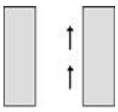
Dangerous railway crossing

Dangerous double railway crossing

Typical accidents:



Accidents between train and vehicle

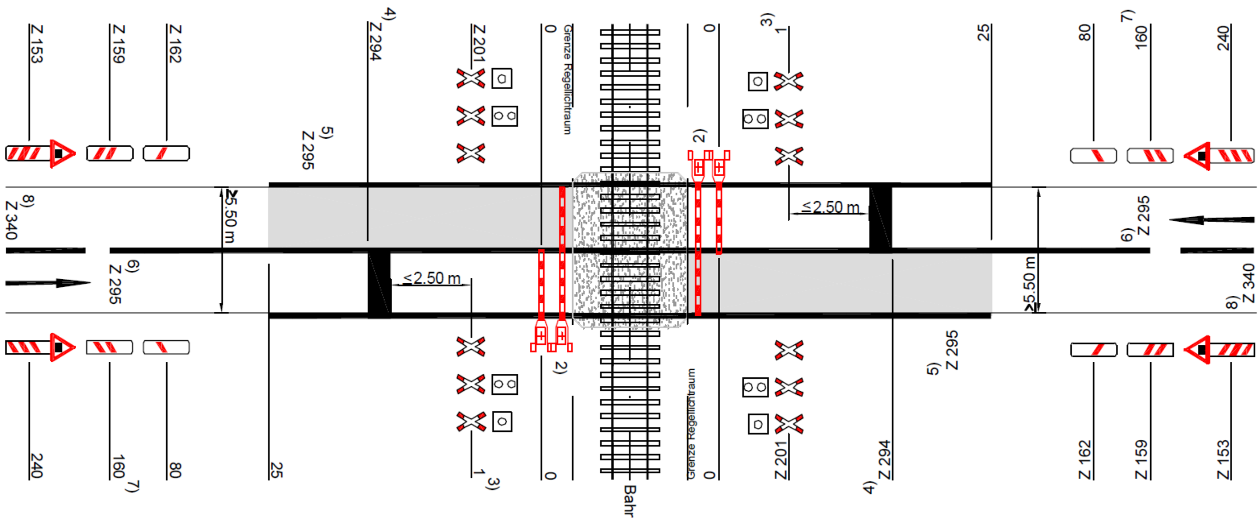


At least two vehicles - same direction - rear end collisions

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Improvements to railway crossings - installing warning lights ($) - installing barriers (automatically controlled ramps) ($-$$) - grade separation ($$$)	**60 % or more**	 Railway crossing with barriers and additional warning equipment  Overpass instead of level crossing

Sketches (with dimensions):



Possible layout (Germany)

5 PUBLIC AND PRIVATE SERVICES

5.1 SERVICES ALONG ROADSIDE

Background and possible problems

Roadside facilities (rest places and petrol stations) are necessary to serve the long-distance traffic between regions and towns (villages). Drivers need to rest at least once every 2 or 3 hours in order to maintain their concentration when driving. It is useful to combine rest areas with petrol and service stations at 30 – 50 km distances. Entrances and exits to and from Service and Rest areas can cause disruption to traffic on the main carriageway if they are not separated well, and particular attention must be given to design and maintenance of deceleration and acceleration lanes. It is vital that sufficient rest areas are provided at around 10 km intervals but not too many to avoid constant disruption of the main flow of traffic by continually exiting and merging traffic. Local farmers may use such rest areas for selling goods. To minimise such activity along the roads vendors should reach the areas from minor service roads behind the service area and be warned that if anyone encroaches to sell on the main road then that layby might be closed off. Local vendors must police and prevent encroachment onto the road.

In the LMICs there are many examples where roads are encroached upon by unacceptable commercial services, or where there are unsuitable rest areas. This is dangerous for all road users, because of the enormous speed difference and a mixture of different categories of road users (sudden vehicle stops and entering the traffic, as well as the presence of unprotected pedestrians on high-speed roads).

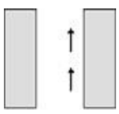
Master plans, land usage, urban development, and restrictions on access to the public road network are key elements for preventing these types of crashes. In good planning system, these types of crashes could be prevented in the early stage of planning, during Road Safety Impact Assessments (RSIA). Effective access and development controls can prevent such unsafe conditions developing.

Examples of unsafe designs

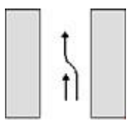
Services along road

Services along road

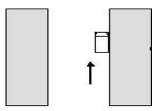
Typical accidents:



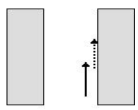
At least two vehicles - same direction - rear end collisions



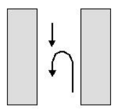
At least two vehicles - same direction - entering traffic



Hitting parked vehicles right (left) side of the road



Pedestrian walking along the road

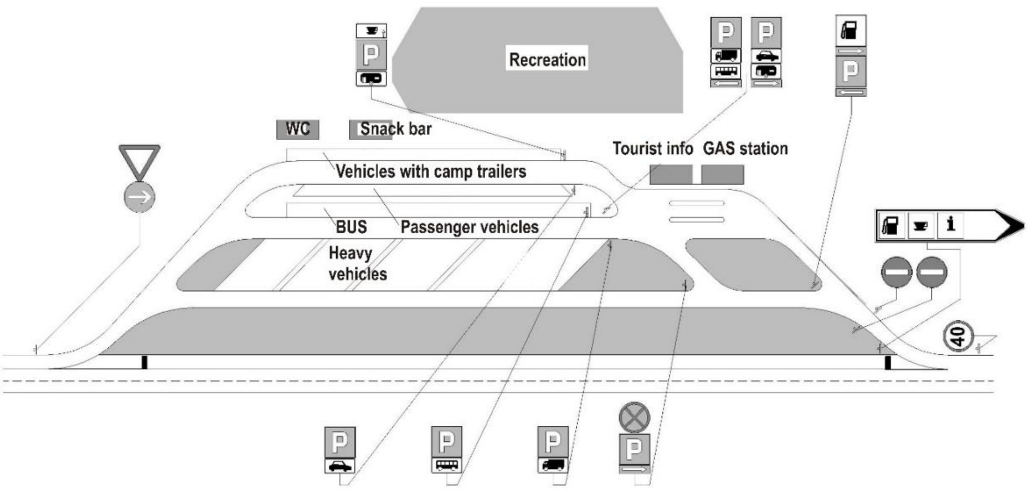


At least two vehicles - U-turn in front of the other vehicle

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Improving entrance/exit to services along roadside - Construction of adequate deceleration and acceleration traffic lanes also at non-divided and rural highways ($$$-$$) - Channelization of traffic flows at entrance/exit ($$)	**15 – 37 %**	
2. Improving parking areas - Separation from traffic ($$) - Adding and remarking of pedestrian walkways ($$) - Adequate position of parking regarding objects and services ($$/$$$)	 **16 – 33 %** **10 – 32 %** **No reliable data**	
3. Improving signing and marking of services along the roadside - Proper signing/marking (speed limit signs, directional signs, wrong way signs, parking places, pedestrian crossings, etc.) ($) - Adding of proper lighting ($$) - Additional installation of guardrails ($)	 **2 – 10 %** **25 – 74 %** **31 – 54 %**	

Sketches (with dimensions):



Example of organisation of Rest area with parking and design of traffic signs

5.2 FACILITIES FOR PUBLIC TRANSPORT (BUS STOPS)

Background and possible problems

In the most of the LMICs, there is a diverse range of public transport modes. Economic factors can result in many of these being unsafe, but often they are the only available modes of travel for the majority of people. In such circumstances, the priorities need to be aimed at limited regulation to ensure that the safety of passengers is adequately catered for through regular roadworthiness screening of vehicles and by having basic minimum standards for drivers and operators providing such services. Drivers are often poorly trained and educated, and road crashes involving public transport vehicles are sadly commonplace with at times, major catastrophes occurring.

In rural areas, bus bays provided with a divider from the main carriageway are often not used by buses, which stop on the carriageway instead. This is because bus bays without dividers are often used by different activities (trading, parking, etc.) which encroach into the bus bay. In urban areas, such bus bays with dividers seem to operate better.

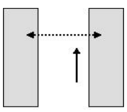
At those stops, conflict can exist between the bus and other vehicles and vulnerable road users such as pedestrians and cyclists. Usually, pedestrian flows to and from Bus stops are not well catered for. Pedestrian crossings on routes to the Bus stop (say 100 m to each direction) are often inadequate.
In discussions regarding the public bus network there is a need to have the safety of potential users more in focus. For example, in some countries, bus stops are located directly on the highway and on the wrong of the villages. The passengers have to cross, in some cases 4-lane roads, under very unsafe conditions and unsafe facilities (e.g. marked pedestrian crossing where the legal speed is 100 km/h). Therefore, especially when there is a combination of a high-speed highway with a high traffic volume and a reasonable number of bus users and/or special groups of users (elder people, pupils) the bus should go directly to a bus stop in the village and before going back onto the main road to resume its journey direction.

Examples of unsafe designs

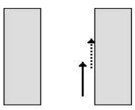
BUS stop at highway

BUS stop at highway

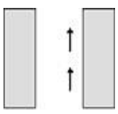
Typical accidents:



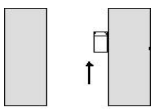
Pedestrian crossing street outside a junction



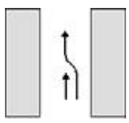
Pedestrian walking along the road



At least two vehicles - same direction - rear end collisions

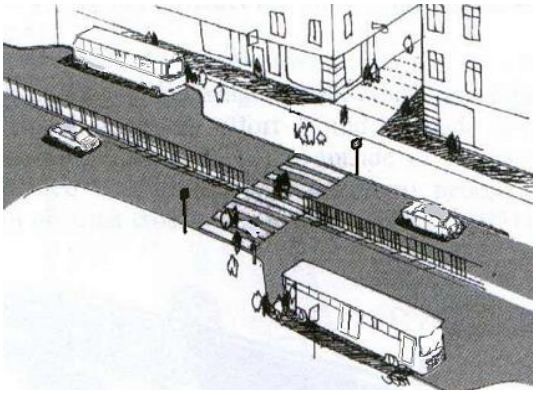


Hitting parked vehicles right (left) side of the road

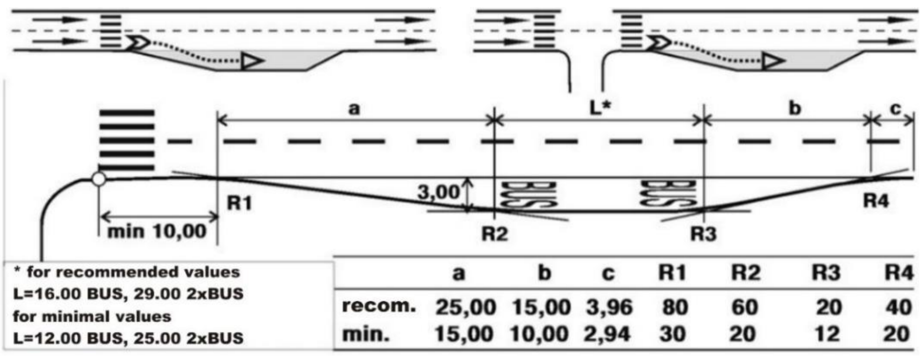


At least two vehicles - same direction - entering traffic

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Removing Bus stops from main traffic flow - Separation of Bus bays from main traffic flow and connection with pedestrian crossings ($$$) - Construction of pedestrian footpath to and from Bus stops ($$/$$$) * The locations of bus stops at the exits of roundabouts are very useful and safe because the speed of passing vehicles is still low.	**34 – 90 %**	
2. Improving Bus bay within existing traffic - Traffic calming measures in zone of Bus bay ($$$-$$) - Relocation of BUS bay ($$$) Note that the pedestrian crossing is located behind the bus, stop bay to reduce risks. Ideally, the pedestrian crossing should be raised, and there should be a safe waiting area at the centre of the road to permit pedestrians to cross in 2 movements.	**25 – 54 %** **No reliable data**	
3. Improving signing /marking and road furniture of Bus Stops - Improved signs and marking of Bus Stop ($) - Adding of proper lighting ($$) - Additional installation of guardrails ($) - Additional installation of pedestrian fence ($) - ITS installation in Bus stop location (see example from chapter 7.1 Signing) ($$)	**2 – 10 %** **25 – 74 %** **31 – 54 %** **No reliable data in this context**	

Sketches (with dimensions):



Recommended and minimal values for Bus bay
(Note that pedestrian crossing is behind the bus bay so passengers coming off from Bus and crossing the road can be seen by the following traffic).

6 VULNERABLE ROAD USER NEEDS:

6.1 PEDESTRIAN CROSSINGS

Background and possible problems

There are different possibilities to increase the safety for crossing pedestrians. To define the appropriate measure the local circumstances must take into consideration: - the expected traffic volume of pedestrians (e.g. high numbers of crossing pedestrians); - the urban pattern; - the traffic volume, etc.

Serious problems can arise when we have road sections of important highways with a high traffic volume passing through towns or cities combined with a high numbers of pedestrians. The best long-term measure would be for the core network of highways to have bypasses constructed around towns. This is of course, is not possible everywhere.

The single main contributing factor regarding pedestrian safety is the speed of traffic. To increase safety, the maximum speed limit in built-up areas should be 50 km/h and reduced further to 30 km/h at areas of high risk (e.g. in front of schools ,near busy shopping streets etc.). There are many guidelines and handbooks specifically for the design of safe pedestrian crossings. The German Guidelines for Pedestrian Traffic (EFA) includes a method to choose safe and cost-effective solutions for pedestrian crossings. The solution depends on the number of lanes, road width, number of crossing pedestrians and the legal speed. On 4-lane roads, there are higher risks for those crossing the road because of sight line and visibility problems. It is recommended to construct at least median stripes as a help to crossing and to have separate pedestrian traffic lights there or to use a combination with the traffic lights at junctions.

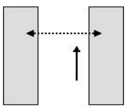
In the case of high traffic volume or/and a character of the road like a city motorway, the at-grade pedestrian crossing should be forbidden. Heavy crossing demands may often occur away from junctions where vehicle speeds are very high. The provision of underpasses or overbridges, however, may be too expensive and may not be well used by pedestrians. It is no use just fencing off the pedestrians and making them walk excessive lengths to reach a footbridge, as they will just try to cross the busy road at grade. Designers and the road authority need to provide crossings, which the pedestrians will willingly use.

Examples of unsafe designs

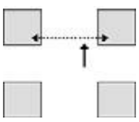
Pedestrian crossing over four lane carriageway

Useless pedestrian crossing

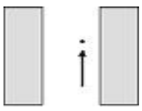
Typical accidents:



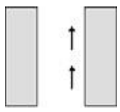
Pedestrian crossing street outside a junction



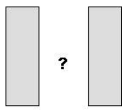
Pedestrian crossing street at a junction



Pedestrian in the road



At least two vehicles - same direction - rear end collisions

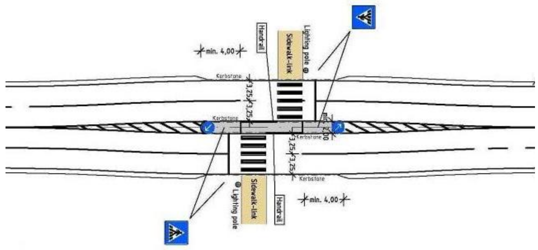


Single vehicle accidents - others

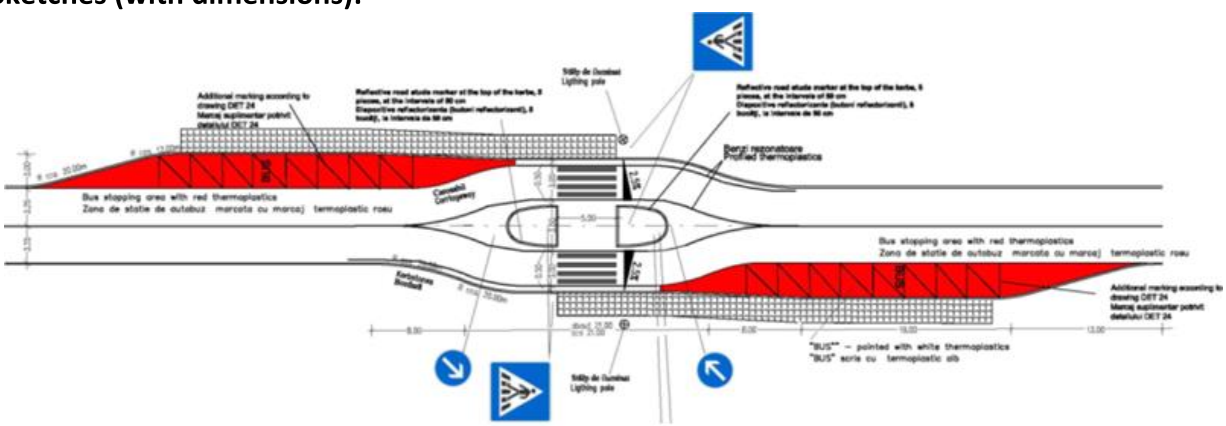
Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations

1. Separated pedestrian crossings
- Construction of underpasses or overbridges - costly and efficient solution – attention should be paid to pedestrian wiliness to use ($$$)
- Underpass/overbridge lighting ($$$/$$)
- Installation of pedestrian guardrail in wider zone of underpass/overbridge ($$)
- Motivation of pedestrians to use bridge or underpass by installing:
  - Different advertisements
  - Signage and markings
  - Violation recording of offenders
  - Good lighting
  - Clean, well-maintained underpasses
	13 – 44 %
	
	9 – 32 %
	N/A
	
	N/A
		
		
		* Using ramps instead of stairs encourages use by less able persons

2. Narrowing of road and usage of refuge islands - Narrowing of the traffic lanes ($$) - Installation of refuge island with fencing to redirect pedestrians to face traffic before crossing ($$) - Adding pedestrian traffic lights ($) can be combined with medians and islands or incorporated into existing installation at intersections - Lighting of pedestrian crossing ($$$/$$) - Installation of pedestrian guardrail ($)	**15 – 37 %** **3 – 21 %** **25 – 40 %** **17 – 64 %** **25 – 40%**	 (Pedestrians at Central Island can be redirected via safety fences, so they face traffic before making second crossing)
3. Connecting of pedestrian paths (walking routes) with crossings - Marking of pedestrian crossing ($) - Raised pedestrian crossing ($) - School crossing patrol ($) - Adding to speed-reducing devices (humps, rumble strips, etc.) near pedestrian crossing ($)	 **10 – 58 %** **35 – 67 %** **25 – 54 %** **20 – 80 %**	

Sketches (with dimensions):



Good example of pedestrian crossing and BUS stops

6.2 FOOTPATHS AND FOOTWAYS

Background and possible problems

Pedestrians should not have to walk at all along interurban, high-speed roads. Hard shoulders are not intended for vulnerable road users but for emergency use by vehicles only. That means that on through road sections or comparable road sections along built-up areas there is a need in every case for separate footpaths. If there are building along both side of the through road, the footpaths should also be on both sides of the road. This can reduce risk because the need to cross the road is minimised.

Pedestrian accidents contribute a substantial proportion of road accident deaths and injuries. Pedestrians are particularly at risk in urban surroundings. In LMICs they typically contribute one third to one half, or even more, of total deaths. Roads in towns are usually designed with raised pedestrian footways as part of the cross-section, but on interurban roads, footways are rarely provided, although, in some locations, pedestrian flows may be very high.

Footways have great implications for safety, and every effort should be made to segregate pedestrians and vehicles where space allows. Separate routes make travel much safer for vulnerable road users. Special care must be taken to ensure that footways do not become obstructed, especially by street traders and parked vehicles, that the surfaces are comfortable to walk on and that they provide a continuous route.

Substantial conflict problems usually exist where roads pass through rural settlements as the main road traffic travelling very fast often passes very close to the existing buildings leaving no or very narrow footpaths for pedestrians resulting in increased risk and danger for pedestrians.

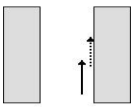
In the case of reconstruction of an inner urban road, the main design principle should be that, there must first be enough space for pedestrians and cyclists and the rest of the space remaining will then be used for the motorised traffic.

Examples of unsafe designs

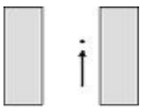
Pedestrian “footpath.”

Missing of pedestrian footpath

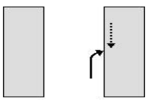
Typical accidents:



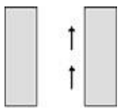
Pedestrian walking along the road



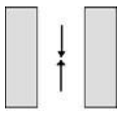
Pedestrian in the road



Pedestrians on pavement or bicycle lane



At least two vehicles - same direction - rear end collisions

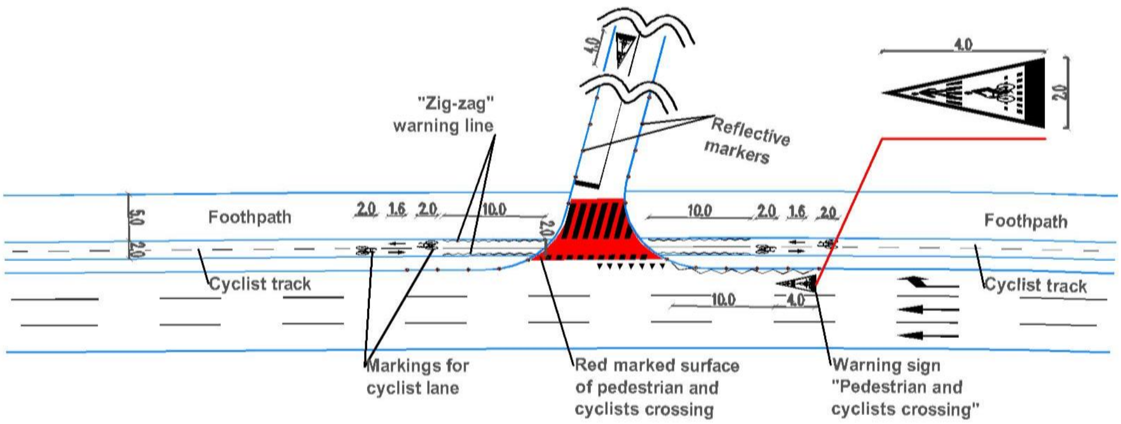


At least two vehicles - head-on collision in general

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Separation of motorised traffic and vulnerable road users wherever possible - Construction of separated pedestrian footways and cyclist tracks ($$$) - Building of footpaths and cyclist lanes/tracks where the road passes through urban areas ($$$) - Building of wider hard shoulder outside urban areas with separation by a barrier or grass verge is needed ($$)	**35 – 67 %** **10 – 32 %** **21 – 32 %**	
2. Time separation - Installation of traffic lights where footpaths (footways) and cyclist tracks/lanes cross the road ($$)	**2 – 12 %**	
3. Good signing and marking of urban and rural footpaths, footways, and cyclist tracks/lanes ($) - speed limitation for vehicles ($) - access control for specific vehicles category ($)	**2 – 10 %**	

Sketches (with dimensions):



Example of marking of footpaths and cyclist tracks on crossing of the road

7 TRAFFIC SIGNING, MARKING, AND LIGHTING:

7.1 SIGNING

Background and possible problems

The proper signing and marking will support road safety by establishing clear communication with road users. There are different categories of signs, which support road users. Within United Nations Vienna Convention on Road Signs and Signals (1968), eight categories of signs have been defined: A. Danger warning signs; B. Priority signs; C. Prohibitory or restrictive signs; D. Mandatory signs; E. Special regulation signs; F. Information, facilities, or service signs; G. Direction, position, or indication signs; H. Additional panels. Nevertheless, all signs should be located in an effective way to maximize road safety.

Warning signs and warning markings are used to give notice of a potential hazard ahead or any unexpected feature of the road geometry. The signs are used in specific situations when there is a change in the road, such as in a bend, on a high-speed road or the approach to a junction. The location of signs is critical because they should provide adequate warning or information at sufficient distance. However, they should not obscure important road features. Of great importance for the visibility of the signs is that they are located in positions where overgrown vegetation cannot obscure the visibility of the sign. Signs must be visible at all times, so reflective materials should be used for night-time visibility, and urban signs may require being lit internally or externally. In many LMICs ,Sadly it is common for signs to be missing (even at dangerous locations), not properly positioned, without reflectivity, non-standardized or even not uniform to International UN Conventions so efforts must be made to have signs installed wherever possible. Conversely, too many signs can detract from their objective by overloading the driver with too much information too quickly, which leads to confusion or to a situation where the driver ignores certain signs. If reflective signs are not regularly cleaned, they may not retain their designed visibility properties.

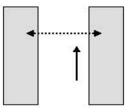
Special issues regarding directional signing: In the existing network, there can be requests for specific, customised direction signing which will follow the real geometry of intersections. The best practice is to use the big directional sign to inform the driver about actual road geometry.

Examples of unsafe designs

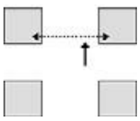
Hidden sign by tree

Hidden traffic light by sign

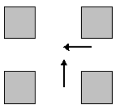
Typical accidents:



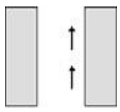
Pedestrian crossing street outside a junction



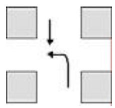
Pedestrian crossing street at a junction



At least two vehicles - crossing (no turning) - different



At least two vehicles - same direction - rear end collisions

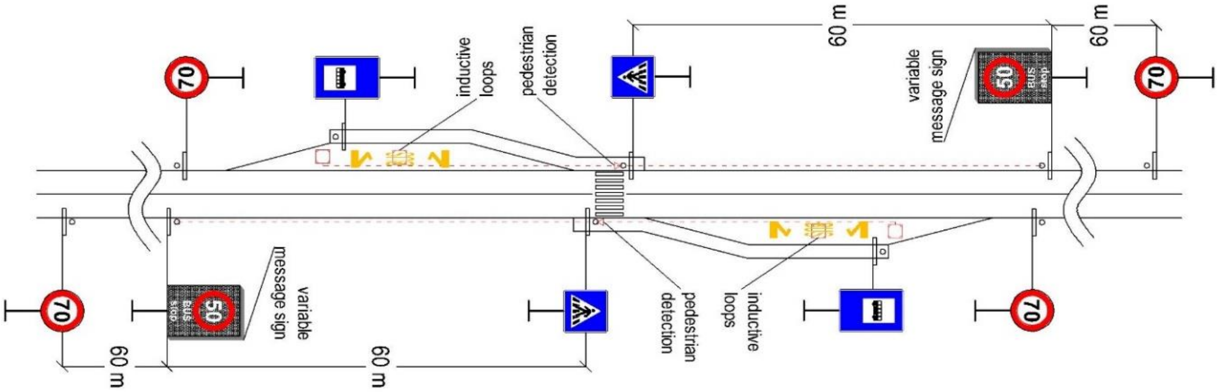


At least two vehicles - same road - opposite direction - turning left (right)

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Usage of high class of reflectivity materials for traffic signs - usage of the higher class of reflectivity materials for signs on motorways and highways (roads with higher speed limit) ($) - usage of the higher class of reflectivity materials for traffic signs “Yield at entry”, “Stop”, “Pedestrian crossing”, etc. ($) - yellow-green border usage for highlighting of signs on dangerous places ($)	**10 – 33 %**	 Directional sign shows shape of junction
2. Variable message signs (VMS) usage - accident warning signs ($$) - fog warning signs ($$) - queue warning signs on motorways ($$) - Average over speeding control signs ($$) - Information signs of average violations at pedestrian crossings ($$)	 **22 – 59 %** **63 – 93 %** **4 – 26 %** **24 – 62 %** **65 – 96 %**	
3. Maintenance of traffic signs - Traffic sign maintenance ($) - Displacement of traffic signs ($) - Removal and replacement of traffic signs ($) - Visibility of colours in traffic signing, Yellow – red chevrons are earlier detected than red-white (Black-white are even worse) ($)	**7 – 15 %**	

Sketches (with dimensions):



Example of usage of VMS for speed limit in accordance with BUS stop detection and pedestrian crossing detection

7.2 ROAD MARKINGS

Background and possible problems

Road markings play a very important role in guiding the driver and providing him with the information necessary to negotiate conflict points on the road network and should be of high priority for those seeking to improve road safety. Appropriate information should be given to the driver through the use of different types and colours of road marking. Stop, and give-way lines at junctions help to position the driver on the road to minimise his risk. Center lines can be used to indicate locations where overtaking is dangerous while edge lines give warning of changes in alignment and if corrugated can be used as a warning of drifting towards the shoulder. Where possible, high-quality paint containing small glass beads (for reflectivity at night) should be used. Centre and edge lining reinforced through the use of studs or vibrolines (corrugated) to provide rumble warning are strongly recommended.

Although some of the LMICs have national standards for road marking, some of the roads often do not have good markings (e.g. without reflectivity and/or are partially missing). This is partly because road marking paint available locally often tend to be of poor quality while imported road marking paint is often considered to be too expensive (although it lasts longer and reduces the risk of crashes).

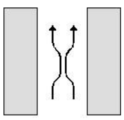
The poor conditions of roads (potholes, deformations, etc.) can also make road marking difficult to apply in any effective manner. Shortage of specialised machinery, skilled/trained technicians and the cost of imported thermoplastics prevents more widespread use.

Examples of unsafe designs

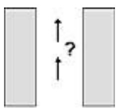
"Phantom" markings

Too narrow accelerating lane

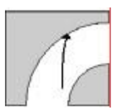
Typical accidents:



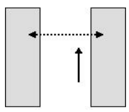
At least two vehicles - same direction - side collision



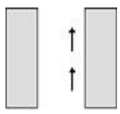
At least two vehicles - same direction - others



Single vehicle accidents in a bend - going either side of the road



Pedestrian crossing street outside a junction

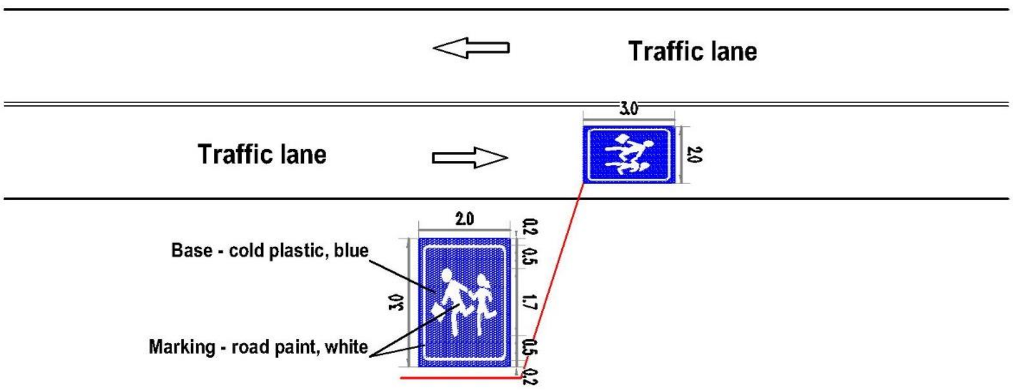


At least two vehicles - same direction - rear end collisions

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasures with (EC)	CR	Illustrations
1. Improved road markings: - Reflective glass beads for road markings ($) - Durable road marking materials (cold plastic, thermoplastic, fabricated tapes) ($$/$) - Delineators ($) - Reflective road markers / studs ($) - Rumble strips, edge rib-lines, reflective road studs, etc. ($) - Non-standard markings for school zones, dangerous locations, etc. ($) - Marking of traffic signs on pavement ($) - Different colours of road markings (for highlighting of standard elements of road markings) ($) - Different pavement color ($)	 **2 – 7 %** **8 – 21 %** **17 – 45 %**	 
3. Maintenance of road markings - Remarking ($) - Cleaning of markings ($)	**No reliable data**	

Sketches (with dimensions):



Example of road marking of traffic sign for school zone

7.3 LIGHTING

Background and possible problems

Night-time crashes on roads passing through urban areas or on streets in urban areas can be substantially reduced by the implementation of adequate road/street lighting. It is particularly important where there are high proportions of pedestrians, cyclists, or other poorly lit road users, including animals. Lighting should provide a uniformly lit road surface in order to provide visibility of all road users (vehicles and pedestrians) and not to hide them in shadow. The design of the lighting system should be designed to the road surface reflection characteristics in order to provide the optimum quality and quantity of illumination. Light coloured surfaces give better silhouette vision than the dark ones. If only limited funds are available, efforts should be made to provide lighting on at least the most important routes and dangerous locations along such routes such as intersections and pedestrian crossings involving the greatest movement of pedestrians.

Lighting is expensive to install and maintain, but the usage of cheaper LED lighting and solar power lighting system can reduce costs in future years. However, without proper maintenance, the resulting inconsistency in lighting can itself be a safety hazard. Maintenance could often be a problem, because of the inadequacy of the allocated funds. Careful attention needs to be paid to the siting of lamp posts as they can be hazardous for an errant vehicle and if possible, frangible (break away) posts should be used. The column also sometimes can be a significant visual obstruction at critical locations.

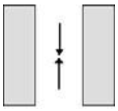
For the practical audit, there are more tasks. In some cases, will lighting misguide (e.g. lighting of adjacent areas like a public service besides the highway) the driver or can lead to problems regarding the recognition/conspicuity of traffic signals (glare effects).

Examples of unsafe designs

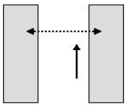
No lights in tunnel

No street lighting + pedestrian crossing

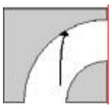
Typical accidents:



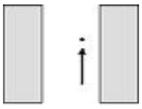
At least two vehicles - head-on collision in general



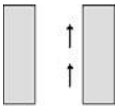
Pedestrian crossing street outside a junction



Single vehicle accidents in a bend - going either side of the road



Pedestrian in the road

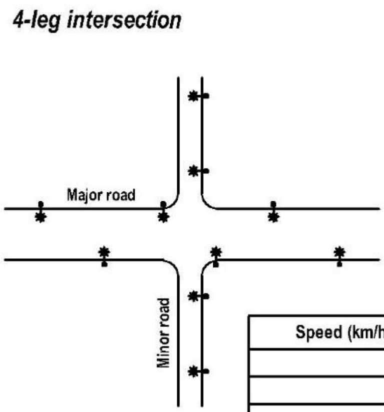


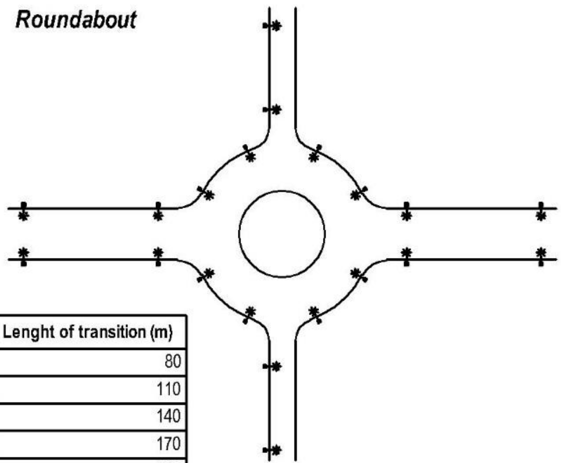
At least two vehicles - same direction - rear end collisions

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Addition of light where needed ($$$)	**25 – 74 %**	
2. Evenness of illumination (improving existing lighting quality) ($$) - Usage of solar power and LED for energy saving system	**8 – 20 % (for up to double)** **25 – 79 % (for up to 5 times)**	
3. Maintenance of lighting - Changing of lamps/LED ($) - Cleaning of lamps/LED/solar panels ($) - Installation of guardrails for protection of lamps from traffic and vice versa ($$)	**No reliable data**	

Sketches (with dimensions):





Speed (km/h)	Lenght of transition (m)
50	80
60	110
70	140
80	170
90 and higher	200

Example of lamp placement on 4-leg intersection and roundabout with recommended length of transition zone from lighted section to unlighted one for different speeds ("tunnel effect")

8 ROADSIDE FEATURES, PASSIVE SAFETY INSTALLATIONS, CIVIL ENGINEERING STRUCTURES

8.1 ROADSIDE OBSTACLES (PLANTS, TREES, LIGHT POLES, ADVERTISEMENTS, ETC.)

Background and possible problems

The presence of roadside obstacles, street furniture (for example, road signs and lighting columns) advertising signs and trees has safety implications. The first is the potential danger of collision, and the second is their obstruction of visibility. Visibility is important not only to the driver but also to other road users. Obstructions caused by trees, for example, may result in a pedestrian making an unwise decision.

Great care should be taken concerning the positioning of roadside features which may obstruct visibility, lead to crashes, or increase crash severity. Where it is not practical to remove obstructions which contribute to hazardous situations, consideration should be given to (1) moving the hazard further from the travelled way to create a larger clear zone or recovery area, (2) modifying the hazard to make it more forgiving or (3) shielding the hazard with a properly designed and tested barrier or crash cushion. Once a road is completed, care must be taken to ensure that other institutions such as telephone or electricity authorities do not introduce obstacles subsequently. Vegetation should be trimmed regularly, and planning controls should be enforced to prevent stalls and structures being too close to the road edge.

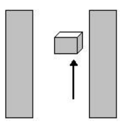
At some roads in LMICs, trees are planted adjacent to roads to provide shade for pedestrians, animals, and parked vehicles and in other countries to prevent the wind from bringing snow onto the road. If these trees must be planted, they must be recognized as roadside hazards and efforts made to plant the trees further from the travelled way or to shield these trees with a properly designed and tested barrier or crash cushion.

Examples of unsafe designs

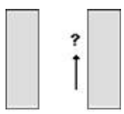
This drainage system as an obstacle

Other obstacles

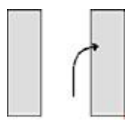
Typical accidents:



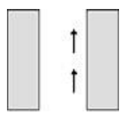
Single vehicle accidents with obstacles on or above the road



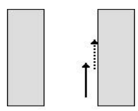
Single vehicle accidents with obstacles - others



Single vehicle accident - Leaving straight road - either side of the road

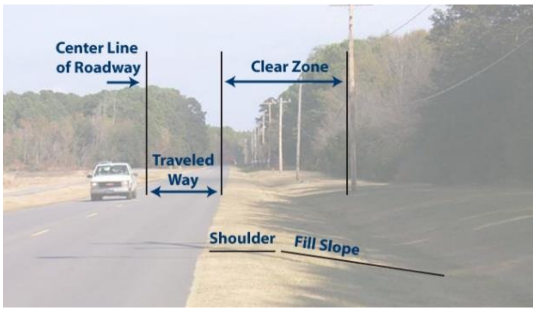


At least two vehicles - same direction - rear end collisions

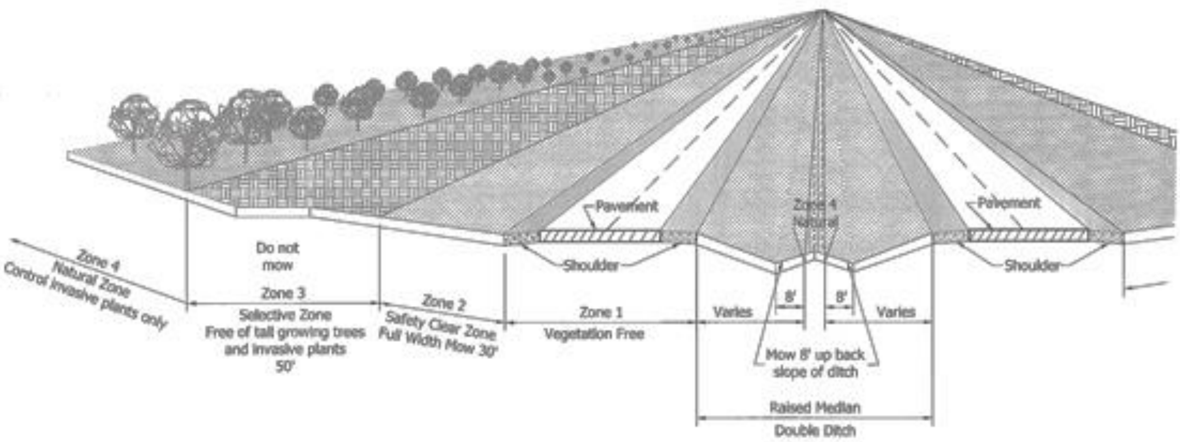


Pedestrian walking along the road

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Removing roadside objects from road to create a “clear zone” without potential obstacles - Removing of hard (un-deformable) roadside objects from clear zone ($$$/$$) - Relocation of road layout ($$$)	 **43 – 46 %** **No reliable data**	
2. Relocation of hard roadside objects - Relocation of hard objects out of clear zone (on safe distance) ($$$/$$) - Providing better visibility in clear zone – traffic mirrors, ITS, etc. ($$) Note: There must be obstacle-free zones of minimum 9 m for speed limits of 100 km/h, 6 m for 80 km/h and 3 m for 60 km/h	 **20 – 24 %** **20 – 38 %**	
3. Alter to reduce severity or protect roadside hazards - Frangible lighting/sign/etc. poles ($) - Grade steep slopes, 4:1 or flatter ($$) - Safe culverts ($) - Installation of guardrails ($$$-$$) - Marking of roadside object to make them more visible (usage of reflective signs, etc.) ($) - Marking edge lines in the form of rumble strips ($)	 **25 – 72 %** **38 – 46 %** **No reliable data** **41 – 52 %** **11 – 45 %** **2 – 20 %**	 Barrier around/in front of a tree

Sketches (with dimensions):



Example of vegetation management in cross section of highway

8.2 LONGITUDINAL BARRIERS (GUARDRAILS)

Background and possible problems

Many crashes on high-speed roads involve vehicles leaving the road and colliding with hazardous obstacles such as trees, bridge supports or simply rolling over down a high embankment. Therefore, the safest and best solution would be to ensure an obstacle-free area along the road. If this is not possible, modern, and approved vehicle restraint systems (VRS) should be installed. Similarly, a vehicle running off onto the lane in the opposite direction of a dual carriageway runs the risk of collision with an oncoming vehicle which usually has serious consequences. The risk of these types of crashes can be significantly reduced by the use of properly designed, tested, installed and maintained longitudinal barriers. The purpose of the longitudinal barrier is to provide positive protection to prevent an errant vehicle from impacting a rigid object, slope, drop off, body of water, etc. that may be located behind the barrier if impacted, the longitudinal barrier must safety redirect the errant vehicle back into the original direction of travel. Longitudinal Barriers themselves can be a danger to motorists and they should only be used if impacting the barrier will result in less severe consequences for a motorist than impacting what is behind the barrier.

Properly designed and tested reinforced concrete sections that are appropriately connected to each other may be used. Unconnected, untested concrete blocks located close to the travelled way can become a roadside rigid hazard. They are intended to be placed between the carriageway and the objects which cause severe crashes if hit, such as bridge abutment. They are also used to retain vehicles on high embankments or mountain roads. Their use on high-speed roads is justified, but care needs to be taken concerning details, particularly at the start and end points and minimum barrier length in order to work safely. Damaged barriers must be repaired immediately as they can cause severe damage if hit by passing vehicles and if they are not in their designed condition.

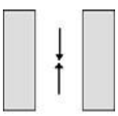
The auditor should check if the designed or existing systems are officially tested and approved. In the European Union, every system needs at least a “CE” – approval (exception mix-in concrete barriers). The approved systems must have defined containment level and working width. The assembling has to be done according to the demands of the producer. Otherwise the system will not work with the planned performance.

Examples of unsafe designs

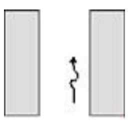
Dangerous guardrails (not a system)

Dangerous “end treatment”- concrete block

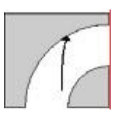
Typical accidents:



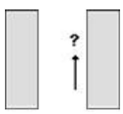
At least two vehicles - head-on collision in general



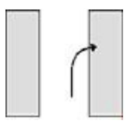
Single vehicle accidents on the road



Single vehicle accidents in a curve - going either side of the road



Single vehicle accidents with obstacles - others

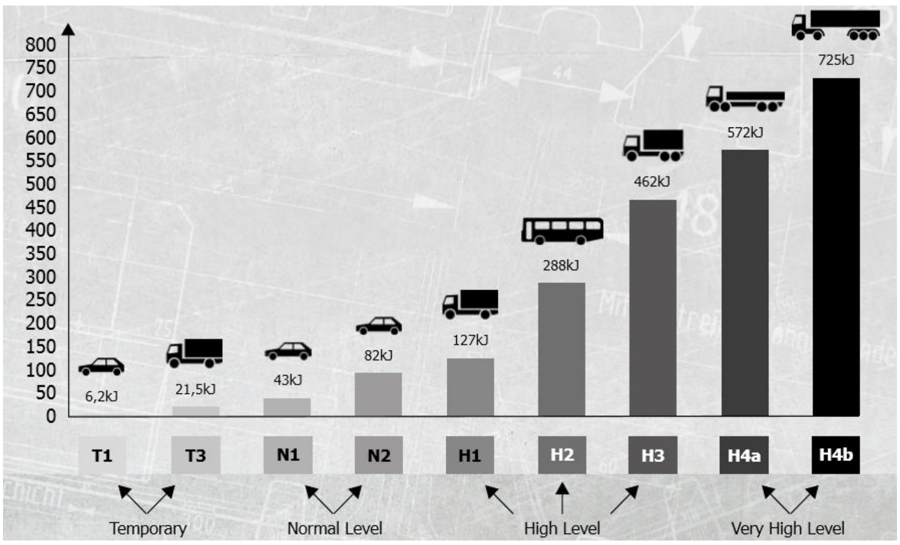


Single vehicle accident - Leaving straight road - either side of the road

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Adding right type of guardrails when missing - Adding missing guardrails ($$$-$$) - Installation of proper barrier type ($$$) - Adding barriers connection elements ($) - Usage of approved systems (e.g. with "CE")	**31 – 54 %**	 
2. Improving existing guardrail system - Closing of "open windows" ($$-$) - Adding transition elements between two different types of barriers ($$) - Using of appropriate beginning/end elements - guardrail extension in front of dangerous point ($$) - Smoother slopes ($$)	**20 – 42 %**	 

Sketches (with dimensions):



The norm EN 1317 Containment Level

8.3 CIVIL ENGINEERING STRUCTURES

Background and possible problems

There are some typical problems regarding the design and existing civil engineering structures like bridges, overpasses, underpasses, etc.

A civil engineering structure can be an obstacle for road users, and there is a need to prevent cars from running off bridges with severe consequences. This means that there is a need for sufficient restraining systems. Often there is a lack of coordination in design with the adjacent road section. For example, the bridge guardrail system should have a connection to the guardrails in the adjacent road sections.

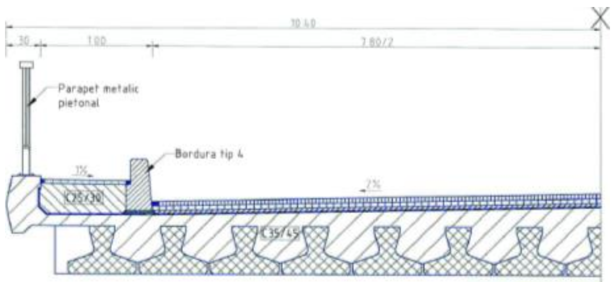
In some cases, the only pedestrian handheld fence is planned at bridges which is not an acceptable safe solution (fence is not designed to keep cars on the road and can even hurt car occupants if hit by a car).

The auditor should have in mind furthermore the geometric issues for cars and (if there are) pedestrians and bicyclists. Sometimes we can see also deficiencies regarding the drainage. In the case of overpasses, the bridge is often designed with a crest curve in the vertical alignment. The bridge designer should ensure a good drainage, e.g. with additional gutters.

Examples of unsafe designs

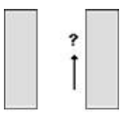
Unsafe headwall of a culvert

This bridge construction is a hard obstacle



Unsafe bridge design

Typical accidents:

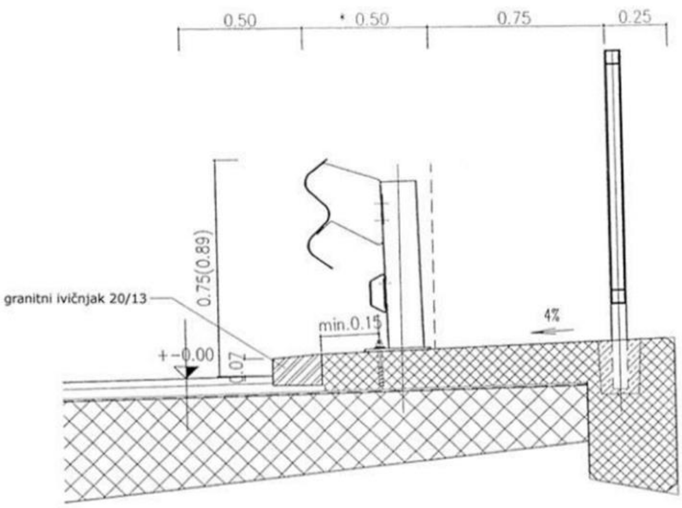


Single vehicle accidents with obstacles – others

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Improvements in bridge design - Adding right type of guardrails - Functional connection to the adjacent guardrail system - Improved drainage solutions		 Bridge parapet and guardrail according to German guidelines

Sketches (with dimensions):



Possible solution for installing guardrail and fence on the bridge

9 TEMPORARY SIGNING AND MARKING AT WORK ZONES

Background and possible problems

A work zone is an area of road or roadside where construction, maintenance or other works are performed and which may affect the safety and limit the free movement of road users through and in the vicinity of the Work Zone. Work zones are zones on the road with a higher risk of crashes for both road users (vehicle occupants and vulnerable categories) and workers. A Traffic Management Plan (TMP) of good quality should be made and followed so that all participants in traffic are protected against the risk of a traffic crash. Such TMP should contain all elements starting from design, placement, maintenance to the removal of all elements regulating the road traffic.

To minimise the problems and increase safety, work zone layout (marking and signing) requires special consideration for the following reasons:

- Work zone is a section of road where, most often, geometrical characteristics of the road and the traffic conditions are changed to poorer conditions (less safe). The types of executed works are often road construction, rehabilitation, and maintenance, but there are other types of work on the road that need the same treatment, for instance, work with cables, pipes etc. located in the road area.
- Employees in work zones spend most of their working hours directly exposed to traffic. In crashes, happening in work zones, these employees are sometimes the victims.

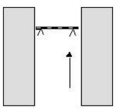
The growing international transit traffic flow in LMICs implies the need for main traffic corridors to be constructed according to international standards and requires European standards and a widely recognised and consistent system for roadworks signing and work zone safety.

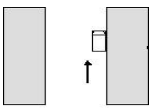
Examples of unsafe designs

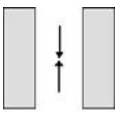

Dangerous work zone

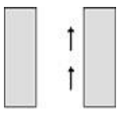

Dangerous work zone

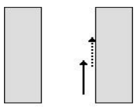
Typical accidents:


Single vehicle accidents with roadwork materials


Hitting parked vehicles right (left) side of the road

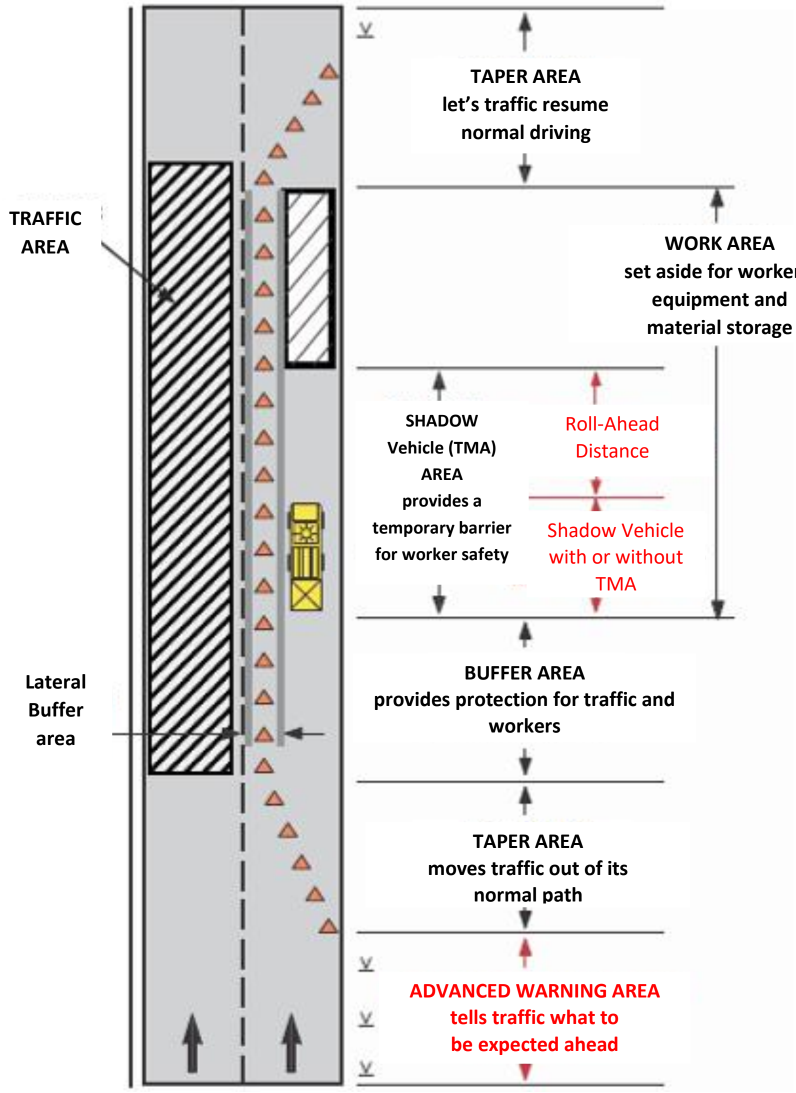

At least two vehicles - head-on collision in general


At least two vehicles - same direction - rear end collisions


Pedestrian walking along the road

Possible countermeasures with expected costs (EC) and crash reductions (CR):

Countermeasure with (EC)	CR	Illustrations
1. Establishing regular (best practice) of working zone, the road markings in working areas should be in yellow ($$)	5 – 65 % (for traffic crashes in work zones)	



Sketches (with dimensions):

Speed limit (km/h)	Minimal buffer area (m) in Work Zones	
	Lateral	Longitudinal
40	0.5	30
50	0.5	35
60	0.5	40
80	0.5	60
100	1.0	100
120	1.0	100

10 ACCIDENT TYPE SKETCHES:

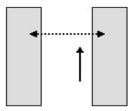
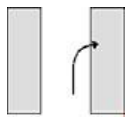
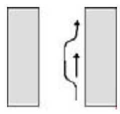
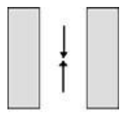
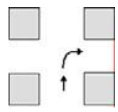
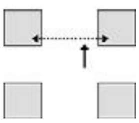
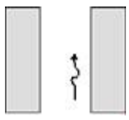
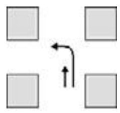
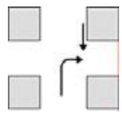
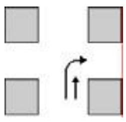
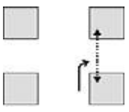
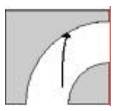
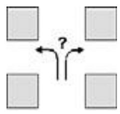
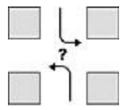
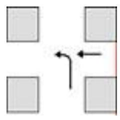
10.1 BASICS OF COMMON ACCIDENT DATA SET (CADaS)

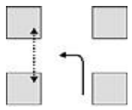
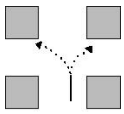
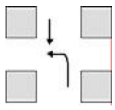
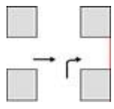
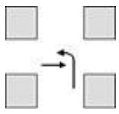
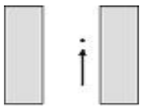
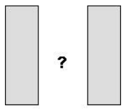
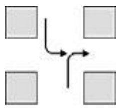
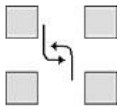
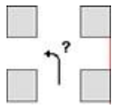
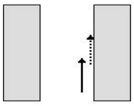
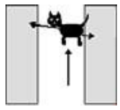
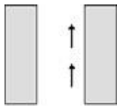
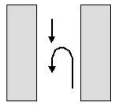
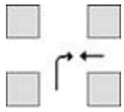
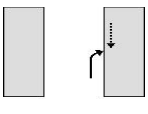
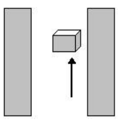
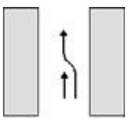
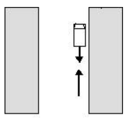
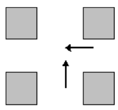
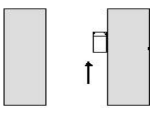
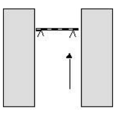
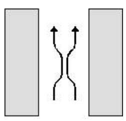
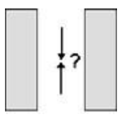
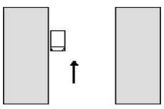
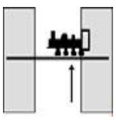
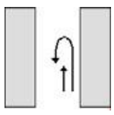
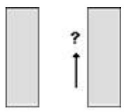
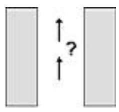
Introduction

European Union countries have a long history in collecting accident data via different national collection systems. At European level, road accident data are also available since 1991 in disaggregate level in CARE (Community database on road accidents resulting in death or injury). The purpose of CARE system is to provide a powerful tool, which would make it possible to identify and quantify road safety problems throughout the European roads, evaluate the efficiency of road safety measures, determine the relevance of Community actions, and facilitate the exchange of experience in this field. It also allows countries to benchmark themselves against other countries to assess areas where they need to do more.

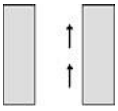
Due to differences in accident data collecting between EU countries, new recommendations have been agreed for a Common Accident Data Set (CADaS) consisting of a minimum set of standardised data elements, which will allow comparable road accident data to be available throughout Europe. In this way, more variables and values with a common definition will be added to those already contained in the previous models of the CARE database. They will maximise the potential of CARE database allowing more detailed and reliable analyses at European level.

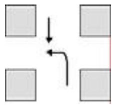
Common Accident Type Sketches

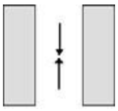
Pedestrian crossing street outside a junction 	Single vehicle accident - Leaving straight road - either side of the road 	At least two vehicles - same direction - overtaking 	At least two vehicles - head-on collision in general 	At least two vehicles - turning or crossing - same road - same direction - rear end collision 
Pedestrian crossing street at a junction 	Single vehicle accidents on the road 	At least two vehicles - turning or crossing - same road - same direction - turning left (right) 	At least two vehicles - same road - opposite direction - turning right (left) in front of another vehicle 	At least two vehicles - turning or crossing - same road - same direction - turning right (left) 
Hitting pedestrian - turning right (left) 	Single vehicle accidents in a bend - going either side of the road 	At least two vehicles - turning or crossing - same road - same direction - others 	At least two vehicles - same road - opposite direction - turning others 	At least two vehicles - different roads - turning left (right) into traffic from the right (left) side 

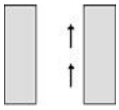
Hitting pedestrian - turning left (right) 	Single vehicle accidents in junctions or entrances 	At least two vehicles - same road - opposite direction - turning left (right) in front of another vehicle 	At least two vehicles - different roads - turning right (left) in front of vehicle from the left (right) 	At least two vehicles - different roads - turning left (right) into traffic from the left (right) side 
Pedestrian in the road 	Single vehicle accidents - others 	At least two vehicles - same road - opposite direction - turning into the same road 	At least two vehicles - same road - opposite direction - turning into opposite roads 	At least two vehicles - different roads - turning into traffic - others 
Pedestrian walking along the road 	Single vehicle accidents with animals 	At least two vehicles - same direction - rear end collisions 	At least two vehicles - U-turn in front of another vehicle 	At least two vehicles - different roads - turning right (left) - head-on collision 
Pedestrians on pavement or bicycle lane 	Single vehicle accidents with obstacles on or above the road 	At least two vehicles - same direction - entering traffic 	At least two vehicles - opposite direction no turning - reversing 	At least two vehicles - crossing (no turning) - different 
Hitting parked vehicles right (left) side of the road 	Single vehicle accidents with roadwork materials 	At least two vehicles - same direction - side collision 	At least two vehicles - opposite direction no turning - others 	
Hitting parked vehicles left (right) side of the road 	Accidents between train and vehicle 	At least two vehicles - same direction - U-turn in front of another vehicle 	Single vehicle accidents with obstacles - others 	At least two vehicles - same direction - others 

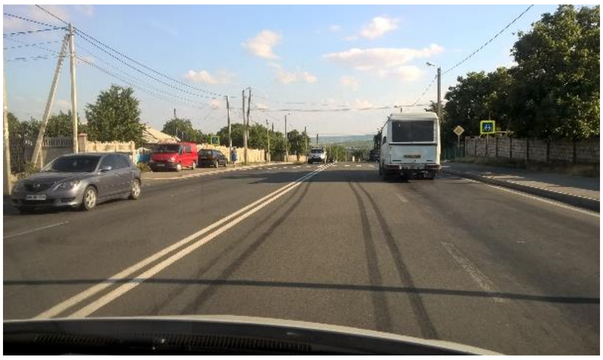
Examples of real accidents and respective CADaS sketches

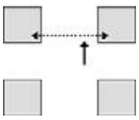


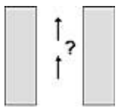


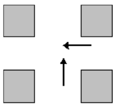


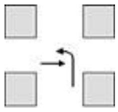


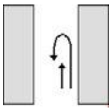


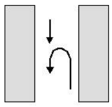










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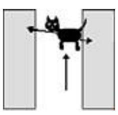

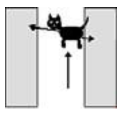

11 POTENTIAL CRASH REDUCTION FROM COUNTERMEASURES/TREATMENTS

Introduction

For any countermeasure proposal, it is necessary to know the crash reduction potential. Therefore, a list is proposed of the most common low-cost countermeasures with their expected effects.

The following table is collated from results of different international research projects and case studies and can be used for understanding the potential crash savings after implementation of different countermeasures.

Table 11.1 presents each differently proposed countermeasure (treatment) and its range potential crash reduction effects as a percentage. (Usually, minimum, and maximum effects are presented).

Table 11.1: Efficiency (crash reduction) of different countermeasures

Treatment	Potential crash reduction [%] (different sources/research)
Road Standard	
Improve to higher standard	19-33
Increase number of lanes	22-32
Lane widening 0.3 – 0.6 m	5-12
Paved shoulder widening 0.3 - 1 m	4-12
Add median strip	40
Bridge widened or modified	25
Widen shoulder	10
Overtaking lane	20
Left turn lane	40
Right turn lane	15
Pedestrian overpass	10
Side slope flattening from 2:1	
to 4:1 ... 7:1 or flatter	6 ... 15
Side slope flattening from 4:1	
to 5:1 ... 7:1 or flatter	3 ... 11
Service roads	20-40
Traffic calming	12-60
Speed reduction from 70 km/h to 50 km/h	10-30
Speed reduction from 90 km/h to 60 km/h	17-40
Horizontal Alignment	
Improve geometry	20-80
Curvature: improving radius	33-50
Vertical Alignment	
Gradient / removing crest	12-56
Super elevation improvement/introduction	50
Passing lane	11-43
Climbing lane	10-40
Road Structure	
Lane widening	12-47
Skid resistance improvement	18-74
Shoulder widening	10-40
Shoulder sealed	22-50

Road verge widening	13-44
Junction Design	
Staggered (from straight) crossroads	40-95
T-junctions (from Y-junctions)	15-50
Fully controlled right turn phase	45
Roundabouts (from uncontrolled)	25-81
Roundabouts (from traffic signals)	25-50
Mini roundabouts (from uncontrolled)	40-47
Turning lanes	10-60
Traffic islands	39
Sheltered turn lanes (urban)	30
Sheltered turn lanes (rural)	45
Additional lane at intersection	20
Skid-resistant overlay	20
Red light camera	10
Law enforcement by the Police	7-25
Traffic Control	
Regulatory signs at junctions	22-48
Guidance/directional signs at junction	14-58
Overhead lane signs	15
Side road signs	19-24
Brighter signs and markings	24-92
Signs and delineation	29-37
Bend warning signs	20-57
Stop ahead sign	47
Speed advisory sign	23-36
Warning/advisory signs	20
Speed limit lowering - & sign	16-19
Yield/Give Way	59-80
Stop sign	33-90
Signals from uncontrolled	15-32
Signals - modified	13-85
Junction channelization	10-51
Remove parking from roadside	10-25
Visibility	
Lane markings	14-19
Edge markings	8-35
Yellow bar markings	24-52
Raised reflective pavement marking	6-18
Delineator posts	2-47
Flashing beacons	5-75
Lighting installations	6-75
Sightline distance improvement	28
Channelization medians	22-50
Crash Amelioration	
Median barrier	14-27
Side barriers	15-60
Frangible signs	30

Tree removal (rural)	10
Pole removal (lighting poles, urban)	20
Embankment treatment	40
Guardrail for bridge end post	20
Impact absorber	20
Pedestrian Facilities	
Pedestrian walkways	33-44
Pedestrian zebra crossings	13-34
Raised zebra crossings	5-50
Pelican crossings	21-83
Marking at zebra crossing	-5-14
Pedestrian refuges	56-87
Footbridges	39-90
Pedestrian fencing	10-35
Cycling Facilities	
Cycle schemes	33-56
Marked cycle crossing at signals	10-15
Cyclist advanced stop line at junctions	35
Rail Crossings	
Flashing signals	73-91
Automatic gates	81-93
Traffic Calming	
30 km/h zones (Inc. humps, chicanes etc.)	10-80
Rumble Strips	27-50
Rumble Strips and Bumps	20-80

NOTES:

1. Crash Reductions are NOT ADDITIVE, use the highest value if multiple treatments are proposed for a particular location.
2. Reductions apply to all crashes within single intersections or single midblock that contains the treatment.

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GRSA e.V.

The GRSA association was founded in the town Königs Wusterhausen near Berlin in April 2005. Our interdisciplinary team includes experienced road safety experts, road safety auditors and traffic psychologists. However, our main principle is "accident prevention instead of reaction" is independent of our profession. Because after the accident is before the accident!

As road safety auditors trained and certified by the Bauhaus University of Weimar or the University of Wuppertal, we bring our experience to our clients. No project is too small for the execution of a Road Safety Audit. We particularly want to encourage administrations and communities to use this method as a quality-assurance system with a focus on the safety. If you want to install such an audit system, we would be happy to help you. We want to share experiences with all colleagues from foreign countries. In fact, two of our members currently are working in the "Road Safety"-committee of the World Road Association (PIARC).

The primary emphases of our actions are the support of the Road Safety Audit as a component of the accident prevention. The development of measures for improving the safety of existing traffic facilities, the preparation of concepts for eliminating accident black spots, a technical and scientific exchange of national and international experiences including the training and further education of members and interested colleagues.

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SARSA

Serbian Association of Road Safety Auditors - SARSA is a non-governmental, non-partisan and non-profit association established for an indefinite period in order to achieve goals in the field of improvement of various scientific and professional aspects of the road safety audit, in particular the exchange and transfer of knowledge, as well as the experience of international experts through projects of road safety audit and development and distribution of publication in this field.

Goals of SARSA are:

- improvement of scientific and professional work in the area of RSA in the country and abroad,
- support the strengthening of the audit and improvement of road safety,
- preserving the reputation and dignity of the road safety auditors,
- providing protection to members when their professional rights are violated or threatened,
- improvement of professionalism and education of the road safety auditors,
- exchange and dissemination of experiences,
- exchange and transfer of knowledge and experience of international experts,
- development and distribution of publications,
- development and distribution of accompanying learning materials,
- establishing cooperation with other similar associations and organisations,
- encouraging the exchange of scientific and technical information between experts and
- implementation of other measures and activities that promote and strengthen the RSA

The SARSA achieves the goals independently or in cooperation with institutions, associations and organisations dealing with the improvement of road safety.

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Romanian Society of Road Safety Auditors - **SoRASR** represents an exciting initiative in providing a home for the development of professional highways and other type of the roads safety auditing best practice. **SoRASR** was established in 2015 as a response to a growing call for professionals operating in the field of safety auditing and safety engineering practice in Romania, for a forum to exchange best practice and, importantly, to provide advice and ultimately routes to professional recognition for safety auditing practitioners. The members of SoRASR are specialists in road safety engineering & design, road transport and road construction. **SoRASR** develops and sustains the strategic guidelines consistent and uniform policies in the field of road safety through specialised auditors in identifying and solving problems in the road transport sector. Its aim is:

- Promoting the general interest over Road Safety Audit in order to increase safety of road infrastructure in Romania and to reduce the number and severity of traffic accidents, thus emphasising, the need to expand its importance and influence in the road safety field,
- Functioning as a concentrator pole for inspectors and auditors of road safety in Romania,
- Providing a network of experts to promote and provide training and consultancy in the field of RSA,
- Conducting professional road safety audit training courses,
- Promoting specific activities to support the professional development of members and
- To boost the factors directly involved in the issue of road safety on the roads in Romania.

SoRASR is based on the principles of the concept of the continuous professional training system in the field of road safety, in order to create the framework in which we can solve the industry's requests related to training of the staff involved in road safety activities.

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The Centre for Road Safety ''CBS'' Banja Luka was established on January 12th, 2015. and it was registered in the unified register under the number F-1-14 / 15 at the Court in Banja Luka. The primary mission of the Center is to raise the level of road safety through various activities and in cooperation with all interested stakeholders and legal entities and individuals.

The fundamental goals of the association related to the improvement of the Road Safety Audit and Road Safety Inspection process are to support the strengthening of the RSA and RSI procedures, to preserve the reputation and dignity of road safety auditors and road safety inspectors, to provide protection to members when their professional rights are violated, to raise the professionalism and professionalism of road safety auditors and road safety inspectors, to exchange and disseminate the experiences of countries that have implemented measures and programs for RSA and RSI, to exchange and transfer the knowledge and experience of international experts through projects of auditing and inspections of traffic and case studies, to develop and distribute various publications in the field of RSA and RSI, to develop and distribute various accompanying learning materials (presentations, presentation instructions) in relation to publications, to establishing cooperation with other similar associations and organizations in the country and abroad.

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International Road Safety Center - IRSC is a not-for-profit organisation, established by a number of international road safety advocates, Belgrade University, and other key local and international road safety organisations specifically to meet the needs of development banks, aid agencies and governments of Low and Middle Income Countries (LMICs). **It assists Governments to do capacity building in road safety.** It trains LMICs officials and organisations in road safety issues related to the 5 UN Decade pillars of road safety and in management development and implementation of national road safety programs. Training can be delivered at IRSC or its local partner organisations (e.g. University, police academy, road safety agency, driver training centre, Centre for Motor vehicles) in Belgrade or at partner organisations in client countries. Course leaders and trainers are drawn from a pool of international experts who all have practical experience of implementing major reforms and successful safety improvement programs. Some of them are government officials who were or still are responsible for road safety activities in their countries, and many are former senior staff from specialist Consultants, Development banks, aid agencies and international organisations dealing with road safety at Global level. Between them, our pool of expert trainers has advised on road safety issues, programs, and Action plans in over 120 countries (more details from www.irscroadsafety.org).

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AMSS – Centre for motor vehicles Ltd. (AMSS – CMV) is a company specialised in technical services in the field of road safety and other related areas. Nowadays, AMSS – CMV is also designated as Research and Development Centre (IRC). The scientific research team of AMSS – CMV is comprised of very experienced researchers led by 5 PhDs level experts with international references in the field of transport, especially in road safety, as well as numerous associates with the specialist knowledge and experience in transport and road safety issues. The scope of AMSS – CMV activities includes areas of vehicle safety, road and road environment safety, and a wide range of research and development projects in the field of road safety.

AMSS – CMV is one of the leading companies in the field of vehicle safety, covering almost 80% of the Serbian market in the field of testing and inspection of vehicles. The company has a long history in implementing road safety projects, with a focus on recording and assessment of road safety in accordance with EuroRAP/iRAP methodology and has a considerable experience at the national and global level. AMSS – CMV implements different development projects and researches that contribute to road traffic safety improvement, in line with current scientific achievements and international best practices in this field. Some of the projects are aimed at: evaluation of the state of road safety, risk analysis and risk assessment on roads, development and establishment of road safety portals and road safety databases for national and local level administrations, using cutting-edge software solutions in GIS environments; development of the methodology for identification of potential black spots on the basis of road accidents locations, including the software solution; development of the methodology for benchmarking road safety in the closed systems; preparation of road safety strategies and action plans; analysis of children's safety in road traffic, etc.

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RESEARCH AND DEVELOPMENT CENTER

R&D Department of AMSS-CMV is registered as "**Research and Development Center**" sertificate by Ministry of Education, Science and Technological Development of Republic of Serbia, num. 391-00-12/2016-16 since July 2016.

Projects, studies and analyzes in the field of Road Safety

Road Safety Strategy and Action plan

Road Safety Portal

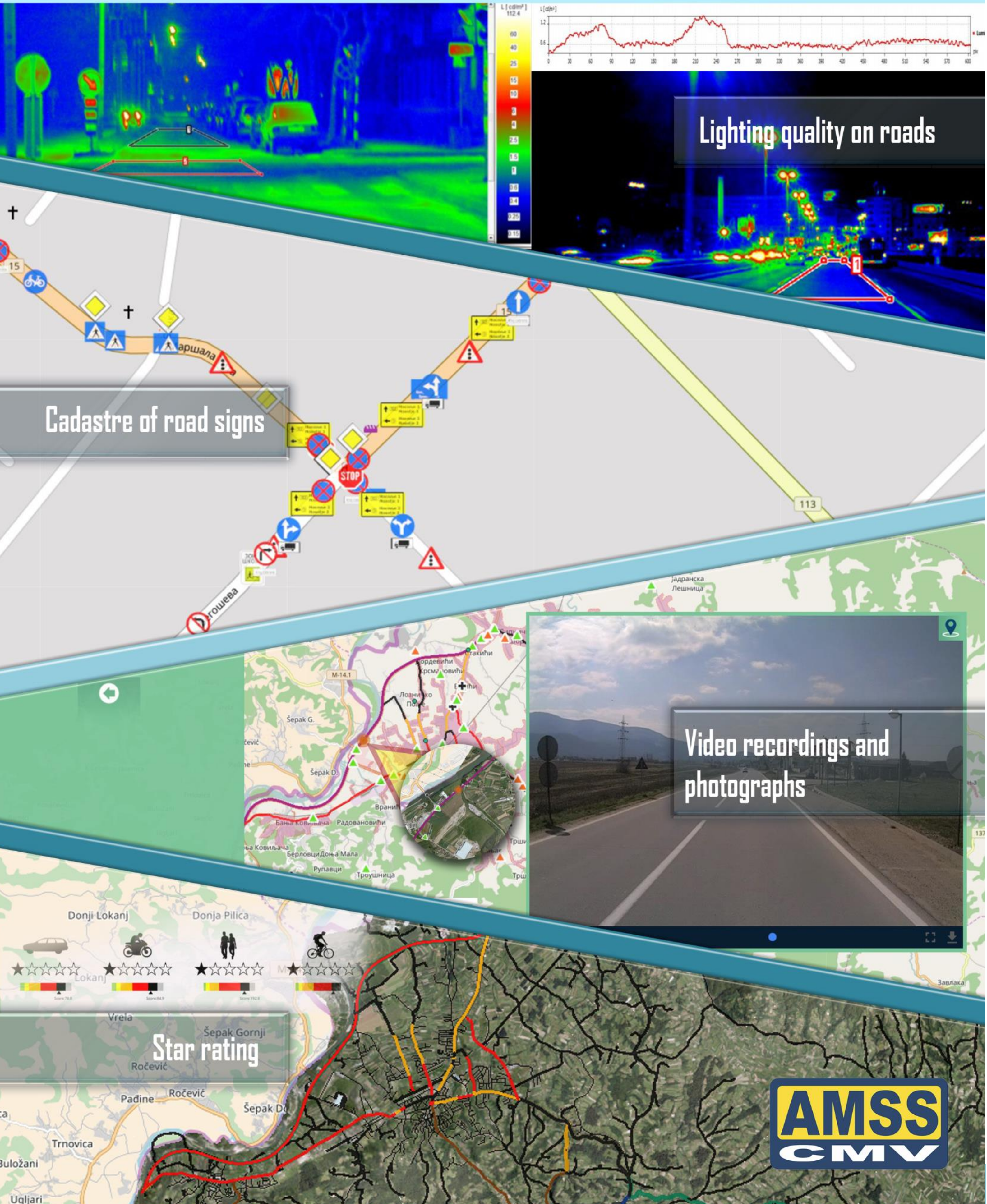
RDC CMV

AMSS (The Automobile and Motorcycle Association of Serbia) - Center for Motor Vehicles

AMSS CMV

ROAD SAFETY PORTAL FOR CITIES AND MUNICIPALITIES

Roads and road safety characteristics of roads



PRACTICAL GUIDE FOR ROAD SAFETY AUDITORS AND INSPECTORS