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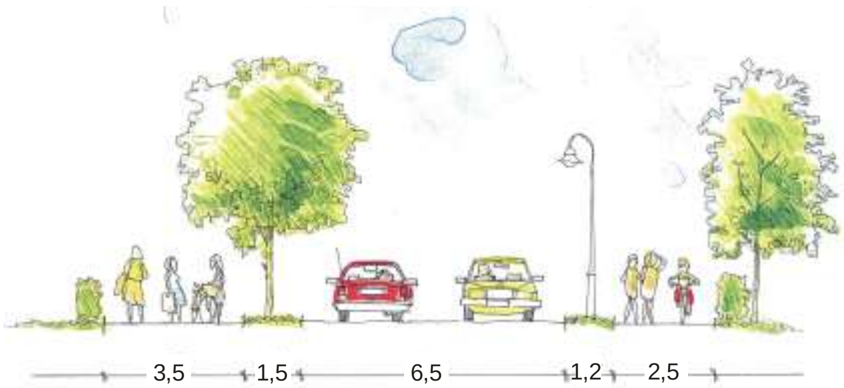
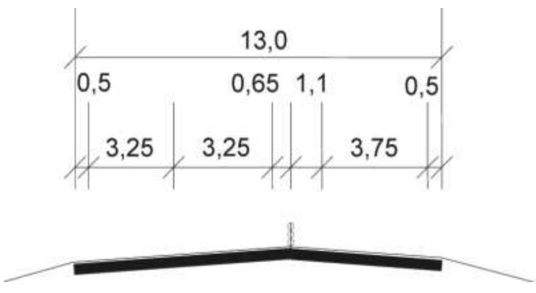
Consulting Services for Safe Road Design

Safe Road Design Manual

Amendments to the WB Manual

2011-02-25





Safe Road Design Manual

Amendments
to the World Bank Manual

FOREWORD

Background

As part of the project “Consulting Services for Safe Road Design in Serbia” a **Safe Road Design Manual** based on the World Bank manual “Sustainable safe road design” (September 2005) will be produced. It consists of two parts:

- The World Bank practical manual “Sustainable safe road design”
- Amendments to the World Bank manual

The WB manual is written to:

- give designers guidance to find adequate solutions for a problem area
- provide decision makers with proof of the possible benefits of a specific solution
- use as a reference book
- use as teaching material

The Amendments are based mainly on:

- **PIARC Road Safety Manual** (2003)
- **Best practices in road safety**, Handbook for measures at the country level, EU 2010 (The SUPREME project (**SU**mmary and publication of best **P**ractices in **R**oad safety in the **E**u **ME**mber States)
- **RiPCORD-iSEREST**, European Safety Project
- **Swedish Design Guidelines** (VGU, Vägars och Gators Utformning)

Purpose and target group

The purpose with the **Safe Road Design Manual** is to emphasize safety considerations in mainly the design of rural roads. The target group is road designers and road administrators engaged in road planning and road design.

The manual contains general safety principles and typical examples on safety aspects in the design of different road elements.

The purpose is not to give detailed design rules for different road elements. Such rules can be found in Serbian and international Design Guidelines in which not only safety but all other design aspects are considered.

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2011-02-25

1 INTRODUCTION

1.1 World Bank manual "Sustainable safe road design"

*The **World Bank manual "Sustainable Safe Road Design, a practical manual"** (WB manual) is presented in a separate document. This section presents a short description of the purpose and the contents.*

1.1.1 Purpose

The WB manual has been created during the project "**Safe Road Design**", funded by the World Bank and in cooperation with the Dutch Ministry of Transport, Public Works and Water Management.

"Sustainable Safe Road Design, a practical manual" is a manual to assist when developing national roads outside urban areas. The three core aims are to:

1. *provide an overview of relevant safe road design practices;*
2. *provide material for future training courses;*
3. *guide experts in applying safer road design measures in different countries*

This manual is not a guideline on road design for one specific country. The manual is based on both the Dutch philosophy of sustainable safe roads based on the Dutch standards and guide lines and on the training sessions given in Bulgaria, Estonia, Latvia, Lithuania, Poland, Romania and Turkey in autumn 2004 and spring 2005.

Every location, every country and every culture is distinct in its own way and an appropriate solution needs to be found for each location. The information contained in this manual should always be adapted for the specific situation.

Not all weather and geographical conditions are treated separately from each other. It is important to develop country guidelines which consider the specific conditions encountered on the roads.

The manual is written:

1. *to give designers guidance to find adequate solutions for a problem area*
2. *to provide decision makers with proof of the possible benefits of a specific solution*
3. *to use as a reference book*
4. *to use as teaching material*

1.1.2 Contents

The manual "Sustainable safe road design – a practical manual" contains information on the principles of sustainable road design, looking at the specific engineering implications. This manual focuses on the engineering principles of sustainable road safety, and covers to a lesser degree the principles that education and enforcement play in sustainable safety. The manual focuses only on two-lane roads (single carriageway) outside built-up areas.

The WB manual consists of twelve chapters. The first three chapters present a strategy for the management of safety problems and general principle for safe road design.

1. INTRODUCTION
2. STRATEGY
3. THEORY

The following five chapters present general principles and examples of the design of different road elements.

4. CROSS SECTION
5. JUNCTIONS
6. ALIGNMENT
7. LINEAR VILLAGES
8. PEDESTRIAN CROSSING

The last four chapters present examples on and principles for the identification of safety deficiencies and the evaluation of countermeasures as well as other measures than design.

9. CASE STUDIES IN DIFFERENT COUNTRIES
10. ANALYSIS OF BLACK SPOTS
11. COST BENEFIT AND COST EFFECTIVENESS ANALYSIS
12. EDUCATION AND ENFORCEMENT

1.1.3 Recommendations and changes to strengthen the WB manual

According to the Contract the assessment of the Manual of Safe Road Design should consider the following:

- ***Content of the Safe Road Design manual*** in terms of completeness of aspects covered, the information per aspect, the quality of case studies and additional information;
- ***Ease of use of the Safe Road Design manual*** in terms of clarity of the manual, accessibility of information, balance between aspects, logical order of aspects presented, flexibility in use, etc;
- ***Practical use of the Safe Road Design manual*** in terms of usefulness of manual elements for practical work;
- ***Application of the Safe Road Design manual*** in terms of being useful for the road administration, regional bodies and traffic police;
- ***Transferability of the Safe Road Design manual*** in terms of the extent to which the manual applies to the Serbian situation; and
- ***An Amended Safe Road Design Manual, suitable for use in the Serbian Context***

Some comments to those points and references are given below.

Content of the Safe Road Design manual

The need for amendments is described in the section “1.2 Need for amendments” below. The case studies presented in chapter 9 in the WB manual are to a great extent applicable in Serbia.

Ease of use of the Safe Road Design manual

The information in the WB manual is judged to clear and easily accessible. The aspects are presented in a logical order, but some aspects are not treated sufficiently. Thus, there is a need for amendments. See section 1.2 below!

Practical use of the Safe Road Design manual

The manual should be used as a complement to other guidelines, e.g. for road design and traffic control, to highlight the safety considerations in road design.

Application of the Safe Road Design manual

In practical work, the manual is foremost usable for designers and road administration staff working with design. For others, e.g. the traffic police, the manual can be used for training and information about safety aspects regarding existing road conditions and design.

Transferability of the Safe Road Design manual

All information in the manual is not directly applicable to Serbian conditions. However, the information in the manual gives basic knowledge and understanding of safety problems related to existing road conditions and design. For some sections, e.g. road types the information must be related to existing Serbian road conditions and guidelines.

An Amended Safe Road Design Manual, suitable for use in the Serbian Context

Together with the amendments proposed in this document the WB manual will hopefully be a usable tool for in the upgrading of existing and design of new Serbian roads.

1.2 Need for amendments

The WB manual is not adapted to specific conditions in every country and it does not cover all design items important for safety. Thus, there is a need for amendments for two reasons:

- Adaptations to Serbian conditions
- Addition of design items not considered or only briefly discussed

Often the need for adaptation to Serbian conditions and the addition of design items coincide.

1.2.1 Adaptation to Serbian conditions

The need for adaptation must consider the existing road and traffic conditions as well as the current design practices and existing Serbian guidelines.

Concerning the existing road and traffic condition the following has been noted:

- The design of intersections are not according to modern standards
- There are often obstacle too close to the road
- There are generally no provisions for vulnerable road users (pedestrians and cyclists)
- There are no speed control measures at intersections or roads passing through built up areas
- Bus stops are often missing or have a low design standard
- The standard on traffic signs and road markings is often low
- There are sometimes too many signs
- Speeding is a common problem
- The road users' respect for traffic signs seems to be low

The current design practices seem to be more focused on capacity for motor vehicle traffic than the safety for all road users. Examples are e.g. the use of right turning lanes in intersections, the number of lanes in intersections (e.g. roundabouts) and the lack of facilities for pedestrians and cyclists and of speed control measures.

The safety deficiencies in current design practices reflect the deficiencies in the Serbian design guidelines. The official design guidelines are old. New, in some aspects rather comprehensive, design guidelines have been worked out but are not yet adopted. Even the new proposed guidelines seem to be more focused on capacity than safety and there is a lack of guidelines for some important safety items. The lack of or deficiencies concerning safety have been noted for the following design items:

- T-intersections
- Pedestrian facilities
- Median separation
- Design of road side areas
- Bus stops
- Traffic calming
- Speed control measures
- Guardrails
- Local access roads (frequency, location and design)

1.2.2 Addition of design items

Some design items important for safety are not included or only briefly discussed in the WB manual. For others there is a need for amendments. The following design items are concerned:

- Median separation
- Clear roadside area
- Roadside barriers
- Traffic calming and speed control measures
- Pedestrian and cyclist facilities
- Road side facilities
- Signs and markings

1.3 Overview of amendments

Based on the need for adaptations to Serbian conditions and for addition of design items not included or only briefly discussed in the WB manual as well as considering discussions during the workshop, the following amendments have been prepared.

Safety considerations in design

To focus on safety consideration in design some principles for general design consideration and for special safety considerations are presented.

Rural road links

On Serbian roads there are many of the serious accidents are head-on collisions and run-off accidents. Important safety measures are to reduce the number of and mitigate the consequences of those accidents. Thus, median separation, guardrails and the provision of a forgiving roadside are presented.

Road with many head-on collisions (M-19 Ostruznica)

A good alignment and ample possibilities for overtaking are also important safety factors. Therefore, some general advice for alignment choice and terrain adaptation and for the use of overtaking lanes is presented.

Road links through built up areas

On road links through built up areas are conflicts between through traffic and local traffic and between motor vehicles and vulnerable road users. On rural roads in Serbia there are many links through built up areas (linear villages) with big safety problems.

Important measures to deal with those conflicts are to control the speed and to separate vulnerable road users from motor vehicle traffic. Speed control principles and measures as well as design principles and example for different types of road links through built up areas are presented.

Intersections

Many accidents occur in intersections. Existing intersections in Serbia are generally not designed according to modern safety standards.

Unsafe design of T-intersection (M-22, Barajevo)

To reduce the number of accidents and mitigate the consequences suitably selected and well designed standard intersection should be used. Thus a set of standard intersections to be used is proposed and a method for selection of intersection type is presented.

Road side facilities

On most rural roads in Serbia there are bus lines. Bus stops are often missing or badly designed. Passengers are sometimes waiting and dropped directly on the roadside or in the middle of intersection creating safety problems for the passengers as well as for other road users.

The provision of well located and correctly designed bus stops is an urgent safety measure. Therefore, general recommendations and design examples are presented. From a safety point of view it is also important to offer possibilities for drivers to safely stop for shorter and longer breaks to for example rest or use the mobile phone.

Pedestrian and cyclist facilities

The perhaps most serious safety deficiency on rural roads in Serbia is the lack of facilities for pedestrians and cyclists (vulnerable road users). Pedestrian crossings, if any, are generally not located or designed according to modern safety principles. There seems to be very few separate roads or lanes for pedestrians and cyclists along rural roads.

An overview of different types of separation of vulnerable road users and examples on design of pedestrian crossings are presented.

Signs and markings

Signs and markings can provide important information to improve road safety. Some general requirements are presented.

2 SAFETY CONSIDERATIONS IN DESIGN

People working with road design should have sufficient knowledge about three different aspects of road safety:

1. General understanding of the road safety problem
2. How to handle safety problems – find the problems and the countermeasures
3. How to take safety considerations in design and equipment of roads

The first aspect includes e.g. the understanding of the need to adapt the infrastructure to the human capabilities and the importance of speed for accident risks and consequences.

The second aspect includes programs like RSA (Road Safety Audit), RSI (Road Safety Inspection), and BSM (Black Spot Management).

The third aspect includes the design of different road elements - like cross section and intersections - and the equipment with signs, markings, guardrails etc.

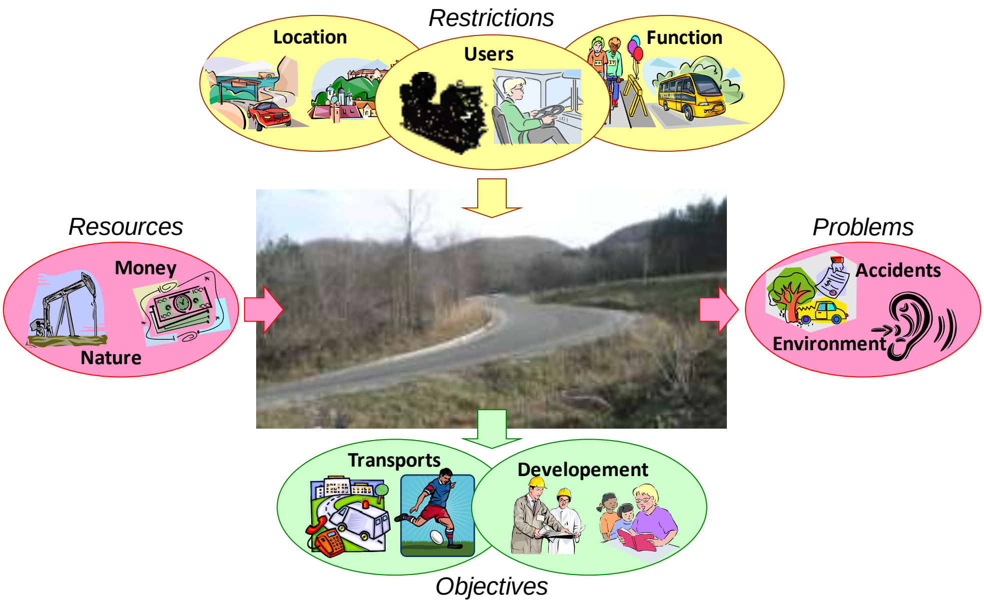
The World Bank manual "Sustainable safe road design" and consequently these amendments, describes different parts of those three aspects.

2.1 Design considerations

2.1.1 Introduction

The road network is an integrated part of the society. Thus, road design is influenced by many interacting factors. The ***objectives*** with roads are to achieve positive effects for example to make services and other activities available and contribute to the development of the society. However, the construction and use of roads also causes negative effects. It consumes monetary and natural ***resources***, and creates ***problems*** like accidents and environmental impacts. Roads must also be adapted to different kinds of ***restrictions*** like the capabilities of road users and vehicles, the intended function and the location. Considering the restrictions roads should be designed to meet the objectives and to avoid the negative effects.

The objectives, restrictions and demands on roads, and consequently in road design, can be illustrated by the picture below.



2.2 Safety considerations

2.2.1 General Principles

Background

The view on traffic safety and traffic safety work has changed with the development of traffic and the role of road traffic in the society. In the early years of motorization, cars were looked upon as horse drawn carriages. Safety measures were mainly focused on vehicle requirements. The development of technology, especially increased power and speed of motor vehicles, made the comparison with horse-drawn carriages out-of-date. Safety measures were focused on adapting people to this new traffic situation.

Today, the whole transportation system, of which the road traffic system is one part, is contemplated. Safety measures are focused on reducing the exposure of risks, eliminating risk factors and reducing the consequences of accidents. Typical measures are speed limits and separation of motorized traffic from other types of traffic. With this approach, the purpose of traffic safety work in road design is mainly to eliminate the risk factors and mitigate the consequences of accidents. The long-term objective is that no one should be seriously injured or killed when using the road traffic system as long as the traffic rules are followed.

Injury risks

The risk of being injured or killed in an accident increases considerably with increased speed. In summary, many studies have shown that:

- The number of injury accidents increases with the square of the vehicle speed
- The number of fatal accidents increases with the fourth power of the vehicle speed.

The figure on the next page shows how the risk of being killed in a crash varies with collision speed. The graph for pedestrians is well supported by research results, while the graphs for vehicle collisions are partly based on expert assessments.

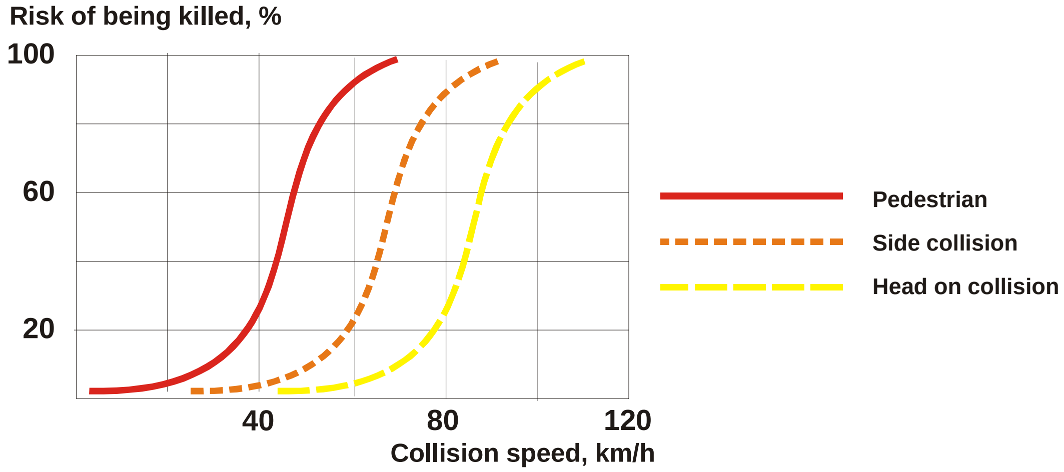
The graph shows that the risk of being killed increases rather slowly up to a speed where the risk of being killed is around 10 percent - and then the risk increases rapidly. The conclusion is that a road transport system should be designed to avoid conflicts at speeds where the risk to be killed is higher than around 10 percent. This means that speeds should not exceed:

- 30 km/h in a pedestrian/vehicle collision
- 50 km/h in a side-on vehicle/vehicle or vehicle/object collision
- 70 km/h in a head-on vehicle/vehicle or vehicle/object collision.

From this, some basic planning and design rules can be derived, for example:

- Vulnerable road users should be separated from motor vehicle traffic
- At points of conflict between vulnerable road users and motor vehicles, speeds should be low (preferably 30 km/h or lower)
- Intersections should be designed to reduce collision speeds, especially for side-on collisions (preferably to 50 km/h or lower)
- The risk for head on collisions and collisions with rigid objects must be reduced to the greatest possible extent especially where speed is 70 km/h or higher.

However, measures to lower the speed, for example in intersections, are not sufficient. Measures to reduce the risk of conflicts and the consequences of collisions must also be taken. Examples of such measures are: the use of standard type intersections and reducing the number of potential conflict points and the sizes of conflict areas.



The risk of being killed in traffic accidents depending on collision speed

Safety responsibility

Research has shown that the human being is an unreliable operator in the road traffic system. The most typical mistakes made by drivers and other road users are common to almost all drivers and not limited to only a few. Consequently, all road users can be expected to make mistakes which can lead to accidents. A road traffic system in which such common human mistakes leads to fatal and serious injuries cannot be accepted. Common human mistakes should not lead to catastrophes.

The responsibility for road safety must be shared between the road users and the road transport system providers (mainly road authorities and vehicle manufacturers as well as legislative, surveillance and enforcement bodies). The road users' responsibility is to follow the system requirements – i.e., to obey the traffic laws and regulations, use available protection equipment and behave with good judgement and responsibility. The responsibility of the system provider is to provide a road system designed to minimize the risk of accidents and to only allow accidents imposing forces to the human body that can be resisted without serious injuries. This responsibility lies to a great extent with the road designer.

2.2.2 Safety considerations in design

Designing safety into roads is one of the main objectives of geometric design. It is important that safety features are built into the road from the very start of the design. To make corrections afterwards are often more expensive and difficult to introduce.

Safety considerations in roads have the two objectives to:

- Prevent accidents
- Reduce the seriousness of the accidents that occur.

Accident prevention

For the prevention of accidents the following points are especially important:

- Creating a road design and environment that is self explaining for the road users, so they understand what is expected from them and how to behave
- Provision of physical separation between motor vehicles in opposing directions and also with other road users (especially pedestrians and cyclists)
- Avoidance of surprise elements for the drivers, for example abrupt changes in standard, insufficient visibility or poor phasing of horizontal and vertical alignment
- Avoidance of situations where drivers must make more than one decision at the time
- Provision of design features that reduce speed differentials between vehicles, for example flat grades and speed change lanes
- Proper location and design of intersections

- Proper design, application and location of traffic signs, road markings and other traffic control devices
- Provision of design elements compatible with traffic volumes and type of traffic
- Provision of road design compatible with the roads traffic function
- Provision of proper drainage of the road surface.

Reducing the severity of accidents

A lot can be done to reduce the severity of accidents that we fail to prevent. The basic principles are:

- There should be a clear zone (safety zone) along each side of the road that is free from hazards such as lighting columns, other utility poles, rocks, drainage structures, etc.
- Roadside slopes should be as flat as feasible (1:4 or flatter)
- Sign posts and other supports which must be located within the clear zone should be of a breakaway type or protected by guard rail

Safety barriers should be provided to protect vehicles from hitting dangerous obstacles that cannot be removed or made breakaway and also to protect vehicles from running off the road down embankments.

Ripcord WP3 - Best practice on Road Design and Road Environment:

One prerequisite for a safe traffic is that the road design is in accordance with the function of the road. The road user has to be informed about the function of the road by the road design. To achieve that road users choose their traffic behaviour in accordance with the function of the road, the design of the road must be self explaining.

As a second prerequisite, the road and the roadside environment must be designed in such a way that mistakes of the drivers do not lead to serious accidents (forgiving roadside environment). Based on information on road classification in European countries as well as information on road design, the design of the roadside environment and traffic regulation best practice guidelines on road classification and the design of self explaining roads will be formulated.

Since most fatalities on rural roads are caused by two types of accidents, information on measures to avoid and to reduce the severity of head-on-collisions and run-off-the-road-collisions will be collected. Based on validated established measures in European countries the best practice concerning these aspects will be worked out.

2.3 The four-stage principle

2.3.1 Overview

The four-stage principle should be seen as a general approach to analyses of measures for the road transport system and not as a strict model that should be applied at some specific planning stage. It was originally launched in order to manage investment funds, but has been developed to a general planning principle for management of resources and reduction of the road transport system's negative effects.

The principle is constructed on a general transport-type approach, but primarily deals with deficiencies and problems within the road transport system. A basic consideration is that measures outside the road transport system can reduce the demand for road transport, and thus the requirement for measures within the road transport system. As a first step therefore, measures outside the road transport system should be tried. After that, the principle is, to a very large extent, concerned with analyses of measures within the road transport system.

The four steps involve measures being analysed in the following order:

2.3.2 Step 1

Measures which reduce the demand for transport and the choice of modes of transport

This step include planning, control, regulation, effect and information bearing on both the transport system and society at large, in order to reduce the demand for transport or transfer transport to less space-requiring, safer or more environmentally friendly means of conveyance.

2.3.3 Step 2

Measures that give more efficient utilisation of the existing road network

This step include input within control, regulation, effect and information directed towards the various components of the road transport system, in order to use the existing road network more efficiently, more safely and in a more environmentally friendly way.

2.3.4 Step 3

Road improvement measures

This step include improvement measures and rebuilding of existing segments, for example, traffic safety measures or load-bearing capacity measures.

2.3.5 Step 4

New investment and major rebuilding measures

This step include rebuilding and new building measures, which often demand new land, for example, new segments of road.

2.3.6 Application

The four-stage principle describes an approach in the analyses of measures for solving identified problems and deficiencies. It therefore presupposes that an analysis of deficiencies has been carried out, in which the existing situation is compared with the transport-policy goals.

- An accessible transport system
- High transport quality
- Positive regional development
- Safe traffic
- Good environment

2.3.7 Example

Problem: Many head-on collisions on a 13.0 m wide 2-lane main road.

	Possible measures	Evaluation and suggestion
Step 1	No measure found	- immediate: speed reduction - short-term: 2+1 - long-term: motorway
Step 2	Reduce speed	
Step 3	2+1 road with median barrier	
Step 4	Reconstruction to motorway	

3 RURAL ROAD LINKS

3.1 Alignment choice and terrain adaptation

3.1.1 Introduction

To locate a road in a landscape is a challenge with constraints and possibilities. It is a technical and also an architectural process.

The main principle is to adapt the road to the surroundings considering technical requirements on sight distances such as sufficient overtaking possibilities, minimum geometric elements and visual guidance not to adorn or to emphasize.

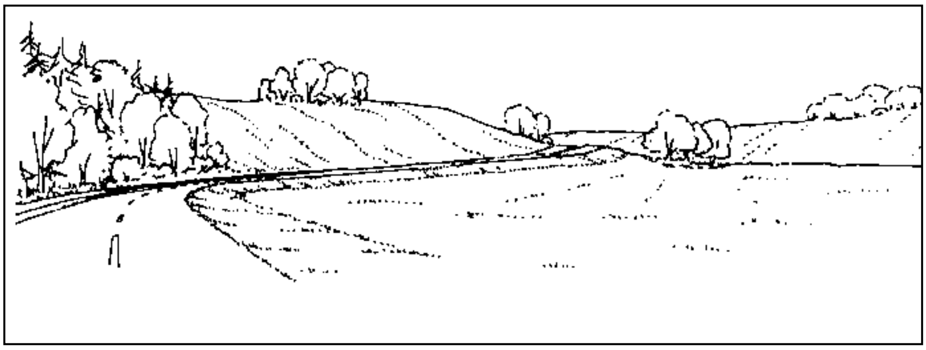
3.1.2 Design concepts

Three basic concepts unite and constitute the technical and the architectural process to locate the road in the landscape:

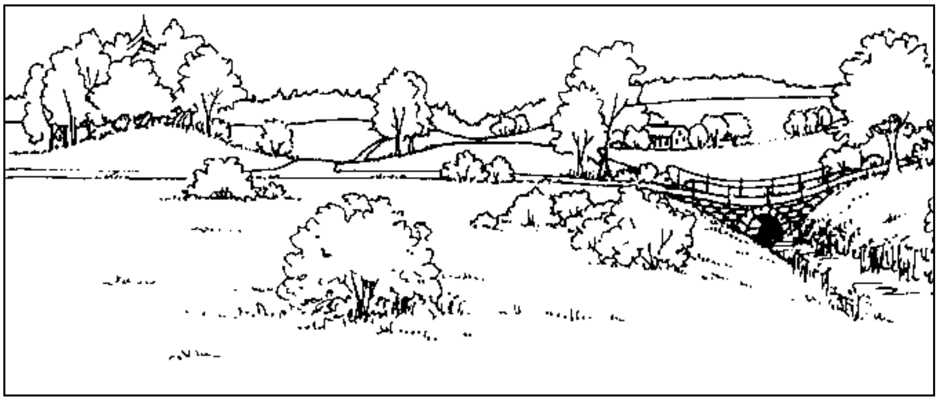
- Scale and form
- Space
- Rhythm.

Scale and form

The landscape can be large-scaled or small-scaled as illustrated in the figure below.

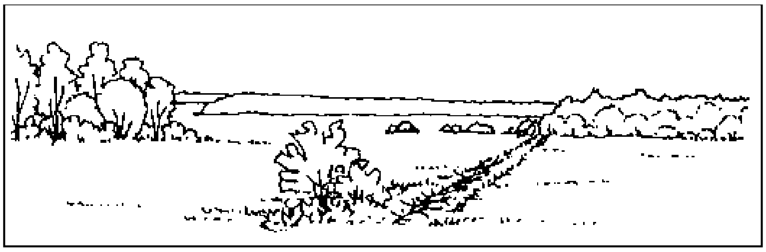


Large-scaled landscape



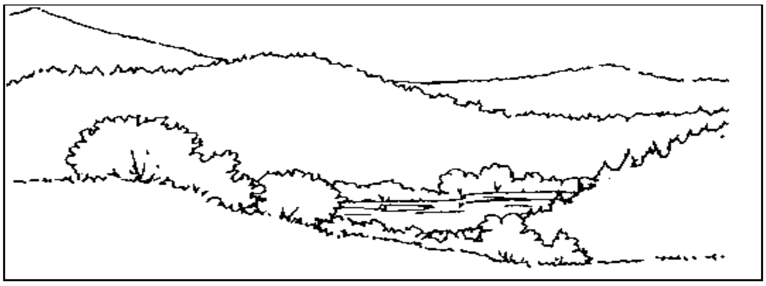
Small-scaled landscape

Landscapes can be differentiated in types such as:



Flat landscape

Slightly hilly landscape



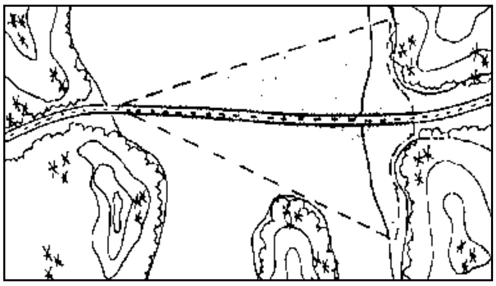
Hilly landscape

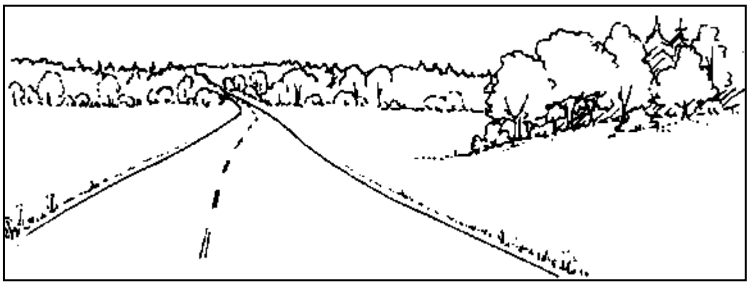
Space

The space or room is a defined part of the landscape – as far as you can overview from a specific point. The limitations of the space or room could be:

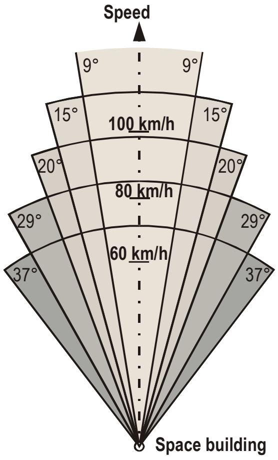
- Terrain (mainly topography), vegetation, buildings
- Road design, i.e. cross-section, horizontal and vertical alignment
- Crossing bridges and road embankments.

Driver's space or room concept:





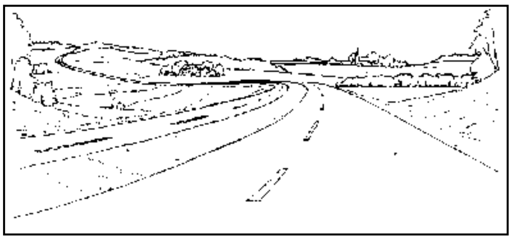
Space limited by ridges and trees



The eye view angle decreases with speed

Rhythm

The rhythm of a trip along a road – the experience and enjoyment – depends on the design and how this design is located in the landscape. The designer should use the landscape combined with the road alignment, cross-section and road side area to create a variation, rhythm, in impressions and outlooks. The objective is to create a road that is enjoyable to drive.



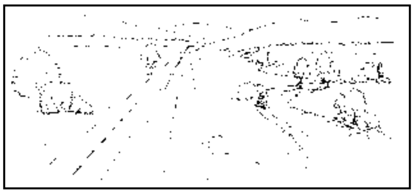
Some examples on rhythmical landscape adaptation

3.1.3 Design requirements

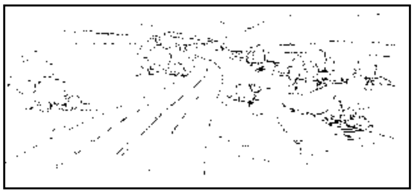
The alignment should, together with the cross-section, the roadside area, and the surroundings, create variation in outlooks for the driver and also support him in his driving task with visual guidance. Outlooks should be long enough to be comprehensible at the design speed. A simple rule of thumb is that outlooks should have at least the same length in metres as the design speed in km/h representing 4 to 5 seconds driving time.

The alignment is three-dimensional. It is of utmost importance to look at and treat the alignment design as a space curve following as far as possible the laws of perspectives.

The road should have an inner and an outer harmony. The inner harmony means that the road should have a satisfying, calm and graceful geometric form – considered only as a space curve without terrain. The outer harmony requires the space curve to be tuned with the terrain and in harmony with the landscape. The geometric elements should have the same scale as the surrounding terrain.



No harmony



Harmony

Example of adaptation to the landscape

3.2 Overtaking lanes

3.2.1 Definition and design principle

An overtaking lane is an extra lane to left of the through lane to facilitate overtaking in steep ascents or descents or on roads with limited overtaking possibilities.

The widening to create space for the extra lane can be made in different ways. Important is that the traffic is kept in the through lane and that the extra lane is used for overtaking only.

Widening to the right

Widening to the left

Symmetric widening

Offset of the centre line

3.2.2 Climbing/descending lanes

The use of climbing/descending lanes

Climbing lanes should be considered if the design truck speed decreases more than 20 km/h under the truck speed limit, normally 80 km/h in rural conditions. This gives the threshold criteria shown in the table below on combinations of grade and length. For example, an average grade of 2% requires a length of 1500 m before the design vehicle speed has dropped 20 km/h.

Average grade (%)	Minimum length (m)
2	1500
3	500
4	300

Threshold criteria for climbing lanes

Descending lanes should be used on long, steep, downgrades due to risk of overheating and brake failures. It is recommended that downgrades longer than 1000 m with average grades over 5% are reviewed for the need of descending lanes.

It is difficult to give specific traffic flow warrants when to justify climbing/descending lanes. Improved level-of-service and traffic safety should be weighed against costs and intrusion. The traffic safety effect is estimated to be some 20 – 30 % according to a number of studies. Level-of-service effects could be estimated using the US Highway Capacity Manual and depends to a large extent on traffic flow, ratio of heavy vehicles and over all alignment. The traffic flows in the table below are suggested.

Grade %	AADT design year
3-4	3-5000
5-6	2-4000

AADT-volumes to justify climbing/descending lanes

Design

The climbing lane should have full width over the section with design truck speed below 60 km/h with entry and exit tapers according to the table below. The design should be smooth. At lane-drops the sight distance should exceed that required for "no overtaking" centreline markings, and should preferably be much more than this.

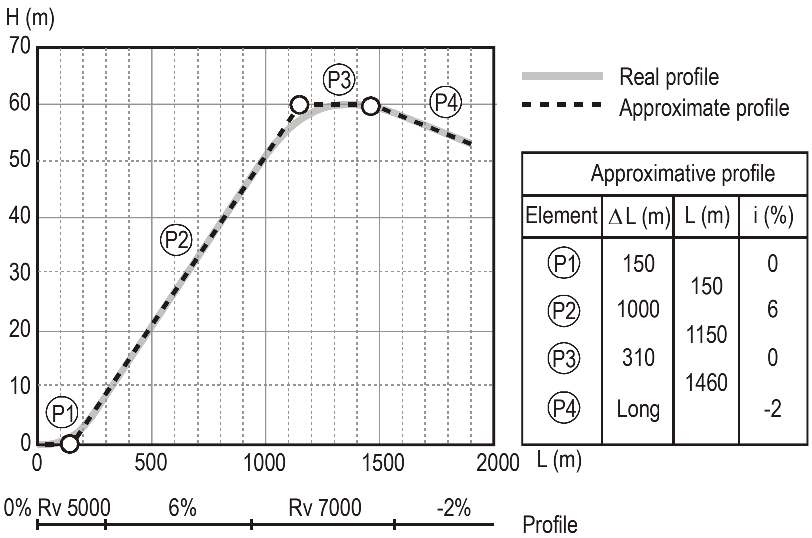
Speed (km/h)	Entry taper (m)	Exit taper (m)
80	150	200
100	200	300

Entry and exit taper widths

The climbing lane width should normally be 3.5 m. but this can be relaxed to 3.0 m where space is limited. The paved shoulder width should be unchanged, as the shoulder will continue to be used by pedestrians and cyclists.

Speed profile

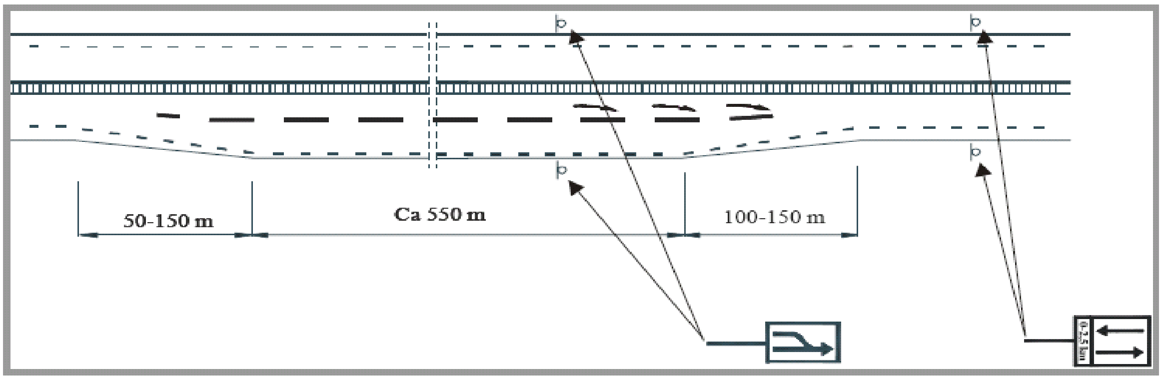
The speed profile graph can be used to assess truck speed behaviour on combined vertical alignments as shown in the following example.



Example profile

3.2.3 Overtaking lane

Overtaking lanes can be used on roads with median separation (see 2+1 or 1+1 roads) or with limited overtaking possibilities. A typical design of an overtaking lane is shown in the figure below.



Typical design of an overtaking lane

3.3 Median separation

3.4 Type of separation

The separation can be made with or without a median barrier. From a safety point of view a median barrier is preferred, and should always be used when the road is wide enough.

Separation with median barrier

Separation without median barrier

If the road width is not sufficient to install a median barrier, centre line crossings can be limited by a centre line marking reinforced with cat-eyes or milled rumble strips. Based on Swedish experiences milled rumble strips is recommended for Serbia based on problem with cat-eyes for winter maintenance.

Median barrier

Milled median rumble strips

3.4.1 2+1 roads with median barrier

Introduction

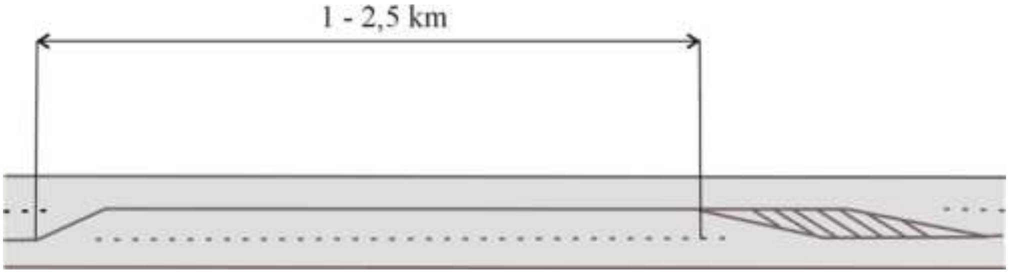
Two plus one (2+1) road construction is a measure where an existing road is updated to have a middle lane changing direction every 1 – 2.5 kilometre. Alternatively the construction method can be applied to new roads. The distinctive advantage of the 2+1 solution is that a median barrier prevents the head-on collisions.

Number of lanes

A 2+1 road can have road links with 2+1, 1+1 or 2+2 lanes. The main alternative is 2+1 where a central overtaking lane changes directions.

The overtaking lane should be between 1 and 2.5 kilometres according to the figure below. The difference between successive sections should not be too big. From a capacity point of view the sections should be short when the traffic volume is high.

The length of overtaking lanes in each direction should not be less than 35% of the total road length.



Normal section length on a 2+1 road

The length and location of overtaking lanes should consider:

- if possible, transitions from 1 to 2 lanes should be located at intersections
- 1-lane sections should not be located at steep ascents
- transitions from 2 to 1 lane should be easily visible

Road sections with 1+1 lanes should be considered:

- if the separation of pedestrians and cyclists is difficult or too expensive
- if roadside measures are too expensive
- if there are bridges or other conditions limiting the total width
- if the overtaking lane will be too short

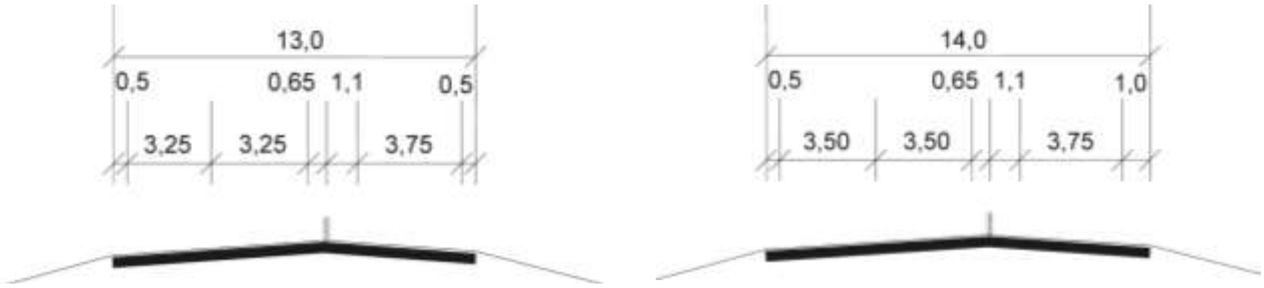
Road sections with 2+2 lanes should be considered:

- to balance the length of overtaking lanes in both directions
- to avoid 1-lane road sections in long ascents
- if the proportion of slow moving vehicles are high

Cross section

2+1 sections

Typical cross sections for existing and new or widened roads are shown below.



Existing roads

New or widened roads

Typical cross sections

One lane sections should be 5.15 – 5.85 m wide with:

- 0.50 – 1.0 m wide outer shoulder
- 3.50 – 3.75 m wide traffic lane
- 0.90 – 1.10 m wide median shoulder

1+1 sections

The design should "deterr" from overtaking. Thus, wide lanes and shoulders should be avoided. Shoulders wider than 1.0 m should be separated from the traffic lane by e.g. a milled edge line.

The total width should not be less than the recommended width for 1-lane sections (see above).

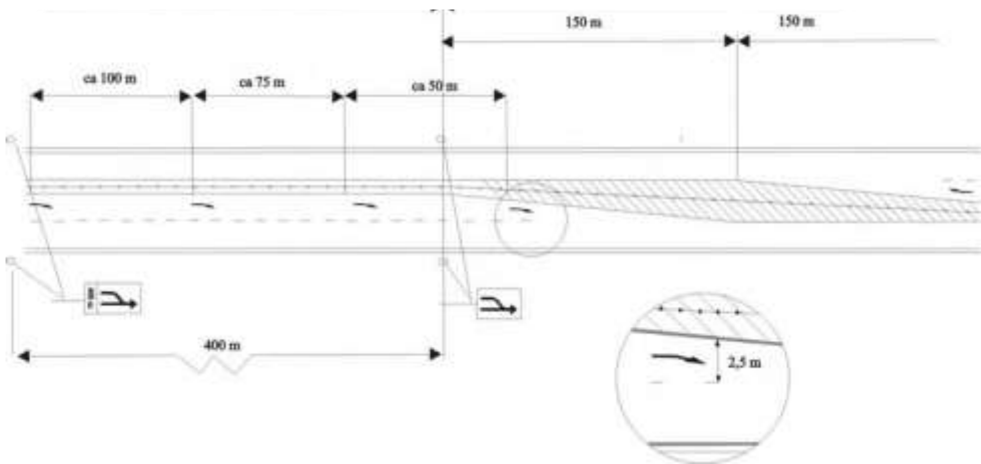
2+2 sections

The design should be symmetric and have the same lane widths and shoulder widths as connecting road sections.

For reconstruction of existing roads the2+2 sections can be designed with the total width of 15.25 m. For new roads the total width should normally be 15.75 – 16.75 m.

Transition sections

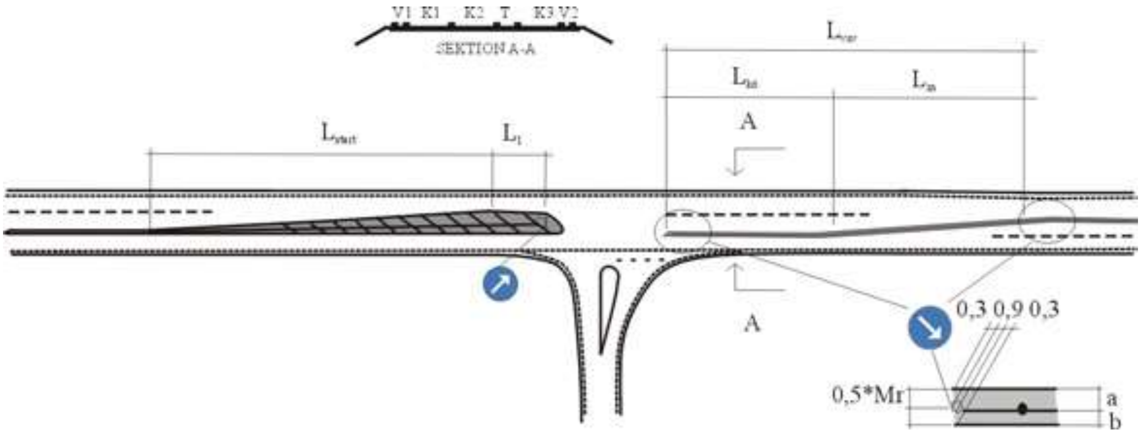
A typical design of a transition section is shown in the figure below.



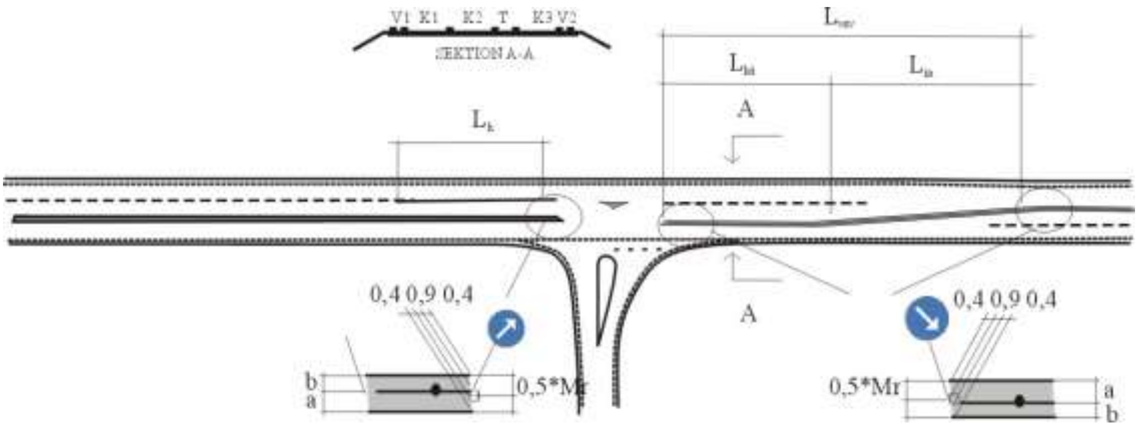
Typical design of a transition section

Intersections

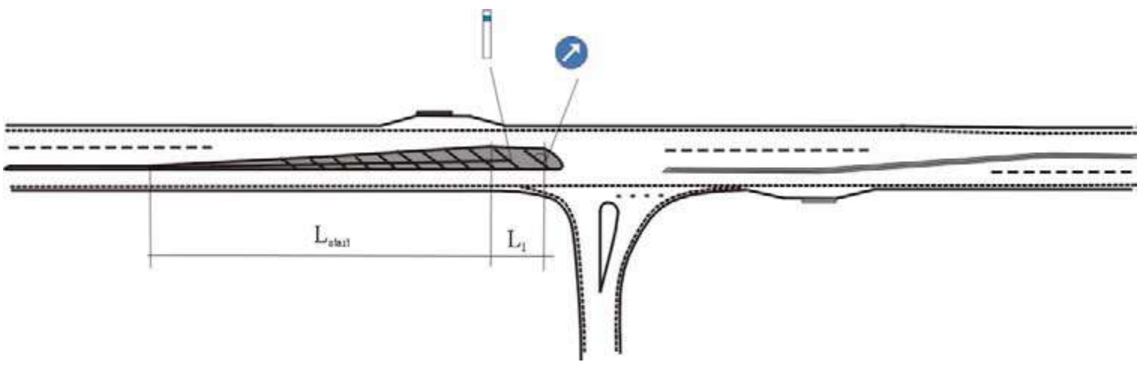
Intersections should normally be designed as standard T-intersections. The figures below show some typical design examples.



Typical design of a T-intersection with a left turn lane



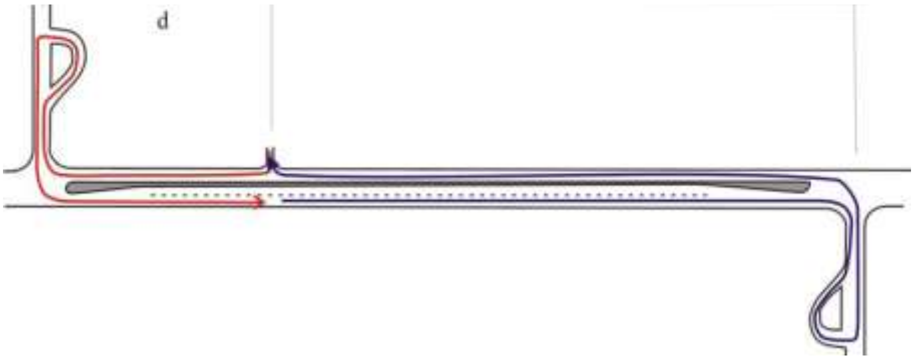
Typical design of a T-intersection with a left turn lane and provisions to facilitate left turn from the secondary road



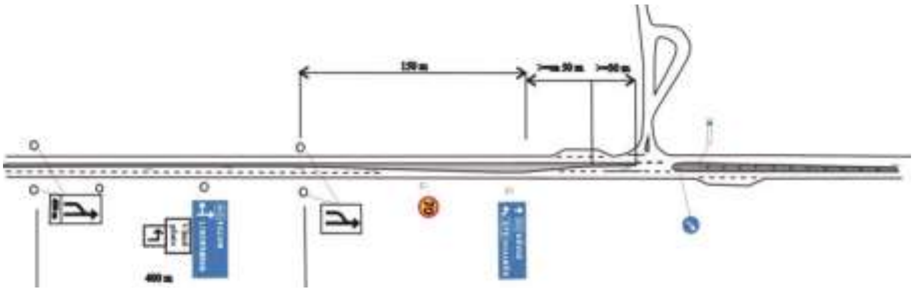
Typical design of a T-intersection with a left turn lane and bus stops

Access roads

At access roads between intersections only right turns to and from the major road should be allowed. Then there is a need to turn back around at the nearest intersections. See figures below!

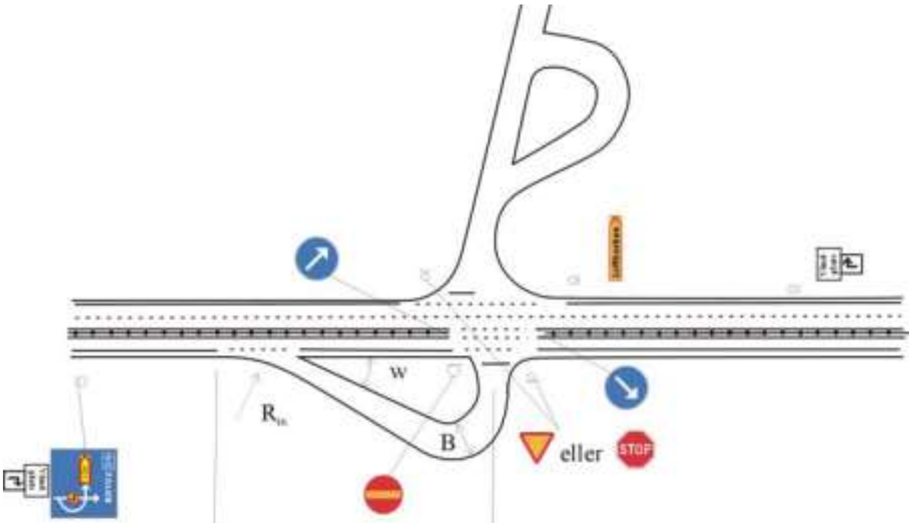


The principle for connection of access roads



Typical design of a T-intersection with possibilities to turn around on the secondary road

Alternatively left turns can be made possible at access roads by constructing a "shepherd's hook" and allowing perpendicular passing of the median.

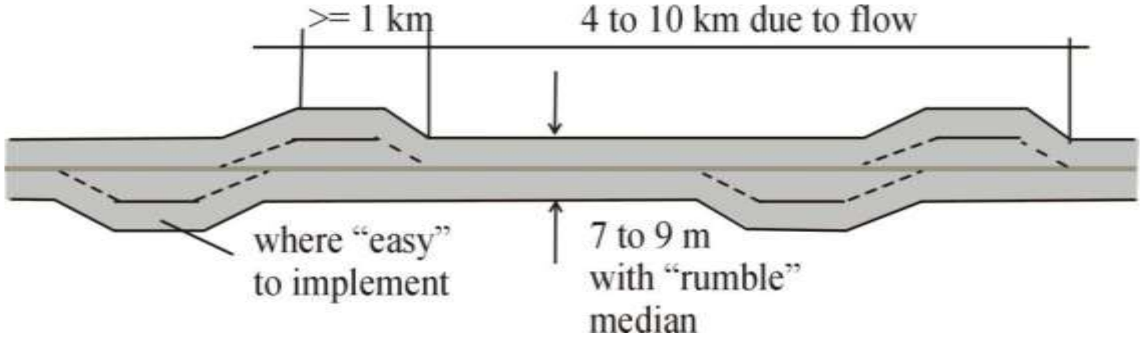


Typical design of a connection of an access road with left turn possibilities

3.5 Roads with reinforced centre line marking

On roads with road widths less than 12.5 metres the risk for head-on collisions can be decreased by reinforcement of the centre line markings and provision of overtaking lanes.

The reinforcement of the centre line marking is described above. The principle for provision of overtaking lanes is shown in the figure below.



The principle for provision of overtaking lanes on roads with reinforced centre line markings

The use of milled median rumble strips is a standard design in Sweden since 5 years. Below some experiences are presented.

- Should not be used on roads with widths less than 7.0 m because heavy vehicles frequently cross the centre line
- Due to noise problems the distance to residential houses should be at least 150 m.
- Road users are generally positive
- The safety effect is not statistically proven

3.6 Roadside barriers

3.6.1 The use of roadside barriers

Purpose

The purpose of roadside barriers is to prevent vehicles from running off the road and hitting or falling into a hazard - such as hitting an obstruction near the edge of the road or falling down a steep slope or into a river.

When a roadside hazard is identified measures should be considered in the following order:

1. remove the hazard
2. make it less hazardous
3. shield the hazard with a barrier

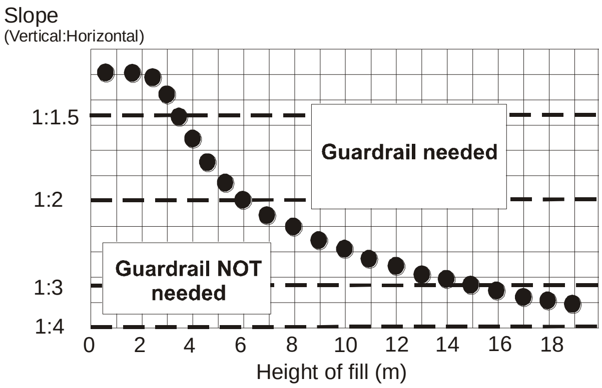
However, safety barrier is a hazard in itself. Collision with a barrier can cause serious injuries, particularly to riders of two-wheelers. This means that safety barrier should only be installed when the consequences of an out-of-control vehicle hitting the unprotected hazard are likely to be more severe than those of impact with the safety barrier.

It is not economic to try and shield every hazard. The risk increases with traffic volume, traffic speed, and road curvature. Cost-benefit analysis can help determine if it is advisable to install a barrier.

Criteria

For roadside barriers on roads with speed limits over 50 km/h the following criteria should be used:

- To shield any solid object within the clear zone
- Where there is a risk that vehicles could fall into a body of water deeper than 1 m
- On embankments as indicated in the figure below



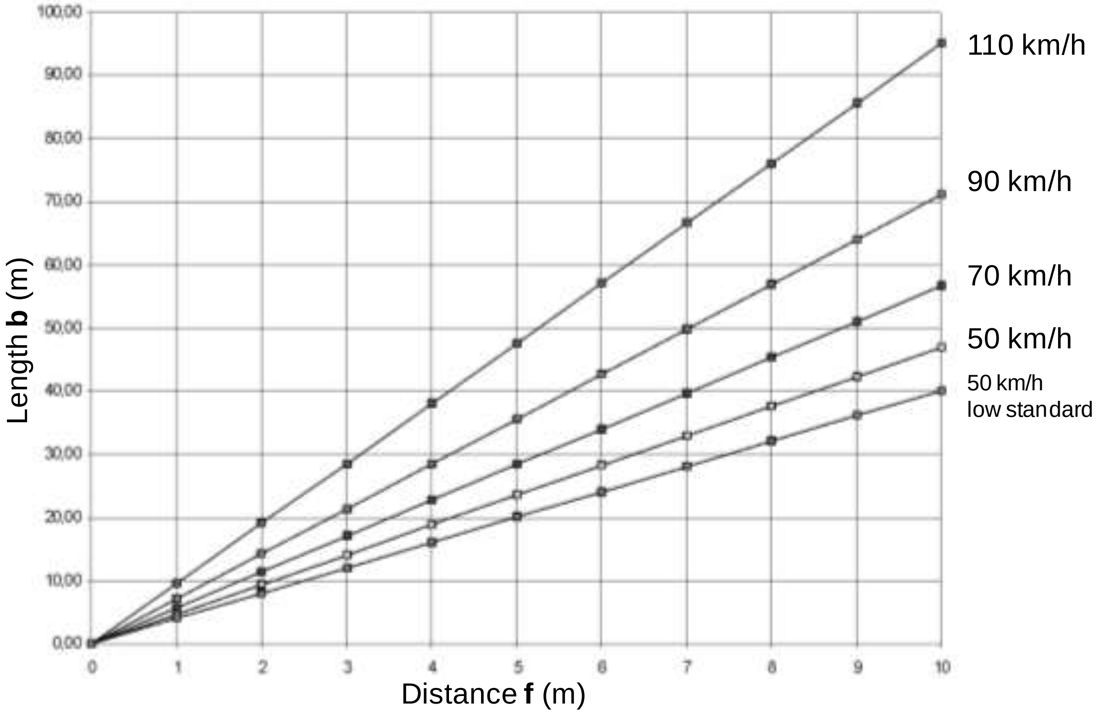
The need of guardrails on embankments

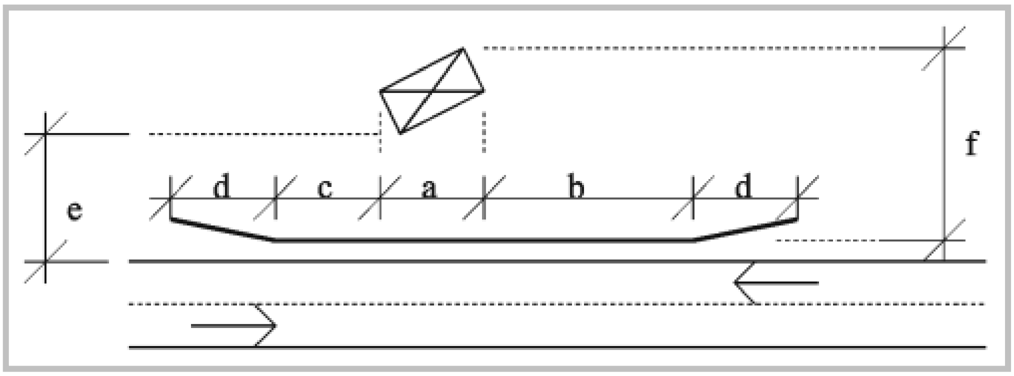
3.6.2 Design

Length of need

To keep costs down roadside barriers are often too short to be effective. Generally the barrier must be at least 30 m to perform satisfactorily. On a two-way single carriageway road both directions of travel must be consider.

The calculation of the length of need according to the Swedish guidelines is shown below.





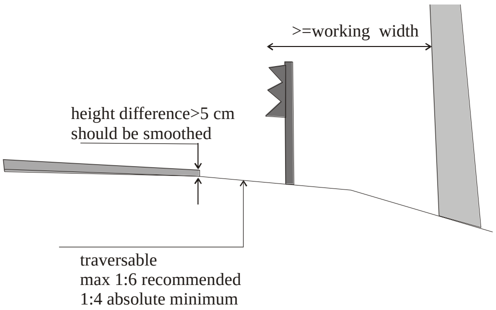
Determining the length of need

The total length of the guardrail is a+b+c+2d where:

a = the length of the hazard parallel to the road
b = the needed length before the hazard according to the diagram below
c = b/2
d = terminal length (normally 12 m)

Lateral placement

The area between the carriageway and the guardrail should normally be designed according to the general rules for smoothed roadside areas, i.e. with maximum height differences of some 5 cm and slopes maximum 1:6 to allow a controlled guard-rail hit.



Normal lateral placement of barriers

The barrier should normally be placed at least 0.5 meters from the carriageway. Normal beam types should have a back support of about 0.5 m before the slope starts.

The distance to the obstacle is determined by the working width for the barrier type. The clear zone between the guardrail and the fixed object should be at least as wide as the working width of the guardrail.

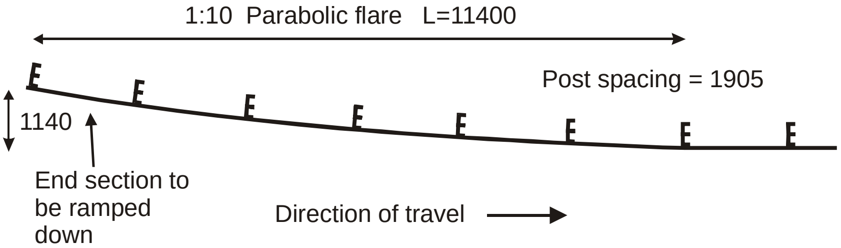
Alternative lateral placement of barriers

Barrier terminals

The end of a steel beam guardrail is a major hazard, as vehicles can become impaled on it. There is no wholly safe way of terminating guardrail but the main options are:

- flare the end section of the guardrail away from the edge of the shoulder and ramp the beam down into the ground
- use a special impact-absorbing terminals

On a two-way road both the upstream and downstream ends of the guardrail will need to be terminated in the above way. One of the problems of ramped ends is that they can launch out-of-control vehicles into the air, with disastrous consequences. Flaring is an effective way of reducing the risk of impact but this can be difficult to achieve in some situations, such as on narrow embankments.



Eample on flaring of the end of guardrail

3.6.3 Barriers types

There are three main types of barriers:

- steel beam guardrail
- wire rope barrier
- concrete barrier

Steel beam guardrail

Steel beam guardrail is the most common type of safety barrier. It consists of a W-shaped steel beam mounted on steel posts. A typical height is 550 mm above the height of the road surface. The containment capability can be increased by using two beams, one mounted above the other.

Concrete barrier

Concrete barriers are strong enough to stop most out-of-control vehicles, and being rigid there is no deflection on impact. This makes them suitable for use on narrow medians and where it is essential to keep vehicles on the road, such as at bridges. Small angle impacts usually result in little damage to the vehicle. However, large angle impacts tend to result in major damage to the vehicle, and severe injuries to the occupants. Research has shown that the conventional profile (commonly called New Jersey Barrier) tends to cause small vehicles to overturn, and the preferred shape is now a vertical or near-vertical wall. Concrete barrier generally requires very little routine maintenance except after very severe impacts.

Wire rope barrier

Wire rope barriers are often used as median barriers, but can also be used as roadside barriers. The barrier is usually 550 -700 mm high and the diameter of the wires around 20 mm. There are several types of wire rope barriers. The number and placement of wires and the post cross section vary. The figure to the right shows some typical designs.

3.6.4 Barrier performance

The safety barrier should perform to prevent vehicles from passing through the barrier and enable the drivers to retain control of the vehicle. In order to do so the barrier should absorb the impact of the vehicle without injuring the occupants (no severe deceleration) re-direct the vehicle along the road parallel to the barrier. Consequently, the performance is depending on barrier design and barrier material.

Impact speed and angle

Conventional safety barriers are designed for impacts by passenger cars travelling at 65 km/h hitting the barrier at a 25 degree angle. Barriers can be made that will cope with trucks and buses, but the high cost means that they can only be justified in exceptionally risky situations.

Most barriers will not perform well when hit at a large angle - such as can happen when barrier is installed on the outside of a sharp bend.

Deflection

The maximum permissible deflection is an important consideration. The deflection varies with the type of barrier. The table below shows a classification as to deflection.

Category	Type	Deflection	Comments
Rigid	Concrete	≈ 0	Expensive, low maintenance costs
Semi-rigid	Steel beam	≤ 1 m	Performs well in moderate-speed situations
Flexible	Wire rope	≥ 1 m	Expensive; technically complicated; quick to repair

Classification of safety barriers as to deflection

3.7 Forgiving roadside

3.7.1 Definition

“Forgiving roadside” is also called “clear roadside area” or “obstacle free zoon”.

The clear zone is a safety zone adjacent to the traffic lanes. It provides space for a driver to recover control of his vehicle if he is in danger of running off the road. The clear zone must:

- Be free of hazardous objects (such as posts, trees etc) and other hazards
- Have a smooth design with no steep slopes, open drains, etc.

There are a number of empirical studies in Europe and US indicating major safety benefits from clear zones. It is obvious that the need for clear zones increases with speed and curvature.

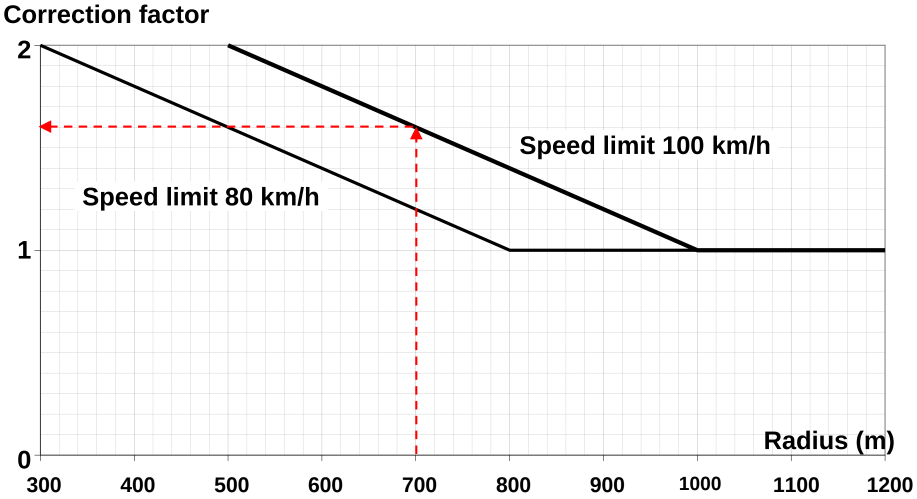
3.7.2 Width

The following clear zone widths, measured from the edge of the traffic lane, are considered to give an acceptable standard of safety. Traffic volume is also a factor, as, generally, the higher the traffic volume the greater the frequency of run-off-road incidents –which supports the use of wider clear zone widths.

Speed (km/h)	Standard	
	Desired	Minimum
70	5 m	3 m
80	6 m	4 m
100	9 m	6 m

Clear zone widths

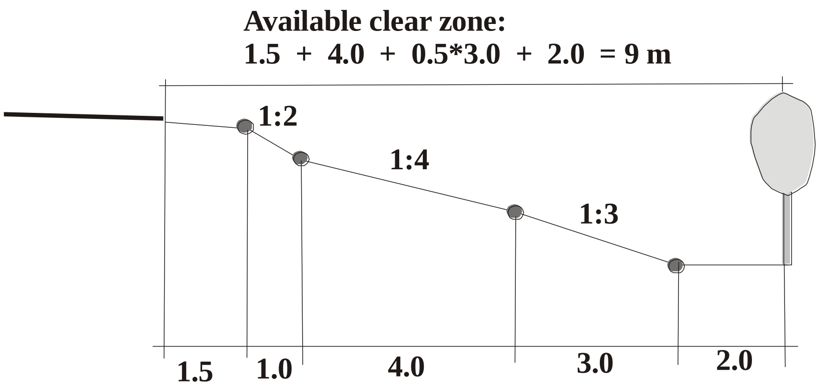
The clear zone widths given in table above should be increased at sharp bends on high-speed roads according to the diagram below.



Clear zone correction factor for bends

Example: Radius 700 m and speed limit 100 gives the correction factor 1.6.
Desired clear zone is extended from 9 m to 1.6 * 9 = 14.4 m

Front slopes steeper than 1:3 cannot be counted as part of the clear zone because they are too steep. Slopes that can be traversed safely by out-of-control vehicles need to be at least 1:4 or gentler. Slopes between 1:3 and 1:4 are marginal; the normal practice is that half the width of these slopes is counted as part of the clear zone – see the figure on the next page.



Example how to calculate clear zones

3.7.3 Fixed Objects

There should be no hazardous objects, sometimes called fixed objects, in the clear zone. A fixed object is rigid object close to the road, which constitutes a safety hazard for road users.

The object must be **rigid** to be a fixed object. Posts for traffic signs are normally not considered fixed objects.

The object should also be **close to the road** to be a fixed object. From a safety point of view that means up to about 5 meters from the edge of the road depending on the speed.

The following objects are some examples on fixed objects:

- Electricity Pole
- Telecom Pole
- Lamp Post
- Other Rigid Post
- Information Traffic Sign of Concrete
- Bus Shelter
- Tree (diameter >0.1 m)
- Rock

Such objects should be removed, made “softer” (e.g. break-away lighting poles) or shielded by a safety barrier.

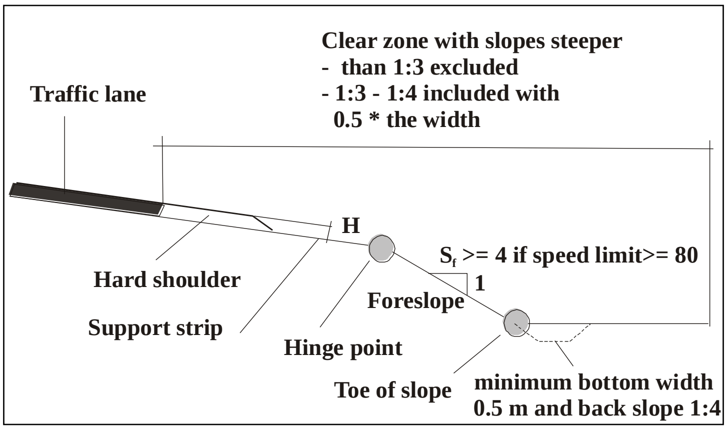
3.7.4 Road Side Design

Transition to carriageway

Safety zones should be designed with the objective to give a small risk for turnover and skid accidents. This indicates that the height difference between the overlay and the adjacent strip should not exceed some 5 cm without smoothing measures, which could be grades at least 1:6.

Side slopes

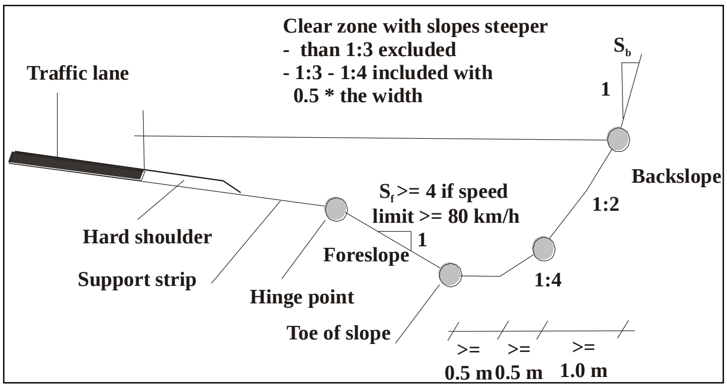
The shallower the slope, the safer it will be. And the transition from the shoulder to the front slope must be smooth enough to prevent the vehicle becoming airborne. A safe transition is also needed between the front slope and the back slope so as to avoid causing the vehicle to rollover. The figures on the next page show the principles of smooth roadside area design. The front slope should be 1:4 or gentler. The transition at the top and toe of the slope should be smooth. The height difference H between the shoulder and the support strip should not be more than 50 mm



Design of clear zone on embankments

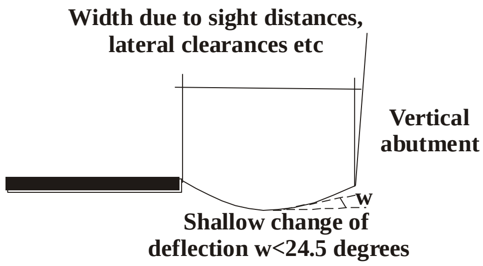
The back slope design in cuts with a cut drain should be designed with a 0.5 m wide ditch bottom followed by a 1:4-backslope for half a metre and then a 1:2-backslope for 2.0 m. This will help to redirect a run-off vehicle to the roadside area.

When the embankment (fill) height is greater than about 3.0 m, the 1:4 front slopes recommended above become uneconomic. This is because a large amount of fill material will be needed and the structure will extend over a large area – thus increasing land acquisition costs. In these circumstances the front slope is best determined by the natural angle of repose and erosion of the material (often 1:1.5). Where steep front slopes have to be used, consider installing safety barrier.



Design of clear zone in cuts

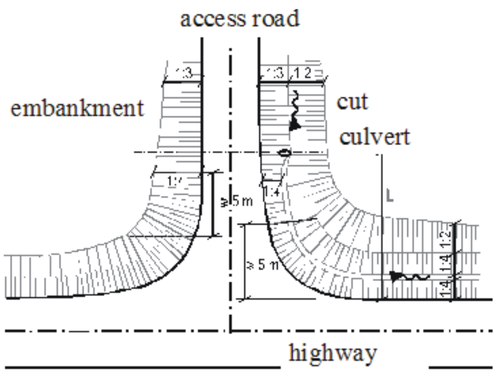
The area in front of roadside obstructions such as bridge abutments, retaining walls, etc. should be smooth, with a maximum change of deflection (w) of 24.5 degrees. Ensure that the lateral clearance is adequate, and that the obstruction is outside the clear zone. If it is not, consider installing a safety barrier.



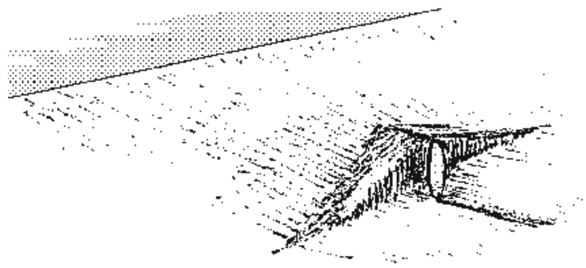
Design of area in front of obstructions

Side roads and culverts

Side roads are often built up on a little embankment so that they enter the main road on the same level. This embankment can be an obstacle to vehicles that run off the road. And the culvert carrying the main road drain under the side road will often have a large, solid headwall. Where there is a culvert under the main road, the culvert headwall is often close to the edge of the carriageway, especially if the road has been widened at some stage. These are hazards. With side roads it is best to try and construct gentle embankment slopes and move the culvert further away from the main road. In the case of the culvert under the main road it should be extended in order to move the ends away from the carriageway edge. It is also important to assess if culverts really need large solid headwalls. It may be possible to provide a smooth opening instead.



Access road design



Culvert end design

4 ROAD LINKS THROUGH BUILT UP AREAS

4.1 Safety Problems

The specific safety problems for roads passing *through or at the border of* built up areas are mainly conflicts between through traffic and local traffic and between motor vehicles and vulnerable road users (primarily pedestrians). The demand for accessibility for the through traffic is often in opposition to accessibility and safety for local traffic and vulnerable road users. This creates conflicts at intersections, for local access to shops etc. and for pedestrians.

4.2 Design principles

4.2.1 Basic safety principles

Speed control

In order to reduce the risk for severe accidents, the planning and design of roads and streets in general should be made so as to minimize the number of conflicts and to make sure that the speeds do not exceed:

- 30 km/h in **pedestrian/vehicle** conflicts,
- 50 km/h in **side-on vehicle/vehicle** conflicts,
- 70 km/h in **head-on vehicle/vehicle** conflicts

The control of speed is the most important design question. To ensure that the intended speed is not exceeded, the design must be based on a proper design speed and the expected traffic volume. In addition, some kind of speed control measure must often be applied. There are many different speed control measures available, such as:

- measures at intersections,
- single measures along a road section,
- general measures along a road section

Separation of road user categories

The collision-casualty diagram shows that the risk for pedestrians to be killed is high even at speeds lower than generally accepted from an accessibility point of view. Consequently, the fundamental safety principles are that:

- vulnerable road users should be separated from motor vehicle traffic,
- at points of conflict between vulnerable road users and motor vehicle traffic, the speed should be low (preferably 30 km/h)

4.2.2 Cross-section

General

The cross-section must be adapted to the expected traffic volume and the intended speed limit. Too wide sections will make it difficult for drivers to keep the speed limit. The need for parking/stopping and for restrictions for pedestrians must also be considered. In principle:

- the number of lanes should be decided by the traffic volume,
- the widths of lanes and shoulders etc. should be decided by the design speed

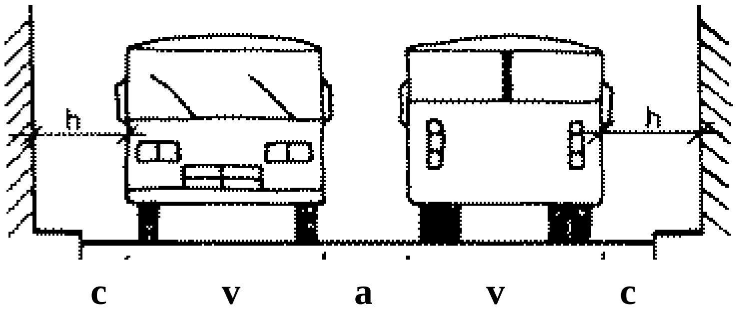
Needed widths

The width of traffic lanes, shoulders, pedestrian lanes, separators etc. can be determined by tables showing widths needed at different speeds. The table on the next page shows examples of values according to the Swedish guidelines.

Distances		30 km/h	50 km/h	70 km/h
h	to obstacle higher than 0,2 m	0,5	0,9	1,2
c	to kerbstone	0,2	0,4	0,7
v	heavy vehicle and bus width	2,6	2,6	2,6
	passenger car width	1,8	1,8	1,8
a	between meeting or passing vehicles	0,7	1,0	1,3
p	between parked vehicle and kerbstone	0,1	0,1	0,1

Example on vehicle widths and needed cross-section widths

For example, the width between the curbstones for a two-lane road or for one roadway of a two-lane divided road according to the figure (except for the walls) will be:



Design speed **30 km/h**: 0,2+2.6+0.7+2.6+0.2 = **6.3 m**
Design speed **50 km/h**: 0.4+2.6+1.0+2.6+0.4 = **7.0 m**
Design speed **70 km/h**: 0.7+2.6+1.3+2.6+0.7 = **7.9 m**

4.2.3 Intersections

Reduction of number of intersections

One way to increase the safety on through roads is to reduce the number of intersections. However, too long distances between intersections may increase the speed and also increase the traffic volumes in the local streets.

Replacement of 4-way intersections

Two 3-way intersections are generally safer than one 4-way intersection. Uncontrolled 4-way intersections should therefore be avoided and if possible replaced by a roundabout or split into two 3-way intersections.

Roundabouts

If possible, every intersection on through roads should be designed as a roundabout, because:

- It is the safest intersection type. Both the number and the severity of accidents are decreased compared to other types of intersections
- It reduces the vehicle speed for all traffic and allows the traffic to flow smoothly.

Signalized intersections

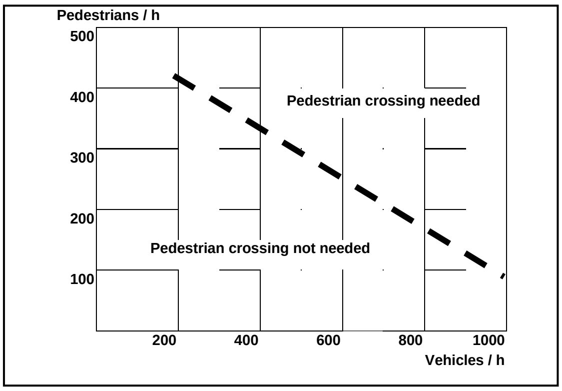
Signalized intersections can be used if:

- there is a system of coordinated signalized intersections
- the available space is too limited for a roundabout
- the traffic volume is very high on the through road and low on the secondary road

4.2.4 Pedestrian crossings

Need and location

The need for pedestrian crossings is depending on the number of crossing pedestrians and the traffic volume. The following diagram shows a Swedish recommendation for when pedestrian crossings are needed.



Example of a diagram to determine the need for pedestrian crossings

Pedestrian crossings should be located to places where the vehicle speed can be reduced to 30 km/h. Generally, pedestrian crossings are located at intersections.

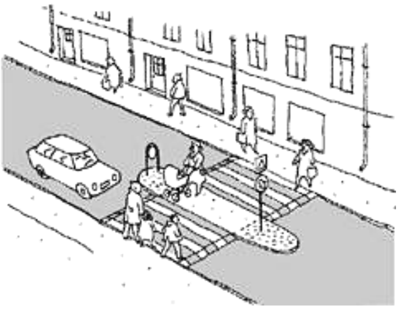
Design of separate pedestrian crossings

Pedestrian crossing on a 2-lane through road

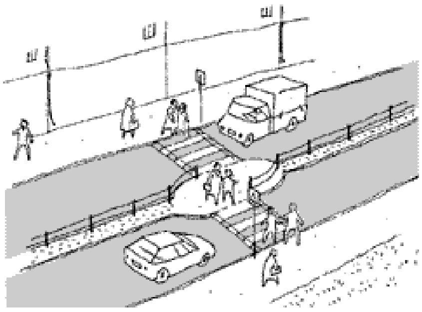
Pedestrian crossings should be constructed with a traffic island to make it possible to pass the road in stages and to make the crossing clearly visible to drivers. On roads with low traffic volumes and few heavy vehicles, the crossing can be raised over the travelled way to reduce the speed and to make it more convenient for the pedestrians.

Pedestrian crossing on a 4-lane through road

On divided roads, pedestrian crossings can be designed with a side displacement in the median to force the pedestrians to turn and face the oncoming traffic before crossing the road.



Pedestrian crossing on a 2-lane through road



Pedestrian crossing on a 4-lane through road

Restrictions for pedestrians

On through roads class I and II, pedestrians are not expected to cross the road in other places than at intersections and special pedestrian crossings (through road class II). To ensure this, it can be necessary to install fences or other kinds of barriers along the road or in the median on sections were pedestrians otherwise can be expected to cross the road.

4.3 Example on design of roads through built up areas

This section presents an example to show how roads through built up areas can be classified and designed. It should not be used in Serbia without adaptation to Serbian conditions.

4.3.1 Classification

For the application of priority rules and design criteria, through roads should be classified into different groups depending on the contact with the urban network and pedestrians. Three classes are suggested.

Contacts with	Through road I	Through road II	Through road III
Urban streets	Only major streets	Major and minor streets	
Pedestrians	Only at intersections	At intersections and pedestrian crossings	At intersections and along sections

Suggested classes of through roads

4.3.2 Design criteria

The main design criteria are the separation of pedestrians from motor vehicles and the speed regulations.

Through road I

Pedestrian separation

- has separated lanes for pedestrians,
- has no at-grade pedestrian crossings between intersections

Speed regulations

- the speed between intersections is 50 or 70 km/h,
- the speed at intersections is 50 km/h,
- physical speed control measures are not accepted

Through road II

Pedestrian separation

- can have pedestrians close to the roadway,
- pedestrians **are expected** to use at-grade crossings between or at intersections

Speed regulations

- the speed between intersections is 50 km/h if pedestrians are separated,
- the speed at intersections is 30 km/h,
- physical speed control measures can be accepted, but are generally not used

Through road III

Pedestrian separation

- has always pedestrians close to the roadway,
- pedestrians **are not expected** to use at-grade crossings between or at intersections

Speed regulations

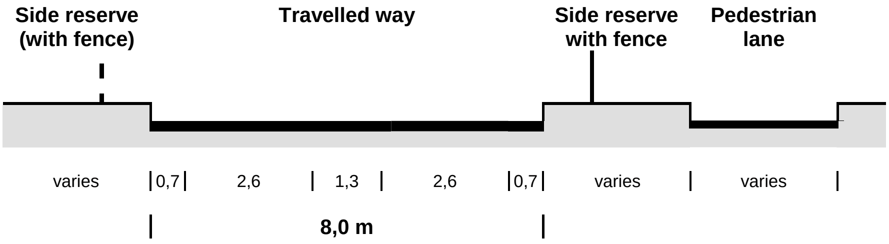
- the speed between intersections is lower than 50 km/h, preferably 30 km/h,
- the speed at intersections is 30 km/h,
- physical speed control measures are accepted

4.3.3 Suggested cross-sections

Based on the needed widths and the Swedish guidelines, the standard cross-sections below are suggested. The figures show two-lane roads, but can be applied for one direction of a four-lane divided road.

Through road I

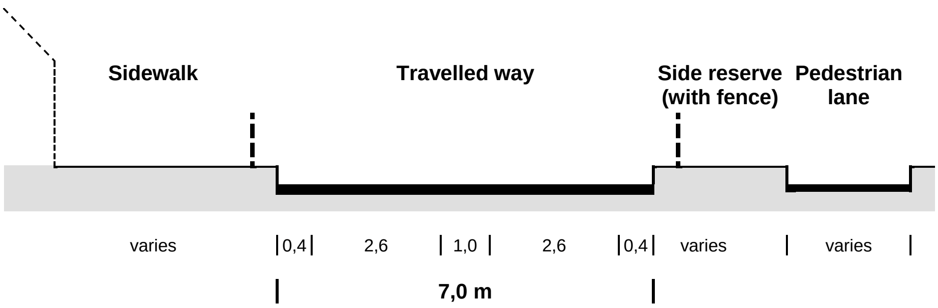
Pedestrians are completely separated. At places where there are pedestrians close to the road, for example at houses and where there are pedestrian lanes, fences should be installed.



Proposed standard cross-section for through road class I (70 km/h)

Through road II

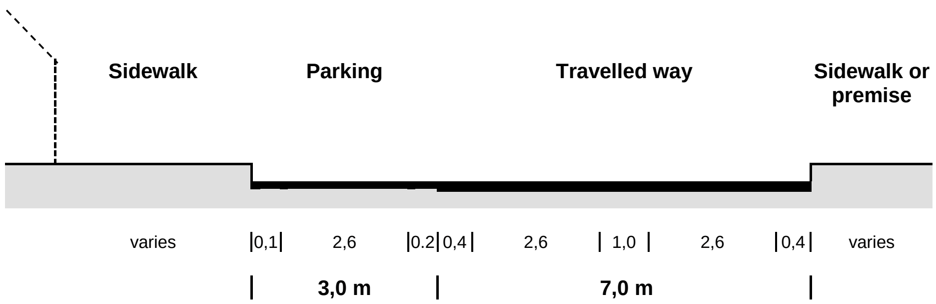
Pedestrians are expected to use pedestrian crossings. If necessary, fences should be installed to direct the pedestrians to these crossings.



Proposed standard cross-section for through road class II (50 km/h)

Through road III

Pedestrians can be expected to cross the road anywhere. If necessary, parking lanes can be accepted.



Proposed standard cross-section for through road class III (50 km/h)

4.4 Traffic calming

4.4.1 Introduction

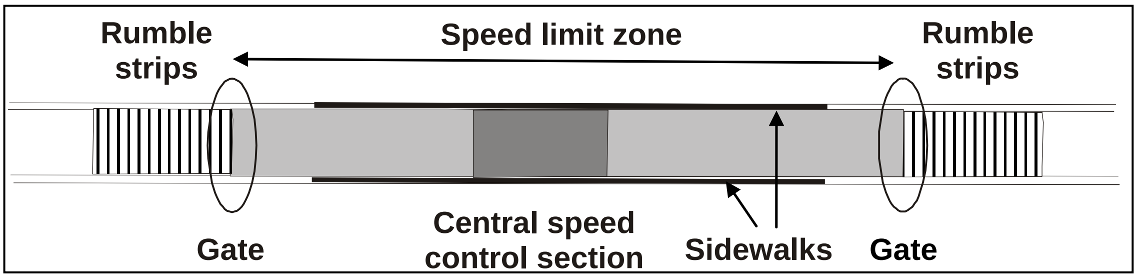
Traffic Calming is a term often used for speed management in built-up areas. The basis for speed management should be created by road planning, e.g. a by-pass for the long-distance traffic, and by a road design adapted to the desired speed, e.g. cross-section and intersection design. Nevertheless, sometimes special speed control measures are necessary.

Speed control measures are mainly used in built-up areas. However, some of the measures can also be used in other situations, such as in advance of hazardous bends or bridges.

4.4.2 General principles

The standard sequence of speed control measures is:

- Rumble strips
- Gate
- Speed controlled section – with humps, narrowings or chicanes



Standard speed control layout

The preferred and maximum intervals between speed control measures for different desired speeds are given in the table below.

Desired speed	Interval between speed control devices	
	Preferred	Maximum
30 km/h	50 m	125 m
50 km/h	125 m	175 m

Maximum intervals between speed control measures

Speed control should preferably be located where judged reasonable for drivers. Pedestrian crossings can be combined with humps. Speed control is most effectively achieved by humps. Other measures are rumble strips, gates, narrowings and chicanes.

4.5 Speed control measures

4.5.1 Rumble strips

Use of rumble strips

Rumble strips are transverse strips across the road used to alert and warn drivers with a vibratory and audible effect before a hazard such as a sharp bend, an intersection or a lower speed limit at the entry to a built-up area. Warning signs are not normally needed when the strips are built to the specifications given below.

Research in other countries indicates that speed reduction effects tend to be minor and also erode over time. Therefore, rumble strips should not be used alone to reduce speeds.

Rumble strips should be used as an introduction to a speed control zone but can also be used for example in the following situations:

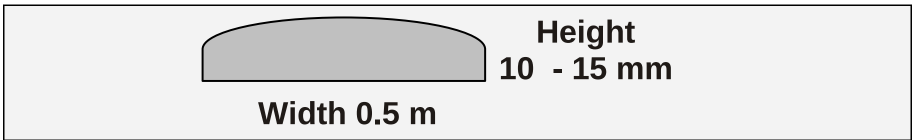
- before a local speed limit
- at an approach to a dangerous intersection
- before a sharp bend
- before a hump

Rumble strips create disturbing noises and can cause vibration problems on soft ground and should be avoided near dwelling-houses, schools, hospitals, etc.

Design of rumble strips

The following principles should be observed when designing rumble strips:

- rumble strips should normally be in groups of 4 strips
- the height of the strips shall be no more than 10 – 15 mm
- the strip width should be 0.5 m
- one set of rumble strips is usually enough within 50 km/h sections
- the last or only strip should be located 30 to 50 m before the hazard
- pre-warning sets can be located 20 to 80 m before the hazard depending on speeds
- rumble strips should have yellow thermoplastic lines across the top for better visibility
- strips should continue across the full width of the carriageway, including the shoulders but be terminated so that they do not interfere with drainage



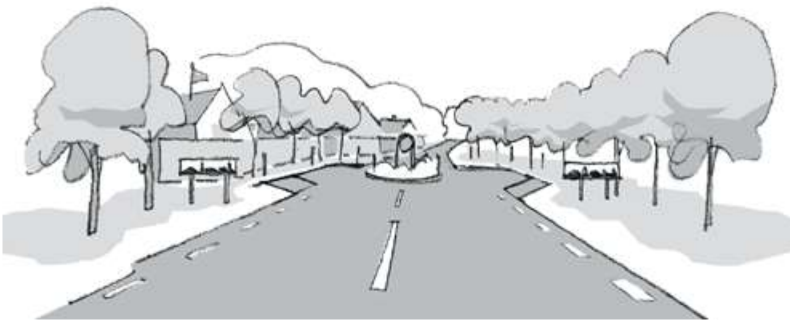
Length of rumble strip zone	50 km/h	20 m
	80 km/h	80 m
Distance between rumble strips	0.5 – 1.0 m	
Distance to obstacle	30 – 50 m	

Design of rumble strips

4.5.2 Gates

Use of gates

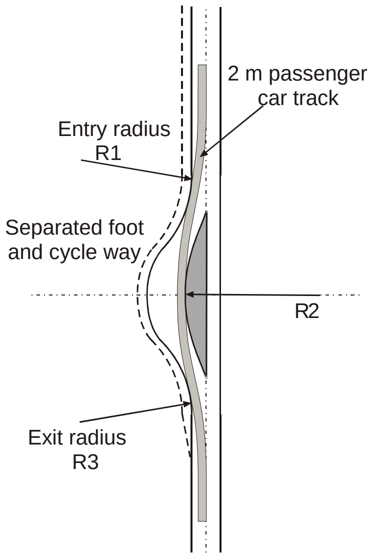
The speed limit change at the entrance to the built-up area can be emphasised by a gate to signal very clearly that driving conditions are to change.



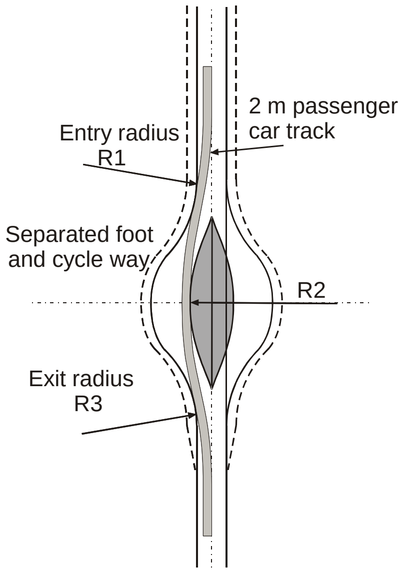
Design of gates

The figure below shows the design of speed control gates. The following principles should be used:

- The toughest vehicle path for a passenger car through the gate should have an entry radius R1 below 100 m for 50 km/h speed control and 50 m for 30 km/h speed control.
- Curves that follow (R2, R3) should have a radius greater than or equal to the entry radius.
- The gate can be one-sided with speed control only in the entry direction or two-sided with speed control also in the exit direction.
- The design should be tapered or smoothed with curves.



One-sided, entry speed control gate



Double-sided speed control gate

Speed control gate

4.5.3 Humps

Use of humps

The installation of hump is the most efficient measure to reduce speeds, but humps should only be used on roads with speed limit 50 km/h or lower. Two alternative designs have proved to be most effective.

	Length profile
Circular	
Plateau	

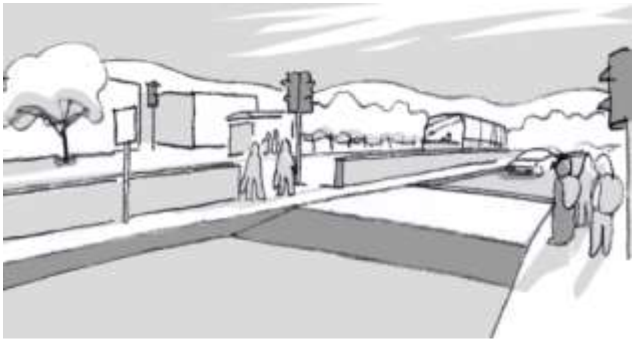
Alternative design of humps

The circular hump is normally recommended for local roads. For roads in residential areas the following is recommended:

Speed level:	30 km/h
Plateau hump:	4.0 m long hump with 1.0 m ramp length
Circular hump:	4.0 m long hump with 20 m radius

For roads with a large number of buses a 6.5 m long circular hump or a 6.0 m long plateau hump is recommended to ease discomfort for bus passengers.

The plateau hump can be used in combination with pedestrian and cycle crossings.



Plateau humps combined with pedestrian crossing

Design of humps

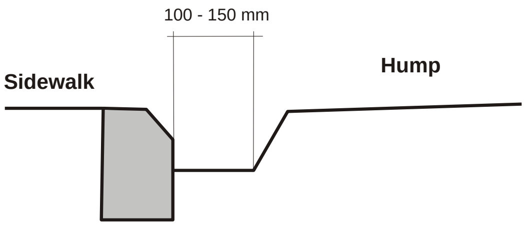
General

The hump can be made of pre-fabricated concrete elements with asphalt ramps or entirely of asphalt. If made of asphalt a template must be used to ensure the right height and shape. On a road with shoulders the hump should be extended about 1.0 m over the shoulder to discourage drivers from going around the hump.

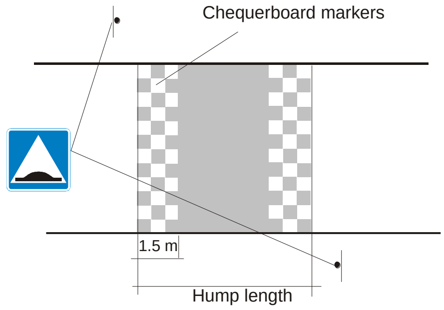
On roads with kerbed sidewalks the hump should be stopped 100 – 150 mm before the kerb to create a drain. This solution cannot be used at a raised pedestrian crossing.

Humps should be clearly marked with chequerboard markers and hump information signs in each direction of the road. Hump warning signs might also be needed.

The recommended detailed design is based on empirical studies into hump dimensions, speed, and driver / passenger discomfort. The design of the hump is base on the desired passing speed for passenger cars.



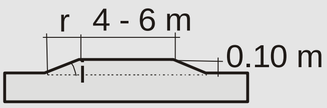
Drainage design at kerbed sidewalk



Markings and signing of humps

Plateau hump

The height of the plateau hump should be 0.10 m. The table below gives recommended ramp lengths and grades.

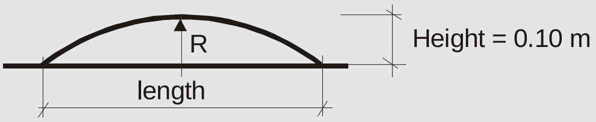


Speed level		Ramp length r (m)	Grade i (%)
Car	Truck		
< 25	<5	0.7	14
25	5	0.8	12.5
30	**10**	**1.0**	**10**
35	15	1.3	7.5
40	20	1.7	6
45	25	2.0	5
50	30	2.5	4
	35	3.3	3
	40	4.0	2.5

Detailed design of plateau humps

Circular hump

The height of the circular hump should be 0.10 m. Hump radii and chord lengths are given in the table below. The traffic level-of-service, especially for buses and trucks, can be improved if the hump entry and exit is smoothed as shown below.



Speed level		Radius (m)	Length (m)
Car	Truck		
20	5	11	3.0
25	10	15	3.5
30	15	20	4.0
35	20	31	5.0
40	25	53	6.5
45	30	80	8.0
50	35	113	9.5
	40	180	12.0

Detailed design of circular humps

4.5.4 Narrowings

Use of narrowings

Road narrowings can be used to control speeds, but they are less effective than speed humps.

The table below can be used to judge the relationship between speed and needed width for different meeting situations. The table shows that a narrowing must be very tough to have some speed impact. For one-way traffic 3.5 m is the recommended width between kerbs.

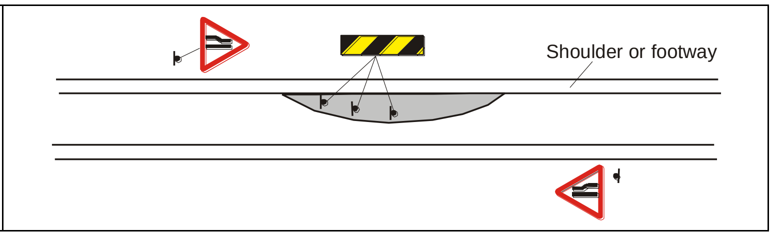
Speed	Meeting situation			
(km/h)	Truck and bicycle	Two cars	Truck and car	Two trucks
30	4.0 m	4.15 m	4.95 m	5.9 m
50	4.5 m	4.5 m	5.5 m	-

Road width for different speeds and meeting situations

Design of narrowings

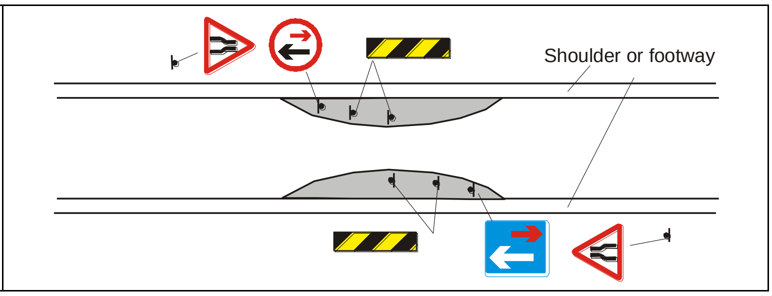
The basic design principles of one-sided and double-sided road narrowings are illustrated the figure below.

One-sided narrowing



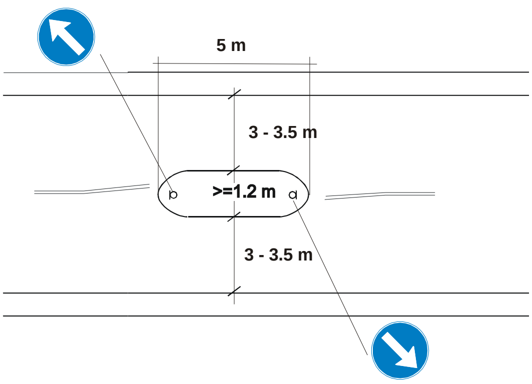
Design of one-sided narrowing

Double-sided narrowing



Design of double-sided narrowing

An alternative is to build a kerbed island (min. width 1.2 m and length 5 m) in the centre of the road, with 3.0 m – 3.5 m wide traffic lanes either side. This could also function as a pedestrian refuge, perhaps combined with a raised pedestrian crossing. The island must be well-signed to avoid it becoming a hazard.



Road narrowing with central island

5 INTERSECTIONS

5.1 Intersection types

5.1.1 Proposed intersection types

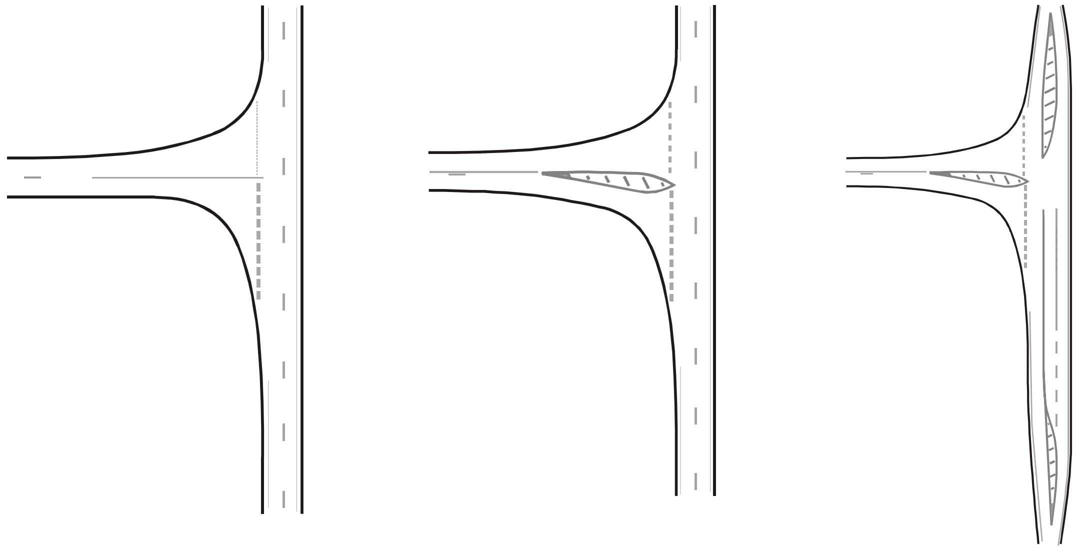
This Manual covers only at-grade intersections. At-grade intersections can be classified into two main ***intersection categories*** depending on the form of control used. For each category, there are a number of ***intersection types***.

Intersection category	Traffic control		Intersection types
	Major road	Minor road	
Priority intersection	Priority	Stop or give way sign	A Unchannelised T-intersection B Partly Channelised T-intersection C Channelised T-intersection
Control intersection	Traffic signals or give way sign		D Roundabout E Signalised intersection

Classification of at-grade intersections

5.1.2 Priority intersections

Priority intersections will be adequate in most rural situations. This Manual gives advice on the design of three types of T-intersection:



Unchannelised Partly channelised Channelised

Typical design of T-intersections

Unchannelised T-intersection (A)

The unchannelised design is suitable for intersections where there is **a very small amount of turning traffic**. It is the simplest design and has no traffic islands.

Partly Channelised T-intersection (B)

The partly channelised design is for intersections with a **moderate volume of turning traffic**. It has a traffic island in the minor road arm. In urban areas, the traffic island would normally be kerbed in order to provide a refuge for pedestrians crossing the road.

Channelised T-intersection (C)

The fully channelised design is for intersections with a **high volume of turning traffic or high –speeds.** It has traffic islands in both the minor road and the main road.

Four-leg priority intersections (crossroads) must not be used. It has a very high number of conflict points, and has a much higher accident risk than any other kind of intersection. Existing crossroads should, where possible, be converted to a staggered intersection, or roundabout, or be controlled by traffic signals.

5.1.3 Control intersections

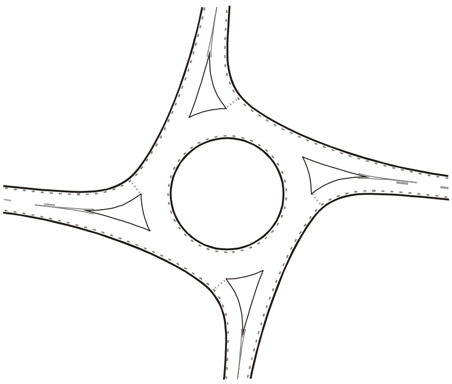
Control intersections are mostly used in towns and trading centres. However, roundabouts can be used in rural areas in intersections between major roads or other intersections with high traffic volumes. There are two types of control intersections:

Roundabout (D)

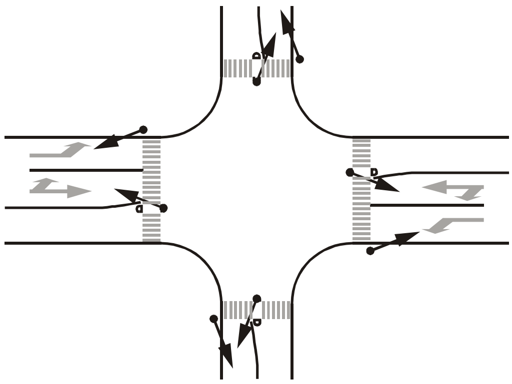
Roundabouts are controlled by the rule that all entry traffic must give way to circulating traffic. The ratio of minor road incoming traffic to the total incoming traffic should preferably be at least 10 to 15%. Roundabouts can be of normal size, i.e. with central island radius 10 m or more, or small size, i.e. with central island radius less than 10 m.

Signalized intersection (E)

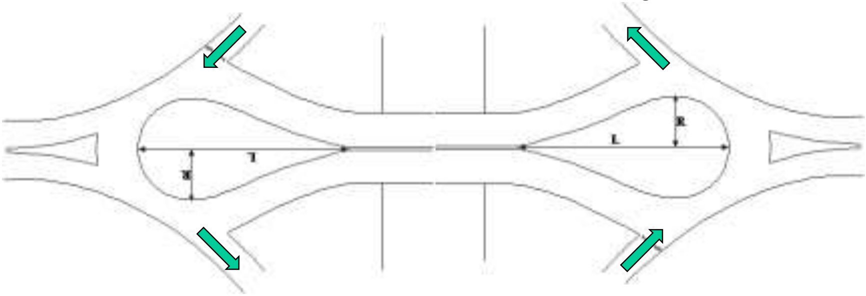
Signalised intersections have conflicts separated by traffic signals. No conflicts are allowed between straight through traffic movements.



Roundabout



Signalised intersection



Alternative design of roundabout (normally used at diamond interchanges)

Typical designs for control intersections

5.2 Selection of intersection type

This section presents an example from Sweden to show principles for the selection of intersection type. It should not be used in Serbia without adaptation to Serbian conditions.

5.2.1 General

These selection guidelines mainly deal with traffic safety. Other important impacts such as capacity / road user costs, environmental issues, investment and maintenance costs should also be taken into consideration. Capacity, delays, queue lengths, road user costs and also exhaust emissions could be estimated using standard software such as Oscady, Picady and Arcady (UK) SIDRA (Australia) or Capcal (Sweden) but they have not been calibrated for Serbian conditions, so they could give misleading results. Some traffic flow threshold values for capacity are given in figure 6.6.

The safety requirement for intersections can be defined as an interval where the expected number of accidents should not exceed a desired level and must not exceed a maximum level. If the expected number of accidents does not exceed the desired level, a priority intersection should be selected. If the number exceeds the maximum level, a control intersection should be selected. Between the two defined levels, a control intersection should be considered. The traffic flow threshold values presented in the following Figures 6.5 and 6.7 are based on this concept using general European traffic safety research results on the relationship between speed and incoming traffic flows on the major and minor road.

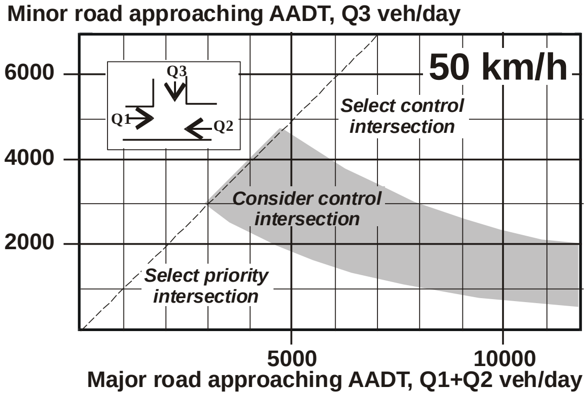
The selection is divided into two steps; selection of intersection category (priority or control) and selection of intersection type. It is based on the following assumptions:

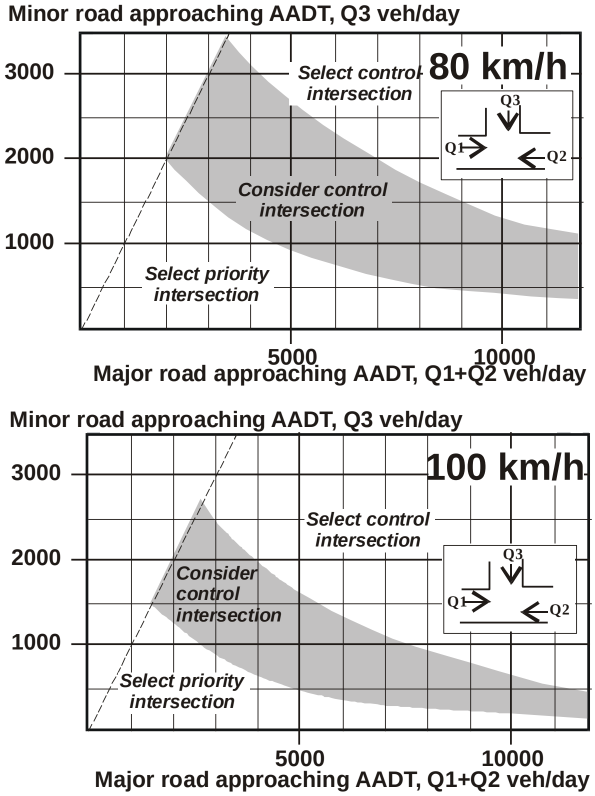
- Priority intersections can be safe and give sufficient capacity for certain traffic volumes and speed limits
- If a priority intersection is not sufficient for safety and capacity, the major road traffic must also be controlled.
- Depending on location, traffic conditions and speed limits, different types of priority or control intersection should be selected.

5.2.2 Selection of intersection category

Safety

The selection of intersection category should mainly be based on safety. The selection can be made by using diagrams with the relationships between the safety levels and the average annual daily approaching traffic volumes (AADT in veh/day) based on accident statistics. The diagrams shown in below are for T-intersections on 2-lane roads with 50, 80 and 100 km/h speed limit. The diagrams are, as already stated, based on general European experience on relationships between speed, safety and traffic flows. They are judged reasonable to be used in Serbia until sufficient local research is available.



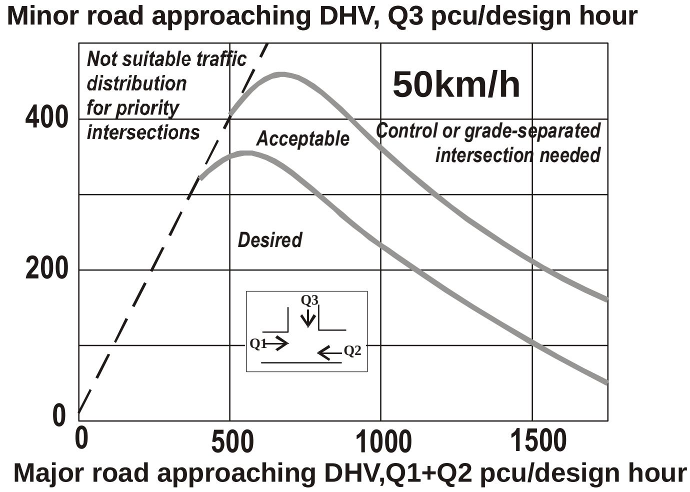


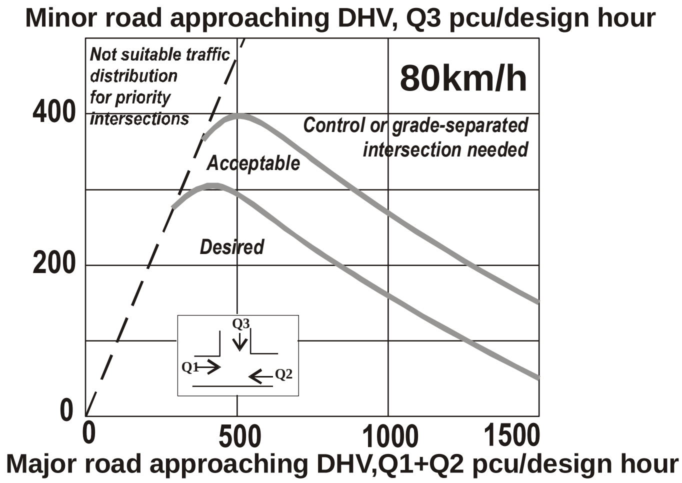
Selection of intersection category as to safety

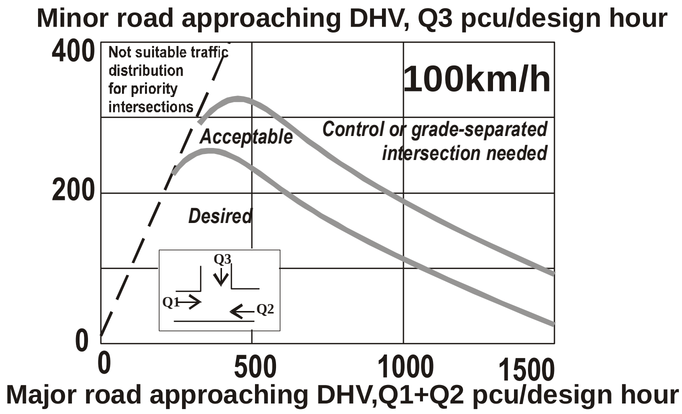
Capacity

The selection of intersection category based on safety should be checked for capacity. It can primarily be made by using diagrams with the relationships between the capacity and the approaching traffic volumes during the design hour (DHV in pcu/design hour, see section 3.2.2 and 3.3.3). The diagrams shown in below are for T-intersections on 2-lane roads with 50, 80 and 100 km/h speed limit. The desired level refers to a degree of saturation (actual traffic flow/capacity) of 0.5. The acceptable level refers to a degree of saturation of 0.7.

The diagrams are based on Swedish capacity studies with findings similar to other European countries. It is judged reasonable to be used in Serbia until sufficient Serbian research is available. Capacity could be checked more in detail using standard capacity software as already stated with the general drawback that Serbian capacity studies are as yet not available.







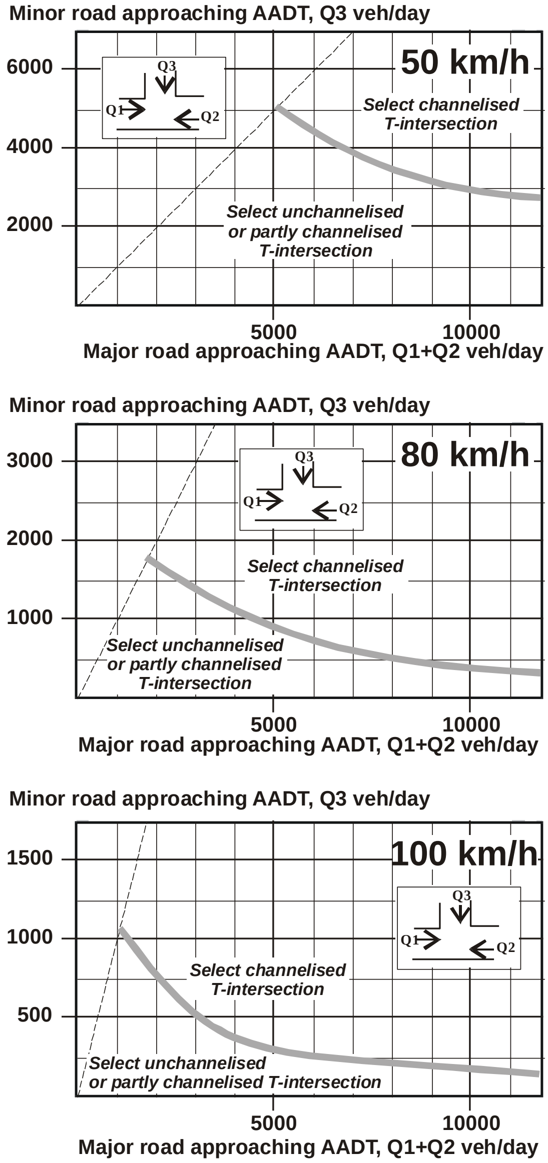
Selection of intersection category as to capacity

5.2.3 Selection of intersection type

Priority intersections

The selection of priority intersection type should mainly be based on safety. The selection can be made by using diagrams with the relationships between the safety levels and the average annual daily approaching traffic volumes (AADT in veh/day, see section 3.2.2) based on accident statistics. The diagrams shown in below are for T-intersections on 2-lane roads with 50, 80 and 100 km/h speed limit. Crossroads should be avoided. The number of right turners should obviously also impact the decision.

The diagrams are based on general European findings on safety effects of right turn lanes. It is judged reasonable to be used in Serbia until sufficient Serbian statistics are available. Note however they are only a starting point for determining the most appropriate form of intersection.



Selection of priority intersection type as to safety

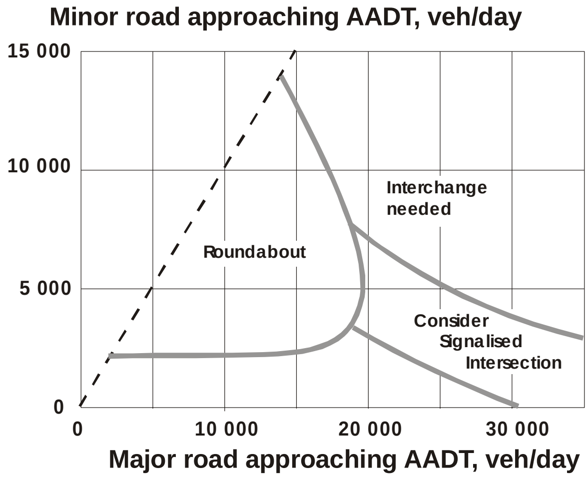
Partly channelised should normally be used if needed to facilitate pedestrian crossings and also if the minor road island is needed to improve the visibility of the intersection.

Control intersections

Roundabouts are suitable for almost all situations, provided there is enough space. Roundabouts have been found to be safer than signalised intersections, and are suitable for both low and medium traffic flows. At very high traffic volumes they tend to become blocked due to drivers failing to obey the priority rules. Well-designed roundabouts slow traffic down, which can be useful at the entry to a built-up area, or where there is a significant change in road standard, such as the change from a dual carriageway to a single carriageway.

Traffic signals are the favoured option in the larger urban areas. Co-ordinated networks of signals (Area Traffic Control) can bring major improvements in traffic flow and a significant reduction in delays and stoppages. However, they must be demand-responsive, in order to get the maximum capacity from each intersection. Observance of traffic signals by Serbian drivers is reasonably good, and could be improved through enforcement campaigns.

For some traffic distributions, for example high traffic volumes on the major road, the total delay can be shorter in a signalised intersection than in a roundabout. The diagram in below shows the traffic conditions for which signalised intersections are most suited, based on Kenyan and UK experience.



Selection of control intersection type

If a signalised intersection is considered due to planning conditions or traffic volumes, a capacity analysis and economic analysis should be made. This should include road construction and maintenance costs, accident costs, travel time costs, vehicle operating costs and environmental costs.

6 ROADSIDE FACILITIES

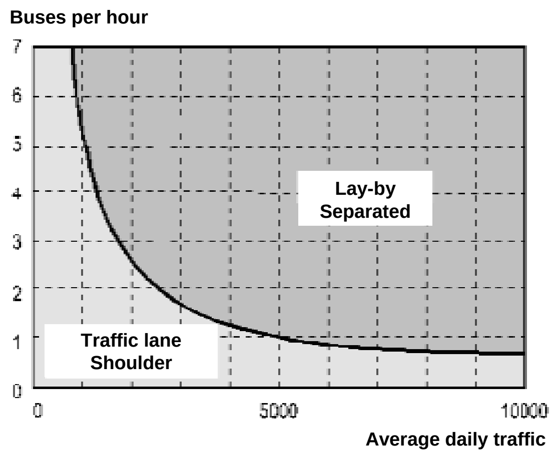
6.1 Bus stops

6.1.1 Bus stop types

On rural roads there are generally four types of bus stops to be used.

1. Separated bus stop
2. Bus stop in the traffic lane
3. Bus stop on the shoulder
4. Bus lay-by

In rural areas, especially on high speed roads, it is important that buses entering or leaving the bus stop not obstruct other road users. Consequently, the type of bus stop to be selected depends primarily on the traffic volume and the number of buses using the bus stop. Other factors influencing the selection are the speed limit, visibility, vulnerable road users, the number of lanes and shoulder width.

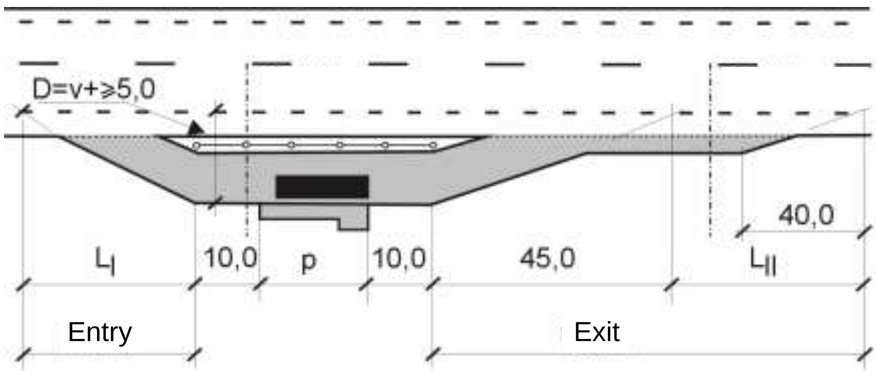


6.1.2 Design of Bus stops

The figures in this section show recommended design from the Swedish guidelines.

Separated bus stop

Separated bus stop should be used on high volume roads, especially on roads with more than two lanes. It should be separated from the travelled way by a fence, a traffic island or a grass strip. Acceleration and deceleration mainly take place on the entry and exit and the obstruction to other vehicles is minimized.



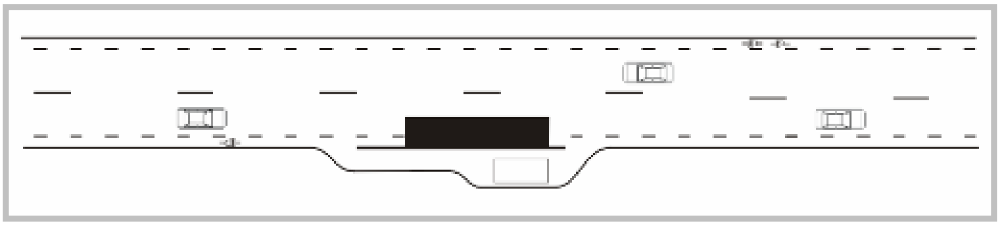
Speed limit, km/h	70	90	110
L_I, m	55	85	115
L_{II}, m	0	60	110

v = shoulder width
p = platform length

Separated bus stop

Bus stop in the traffic lane

Bus stop in the traffic lane can be used on low traffic two lane roads without or with narrow shoulders. There is generally no platform for the passengers. Busses at the bus stop lane block and obstruct the sight for all the vehicles behind.

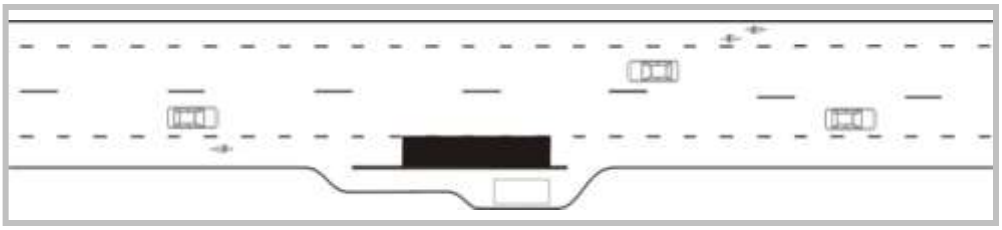


Bus stop in traffic lane

Bus stop on the shoulder

Bus stop on the shoulder can be used where the shoulder is at least 2 meters wide. There is generally no platform for the passengers

Busses at the bus stop lane block and obstruct the sight for vehicles using the shoulder, for example cyclists.

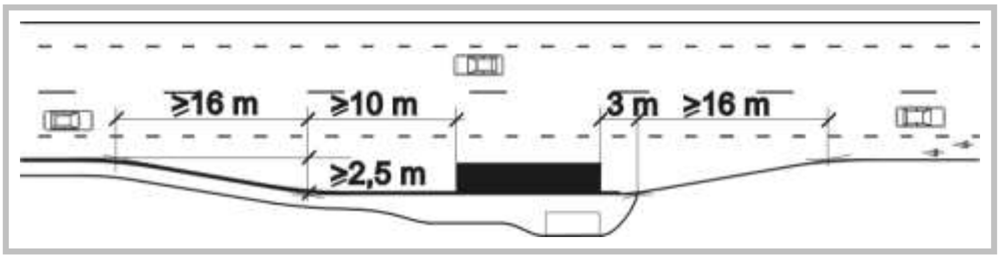


Bus stop on shoulder

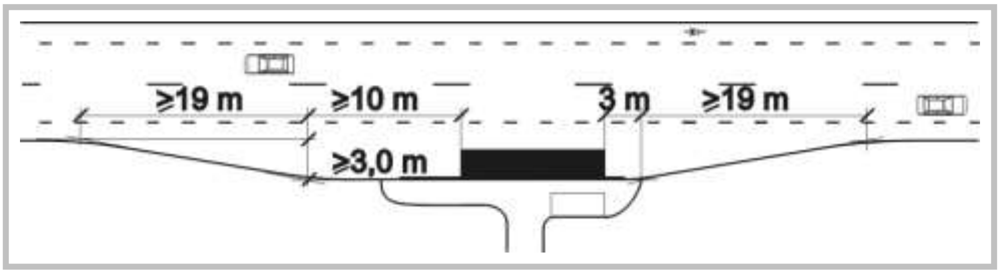
Bus lay-by

A bus lay-by outside the travelled way is the preferred bus stop on rural roads with high traffic volumes. There is generally no platform for the passengers

Busses at the bus stop do not generally block or obstruct the sight for vehicles behind.



Bus lay-by on roads with speed limit < 80 km/h



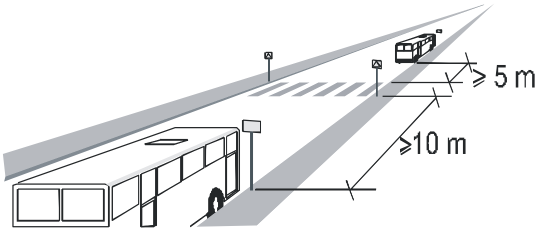
Bus lay-by on roads with speed limit ≥80 km/h

6.1.3 Location of bus stops

Location at pedestrian crossings

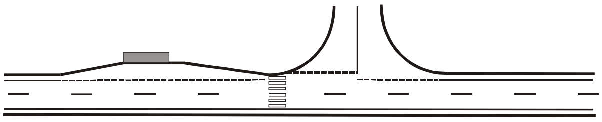
Bus stops should normally be located at least 5 metres after a pedestrian crossing.

If located before the pedestrian crossing the distance should be at least 10 metres.



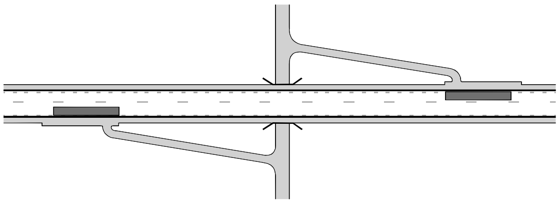
Intersection

Bus stops should be sited after intersections, to avoid stopped vehicles from obstructing the view of drivers entering the main road from the minor road.



Grade-separated crossing

The bus stops should be connected to the pedestrian road network e.g. to a pedestrian underpass as shown in the figure to the right.

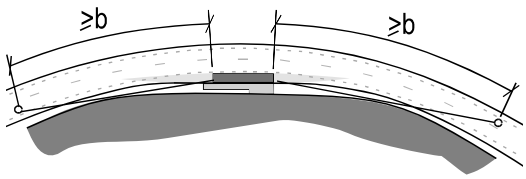


Spacing

The spacing between bus stops on opposite sides of the road should be at least 15 m.

Sight

The sight distance should be at least 1.5 x the stopping sight distance for the speed limit. The sight distance should be checked from a point 2.0 m from the edge of the traffic lane with 1.2 m eye height.



b = 1.5 x Stopping sight distance

Distance between bus stops

The distance between bus stops on the same side of the road should normally not be less than according to the table below.

Speed limit	Distance
60 km/h	300 m
80 km/h	500 m
100 km/h	700 m

Distance between bus stops

6.2 Lay-bys

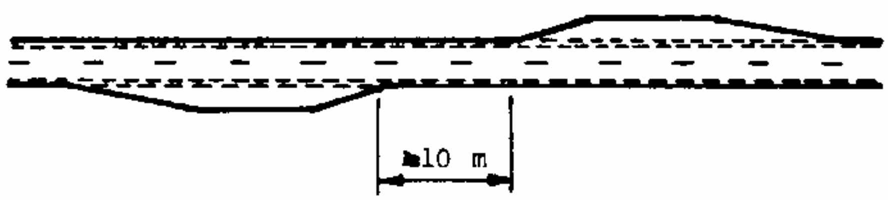
6.2.1 The use of lay-bys

A lay-by is an area adjacent to the road for temporary parking of vehicles. Lay-bys should be used for short rests etc and/or information to road users. Adjoining the lay-by there should be an area for rest and recreation, preferably equipped with seats and tables.

A lay-by for rest and/or information should normally not be used as a bus-stop. For lay-bys designed as bus-stops see the previous chapter!

6.2.2 Location

Lay-bys can be used on all roads except motorways. They should normally be used for traffic in one direction only. To avoid median crossings they should be located in pairs. On roads without medians, the lay-bys should be placed with at least 10 meters displacement with the right hand lay-by first.

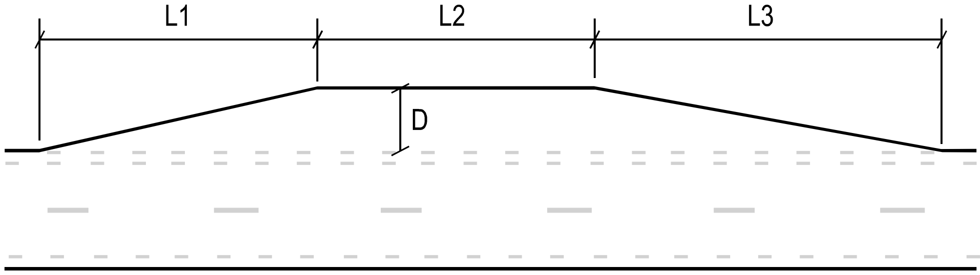


Lay-bys in pairs

Considering the road users disposition to use lay-bys the driving time between two facilities should be about 20 minutes. On roads with a high proportion long distant traffic the distance can be extended to about 30 minutes driving time. That means that the distance can vary from around 20 km (normal roads with 60 km/ speed limit) to around 50 km (national roads with 100 km sped limit).

6.2.3 Design

All types of vehicles should be able to use the lay-bys. Consequently, they should be designed for all normal vehicles including buses and trucks. The figure below shows a suitable design for all normal vehicles.

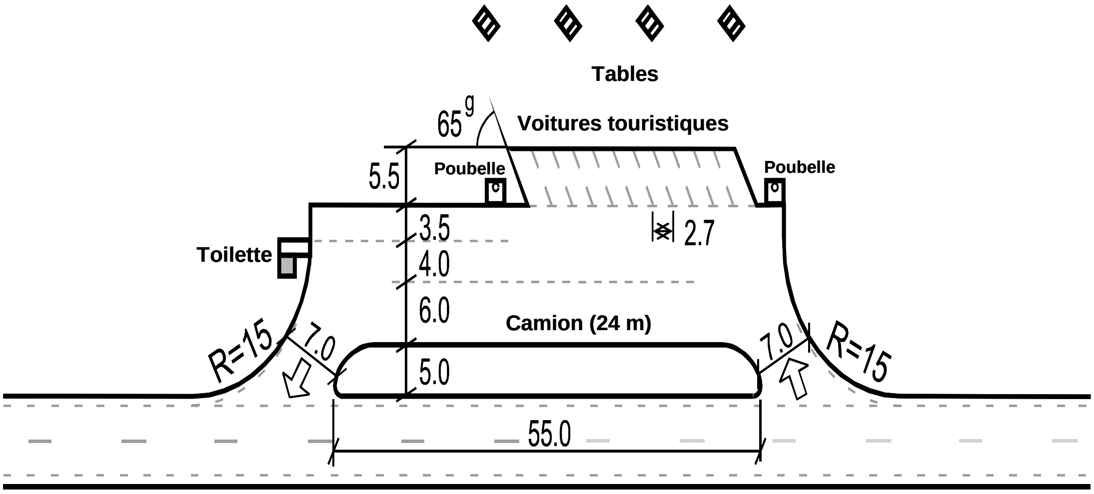


Shoulder width	Width D	Exit L1	Parking L2	Entry L3
< 2 m	4.5 m	15 m	≥ 20 m	25 m
≥ 2 m	6 m	20 m	≥ 20 m	35 m

Design of lay-bys

6.3 Rest areas

A rest area can be used for traffic in one or two directions. The figure below shows a typical design of a rest area used for traffic in one direction.



Typical design of a rest area for traffic in one direction

If the rest area is used by traffic in both directions the entry and the exit should designed as normal T-intersections

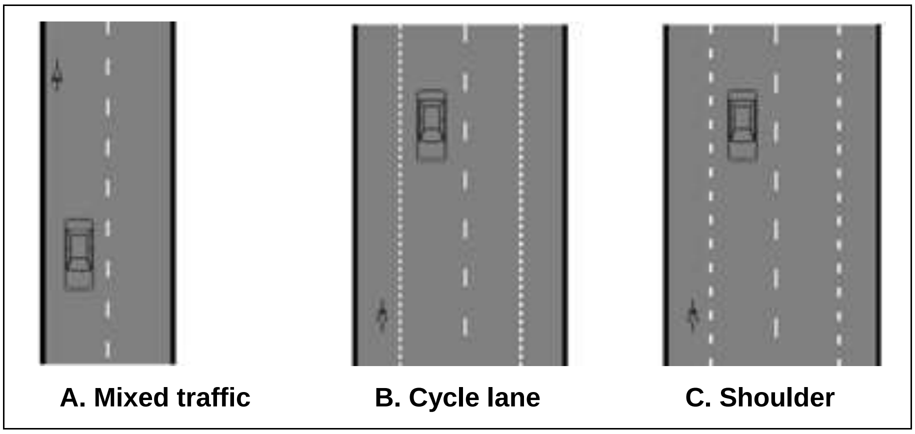
7 PEDESTRIAN AND CYCLIST FACILITIES

7.1 Separation of vulnerable road users

Separation of vulnerable road users from the motorized traffic has great safety benefits.

On many rural roads there is no physical separation of pedestrians or cyclists. On some roads, especially in urban areas, there are sidewalks for the pedestrians while cyclists must use the carriageway in one of the following ways:

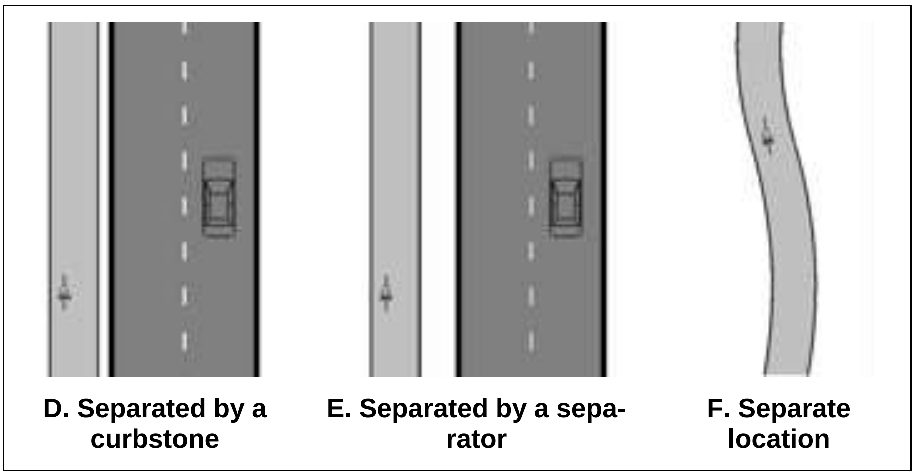
A. In the traffic lane mixed with the motorized traffic
B. In a marked cycle lane
C. On the shoulder



No separation of vulnerable road us

The main ways of separation of vulnerable road user are the following:

D. Separate lane divided by a curbstone
E. Separate lane divided a separator
F. Separate pedestrian-/cycle way located away from the main road



Separation of vulnerable road users

General recommendations on separation should be worked out for different types of roads and traffic volumes.

7.2 Pedestrian crossings

7.2.1 Background and safety considerations

It is difficult to set down criteria for the provision of pedestrian crossing facilities. Factors to take into account include:

- the volume of pedestrians crossing the road
- the speed of the traffic
- the width of the road
- if there are a lot of children crossing
- if there are significant numbers of disabled pedestrians

7.2.2 Pedestrian bridges and tunnels

Location

Bridges and tunnels for pedestrians and cyclists should be used on high-speed and / or high-volume roads. On normal roads bridges and tunnels are not generally recommended, because they are inconvenient to use, and have a number of other problems, including crime, vandalism, and maintenance. However, they are appropriate where the terrain is such that pedestrians can use the bridge or tunnel without having to climb or descend. Thus, the provision of a pedestrian bridge or tunnel depends on:

- The possibilities to locate and design the bridge in a way it will be used
- The costs for the bridge in relation to the number of pedestrians
- The traffic volume

For example, if the terrain is favorable a bridge should be provided even if the traffic volume and/or the number of pedestrians are low. On the other hand, if the traffic volume and/or the number of pedestrians are very high a pedestrian bridge should always be built.

Whenever possible the bridge or tunnel should be in line with the normal path that pedestrians and cyclists take when crossing the road. If they have to diverge from their direct route they will be discouraged from using the facility. Barriers can be used to try and force them to use the facility if the detour not is unreasonable.

Dimensions

Bridges should normally be 2-3 meters wide. The width and height of tunnels depend on the length of the tunnel. Recommended minimum dimensions for tunnels are given in the table below.

Type of tunnel	Width (m)	Height (m)
Narrow (short)	2.3	2.3
Standard	3.3	2.6
Wide (long)	5.0	2.6

Minimum tunnel dimensions

Accesses

Ideally, there should be a both stairs and ramps. Ramps should not normally be steeper than 5% and should have a non-slip surface. If there are many disabled persons the ramp should not be steeper than 3%.

To avoid unreasonable detours steeper ramps can be accepted.

7.2.3 At-grade crossings (Zebra crossing)

General

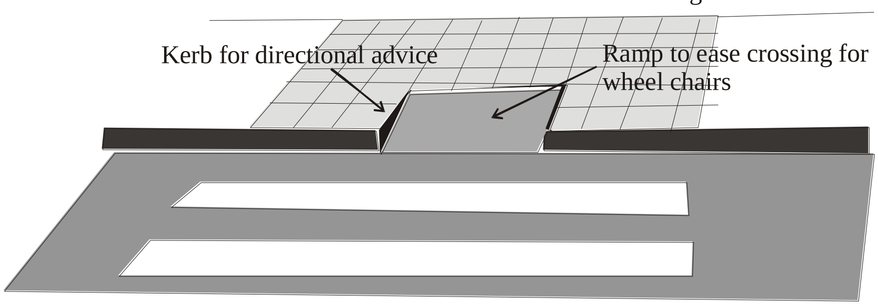
If there is no bridge or tunnel, zebra crossings should be provided to give the pedestrians a reasonable safe way to cross the road. However, zebra-crossings should not be used on roads with a speed limit over 50 km/h since they give a “false sense of safety”.

Crossings on a separated highway should be staggered with short pedestrian road in the median parallel to the roads. The purpose is to let pedestrians face the traffic before crossing the road, as shown in the figure below.

Detailed Design

General

Ramp entry is recommended to the crossing if there is a raised walkway along the road, see figure below.



Recommended ramp entry to pedestrian crossing

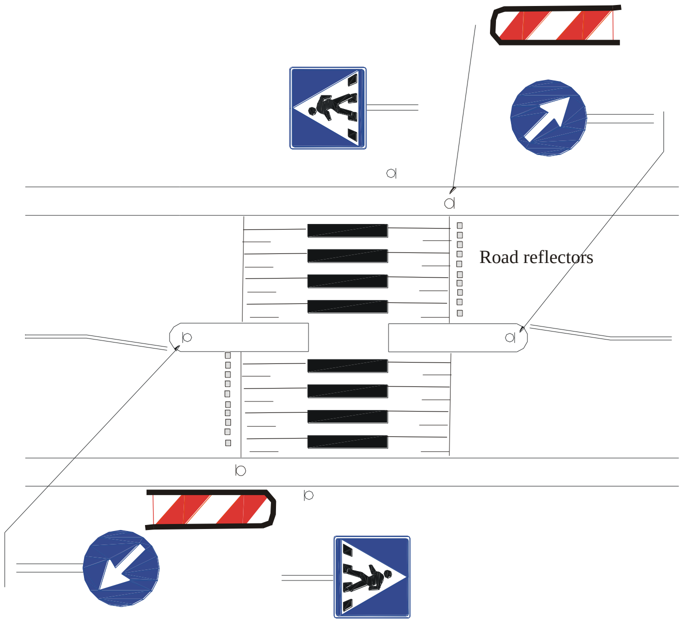
The minimum width of the median island is decided by the sign width chosen, which is normally 0.6 m at intersections m and 0.9 m at single pedestrian crossings. The additional margin would be minimum 2*0.3 m. The minimum width of the markings should be 2.5 m. Wider crossings could be needed at large pedestrian flows, see Highway Capacity Manual.

The island could be made wider to get the desired conflict zone width, which is recommended not to be longer than preferably 4 m and maximum 5 m to avoid the possibility of overtaking. This means that this type of crossing is not recommended on multilane highways.

The kerb height is recommended to be 0.1 m. The minimum length of the island is 1 m and the minimum radius 0.5 m.

Pedestrian could be directed to the crossing by use of rails.

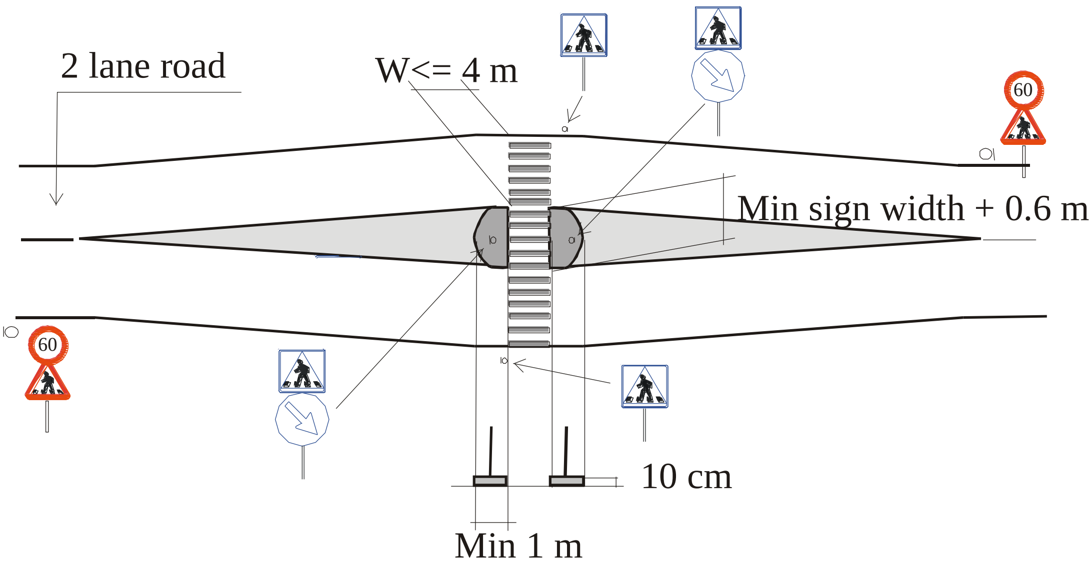
The geometric measures could be strengthened with humps. These could be applied as Watt humps upstream the crossing. Another option is to elevate the crossing itself by use of a plateau hump. Hump design is described more in detail in a separate section.



Example of plateau pedestrian crossing

Zebra crossing with median island

The most common way two reduce the conflict zone for the crossing passenger is to introduce a median traffic island see figure below for a location on a section.

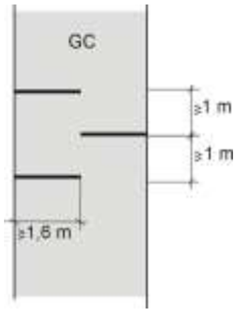


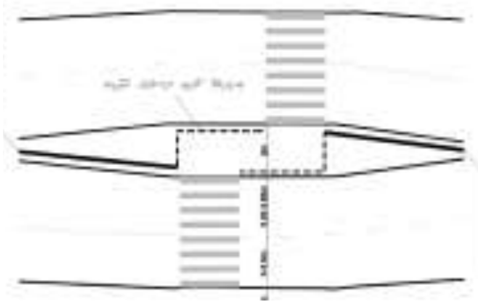
Pedestrian crossing with median island on two-lane road

The speed limit should be decreased to maximum 50 km/h combined with a warning sign for pedestrian crossing if the speed limit is higher. It is strongly recommended that the speed limit would be decreased further to at least 50 km/h. It is also recommended that the crossing should be illuminated.

The median island should be divided with the crossing area in the same level as the carriageway without any kerbs to facilitate conditions for pedestrians. The median should have directional signs and pedestrian crossing signs to improve the visual impact for on coming vehicles.

The pedestrian road in the median between the zebra crossings must be designed to prevent bikes and motorbikes to cross the median, e.g. with a pedestrian gate according to the figure below.





Example of the design of a pedestrian gate (from Swedish Guidelines)

Staggered pdestrien crossing (from Iranian design examples)

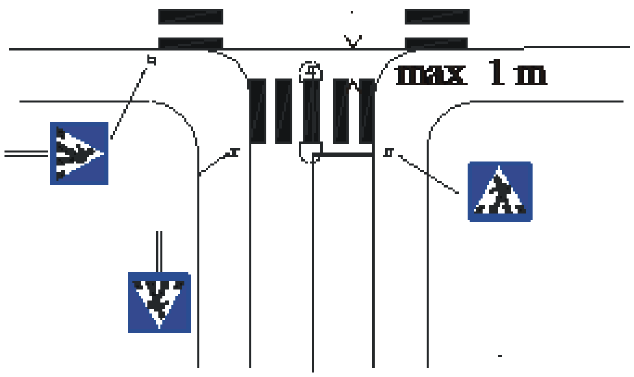
Location at intersections

Pedestrian crossings over the minor road in normal at-grade intersections should located in one of the following three positions:

1. Close to the main road
2. Withdrawn from the main road
3. Away from the main road

Location close to the main road gives good conditions for interplay between pedestrians and drivers turning right from the major road. The lateral displacement should be maximum 1 m, see figure below.

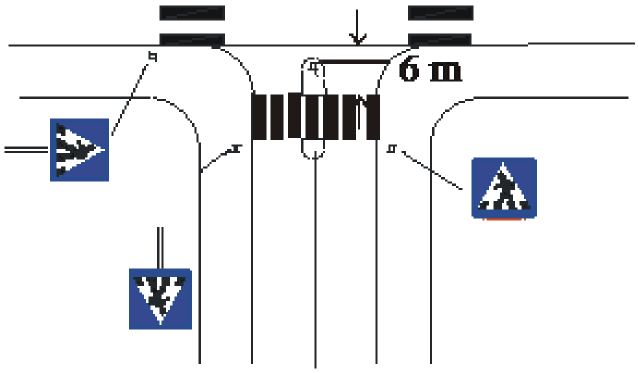
The stop line or give way line would be located up-stream the pedestrian crossing, which is an advantage for the pedestrian but a disadvantage for the driver. It also requires a long sight distance from the minor road.



Location close to main road on minor approach

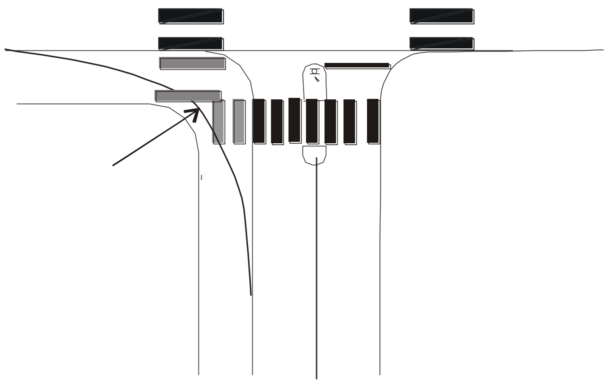
Location withdrawn from the major road enough to ensure a right-angled conflict between a right turning passenger car and a pedestrian crosser and also to give storage for one passenger car between the stop line and the pedestrian crossing. The lateral displacement should approximately 6 m, see figure below. Locations in the interval 1 to 6 m deteriorate possibilities for eye-contact between the car driver and the biker. The driver might even have dead angles due to back mirror location on his car.

This solution gives better level-of-service for cars from the minor road, to catch gaps in the major road due to the better overview. Pedestrian have to take a detour. Many safety researchers claim that the first solution is better from a traffic safety point of view.



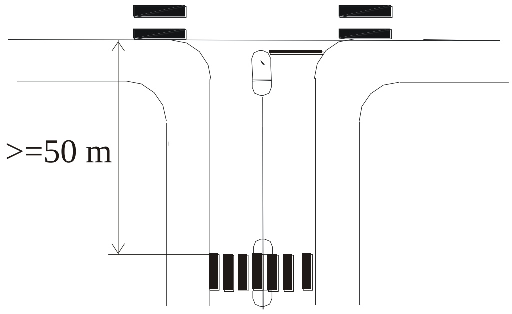
Location 6 m from intersection on minor approach

The intersection curve design is of outmost importance for the traffic safety of pedestrian crossings at intersections. Wide tapers and large radii to facilitate high speeds and to accommodate large trucks are obviously hazardous for traffic safety. Speeds will obviously increase. Sight angles between pedestrians and drivers will deteriorate and conflict zones will grow, see figure below. Right turn lanes are not recommended for the same reason.



Impact of intersection curve design

Location away from the main road aims at dividing the pedestrian crossing and the intersection to two different conflict points. A standard recommendation is a 3 second process time, which would give a recommended distance of minimum 50 m.

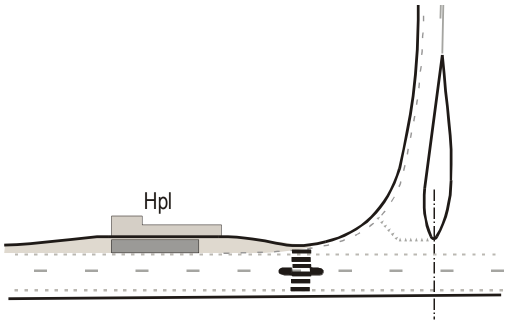


Isolated location

Locations at bus stops

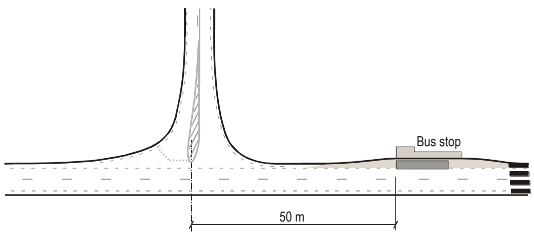
Pedestrian crossings together with bus stops are a common facility. The main principle would be to try to locate the facility so that the pedestrians could walk as straight as possible to and from the bus stop.

Bus stops and pedestrian crossings at at-grade intersections would preferably be located after the intersection to minimize the intrusion on sight conditions in the intersection, see figure below. The pedestrian crossing should be located upstream the bus stop to avoid that the bus will intrude sight distances between pedestrians and motor vehicles.



Recommended location after intersections

If located before the intersection the distance should be at least 50 m to give enough for sight distance.



Alternative location before intersection

7.3 Sidewalk and walk ways

7.3.1 Background and safety considerations

In order to make the pedestrians use the provided bridge, zebra crossings and bus bays attractive walk ways should be built between the pedestrian facilities as well as to and from points of destination for pedestrians. Short cuts used by pedestrians, if any, should be blocked with pedestrian fences or other barriers.

7.3.2 The use of sidewalks and walk ways

In rural areas pedestrians often have to walk on the road shoulders. However, on high-speed and high-volume roads sidewalks or separated walk ways should be provided. Some criteria for the provision of side-walks are given in the table below. These should be used with caution – in some circumstances sidewalks can be justified at lower pedestrian flows especially where children are present.

Location of sidewalk	Average daily vehicle traffic	Pedestrian flow per day	
		Speed limit 60 – 80 km/h	Speed limit 80 – 100km/h
One side only	400 to 1,400	300	200
	> 1,400	200	120
Both sides	700 to 1,400	1,000	600
	> 1,400	600	400

Criteria for provision of sidewalks

7.3.3 Design of sidewalks and walk ways

General requirements

Sidewalks and walkways should generally:

- have sufficient width (min 2.5 m)
- be paved
- have lighting

Cross-section

Standard widths are:

Absolute minimum:	1 m	(two persons cannot pass each other)
Desirable minimum:	1.8 m	(two persons can pass each other closely)
Light volume:	2.25 m	(two persons can pass each other comfortably)
Heavy volume:	3.5 m +	(space for three persons)

8 SIGNS AND MARKINGS

Introduction

Signs and markings can provide important information to improve road safety. They regulate, warn and guide road users. By letting people know what to expect, chances are greater that they will react and behave appropriately. Signs and markings need to be applied in a consistent way, to be placed at logical locations, and be easy to understand and visible.

This also means that underlying traffic regulations such as local speed limits need to be established on clear and consistent principles. The visibility of signs and markings needs to be checked regularly to avoid them being hidden by overgrown trees or blurred by sunlight. The use of retro-reflective material is needed to ensure night-time visibility

Road side signs must be used sparsely. Road users are only able to process a limited amount of information at a time. Too many signs at a particular spot may confuse and distract road users rather than help them. Too many signs may also result in non-compliance and disrespect.

How effective and costly is it? Research from different countries has shown that the number of injury crashes can be reduced by over 30 % by shoulder rumble strips and by over 10 % by centreline rumble strips. Estimations of costs vary largely. Cost-benefit analyses from Norway and USA have estimated that the benefits exceed the costs by factor between ca 3 and 180.

(From: **Best practices in road safety**, Handbook for measures at the country level, EU 2010)

8.1 General requirements

8.1.1 Traffic Signs

Clear and efficient signing is an essential part of the road system, and a road with poor signing or with badly maintained signs is not functioning well. Road users depend on signing for information and guidance, and road authorities depend on signing for traffic control and regulation, and for road safety.

The key requirements for each traffic sign are that it should:

- meet a need
- command attention
- be legible
- convey a simple, clear meaning at a glance
- be placed so as to give road users time to respond
- command respect

Signs must only be used where there is a clear need for them. The incorrect or unnecessary use of a sign annoys drivers, and when this happens frequently, drivers lose respect for the sign, and it becomes ineffective in situations where it is really needed. For the same reason, avoid using signs which impose a restriction which will be unpopular and difficult to enforce. Drivers will stop taking signs seriously when they see others ignoring them without being punished.

Using standard signs assists in their quick recognition, as does uniformity of shape, colour and lettering for each type. To obtain the full benefits of standardisation, the signs must be used in a consistent manner.

It is important that the message is presented in a simple way. The new signs make a great use of pictorial symbols, as these are more effective than words, and can be understood by those who cannot read. Signs with words should be used only where there is no alternative.

Signs must have sufficient impact to be noticed by drivers. This has been taken into account in the design of the signs, but the size and siting of the sign are also relevant. For most signs there are several permitted sizes, and it is largely the speed of the traffic at the site that determines which size is appropriate.

The symbols and legends on signs must be easy to read. This has influenced the design of the symbols, lettering, letter spacing, colours, etc., but size is again of most importance, as drivers who are travelling fast need to be able to recognise a sign from a long distance away. This means that the symbols and lettering need to be large enough to enable drivers to recognise them at the required distance.

Traffic signs must be visible at night. They should preferably be reflectorized so that they show up clearly in vehicle headlights.

Traffic signs should be constructed and erected so that they will last for many years without any attention apart from occasional cleaning.

8.1.2 Road Markings

The purpose of road markings is to control, warn, or guide road users. They may be used to supplement traffic signs or they may be used alone. Their major advantage is that they can give a continuing message to the driver. Thus they can be used to guide drivers in the correct positioning of their vehicles so that the traffic flows smoothly and safely. Some help clarify or emphasise the meaning of signs.

The markings have the limitation that they get covered up by dirt, and they wear away quite quickly on heavily-trafficked roads. Nevertheless, they serve a very important function in conveying to drivers information and requirements which might not otherwise be possible by post-mounted signs.

Where traffic congestion occurs, extensive use of road markings is essential to ensure that full use is made of the available road space. In particular, widespread use of lane markings is desirable; by enhancing lane discipline they add to the safety of traffic, besides improving traffic flows. And at intersections road markings can be very useful in showing drivers where to stop and look.

It is strongly recommended that road markings be considered in detail at the design stage of new or improved intersections.