Bosnia & Herzegovina

ROAD DIRECTORATE
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Public Company
"REPUBLIC OF SRPSKA ROADS "
Banja Luka

GUIDELINES FOR ROAD DESIGN, CONSTRUCTION, MAINTENANCE AND SUPERVISION

VOLUME I: DESIGNING

SECTION 1: ROAD DESIGNING

Part 4: FUNCTIONAL ROAD ELEMENTS AND SURFACES

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1 LEVEL CROSSROADS AND ACCESS POINTS

1.1 AREA OF APPLICATION

These guidelines provide orientation for project-technical design of intersections and points of access at grade (intersections, point of access) on public roads in the Federation of Bosnia and Herzegovina.

The technical guideline includes the area of use of intersections and points of access, types and forms of intersections and points of access, traffic safety factors at intersections and their project-technical elements.

The presented guideline discusses in detail various types of intersections and points of access except roundabouts, which are discussed in detail in a special guideline.

1.2 DEFINITION OF TERMS

Crossing shall be any spot, where a road crosses, at the same or different level, another road or any other infrastructure, such as railway, watercourse, cableway and similar.

Intersection shall be any juncture of three or more public roads.

At grade intersection (intersection) shall be an intersection where the juncture of roads is made at one level – grade.

Grade-separated intersection (interchange) shall be an intersection where the juncture of roads is made at two or more levels.

The intersection area shall be the area including legs of the intersection and the area of direct intersection of two or more roads, i.e. the traffic area belonging to two or more roads at the same time. The intersection area is thus limited by those points on individual legs of the intersection in which the road's shape (carriageway width, turning lanes, measures for channelling, turning radii…) begins to change in any way (as regards the ground plan, longitudinal direction or cross section) due to the intersection. This term is equal to the term wider intersection area.

Limited area of the intersection shall be the area limited by road signs (transverse broken or continuous line of an individual lane) or extensions of edges of intersecting roads determining the traffic regime at the intersection.

Point of access, access point shall be the connection (junction) between a public road and all areas from which vehicles directly move in and out of traffic on a public road. It is a part of the public road whereby the public road of the same or lower category, a non-categorised road or access to a building or land connects to that road. A point of access is a part of the road in the length up to the edge of road area, which is 2.0 m from the outer edge of the final point of cross section of body of the road with road drainage facilities and slope of the body of the road or from the safety fence erected along the body of the motorway.

Point of access area, area of the access point shall be determined by points on particular legs of the categorised road in which due to arrangement of the point of access the road's cross section begins to change in any way (as regards the ground plan, longitudinal or transverse directions) and the point of access leg to the end of arrangement of accessing conditions, which shall be minimally in the width of the road area of the categorised road.

Major public roads shall be roads connecting the entire or larger part of the state Bosnia and Herzegovina and the Federation and integrating it in the European road network while at the same time being an interdependent transport network.

Regional public roads connect settlements and localities within one or more cantons, integrate the entire area of a canton and create an interdependent transport network of one or more cantons connected to the major roads network.

Local public roads, streets in settlements and towns shall be interdependent transport network of a municipality or town connected to the regional or major roads network.

Non-categorised road shall be any traffic area not categorised as a public road.

Traffic areas outside the carriageway shall be rest areas, parking lots, bus stops and turning sites, petrol stations, facilities and buildings for weighing and control of traffic…

Traffic control shall be the method for dealing with the traffic flows determined by the road management entity for a road or its part or a settlement or its part. The traffic control includes setting the directions with right of way and the system and method for traffic management, limitations of use of the road or its part with regard to traffic type, speed limits and determining of measures for slowing down traffic, stand still traffic controls, determining areas of slowed down traffic, areas of speed limits and pedestrian areas, determining other obligations of road users. The traffic control shall be indicated by the prescribed traffic signs and signals.

Settlement through which a public road passes (urban road) shall be the area in which there are rows or groups of buildings on one side of the road and which shall be limited by traffic signs for marking settlements.

Intersection at grade legs shall be access roads or lanes on both sides of a delevelled pedestrian island or such an island marked only by road signs, which direct the traffic from the opposite or the same direction (entry – exit) to/from the intersection.

Special lanes shall be parking lanes, cyclist lanes or pedestrian lanes.

Cyclist way shall be the part of the roadway, which is not at the same level as the roadway or is separated from the roadway in some other way and which is intended for traffic of bicycles and bicycles with motors.

Cyclist lane shall be a longitudinal part of the road intended for traffic of bicycles and bicycles with motors, marked by a longitudinal line on the roadway or the pavement.

Pedestrian lane shall be a longitudinal part of the roadway, intended for pedestrians walking.

Separation lane shall be the part of carriageway, which physically separates directional carriageways and the marked part of carriageway on which traffic is prohibited.

Guiding lanes shall be traffic lanes for guiding traffic flows in an intersection.

Refuge island shall be a raised or otherwise marked area of the roadway, intended for temporary stopping of pedestrians crossing the roadway or intersection, entering or leaving a vehicle for public transport of passengers.

Pedestrian path shall be a public path marked by the prescribed traffic signs and intended exclusively for pedestrians walking.

Pavement shall be the part of the roadway, which is not at the same level as the roadway or is separated from the roadway in some other way and which is intended for pedestrians or pedestrians and traffic of bicycles and bicycles with motors, if it includes a marked cyclist lane.

Visibility field shall be the area along the road, determined by the visibility triangle and the visibility berm, the use of which is limited.

Visibility triangle shall be land along the road, the use of which is limited for the purpose of providing the prescribed visibility at intersections at grade between roads or between a road and railway.

Pedestrian crossing shall be a part of the roadway, intended for crossing of pedestrians across the roadway and marked by the prescribed traffic signs.

Traffic lane shall be a marked or unmarked longitudinal part of the directional carriageway, which is wide enough for unimpeded driving of vehicles in a single line.

Extra width shall be the part of the roadway intended for marking of the roadway's edges.

Directional carriageway shall be the carriageway or its longitudinal part intended for driving of vehicles in one direction and may consist of one, two or more traffic lanes.

Approach radius shall be the radius of the first arc of the right edge of the carriageway on the entry to the intersection.

Exit radius shall be the radius of the last arc of the right edge of the carriageway on the exit from the intersection.

Covered area shall be the area occupied by the vehicle in a particular driving manoeuvre (turning left, turning right, driving straight, reverse turning left or right).

Crossing angle shall be the angle enclosed by axes of the crossing roads.

Main traffic direction (MTD) shall be the main (priority) traffic direction at the intersection.

Side traffic direction (STD) shall be the side (subordinate) traffic direction at the intersection.

1.3 MARKS AND ABREVIATIONS

α	Crossing angle of the MTD and the STD [^{o}], [^{g}]
a_s	Average acceleration [m/s^2]
b	Distance between covered areas in left turning [m]
b_{min}	Minimum distance between covered areas in left turning [m]
D	Total length of the intersection and the vehicle [m]
e	Factor depending on the element type of the route of the leg and position (side) of the widening [-]
f_{TD}	Allowed tangential element of the adhesion ratio between tyres and the roadway [-]
g	Free fall acceleration (9.81 [m/s^2])
MTD	Main (priority) traffic direction at the intersection
i	Size of the widening [m]
l_A	Length of the waiting section [m]
L_K	Length of the intersection in the direction of the side traffic direction [m]
l_{SP}	Length of the section for changing traffic lanes [m]
l_w	Length of the section where widening is implemented [m]
$l_{š'}$	Length of displacement [m]
L_V	Length of the appropriate vehicle type on the side traffic direction [m]
l_Z	Length of the braking section [m]
P_G	The required sight distance on the main traffic direction [m]
P_S	The required sight distance on the side traffic direction [m]
P_Z	Stopping sight distance [m]
q_{MTD}	Cross fall on the main traffic direction [%]
R1	The first (entry) radius of the basket-like curve in the turning arc [m]
R2	The second (middle) radius of the basket-like curve in the turning arc [m]
R3	The third (exit) radius of the basket-like curve in the turning arc [m]
$r_{V\ min}$	Minimum radius of the vertical curvature [m]
r_V	Radius of the vertical curvature [m]
s	Longitudinal fall of the side traffic direction [°%]
s_{MTD}	Longitudinal fall of the main traffic direction [°%]
Sh	Leg length of the visibility triangle for pedestrians and cyclists [mg]
s_{max}	Maximum longitudinal fall at the intersection [%]

STD Side (subordinated) traffic direction at the intersection
s_{STD} Cross fall on the side traffic direction [%]
W_1 Width of a traffic lane [m]
W_2 Width of a traffic lane [m]
W_3 Width of a traffic lane [m]
W_4 Width of a traffic lane [m]
W_5 Width of a traffic lane [m]
t_r Preparatory (reaction) time of the driver 1.5 to 2.5 [s]
u Dynamic resistance of air [-]
V_{85} Speed at the intersection by which 85% of vehicles are driving [km/h]
v_G Design speed on the main traffic direction [m/s]
v_K Final speed at the end of the turning lane [m/s]
V_K Calculative sped at the intersection [km/h]
v_S Design speed on the side traffic direction [m/s]
v_Z Design speed in the intersection area [m/s]

1.4 CRITERIA FOR INTRODUCING AN INTERSECTION OR A POINT OF ACCESS

There are several criteria for introducing an intersection or a point of access, which differ in their nature. Therefore the determining of appropriateness of introducing a new intersection must always include compliance with the following criteria:

- Functional criteria;
- Criteria regarding permeability;
- Spatial criteria;
- Traffic-safety criteria.

Functional criteria

The functional criteria represent the appropriateness of the location and the position of the planned intersection in the global road network of a particular settlement with regard to its function and significance.

It is thus all about assessment of the location and type of the planned intersection from the point of view of its function (purpose/significance).

Criteria regarding permeability

The criteria regarding permeability relate to establishing of the level of traffic permeability of the planned intersection at the end of the planning period and accordingly appropriate control and selection of the intersection's elements (number of lanes, checking the need for guiding lanes, selection of the method for directing traffic flows).

A constituent part of assessment of the criteria regarding traffic permeability of an intersection in an urban area is also checking the distance from the previous and the next intersection and checking the criteria of placement of the intersection between two existing (or planned) consecutive intersections.

Because of the fact that intersections are a disturbing element affecting the traffic flow between intersections, they should be set as apart as possible on the roads of higher categories. The recommended distance between intersections at grade presented below stems from the general function of intersections, their purposes and significance in the global road network and the characteristics of traffic management as well as requirements regarding traffic signs and signals (guiding – "signposting" signs).

Distances between intersections outside urban areas – to the extent they can be freely chosen – should be set so that between intersections requirements stemming from the minimal overtaking distance or the desired overtaking distance are met. In case the requirement specified above cannot be met, we should check for the possibility of combining individual pairs of intersections (the so-called "intersections pair") and the sections between individual intersections or intersections pair should be formed so that overtaking is enabled on them.

The shortest distance between two intersections being a part of an "intersections pair" is obtained by taking into account the intersection elements (e.g. length of lanes for left turning). In such a case, joint guiding signs are to be used for both intersections.

Separate placement of traffic (guiding) signs shall be possible if we take into account the minimum distances between adjacent intersections presented in Table 1, where the distance is measured from intersecting points of axes.

Table 1: Minimum distances between intersections.

V_K [km/h]	50	60	70	80	90
Recommended distance between intersections [m]	140	170	205	235	270

Generally, it is not necessary (or indeed desirable) to enable overtaking between individual intersections of two-lane roads in urban areas. In certain cases, the desirable distances between intersections, resulting from traffic-technical requirements, can only be implemented in case co-ordination of traffic signal lights, the required distances for waiting of vehicles and the required distances for changing direction are brought in line.

The effects of placement of an intersection between two existing (or planned) consecutive intersections should be assessed by a traffic study.

Spatial criteria

The type and method of traffic distribution at intersections and points of access at grade, the number of traffic lanes, implementation of guiding lanes… affect the selection of project-technical elements of an intersection and therefore also the use of space required for implementation of an intersection. It is thus about checking for the adequacy of space for implementation of the planned intersection with elements complying with criteria regarding permeability.

Traffic-safety criteria

The traffic-safety criteria relate to assessment of the level of traffic safety of the planned intersection, which would be offered by the envisaged type and method of traffic distribution, used project-technical elements of the intersection and the available space. It is thus about assessment of the elements used for complying with the functional and spatial criteria and criteria regarding permeability from the point of view of traffic safety.

The aforementioned global criteria should be assessed regardless of the fact whether we are dealing with a reconstruction or new construction. The significance and order of the specified global criteria depend on actual circumstances and vary on a case-by-case basis.

1.5 INTERSECTIONS AND POINTS OF ACCESS AT GRADE TYPES

1.5.1 The Purpose of Intersections and Points of Access at Grade

The purpose of intersections and points of access at grade is to provide safe, comfortable, fast and economical distribution (crossing, intertwining, joining or bifurcating) of traffic flows.

1.5.2 Traffic Distribution at Intersections

The following distributions of traffic flows are used in multi-level knot-points, intersections and points of access and knot-points, intersections and points of access at grade, depending on the significance of the intersection in the road network and the category of intersecting roads:

- Spatial division: Horizontal distribution and Vertical distribution;
- Time division.

Spatial division of traffic flows affects the construction-technical design of the intersection and time division the traffic-technical design of the intersection.

Horizontal distribution is implemented by adding special traffic lanes in the intersection's grade, thereby directing individual traffic flows.

Vertical distribution is implemented by aligning individual traffic flows at different grades – levels, thereby eliminating crossing of traffic flows.

Time division is an artificial interruption of individual traffic flows for the purpose of creating sufficient time vacuum in that flows, which is used by vehicles in another traffic flow. Time division is performed by traffic signal lights or a traffic police officer.

The type and method of traffic distribution at intersections and points of access at grade affect the selection of project-technical elements of an intersection and also determining of traffic-technical elements and the equipment of an intersection.

Traffic-technical elements (the number of traffic lanes, the need for guiding lanes, the method of traffic flow management) are the subject of a special guideline.

1.5.3 Division and Arrangement of Intersections with Regard to the Category of Intersecting Roads

The basis for division of intersections and points of access at grade (see Table 5.1) to different types is the road classification, specified in the Roads Act of the Federation of Bosnia and Herzegovina (Official Journal of the Federation of BiH no. 6/02). This division has already taken into account the proposed new division of public roads in Bosnia and Herzegovina as envisaged in the *Road Classification System, Criteria of Public Road Classification,*. Individual types of intersections and points of access require different arrangement (see Table 3).

The envisaged elements and equipment of an intersection as presented in Table 3 are generally used for new constructions and reconstructions. Any deviation from the conditions specified in the table shall be exceptionally allowed if it is additionally and specially expertly substantiated.

The envisaged elements and equipment of an intersection depend on the intersection's location (inside or outside urban areas). Table 3 presents the envisaged elements and equipment of an intersection for the case of an intersection placed within an urban area. Expertly substantiated deviations are possible with regard to intersections outside urban areas.

A traffic analysis to be used as the basis for determining the arrangement and selection of technical elements shall be prepared for all roads where AADT $\geq$ 3500 vehicles/day.

In case the accessing road is two or more categories below the main traffic direction, the design of location and technical implementation of the intersection shall take into account special conditions discussed in greater detail in a special guideline.

Table 2: Allowed types of intersections and points of access.

	M1	M2	R1	R2	R3	LR	PP	TA	NC
M1	•	•	•	•	•	•		•	
M2	•	•	•	•	•	•	•	•	
R1	•	•	•	•	•	•	•	•	
R2	•	•	•	•	•	•	•	•	•
R3	•	•	•	•	•	•	•	•	•
LR	•	•	•	•	•	•	•	•	•

PP		•	•	•	•	•	•	(•)	•
TA	•	•	•	•	•	•	(•)	•	(•)
NC				•	•	•	•	(•)	•

LEGEND:

M1, M2 Main roads
R1, R2, R3 Regional roads
LR Local road
PP Public path
TA Traffic area outside the roadway
NC Non-categorised road
• Allowed intersection type
(•) Conditionally allowed intersection type (allowed for: rest areas, petrol stations, control stations; forbidden for: parking lots, bus stops and turning sites)

Table 3: Arrangement depending on the intersection or point of access type.

	M1	M2	R1	R2	R3	LR	PP	TA	NC
M1	OG, T, TS, I, C, [PL]	TL, T, TS, I, C	TL, T, TS, I, C	TL, T, TS, I, C	T, I, C, TSI	T, I, C, TSI		TSI	
M2	TL, T, TS, I, C	TL, T, TS, I, C	TL, T, TS, I, C	TL, T, TS, I, C	T, I, C, TSI	T, I, C, TSI	TSI, C	TSI	
R1	TL, T, TS, I, C	TL, T, TS, I, C	TSI, T, I, C	TSI, T, C	TSI, T, C	TSI, C	TSI	TSI	
R2	TL, T, TS, I, C	TL, T, TS, I, C	TSI, T, C	TSI, T, C	TSI, T, C	TSI, C	TSI	TSI	TSI
R3	T, I, C, TSI	T, I, C, TSI	TSI, T, C	TSI, T, C	TSI, T, C	TSI	TSI	TSI	TSI
LR	T, I, C, TSI	T, I, C, TSI	TSI, C	TSI, C	TSI	TSI	TSI	TSI	TSI
PP		TSI, C	TSI	TSI	TSI	TSI	TSI	(TSI)	RR
TA	TSI	TSI	TSI	TSI	TSI	TSI	(TSI)	TSI	(TSI)
NC				TSI	TSI	TSI	RR	(RR)	RR

LEGEND:

OG Off-grade intersection
TL Traffic light controlled intersection
T Special turning lanes
TS Traffic signs (guiding tables, signposts…) on the portal
I Splitter islands (triangular islands, refuge islands, separating lanes…)
C Channelled intersection (drop, triangle)
PL Intersection equipped with public lighting
TSI Traffic lights (II-1 or II-2)
RR "Yield-to-right rule"
[XX] Conditionally allowed

1.5.4 Intersection Design Principles

1.5.4.1 General principles

Intersections and points of access are traffic areas in which traffic flows intersect, access, bifurcate or intertwine, therefore they must be designed so that conflicts between traffic participants appear as rarely as possible and that at the same time losses of traffic flows are as small as possible. These two conditions must be met by using as little finance as possible.

General principles for designing intersections at grade are used for provision of the aforementioned principles, namely:

- Driving conditions at intersections should be to the greatest possible extent equal to those on the road's section before the intersection;
- Traffic safety conditions at the intersection should be optimal;
- The intersection's permeability should not affect the permeability of the section between two consecutive intersections.

1.5.4.2 Traffic Flows at Intersections

Traffic flow types

In general, there are three traffic flow types at intersections:

- Continuous traffic flows;
- Interrupted traffic flows;
- Combined traffic flows.

The continuous traffic flow is formed by vehicles which do not stop at the intersection and the interrupted traffic flow by vehicles stopping at the intersection as a result of external factors: traffic signs, traffic signal lights… In the combined management method, certain traffic flows preserve the qualities of the continuous traffic flow in driving through the intersection, while others obtain the qualities of the interrupted traffic flow.

Traffic operations between traffic flows

The following traffic operations occur at the intersection between two traffic flows with different directions:

Crossing	•
Bifurcation	O
Combining	(
Intertwining	∃

Traffic manoeuvres specified above also result in possible conflicts between two traffic flows with different directions.

1.5.4.3 Management Methods for Traffic Flows at Intersections

Various traffic flows at intersections can be managed by using different methods, depending on the intersection's type and the category of intersecting roads.

The selection of the management method for traffic flows at an intersection determines the level of traffic safety at the intersection (the number of conflict points, their intensity, size of the conflict area) and includes construction-technical solutions (required finance).

Continuous management of traffic flows

Continuous management means that all traffic flows preserve the qualities of the continuous traffic flow in direct driving through the intersection (for example, entering and exiting the motorway). This means that all traffic operations of bifurcation, accessing and intertwining are performed without stopping. This management method is possible subject to meeting of the following conditions:

- Traffic flows have approximately the same speed;
- Sufficient time gaps exist between vehicles driving one after another;
- Sufficient visibility is provided;
- Bifurcation and accessing are performed at a steep angle;
- Only one-way traffic is possible in conflict areas.

The advantages of continuous management are as follows:

- Safe and free flow of traffic providing high capacity;

- Small time losses.

The deficiencies are as follows:

- It requires high-level of concentration of the participants;
- Grave danger in case of erroneous traffic operations;
- High implementation costs.

Interrupted management of traffic flows

In this method, all traffic flows at an intersection obtain the qualities of an interrupted traffic flow. This means that upon entering the intersection, all flows reduce their speed or even stop and then all other traffic operations follow (for example, four-leg intersection of two equivalent roads).

The advantages of interrupted management are as follows:

- Safe flow of traffic;
- Requires lower levels of concentration from participants than the continuous management;
- Requires lower implementation costs than the continuous management.

The deficiencies are as follows:

- Large time losses of traffic flows;
- Small permeability;
- Unnecessary stopping of vehicles on side traffic directions.

Combined management of traffic flows

Combined management is the most common traffic flow management method in practice. In this management method, certain traffic flows preserve the qualities of the continuous traffic flow in driving through the intersection (the main traffic direction – MTD), while others obtain the qualities of the interrupted traffic flow (the side traffic direction – STD) (for example, traffic light controlled intersection, yield-to-right rule, traffic sign II-2).

This traffic flow management method also has its advantages, namely:

- The management method for individual flows is in the function of their importance;
- Small conflict areas.

Deficiencies are as follows:

- Occasional unnecessary stopping of vehicles on side traffic directions;
- Required increased concentration of traffic participants.

The decision for a particular management method by the designer in the preparation of solutions depends on criteria specified in Chapter 1.1.4. The significance and order of the specified global criteria depend on actual circumstances on the field and vary on a case-by-case basis.

1.5.5 Channelling of Traffic Flows

1.5.5.1 General

Channelling of traffic flows (see Figure 1) means controlled management of traffic flows between or along channelling elements, which may be delevelled or already marked on the roadway by appropriate road signs.

Channelling represents the principle of arrangement of an at grade intersection, where each traffic flow (or at least some of them) is provided with a special traffic area in the intersection area. Channelling reduces the number of actual conflict points and the size of the conflict area.

A channelled intersection provides better visibility and perception of users, the possibility for erroneous reactions of drivers in driving through an intersection is thus smaller.

Channelling may be partial or complete. Completely channelled intersection means the arrangement of an intersection where each traffic flow is provided with a special traffic lane.

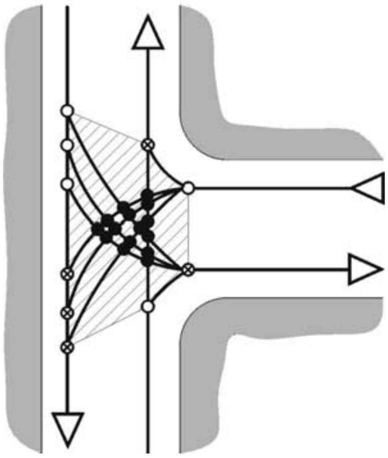


Figure 1a.) Non-channelled three-leg T intersection.

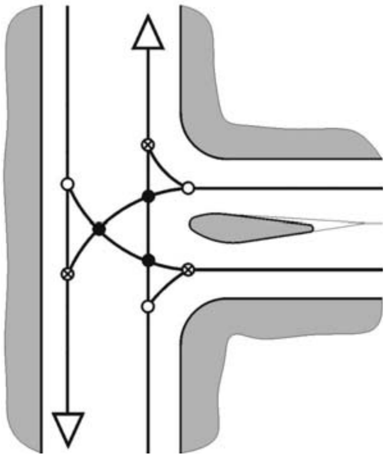


Figure 1 b.) Channelled three-leg T intersection.

By channelling measures, the uncontrolled management of traffic flows (Figure 2) changes to a controlled one (Figure 3). Channelling must be made so that the driver driving through conflict point positions is enabled to drive through an intersection without any surprises during the entire period of movement.

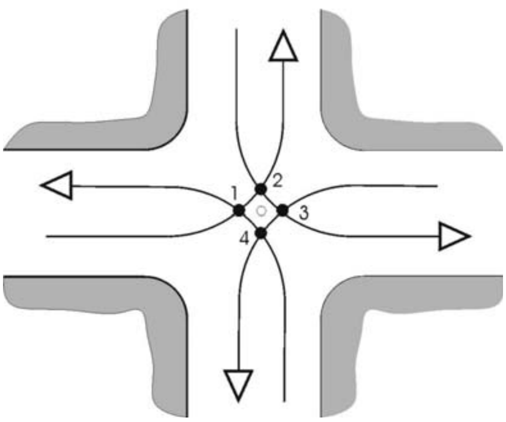


Figure 2a.) Uncontrolled management of left turning in a four-leg intersection.

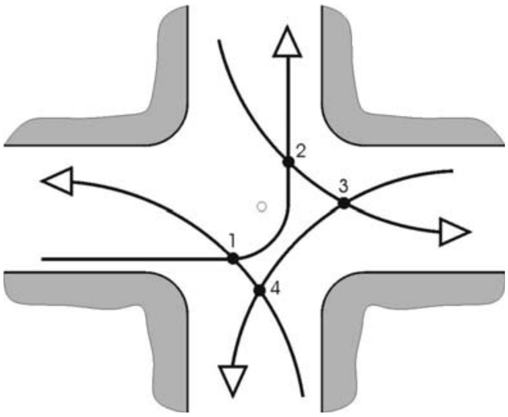


Figure 2 b.) Uncontrolled management of left turning in a four-leg intersection.

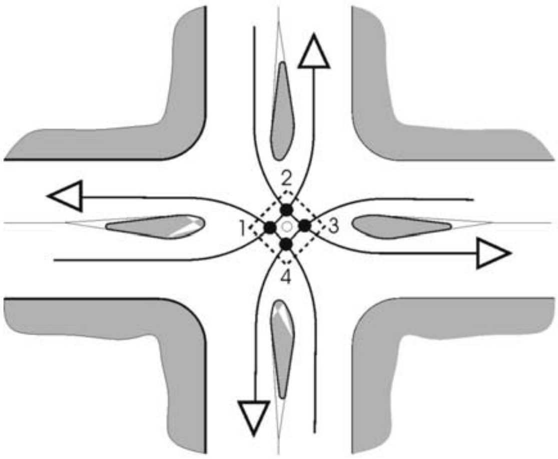


Figure 3 a.) Controlled management of left turning in a channelled four-leg intersection.

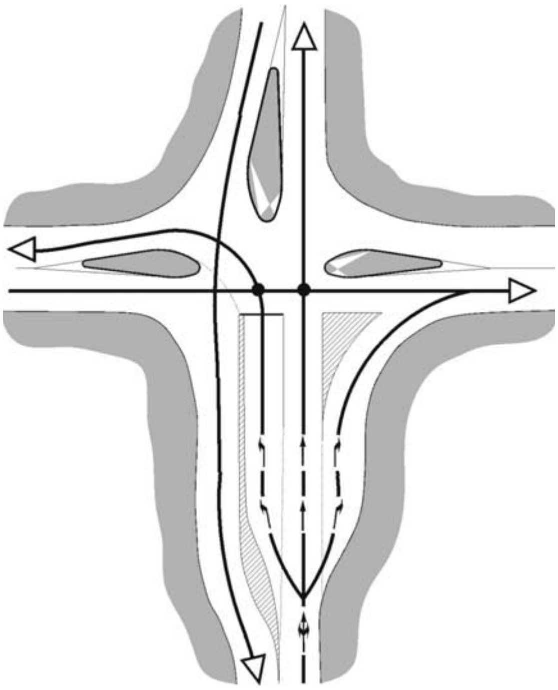


Figure 3 b.) Controlled management of left turning in a channelled four-leg intersection.

1.5.5.2 General Principles of Channelling at intersections and Points of Access

The general principles used for channelling of traffic flows at intersections and points of access at grade are as follows:

- Channelling must follow subconscious reactions of drivers in driving through intersections, however it must not be an element of restriction or illogical constraints;
- Channelling must be clear and understandable;
- Channelling must be brought in line with characteristics of intersecting roads and characteristics of traffic flows (the available area, traffic load volumes, traffic flow structure, driving speed);
- Implementation (and maintenance) costs of channelling elements must be in line with the expected user benefits.

Therefore:

- Traffic flows intersecting at the intersection should be led through it at the shortest possible route and by making their intersecting as right-angled as possible;
- Channelling elements must be arranged so that they prevent incorrect driving (Figure 4);
- Main traffic flows should be impeded during driving through an intersection only to the extent strictly necessary, and appropriate guiding lanes with sections envisaged for waiting of vehicles must be planned for side traffic flows (turning) (Figure 5);
- Speed limits at an intersection and prevention of overtaking are achieved by correct management of individual traffic lanes and by correct dimensions of individual channelling elements.
- Channelling must be made so that conflict points have sufficient distance between them thereby providing that drivers face only one decision at a time when driving through an intersection (Figure 6);
- Channelling must be made so that conflict points are as fixed as possible (that they do not change their position) and that drivers are able to exactly determine their position, correct traffic signs are of extreme importance in that respect;
- Channelling must provide protection to the driver from other traffic flows at the intersection;
- Channelling elements must be implemented so that they enable correct placement of traffic signs, guiding tables, traffic signal lights and public lighting, all aforementioned elements must be placed so that they do not impede the traffic (so that vehicles cannot damage such elements) and that they do not hinder (reduce) visibility;
- As regards intersections with bigger traffic loads (particularly in cases when they are not traffic light controlled), appropriate distancing of main traffic flows should be provided in order to gain the appropriate space for waiting of vehicles (Figure 7);
- Channelling must be adjusted to the traffic management method and the characteristics of traffic flows.

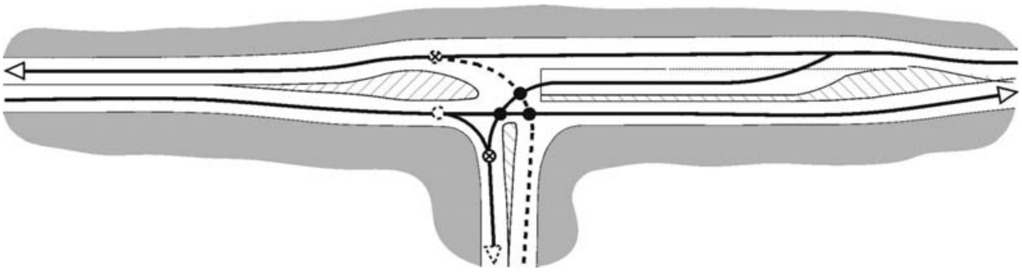


Figure 4: Directing of vehicles with channelling measures – islands.

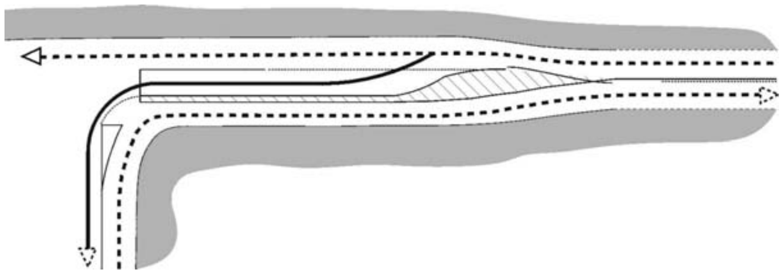


Figure 5:. Guiding lane with guiding area (or traffic island) for left turning on the MTD.

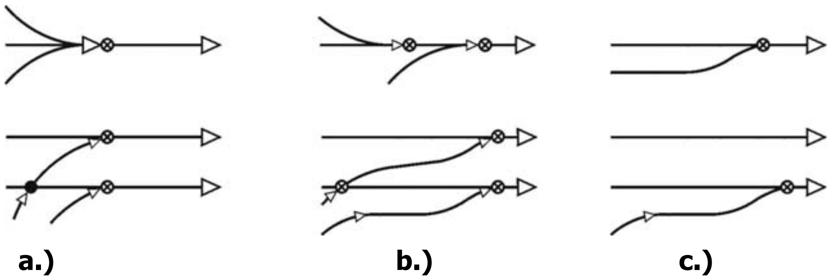


Figure 6: Distancing of conflict points: a) No distance b) Partial distance c) Sufficient distance

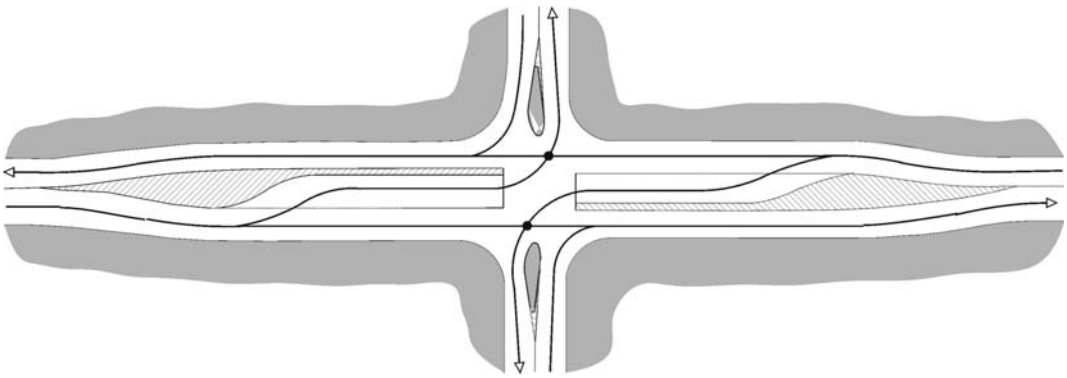


Figure 7: Distancing of main traffic flows.

1.5.6 Division of Intersections and Points of Access at Grade

1.5.6.1 Division of Intersections and Points of Access at Grade

Intersections at grade are divided as follows as regards their form (see Figure 5.20):

- (T) intersections;
- (+) intersections;
- Roundabouts.

Points of access are divided as follows:

- (T) point of access;
- (+) point of access;
- (V) point of access – bifurcation of an one-way road from the MTD.

Intersections at grade are divided as follows with regard to the number of legs:

- Intersections with three legs (three-leg);
- Intersections with four legs (four-leg);
- Intersections with multiple legs (multi-leg (five or more)).

Traffic management at a leg may be one-way or two-way.

Intersections at grade allowed on public roads and non-categorised roads used for road traffic are as follows:

- Three-leg (T) intersection and point of access;
- Four-leg (+) intersection;
- Three-leg, four-leg and multi-leg roundabout.

Intersections and points of access are as regards their location divided as follows, regardless of their form and number of legs:

- Intersections in urban areas; and
- Intersections outside urban areas.

1.5.6.2 Three-Leg (T) Intersection and Point of Access

The three-leg (T) intersection is an intersection where the STD connects to the MTD at the right angle (α = 90°±15°) and in one-way, whereby the vehicles on the MTD continue to drive straight through the intersection (Figure 8).

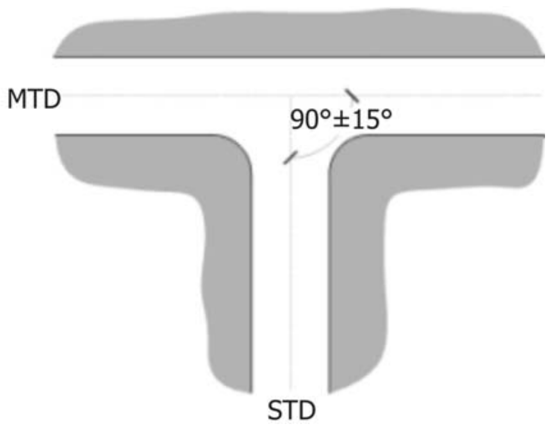


Figure 8: Three-leg (T) intersection.

In case the MTD is implemented so that vehicles at the intersection mostly turn, the route of the STD should be made so that the route of the MTD is unambiguous (Figure 9). The solution presented in Figure 9 a.) is allowed only in urban areas.

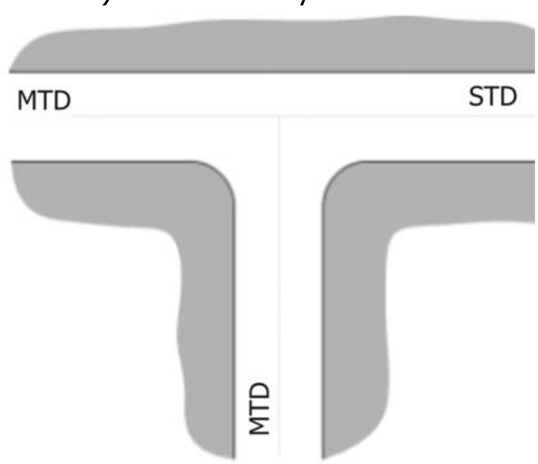


Figure 9a.) Incorrect management of the MTD in a three-leg intersection.

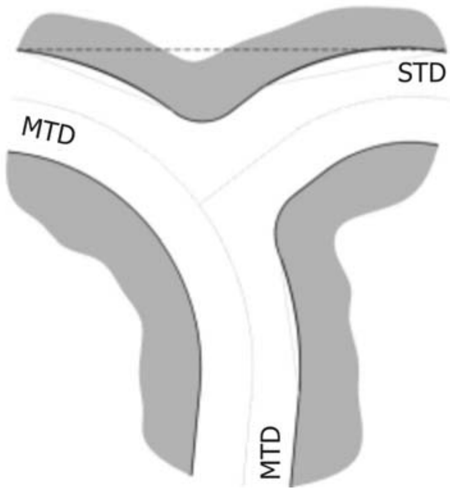


Figure 9 b.) Correct management of the MTD in a three-leg intersection.

1.5.6.3 Four-Leg (+) Intersection and Point of Access

The four-leg (+) intersection is an intersection where the STD crosses the MTD at the right angle (α = 90°±15°) and in both ways, whereby the MTD route continues straight through the intersection (Figure 10 a).

In case the MTD is directed so that the major part of vehicles turns at the intersection, and in case of a large number of right turning, it shall be reasonable to implement a right turning lane or a roundabout, and in case of a large number of left turning, to make a change in the direction of the axis of the MTD and the STD.

An intersections pair can be implemented only in urban areas when the volume of the traffic flow on the main traffic direction is less or equal to 3500 vehicles/day and the distance between axes of intersecting roads is bigger or equal to two braking distances (Figure 10.b).

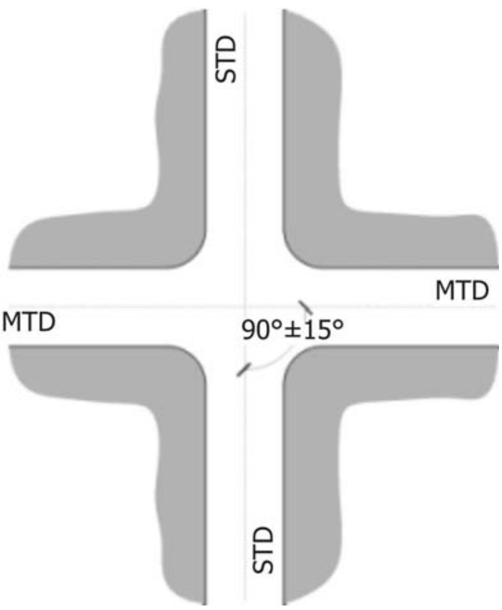


Figure 10 a.) Four-leg (+) intersection.

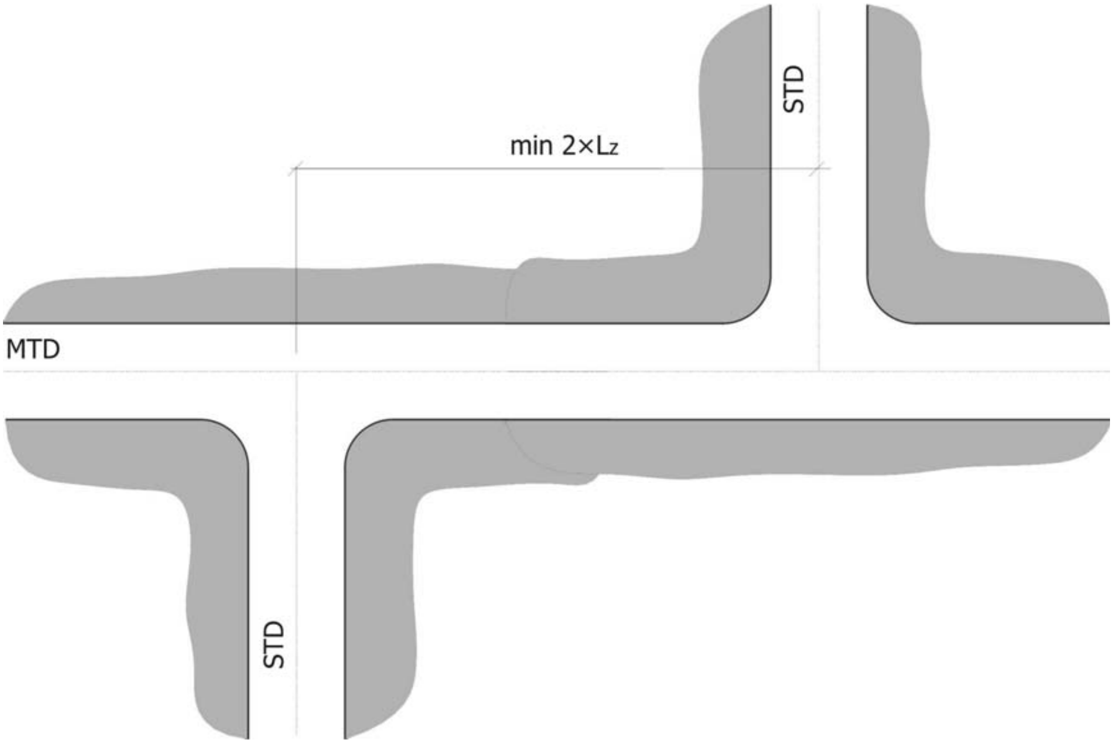


Figure 10.b.) Intersections pair.

1.5.6.4 Roundabouts

A roundabout is a channelled circular intersection with non-mountable, partly mountable or drivable central island and a circulatory roadway tying three or more legs over which the traffic streams counter clockwise.

Roundabouts are intersections with a combination of continuous and interrupted traffic flows in which the MTD is represented by the circular traffic flow and the STD by traffic flows on entries and exits from the roundabout.

Principles and conditions for designing roundabouts are discussed separately, in a special guideline.

1.5.6.5 Design of Typified Solutions for Intersections and Points of Access

Below are typified solutions for intersections and points of access with the description of suitability of their use.

POINT OF ACCESS TYPE I

Point of access of a side road to the main traffic direction is designed in accordance with the type I in cases where no special lane for left turning is required on the main road. Regardless of the used project-technical elements of the side traffic direction, it should be a two-lane road at least in the length of the point of access leg (min. 25 m) (Figure 11).

POINT OF ACCESS TYPE II

Point of access type II (Figures 5.12 and 5.13) is selected in the case the MTD requires a special lane for left turning. In such a case a guiding island in the form of a drop should be implemented on the side road and a triangular traffic island to the left of the side road. The right-turning lane is envisaged if required – by taking into account the required permeability level of the point of access at the end of the planning period.

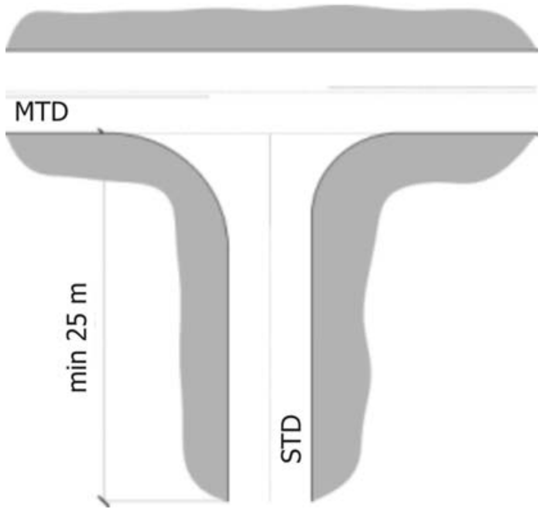


Figure 11: Point of access TYPE I without channelling measures.

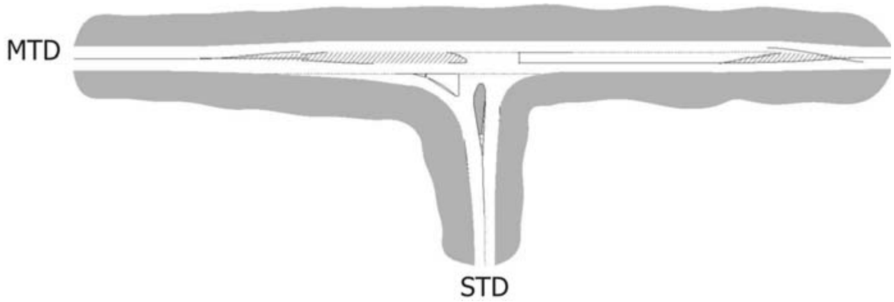


Figure 12: Point of access TYPE II (without right-turning lane).

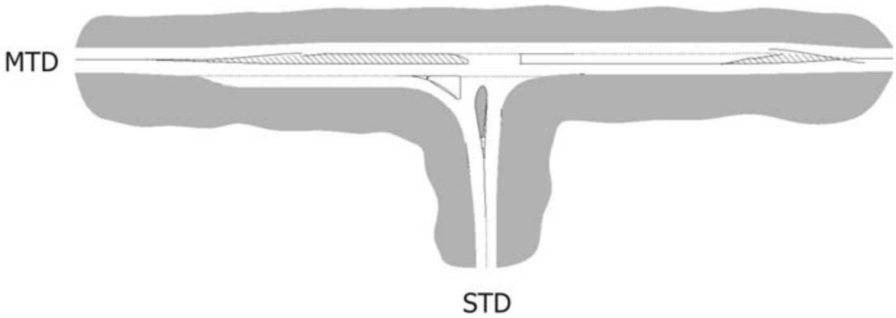


Figure 13: Point of access TYPE II (with right-turning lane).

POINT OF ACCESS TYPE III

Point of access (Figure 5.14) is designed in accordance with type III in case the roadway of the MTD consists of four or more lanes. This point of access type must be designed in accordance with the principle of time distribution of traffic flows i.e. equipped with traffic signal lights.

The MTD must have separate lanes for turning.

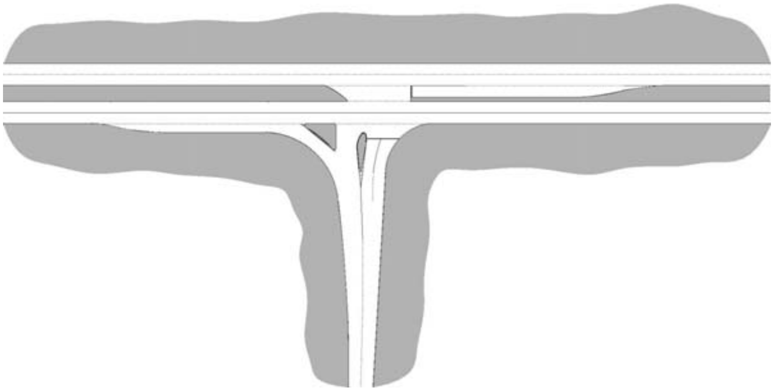


Figure 14: Point of access TYPE III

INTERSECTION TYPE I

The intersection is designed in accordance with type I in cases where no special lane for left turning is required on the main road. Channelling elements are not taken into account in the intersection designed in accordance with this type.

The only exceptions are islands in the form of a drop, located in the axes of side roads (Figure 15).

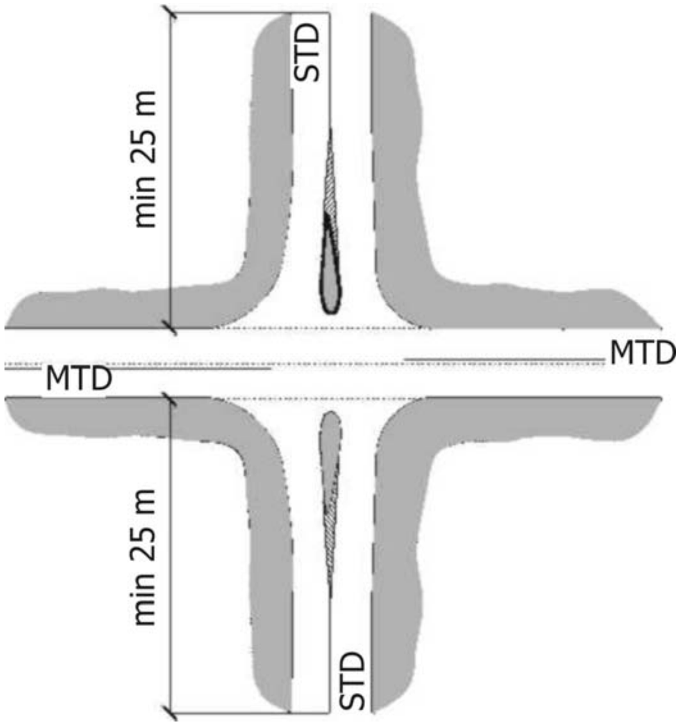


Figure 15: Intersection TYPE I with drops

In case the peak hourly traffic volumes on the side traffic direction do not exceed 20 vehicles per hour and if the width of the side traffic direction does not exceed 4.5 m, drops can be left out.

Regardless of the used project-technical elements of the side traffic directions, they should be two-lane roads at least in the length of the point of access leg (min. 25 m) (Figure 11).

INTERSECTION TYPE II

The intersection type II (Figures 16 and 17) is selected in the case the MTD requires a special lane for left turning. In such a case a guiding island in the form of a drop should be implemented on side roads and a triangular traffic island to the left of side roads.

The right-turning lane is envisaged if required i.e. by checking the permeability level of the intersection at the end of the planning period.

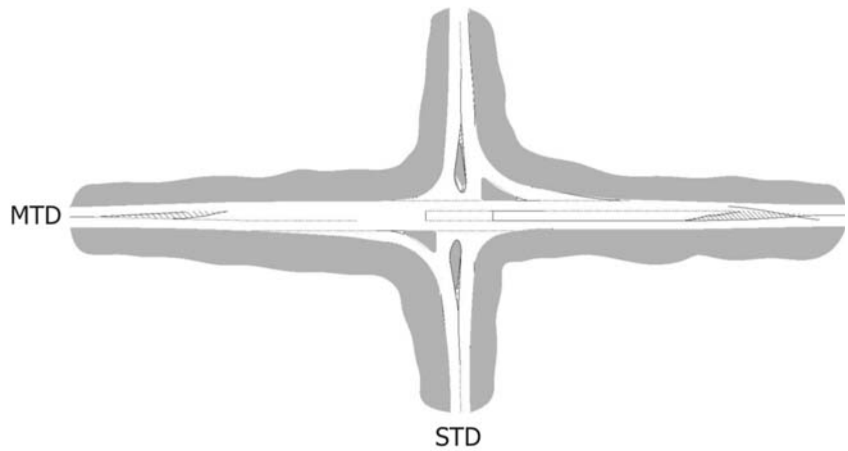


Figure 16: Intersection TYPE II (without right-turning lane).

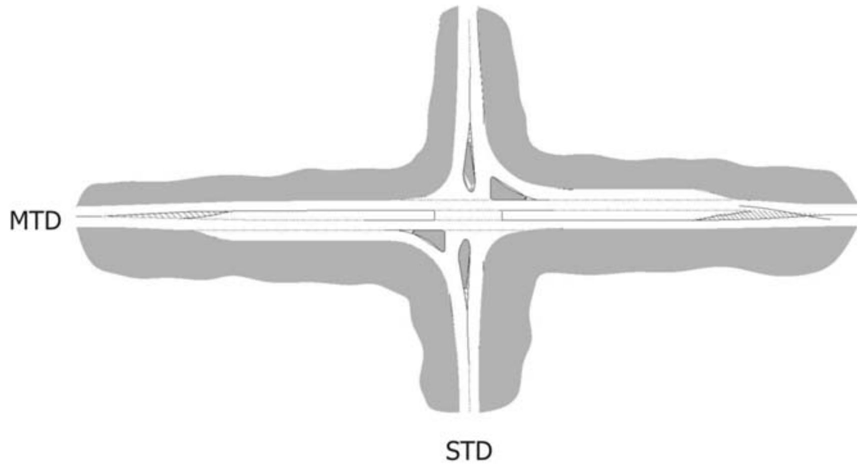


Figure 17: Intersection TYPE II (with right-turning lane).

INTERSECTION TYPE III

The intersection (Figure 18) is designed in accordance with type III in case the roadway of the MTD consists of four or more lanes. This intersection type must be designed in accordance with the principle of time distribution of traffic flows i.e. equipped with traffic signal lights. The MTD must have separate lanes for left and right turning.

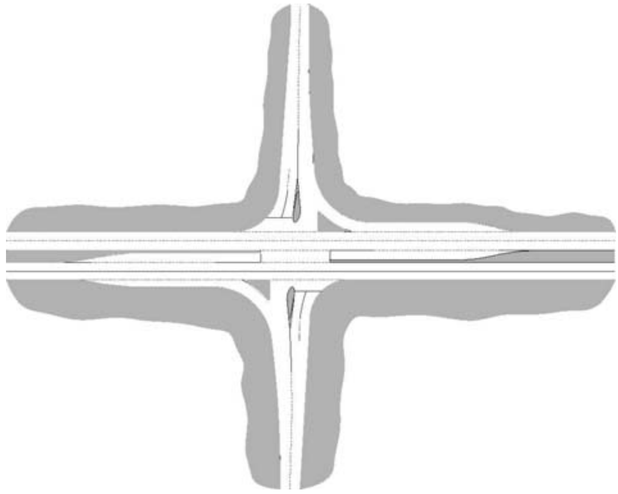


Figure 18: Intersection TYPE III

INTERSECTION TYPE IV

Intersections are designed in accordance with type IV (Figure 19) when both intersecting roads are at different levels and their traffic volumes are big.

This intersection type is also used when required by traffic safety requirements (e.g. unfavourable terrain configuration for implementation of an at grade intersection).

When traffic flows, which intersect are dominant in an intersection with big traffic load so that it is impossible to provide controlled distribution by traffic lights or it is impossible to provide appropriate length of distribution lanes for stopping of vehicles, particularly if the level of the roadway has bigger gradient, only intersection of individual traffic directions shall be envisaged.

The quadrant where the joint is located is determined by taking into account the direction of the strongest traffic flow.

Straight sections, of which the joint's route consists, have different lengths. The section of the joint connecting to the lower-lying road (better visibility) has the longer joint.

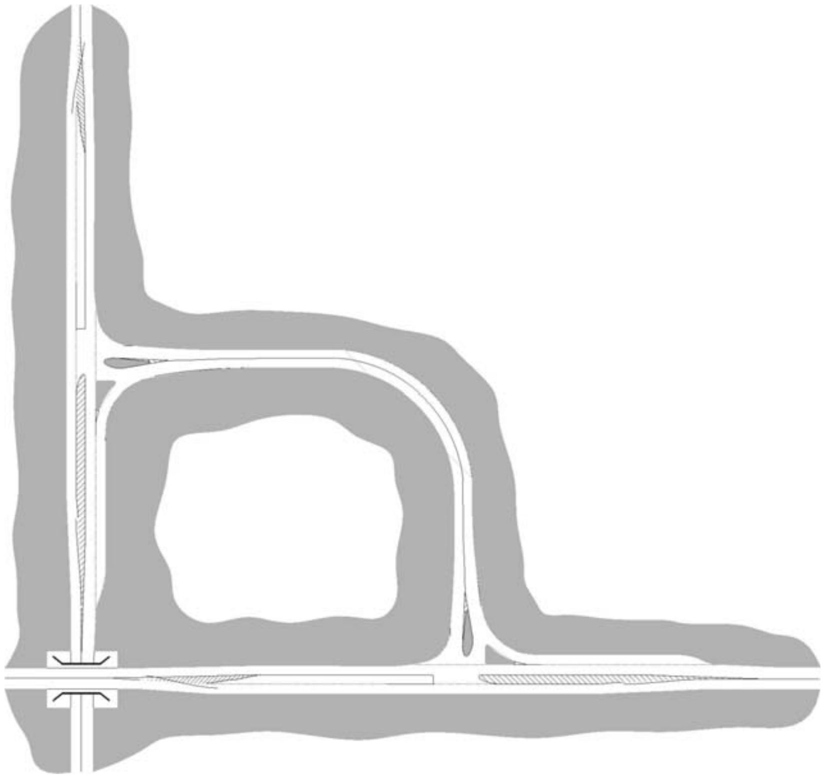


Figure 19: Intersection TYPE IV

1.1.1 Allowed Types of Intersections and Points of Access

For the purpose of perception and understanding as well as safe traffic management, it is not allowed to plan other types of intersections and points of access (Y), (X), (A), (K), (∗). Existing non-allowed types of intersections should be rearranged in reconstructions to one of the allowed intersection types as presented in Figure 20. The rearrangement provides for the right angle of crossing where the visibility field has the most correct form.

In case of the reconstruction of an existing non-allowed intersection type, the decision regarding selection of one of the allowed intersection types shall be made on the basis of required permeability of the intersection at the end of the planning period, direction of the main traffic flow, surrounding buildings, available space and traffic-safety analysis.

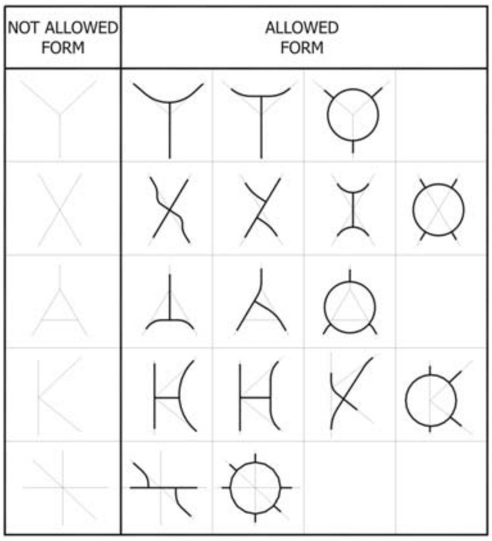


Figure 20: Rearrangement methods for existing non-allowed intersection types to be changed into allowed types.

1.6 TRAFFIC SAFETY AT INTERSECTIONS AND POINTS OF ACCESS

1.6.1 Conflicts Between Motorised Traffic Participants

The conflict in an intersection or a point of access shall be any event where the possibility for a dangerous event – traffic accident – occurs during driving in an intersection due to erroneous reaction of one or more motorised traffic participants.

A conflict may or may not result in a traffic accident. In case it does not result in a traffic accident, the event shall be known as "almost an accident".

Conflicts in intersections and points of access generally occur in previously known places called conflict points.

Conflict points shall be spots at intersections or points of access in which potentially dangerous situations can be expected due to various traffic manoeuvres.

The area limited by outer conflict points shall be called the conflict area.

Conflicts in the intersection or point of access area generally occur in points where traffic flows intersect, divide (bifurcate), combine or intertwine. Consequently, conflict points are divided into points of:

Crossing	•
Bifurcation	O
Combining	(
Intertwining	∃

The theoretical number of conflict points depends on the intersection type and the number of access legs to the intersection as well as other factors (traffic load of an intersection, measures used for channelling the intersection, number of lanes in the circular roadway of a roundabout…).

The intersection or point of access area limited by outer conflict points shall be called the conflict area.

In theory, a four-leg intersection of two two-way roads has 32 conflict points (16 crossings, 8 bifurcations and 8 combinations), while a single-lane roundabout has only 8 lower-level points (4 bifurcations and 4 combinations) (Figure 21).

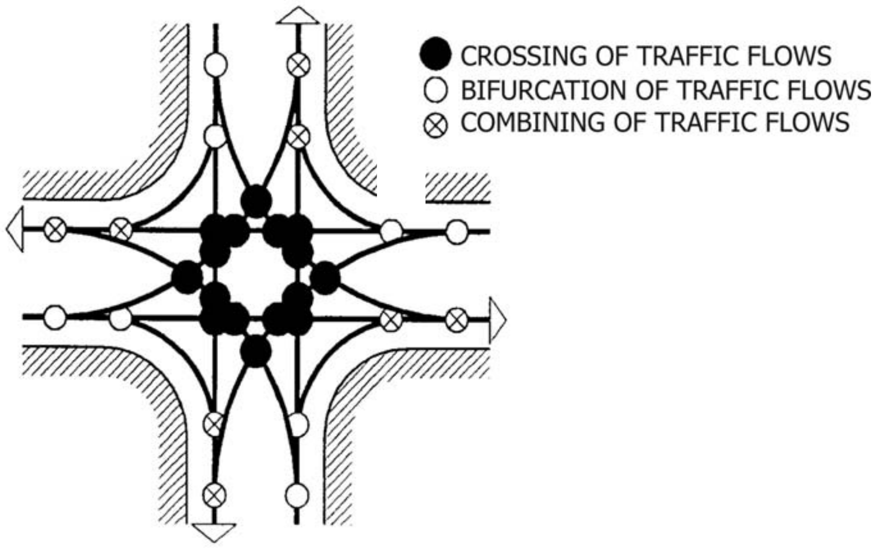


Figure 21: Conflict points in a four-leg intersection.

The level of traffic safety at intersections and points of access can be improved by reducing the number of conflict points and the size of the conflict area, namely by doing the following:

- Elimination of individual legs of an intersection (change from (+) to (T);
- Introducing one-way roads;
- Prohibition of turning and/or turning round in an intersection;
- Channelling of intersections;
- Changing the intersection type (see Chapter 1.4.6.6).

The eligibility of the planned measures for improving traffic safety should be checked by an assessment of traffic adequacy of adjacent intersections or points of access.

1.6.2 Conflicts Between Motorised and Non-Motorised Traffic Participants

Conflicts between motorised traffic participants and pedestrians and/or cyclists shall occur on points of crossing of these flows and bifurcation and combining of previously joint traffic flow, if the same traffic areas are used.

Crossing conflicts occur on spots where the flows of motorised and non-motorised traffic participants intersect (e.g. pedestrian and/or cyclist crossings).

Bifurcation conflicts occur on spots where the flow of non-motorised traffic participants bifurcates from the joint flow of motorised and non-motorised traffic participants (e.g. start of a cyclist way).

Combining conflicts occur on spots where the separate flow of non-motorised traffic participants combines with the flow of motorised traffic participants (e.g. the end of a cyclist way).

The aforementioned conflict points between motorised and non-motorised traffic participants are virtually impossible to eliminate (except for off-grade alignment) and therefore the design of such points should be given a great deal of attention.

1.7 PROJECT-TECHNICAL ELEMENTS OF INTERSECTIONS AND POINTS OF ACCESS

1.7.1 General

The project-technical elements of intersections and points of access shall be elements by which or in accordance to requirements of which intersections and points of access are designed.

They include all design elements of an intersection or a point of access providing safe, comfortable and economical driving in an intersection or a point of access.

1.7.2 Project Elements

1.7.2.1 Elements of the Horizontal Route of Roads in the Intersection and Point of Access Area

Horizontal elements of roads in the intersection and point of access area

Visibility is of crucial importance in the direct intersection area. It is ensured by selection of appropriate elements of the horizontal route of axes of the intersecting roads.

Appropriate elements are straight and circular curves of adequate radius. The adequate size of the radius stems from the speed limit in the intersection.

The following should be taken into account with regard to the alignment of routes of the intersecting roads:

- Axes of intersecting roads or points of access should be made as close as possible to the right angle ($90^o \pm 15^o$);
- Axes of intersecting roads should be straight on the ending parts just before the crossing itself;
- In exceptional cases, when the intersection is located in a curve, the intersection's centre should be placed at the turning point of curves;
- It shall be ideal if axes of intersecting roads are straight in the direct area of the crossing;
- As regards points of access, the combination where one of the axes is straight and the other in a circular curve is also possible. In such a case, the point of access should be located on the outer side of the curve. Access on the inner side of the curve shall thus be prohibited (Figure 22) or allowed only in case the visibility condition has been met. Equally applies to intersections. In case the aforementioned condition cannot be met, another location should be selected for the intersection or the intersection should be reconstructed into one of the allowed intersection types (see Figure 20).

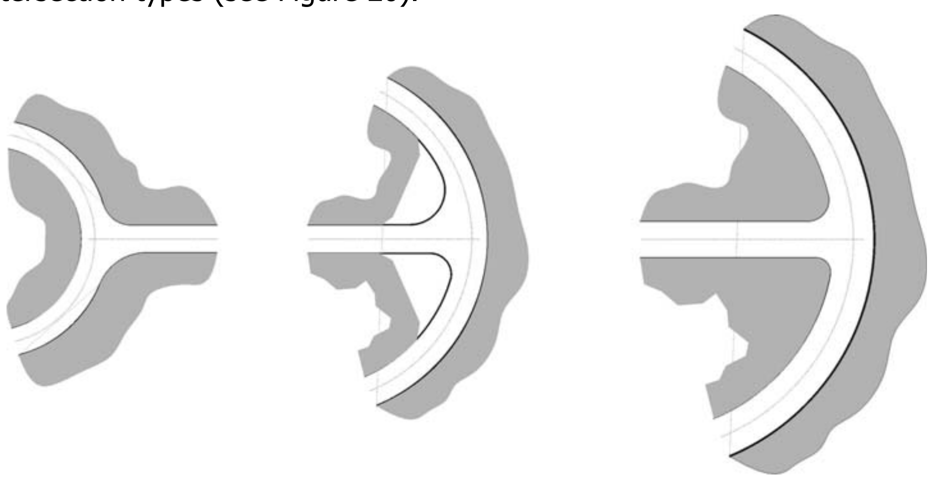


Figure 22: Appropriate, partly appropriate and inappropriate access in a curve.

Turning arcs in intersections and points of access at grade

Turning arcs in intersections and points of access at grade must consist of three arcs (basket-like curve) the ratios of which equal R1 : R2 : R3 = 2 : 1 : 3.

R_2 shall be the minimum value of the turning radius, required by construction characteristics of vehicles, which differ with regard to the vehicle type.

Minimum values of turning arcs for different vehicle types are presented in Table 4.

Table 4: Minimum values of turning arcs for different vehicle types.

Vehicle type	Turning arcs radii R_2 [m]		
	Left turning	Right turning	
		With splitter islands	Without splitter islands
Car	6	10	6
Lorries and buses	10	12	10
Saddle tractors and lorries with trailers	12	15	12
Bending buses	15	25	15

The basket-like curve for forming entries and exits from the intersection is not used in roundabouts. The size of entry and exit radii depends on the size of the roundabout, the number of lanes in the circular flow and the form of the splitter island. A more detailed description of entries and exits to/from roundabouts is included in the special guideline *Roundabouts*.

Regardless of the fact whether a roundabout or some other type of an at grade intersection is being designed, the adequacy of used turning arcs and covered areas should be checked with templates or appropriate software tools, for the appropriate vehicle types and for all directions of driving and the performed checking should be graphically documented. The aforementioned graphic checking is a constituent part of the project documentation.

1.7.2.2 Vertical Route Elements

Longitudinal and cross falls of the intersecting roads

The maximum longitudinal fall of the level of the MTD in the intersection area should not exceed $s_{max} \leq 4\%$. In case $s_{max} > 4\%$, in the direct intersecting area, it should be reduced to 4% in the intersecting area (Figure 23).

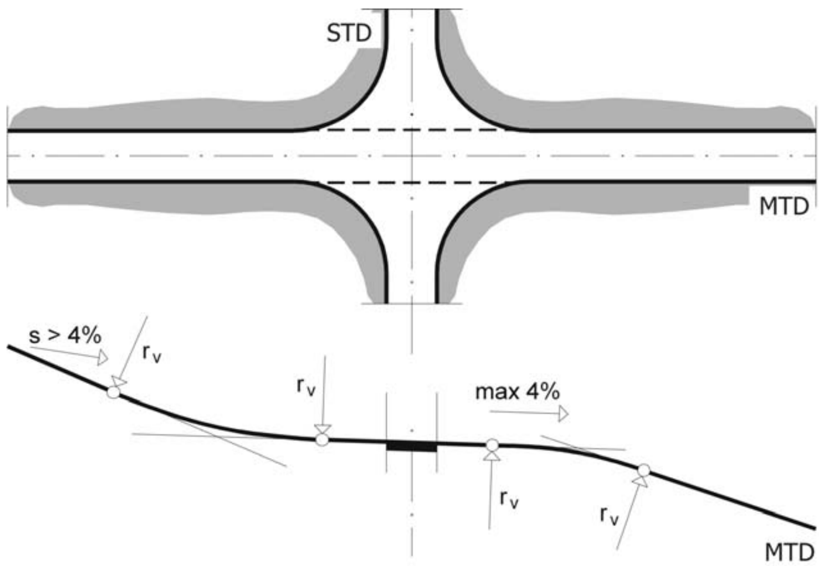


Figure 23: Route of the MTD level in the direct intersecting area.

The ideal situation would be if the longitudinal fall of one intersecting road equalled the cross fall of the other intersecting road or the point of access.

The cross fall of the MTD's roadway is relevant for determining the vertical route of the MTD. The area of vertical break of the level resulting from the longitudinal fall of the MTD, should be adjusted to the cross fall of the MTD's roadway. It should not exceed 2.5% in the direct intersecting area, if the MTD' route is straight. If the MTD's route is curved, it should not exceed 4%, which also equals the maximum fall of the MTD in the direct intersecting area.

A bend may be implemented in other cases (Figure 24), however three conditions must be met in such cases:

- The longitudinal fall of the side traffic direction should equal $s_{STD} \leq 2,5\%$;
- The vertical curvature radius should equal $r_V \geq 500$;
- The sum of the cross fall of the MTD and the longitudinal fall of the STD should equal$q_{MTD} + s_{STD} \leq 5\%$.

In multi-lane intersections, the cross fall may be less than q_{min} however not less than $q_{min} = 1.0\%$.

As regards roundabouts, the condition specifying that the longitudinal cross of access roads levels must equal the cross fall of the roundabout's roadway should be met, at least in the direct area of access.

The radius of vertical curvature on the MTD is generally selected so that $r_v \geq r_{v\ min}$ and that the vertical curvature does not enter the area of the roadway of the side traffic direction or the area of the roundabout.

The minimum longitudinal fall of roads in the direct intersecting area is conditioned by the planned drainage facilities. The minimum longitudinal fall in the direct intersecting area should not be less than 0.5%.

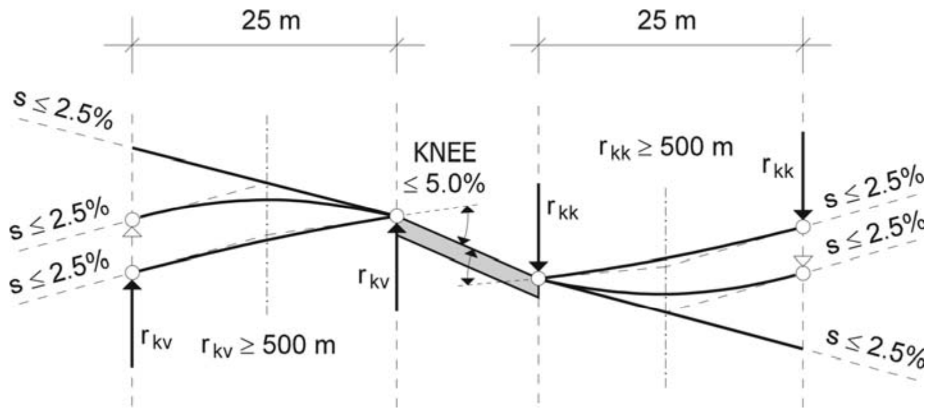


Figure 24: Implementation of a bend on the STD in the direct intersecting area.

In exceptional cases of completely horizontal levels of the intersecting roads, special measures for drainage of the roadway should be envisaged.

The longitudinal fall across the roadway's edge in the intersection is a constituent part of the project documentation for every reconstruction or new construction of an intersection.

Vertical curvatures

Curvatures of breaks of the level in intersections are implemented in the same way as on sections of open road:

$$r_{min} = 0,25 \cdot P_Z^2 \qquad [m]$$

where P_Z is in the function of speed on intersecting roads and represent the stopping visibility.

Vertical alignment

The general principles for designing of vertical alignment of routes of intersecting roads are as follows:

- Straight lines, as elements of the longitudinal route of the intersecting roads, are appropriate elements for the location of an intersection or a point of access;
- Concave vertical curvatures on the intersecting roads are appropriate elements for the location of an intersection or a point of access;
- Concave vertical curvature on the MTD in combination with a straight line on the STD are less appropriate elements for the location of an intersection or a point of access;
- Convex curvatures, as elements of the longitudinal route of the intersecting roads, are inappropriate elements for the location of an intersection or a point of access and should be avoided;
- Convex vertical curvature on the MTD in combination with a straight line on the STD are inappropriate elements for the location of an intersection or a point of access and should be avoided;
- Too big longitudinal falls in the direct intersecting area should be avoided as they may result in longer times required for driving off of vehicles, negative cross falls of turning lanes, the danger of sliding of vehicles in smaller roughness of the roadway and stronger inflow of water to the intersection through the roadway;
- In case the MTD has a two-sided cross fall, it should be reduced to 1.5% in the direct intersecting area;
- The curvature of the level break shall be made by such radius r_v that in the area of 25 m from the edge of the MTD's roadway the longitudinal fall of the STD does not exceed 2.5%.

1.7.2.3 Cross Section Elements of the Road in an Intersection

The cross section elements of the intersecting roads are in the area of intersections and points of access at grade in principle equal to the elements outside the intersection area, their dimensions depend on speed limits in the intersection and any special requirements for driving in the intersection area.

The cross section elements of the road in an intersection are discussed in greater detail in the technical guideline *Cross Section Elements of Roads*.

1.7.2.4 Traffic Lanes

Guiding traffic lanes

The width of guiding lanes is determined in the same way as on sections of open road outside the intersection area by taking into account that the widths of such lanes shall be increased in case lanes are implemented along another guiding lane or traffic island or in the area of turning arcs.

Widths of individual types of traffic lanes in intersections at grade (Figure 25) are given in Table 5.

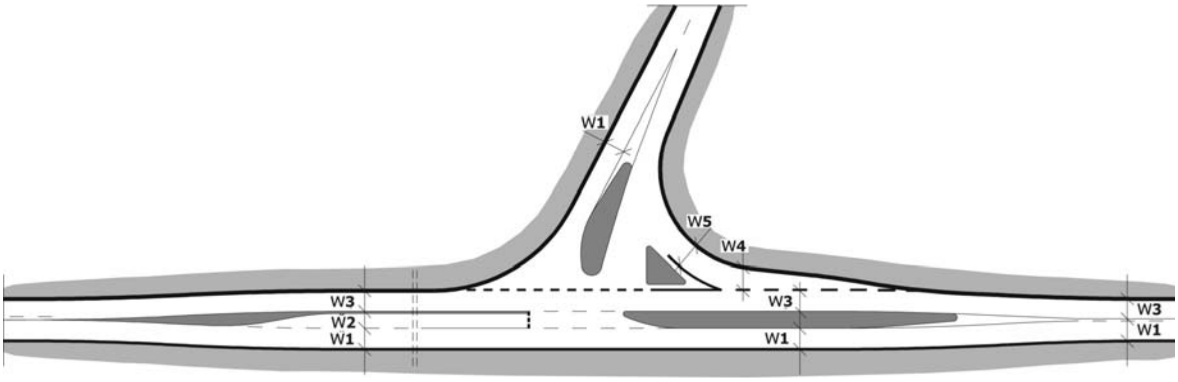


Figure 25: Types of traffic lanes in intersections.

Table 5: Widths of individual types of traffic lanes.

Traffic lane type	Width of a traffic lane	
	Recommended [m]	Minimum [m]
W_1 [m]	Equal to the width outside the intersection area	2.75 (2.5)
W_2 [m]	Depends on W_1 ($W_2 = W_1$)	$W_2 = W_1 - 0.25$; $W_{2\ min} = 2.5$
W_3 [m]	Equal to the width outside the intersection area	2.75 (2.5)
W_4 [m]	Depends on the relevant vehicle	-
W_5 [m]	5.5	4.5

Note: Values in brackets can only be used in exceptional cases for which sufficient grounds should be given.

The widths of entry, exit and circular lanes in roundabouts depend on the radius of the roundabout and are given in the special guideline *Roundabouts*.

Left turning lanes

Left turning lanes are guiding traffic lanes intended for vehicles turning left at the intersection. They start before the intersection and end after it so that in the area of direct intersecting with other lanes they keep only a broken left guiding line as specified in the Rules on Traffic Signs on Public Roads (Official Gazette of the SFRY nos. 48/81, 59/81, 17/85).

In case the intersection lacks sufficient space for implementing separate lanes for left and right turning, the implementation of a left turning lane shall have the priority.

A left turning lane (Figure 26) consists of three sections:

- l_A Length of the waiting section [m];
- l_Z Length of the braking section [m];
- l_{SP} Length of the section for changing traffic lanes [m];
- $l_{\check{s}'}$ Length of displacement [m];
- $l_{\check{s}}$ Length of the section where widening is implemented [m].

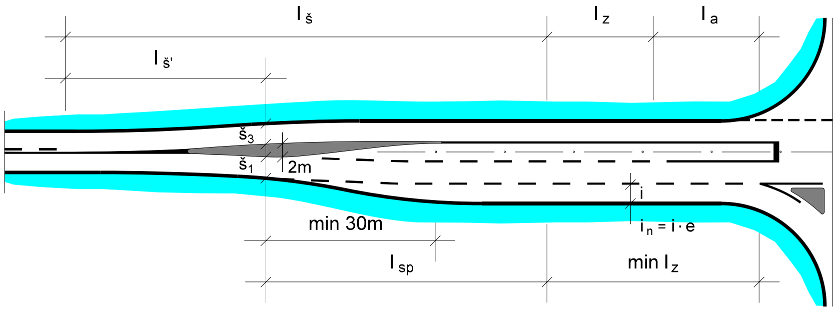


Figure 26: Turning lanes elements

The braking section l_Z is intended for braking of vehicles from the speed V_Z to a compete halt ($V_K = 0$). The braking section begins in the last point of the section for changing of lanes and ends in the first point of the waiting section.

The length of the braking section is calculated by using the following formula:

$$l_Z = \frac{v_Z^2 - v_K^2}{2 \cdot g \cdot \left(f_{TD} \pm \frac{s}{100} \right)} \qquad [m]$$

where:

v_Z Design speed in the intersection area [m/s];
v_K Final speed at the end of the turning lane [m/s];
s Longitudinal fall of the side traffic direction [°%];
f_{TD} Allowed tangential element of the adhesion ratio between tyres and the roadway (f_{TD} = 80% f_{TM}) [-].

The length of the braking section depends on speed at the intersection, longitudinal fall of the section and volume of the traffic flow from which left turning is made (Table 6).

The section for changing traffic lanes l_{SP} is intended for the traffic operation of changing traffic lanes i.e. transit of vehicles from the driving traffic lane straight to the left turning lane.

The lengths of these sections are determined by taking into account the minimum radius for turning from one traffic lane to another and by taking into account the maximum value of the lateral acceleration a_r.

Widths of sections for changing lanes in relation to speed in the intersection area are presented in Table 7.

Table 6: Width of the braking section (l_Z)

Traffic volume from which left turning is made (vehicles/h)	Longitudinal fall s [%] and speed at the intersection V_k [km/h]											
	$s \leq -4\%$				$-4\% < s < 4\%$				$s \geq 4\%$			
	40	50	60	70	40	50	60	70	40	50	60	70
< 400	0	0	10	20	0	0	10	15	0	0	5	10
> 400	0	0	25	40	0	0	20	30	0	0	15	20

Table 7: Width of the section for changing lanes (rounded values).

V_K [km/h]	40	50	60	70
l_{SP} [m]	25	30	35	40

Widening of the roadway required for adding the left turning lane shall be made at the length $l_š$. The easiest method for calculating the length $l_š$ is when the leg of the intersection or a point of access to which the guiding traffic lane is added, is straight:

$$l_š = V_K \cdot \sqrt{\frac{i}{3}} \qquad [m]$$

where:

$l_š$ The length where widening is being performed [m];
V_K Calculative sped at the intersection [km/h];
i Size of the widening [m]; in case the widening is one-sided, I = w_2 (width of the left turning lane), if widening is on both sides, I = $w_2/2$, in case a separation lane is on the edge of the turning traffic lane, its width is added to the width (i).

In case the leg to which the left turning lane is added, passes in the curve of the radius R, the length $l_{š}$ shall be calculated by using the following formula:

$$l_{š} = V_K \cdot i \cdot e \qquad [m]$$

where:

$l_{š}$ The length where widening is being performed [m],

V_K Calculative sped at the intersection [km/h];

i Size of the widening [m];

e The factor depending on the element type of the route of the leg and position (side) of the widening [-], values of the factor e are given in Table 8.

Table 8: Values of the factor e.

Element of the route	e in widening	
	On the inner side	On the outer side
Arc	2.6	3.0
Clothoid	3.0	5.0

The roadway in the straight line is in principle widened on both sides, while in curving it is widened along the outer edge. Intermediary coordinates i_n of the widening in the intermediate point n, which is by l_n distanced from the beginning of the widening of the length $l_{š}$ are obtained by using data for e_n, given in Table 9 (Figure 27).

Widening i_n is calculated by using the following formula:

$$i_n = e_n \cdot i \qquad [m]$$

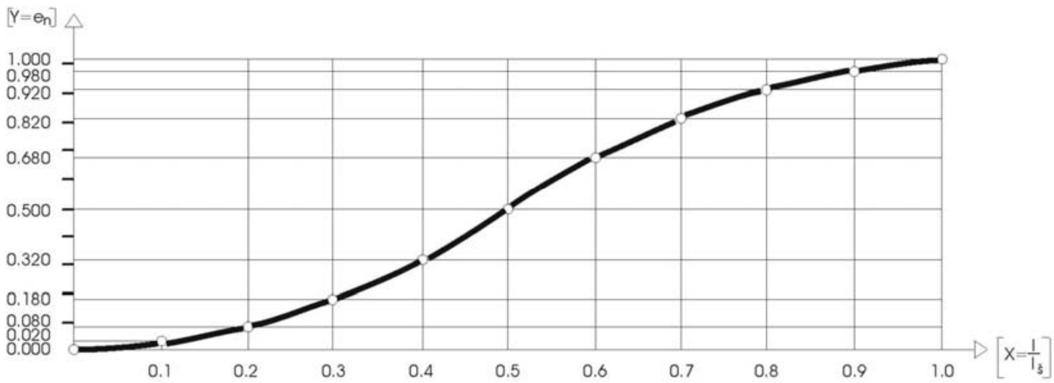


Figure 27: Widening in intermediate point.

Table 9: Values in intermediate points of widening.

$\frac{l_n}{l_{š}}$	e_n	$\frac{l_n}{l_{š}}$	e_n	$\frac{l_n}{l_{š}}$	e_n
0.00	0.0000	0.35	0.2450	0.70	0.8200
0.05	0.0050	0.40	0.3200	0.75	0.8750
0.10	0.0200	0.45	0.4050	0.80	0.9200
0.15	0.0450	0.50	0.5000	0.85	0.9550
0.20	0.0800	0.55	0.5950	0.90	0.9800
0.25	0.1250	0.60	0.6800	0.95	0.9950
0.30	0.1800	0.65	0.7575	1.00	1.0000

In order not to exceed the value of the minimum radius R_{min}, applicable for the assumed calculative speed, in widening of the roadway on the inner side of the curve of radius R, the following conditions must be met:

$$\frac{1}{R_{min}} > \frac{1}{R} + \frac{4 \cdot i}{l_{š}^{2}}$$

If the above condition is not met, the length on which the roadway is being widened must be increased accordingly. An even better solution in such a case would be to form the edge of the widened roadway as a basket-like curve with adequately long transition.

The section for waiting of vehicles l_A is intended for waiting of vehicles for the time gap between vehicles coming from the opposite direction, which drive straight through the intersection.

Length of the waiting section should equal at least 20 m and not more than 40 m, which depends on the turning traffic flow volume and structure.

Right turning lanes

Right turning lanes are intended for vehicles turning right at the intersection.

Splitter islands and pedestrian refuges appear in the placement of such lanes in elements of the cross section of the road in an intersection.

The right turning lane consists of the section for changing traffic lanes, braking section and turning section. The section for changing traffic lanes is designed in the same way as for left turning lanes.

The braking section is designed in the same way as for left turning lanes, whereby its length is determined by values of the starting and final speed. In case a pedestrian crossing is located at the braking section, the final speed shall equal zero. In case when after the turning section, vehicles have a separate traffic lane also on the exit from the intersection and when no pedestrian crossing is located on the turning section, the final speed shall equal more than zero.

A right turning lane may also have a more modest form. In such a case the construction procedure is slightly different (Figures 28 and 29).

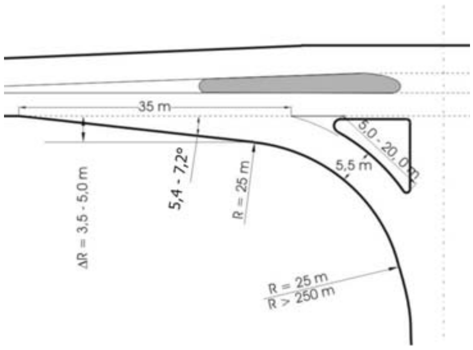


Figure 28: Construction of a right turning lane in intersections outside urban areas.

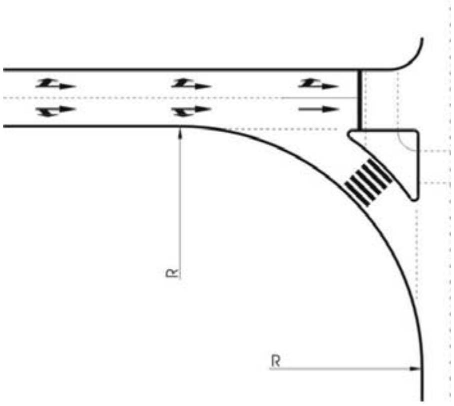


Figure 29: Construction of a right turning lane in intersections inside urban areas.

Implementation of a right turning lane for the purpose of braking and acceleration of vehicles before/after a petrol station shall be obligatory in cases when the road is classified as major or regional, with the exception of tourist roads.

Regardless of the fact whether a roundabout or some other type of an at grade intersection is being designed, the adequacy of used turning lanes widths and covered areas should be checked with templates or appropriate software tools, for the appropriate vehicle types and for all directions and the performed checking should be graphically documented.

Covered areas should not be outside the edge of the roadway.

The documented graphic checking is a constituent part of the project documentation.

Border lanes

Border lanes at intersections are also implemented along outer edges of the roadway.

The width of the border lane along the traffic lane in the intersection area equals the width of the border lane on the road section outside the intersection area and depends on the width of the traffic lane at the intersection.

The border lane shall also be implemented along splitter islands in the intersection area in case such islands are delevelled.

Widths of border lanes are given in a special guideline.

1.7.2.5 Traffic Islands at Intersections

Traffic islands are areas of the intersection not intended for traffic of motorised traffic participants.

They are implemented as delevelled areas or areas marked only by road signs (blocking areas).

The purpose of traffic islands is separation of motorised and non-motorised traffic participants or separation of individual directional flows of motorised traffic participants.

The following traffic islands may appear at intersections:

(a) Islands for motorised traffic participants:

- Directional islands
- Splitter traffic islands

b) Pedestrian refuges and cyclist crossings

Directional islands

Directional islands are the main element for channelling traffic flows of motorised traffic participants.

There are two possible forms of islands (triangle (Figure 30) or drop), which may be implemented as delevelled or marked by road signs.

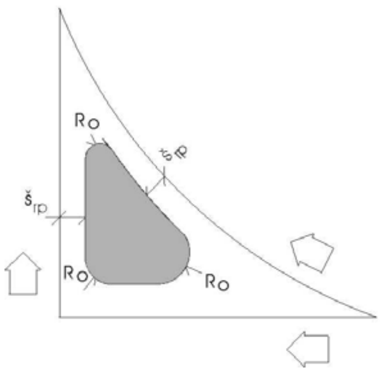
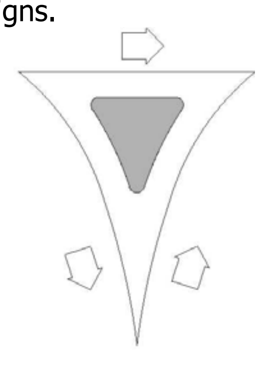


Figure 30a.) Triangular directional island.



30 b.) Triangular directional island.

A triangular directional island is designed by drawing parallel lines to construction lines and then shifting them from constructional lines for the width of the border lane. Thus obtained lines represent the outline of a delevelled island, the breaks and intersecting points of which must be rounded with arcs of an appropriate radius (Ro). The size of the rounding radius depends on the angle of crossing of lines, however in no circumstances can the rounding radius be less than 0.5 m.

In general, drops are divided into those used at intersections where no special left turning lanes exist on the MTD and drops used at intersections which have separate left turning lanes on the MTD.

Regardless of the fact whether the intersection has a left turning lane on the MTD, the covered areas of appropriate vehicle types in left turning may touch (Figure 7.10b) or may be distanced from one another (Figure 7.10c) (in left turning from the STD to the MTD b_{min} = 6.0 m, in left turning from the MTD to the STD b_{min} = 8.0 for $R_2 \geq 15$ m, and b_{min} = 10.0 m for $R_2 < 15$ m).

Only on roads and points of access with smaller traffic loads ($AADT_{MTD} \leq 1500$ vehicles/day and $AADT_{STD} \leq 500$ vehicles/day) can the covered area of appropriate vehicle types turning from the MTD to the STD, cover the traffic area intended for left turning from the STD to the MTD (Figure 7.10a). Equally applies to the covered area of the appropriate vehicle type turning right from the STD to the MTD.

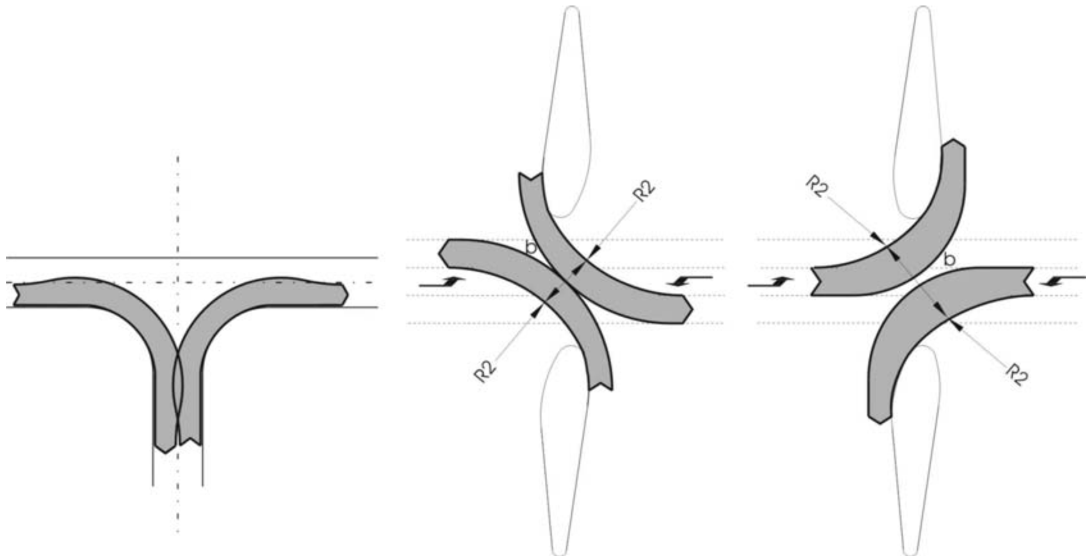


Figure 31: Covered areas of appropriate vehicle types in left/right turning.

Construction procedures differ also with regard to the crossing angle α. Below we present only constructions of a drop for the allowed crossing angle. In case the crossing angle is bigger or smaller than is allowed, the first thing to do is to redesign the axis of the STD so that it shall be right-angled to the MTD, where the used rounding radius $R \geq 50$ m. In order to achieve that drops are facing each other in four-leg intersections, the axes must be shifted for the width of the drop.

In case the MTD has no special left turning lanes and the crossing angle α is between 75° and 105°, construction of the drop shall be as follows (Figure 32):

1. Determine the axis of the side traffic direction.
2. On the axis of the STD determine a point in the distance equalling 10 m from the edge of the MTD.
3. Draw the axis of the drop through the point (2), inclined by 5.4° to the left.
4. Two auxiliary lines are drawn to the left and right from the axis of the drop in the distance equalling 1.5 m from the axis.

5. Construct arcs with radius R = 12 m, which tangent the auxiliary lines (4) and touch the edge of the traffic lane on which left turning from the STD is made and the inner edge of the left turning traffic lane on the MTD.
6. At the intersecting point of arcs (5), design the drop's head with the arc R_1=0.75 m.
7. On the axis of the drop determine a point in the distance equalling 20 m from the edge of the MTD. Draw tangents from that point to the arcs (5).
8. In the point where between tangents (7) the right-angled distance to the axis of the drop equals 1.5 m, form the opposite head of the drop with the radius R_2=0.75 m.
9. Blocking area is determined by a line between the axis of the STD and the right edge of the drop.

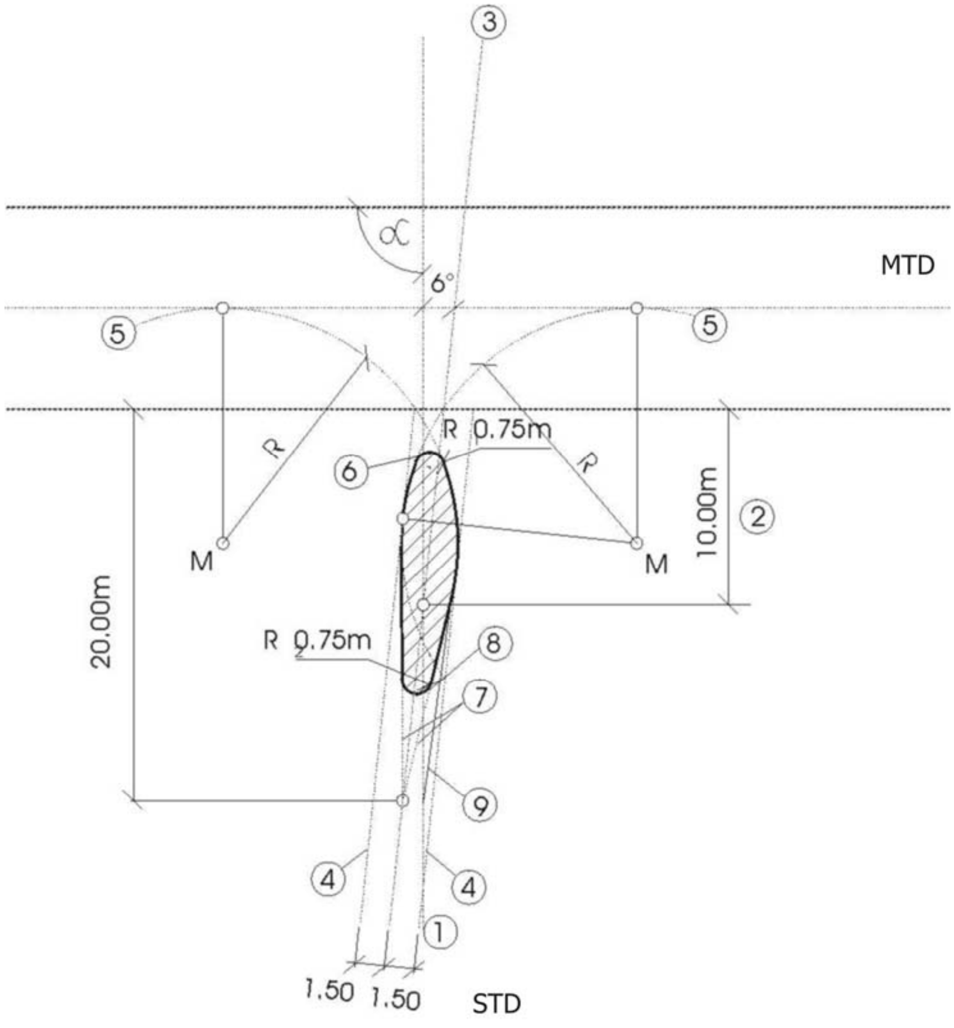


Figure 32: Construction of a directional island in the form of a drop in case no special left turning lanes exists on the MTD.

Construction procedure for a directional island in the form of a drop in case special left turning lanes exist on the MTD (Figure 33) and the angle α is between 75° and 105°.

1. Determine the intersecting point of the point of access (axis of the STD) – axis of the drop – with the edge of the outermost traffic lane of the crossing road (the MTD), Figure 15.
2. Draw a parallel line to the axis of the drop in the distance of Δw, the value of which is read from the chart A.
3. Draw arc with radius R (its size – (R) – is read from the chart B), which tangents the parallel line (2) to the axis of the drop and tangents the edge of the traffic

line to which left turning from the point of access – the STD – is made.

4. Draw from the same centre as the arc with radius R (3) also an auxiliary arc with the radius 2 m bigger than the radius R.
5. Mark the point "P" on the joining line of centres of both auxiliary arcs with the intersecting point of the other auxiliary arc (4) with the edge of the outermost traffic lane on the MTD.
6. Draw an arc with radius R, which goes through the point P and tangents the inner edge of the left turning lane on the MTD. This arc already limits a part of the area of the drop.
7. Construct head of the drop with the arc of R_1=1.5 m. Make sure that the head of the drop is more than 2 m and less than 5 m away from the edge of the outermost traffic lane on the MTD.
8. Draw tangents from the point Z to both auxiliary arcs with the radius R.
9. Determine on tangents (8) the points "I" and "S", the distance between them measured right-angled on the axis of the drop shall be 2.9 m.
10. Measure 1 m to the left of the point "I" thus getting the point "I'".
11. Draw a new tangent from the point "I'" to the arc 3.
12. The opposite head of the drop is rounded with an arc with radius R_2 = 0.75 m or 0.5 m.

The surface between the drop and both tangents 8 is marked as the traffic guiding area (blocking surface or field in front of an island for splitting traffic flows) as specified in the Rules on Traffic Signs on Public Roads (Official Gazette of the SFRY nos. 48/81, 59/81, 17/85).

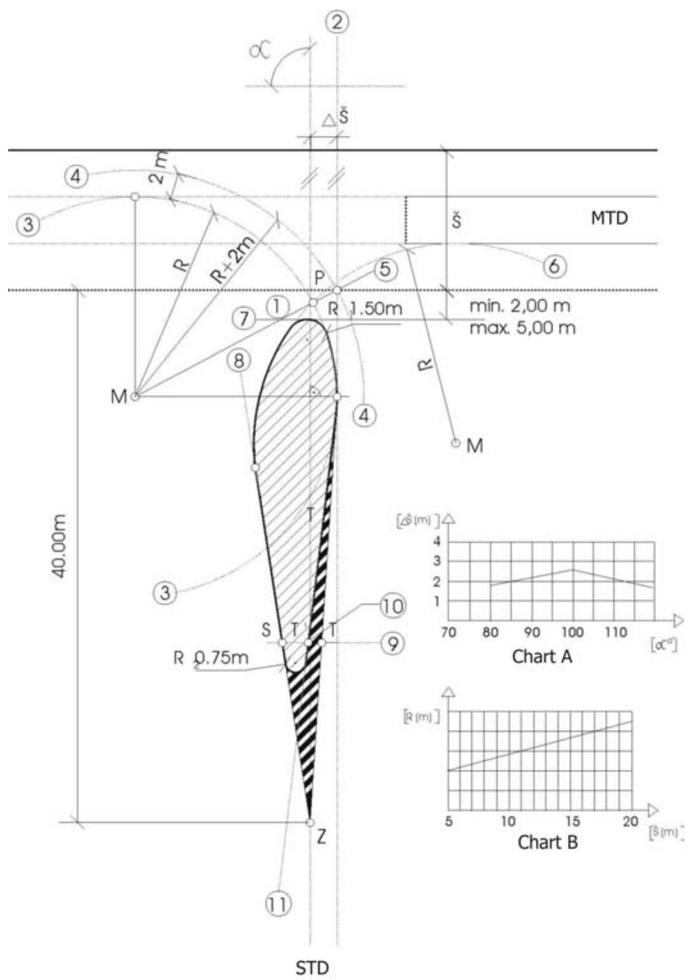


Figure 33: Construction of a directional island in the form of a drop in case special left turning lanes exist on the MTD.

In addition to construction principles for designing typified drop-like islands for guiding traffic flows, the following principles should also be taken into account in their use:

- Simultaneous left turning must be provided in intersections with a drop. For that purpose, a minimum distance of 8 m must be provided between the inner guiding (turning) arcs pointing the way for left turning of vehicles driving from the main road to the side road.
- Equally, the distance between turning arcs pointing the way to left turning vehicles driving from the side road (STD) to the main road (MTD) must equal at least 5.0 m if the intersection is not traffic light controlled and at least 7.5 m if the intersection is traffic light controlled.
- In traffic light controlled intersections, two traffic lanes on the right side of the drop are envisaged also on the side road (STD): a traffic lane intended for vehicles driving straight or turning right and a traffic lane for left turning. In such intersections, the axis of one of STD roads must be shifted to the right by approximately 3 m so that the left turning lane in its extension runs into the opposite placed drop. That ensures that the lane for driving straight is in a straight line between the drop and the island.
- When the angle between the MTD and the STD is different from 90°± 15°, the route of the STD is corrected. We take into account the principle that the radius of the arc used for correction of the line of the STD should not be less than 150 m in urban areas.

In order to implement delevelled islands, the condition requiring their adequate width should be met; the width should not be less than 0.5 m (with the impact edge).

Two conditions must be met for horticulture arrangement of guiding islands:

- Width of the island must exceed 1.5 m;
- The horticulture arrangement (bushes, tall plants…) should not reduce visibility.

Splitter islands – splitter lanes

Splitter islands are implemented along the roadway, usually in the axis of the roadway or parallel to it.

Their purpose is to separate guiding lanes, thereby achieving improved protection of vehicles from traffic from the opposite direction and at the same time offering better traffic safety to non-motorised traffic participants in their crossing of the intersection.

The minimum width of a splitter lane shall be 1.2 m.

Pedestrian refuges and cyclist crossings

A traffic island for pedestrians and cyclists protects them from impact with vehicles. Its length shall on the section between the waiting area equal at least 15 m. The length of the raised part of an island, from the waiting area to the middle of the intersection, shall equal at least 2 m. Total minimum length thus equals 21 m. The impact part of the island must be appropriately arranged. For speed of up to 70 km/h, the usual arrangement will suffice, while higher speeds require an impact barrier in the form of raising of the road kerb.

1.7.2.6 Drainage of Intersections at Grade

The drainage conditions of an intersection are dictated by appropriate horizontal and vertical alignment of the intersecting roads and the selection of suitable elements of horizontal and vertical alignment of the intersecting roads.

Drainage must be provided in all areas of the intersection. The surface water, which cannot be dispersively drained should be caught near the kerb (with or without a pointed channel or in exceptional cases with a cut drain (silt)) and then led from the roadway through rain-water sewage. Water from side traffic directions (STD) should never run across the main traffic direction (MTD) i.e. the intersection.

In sections with an inclination of ≥ 0.2%, drainage is implemented so that the relevant inclination is that on the MTD, while the STD is connected as subordinated.

In sections with an inclination of < 0.2%, the drainage is implemented by intake shafts in all edges of the intersection (Figure 34).

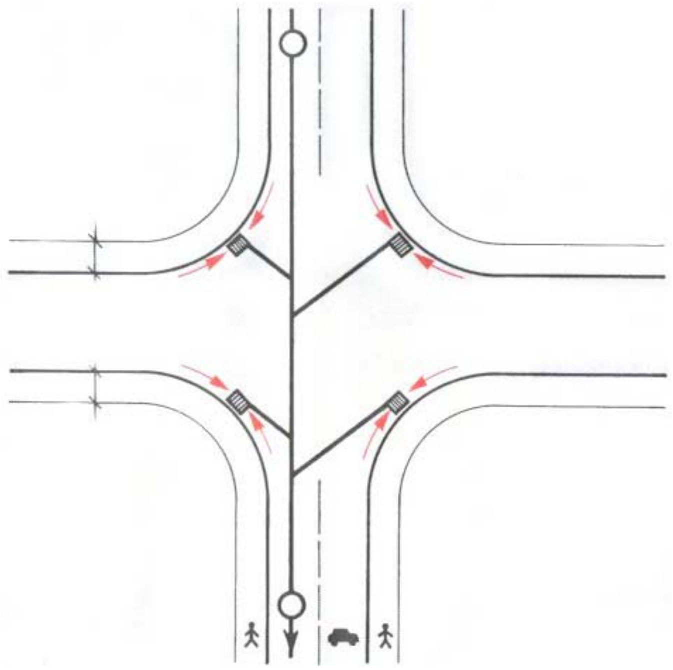


Figure 34: Drainage of intersections with minimum longitudinal inclinations.

Intake shafts along the kerb have a side intake and in exceptional cases mountable grating. The pointed channel or silt has intake shafts with a mountable grating. Revision channels are outside the roadway area so that regular control and maintenance of rain-water sewage is enabled without disturbing traffic.

The solution for drainage of the intersection area and the point of access is shown in the drainage plan by showing contour lines and water lines for individual directions of water draining. The drainage plan is a constituent part of the project documentation.

Drainage of intersections at grade is discussed in greater detail in the technical guideline *Road Drainage*.

1.7.2.7 Pedestrian Flows in the Intersection Area

The design of intersections at grade should to the greatest possible extent take into account the requirements of pedestrians and cyclists, notably requirements for clear, easily understandable and safe arrangement of intersections.

Applicable regulations should be taken into account in determining of the location for a pedestrian crossing, equipment of the intersection in case of a pedestrian crossing and conditions for traffic signal lights.

Pedestrian crossings on roads should be appropriately illuminated and marked by prescribed traffic signs on roads outside urban areas.

Traffic signal lights should be placed on pedestrian crossings on roads with two or more traffic lanes for driving in one direction.

The above-specified requirement does not apply to roundabouts with two-lane entries/exits.

Pedestrian walkways in the intersection area

If pedestrians appear in the intersection, special – separate areas must be provided for them to ensure the safest possible movement and walking.

Pedestrians are guided in the intersection area through pedestrian walkways, parallel to the road and the cyclist way. Generally, a two-path walkway/pavement (width of 2.0 m) is used; one-path solution is only used in exceptional cases (spatial limitations).

Conditions for protecting non-motorised traffic participants with regard to pedestrian walkways are discussed in greater detail in the technical guideline *Safety Fences, Conditions and Methods of Placement*.

Pedestrian crossings

The principles for designing pedestrian crossings in the area of intersections and points of access at grade specified below shall apply if such intersections and points of access are located in urban areas and are substantively used also for intersections outside urban areas (if pedestrian traffic must be taken into account).

The basic rules to be considered in determining of the location for a pedestrian crossing shall be as follows (Figure 35):

In case of a traffic light controlled at grade intersection, the location of the pedestrian crossing should be before the road marking indicating non-priority.

In case of a non-traffic light controlled at grade intersection, the location of the pedestrian crossing should be after the road marking indicating non-priority.

Figure 35: Location of a pedestrian crossing in traffic light controlled intersections and non-traffic light controlled intersections.

The aforementioned rules may be omitted in cases of dense surrounding buildings, which hinder – reduce – visibility, and in intersections with a large number of non-motorised traffic participants from the most vulnerable groups (intersections in front of kindergartens and schools and other areas with large number of children, in front of institutions for the blind and partially sighted, persons with impaired hearing, in front of senior citizens homes, hospitals…).

The aforementioned rules are also omitted in roundabouts.

Regardless of the fact whether an intersection has traffic signal lights, the area of the pedestrian crossing should include enough space for waiting of pedestrians. Traffic on pedestrian walkways should not be hindered.

In traffic light controlled intersections where the pedestrian crossing is implemented across a triangular island (Figure 36) but has no traffic signal lights, the location of the pedestrian crossing should be on the spot with the best visibility.

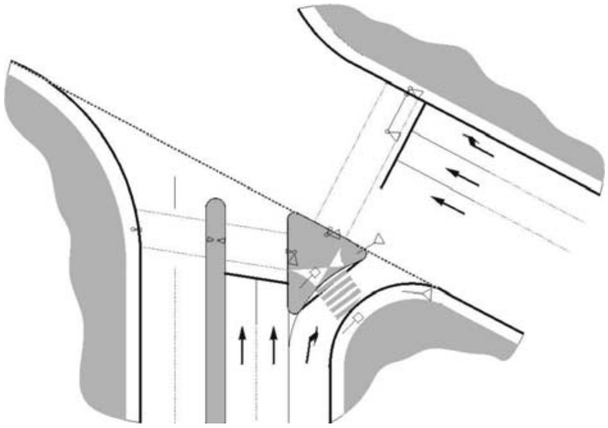


Figure 36: Pedestrian flow across a right turning lane.

1.7.2.8 Cyclist Flows in the Intersection Area

In roads for mixed traffic, intersections should in addition to providing for correct motorised traffic flows also ensure correct cyclist flows.

The following conditions should be taken into account in designing of cyclist areas in intersections in order to provide safe motorised traffic and cyclist traffic:

- Safe separation of cyclist traffic from other traffic;
- Clear and unambiguous cyclist flows in the intersection area;
- Understandable marking of right-of-way;
- Providing sufficient visibility.

Cyclist areas before the intersection area

In case of negligent cyclist flows or in case of a small traffic flow of motorised traffic participants, no special areas shall be envisaged for cyclists before intersections. In such a case, cyclists are guided together with motorised traffic participants and are subject to the same traffic regime.

In case of considerable cyclist flows or in case of a strong traffic flow of motorised traffic participants, cyclists should have special areas – cyclist ways – before intersections.

Two possibilities can occur:

- Cyclist traffic before the intersection area takes place on the same traffic area as motorised traffic (the so-called mixed traffic area or a cyclist lane);
- Cyclist traffic before the intersection area takes place on special traffic areas intended for cyclists (a cyclist way, cyclist path).

Even if cyclist flows outside the intersection area pass on the mixed traffic areas, in the intersection area itself and in case of a strong cyclist flow or strong flow of motorised traffic, special cyclist areas should be provided (cyclist ways).

Cyclist areas in the intersection area

Cyclists may be guided in several ways in the intersection area, which depends on the size of flows of cyclists and motorised traffic:

- Together with the motorised traffic participants (the so-called mixed traffic area);
- By a cyclist lane (on the roadway, separated from the motorised traffic by a continuous white line), the use of a cyclist lane is only allowed in cases when cyclist areas separated by level cannot be provided. Such a case requires a 40 km/h speed limit for motor vehicles. It is also recommended that cyclist lanes are painted red (more details in the special guideline *Materials for Road Markings in Traffic Areas*). The width of cyclist lanes should equal 1.5 m, only in exceptional cases (spatial requirements) may the width equal 1.0 m;

- Cyclist way: Passes along the roadway or pedestrian walkway and is separated by level (with or without a separation green area). The width of a one-way cyclist way placed on both sides of the road (the so-called two-sided cyclist way) shall be 2.0 m. In the areas of bus stops, buildings or in other cases where not enough space is available, the one-way two-sided cyclist way may be 1.75 m wide, which still enables overtaking by cyclists. Narrower cyclist ways (however their width shall not be less than 1 m) are allowed in shorter sections (e.g. along buildings) where the lack of space prevents implementation of a wider cyclist way (in such cases overtaking by cyclists is not possible). Two-way cyclist way shall be 2.5 m wide. In exceptional cases (along bus stops, buildings, spatial limitations), the width may be smaller but not less than 2.0 m.

The required distance of cyclist lanes, cyclist ways and cyclist paths from:

- Fixed short obstacles (e.g. public lighting poles, traffic signs, trees) should not be less than 0.5 m;
- Fixed long obstacles (e.g. building walls, underpasses, fences) should be at least 0.75 m;
- Parking niches, at least 06 m.

Cyclist crossings

Regardless of the intersection type and the traffic regime in an intersection, cyclist crossings shall be made on the inside from pedestrian crossings.

In the areas of crossings and in guiding of cyclists across traffic islands, the kerbs should be lowered to the roadway's level in order to provide easier, safer and more comfortable cycling.

Instructions for designing pedestrian and cyclist crossings in roundabouts are discussed in detail in the special guideline *Roundabouts*.

1.7.2.9 Bus Stops in the Intersection Area

Intersections and points of access at grade are suitable places for bus stops, because:

- Travel directions change in intersections;
- Speed in intersections is smaller than on sections of open road, and consequently the level of safety of passengers – pedestrians crossing the road is increased;
- Concentration and grouping of passengers occur in intersections;
- Pedestrian crossings are easier to implement and more visible and consequently safer in intersections.

Bus stops in intersections are in principle located after the area of direct intersecting of roads. They shall be placed only exceptionally before the intersection, in case no right turning lane exists or when buses change the direction of driving in the intersection.

Provisions of the guideline *Bus Stops* shall be used for selection of the location and designing of bus stops.

1.7.2.10 Horizontal Visibility in Intersections and Points of Access at Grade

Providing the visibility field of suitable dimensions and the sight distance in all possible driving directions at intersections is crucial both from the point of view of safety as well as permeability of an intersection/point of access.

The required visibility for different types of intersections is discussed separately.

Visibility in multi-level knot-points and points of access is discussed in the special guideline *Multi-Level Points of Access and Knot-Points*.

The visibility in intersections and points of access at grade is discussed in the guideline *Intersections and Points of Access at Grade* and *Geometrical and Technical Elements of the Roads Axis and the Roadway*.

Visibility in roundabouts is discussed in the guideline *Roundabouts*.

Traffic signs for various traffic regimes and guiding methods for traffic flows are specified in the Rules on Traffic Signs on Roads (Official Gazette of the SFRY, No. 48/81, 59/81, 17/85).

The driver approaching the intersection from the side traffic directions must have an appropriate visibility field provided. Dimensions of the visibility field depend on the intersection type, traffic regime on the main traffic direction and speed limit at the intersection.

The smallest visibility field (the visibility triangle) is specified in the Rules on Traffic Signs on Roads (Official Gazette of the SFRY, No. 48/81, 59/81, 17/85).

Limitations for land use and conditions for land use inside the visibility field are specified in the Roads Act (Official Journal of the Federation of BiH, no. 6/02).

If, although legal requirements have been complied with, the visibility at an intersection or point of access is reduced or hindered (due to *force majeure*) the solution to the problem of insufficient visibility should be sought among the following options:

- Changing the intersection's location;
- Changing the intersection type;
- Eliminating individual traffic directions;
- Eliminating individual intersection legs;
- Equipping the intersection with traffic lights;
- Introducing measures for slowing the traffic and placing mirrors;
- Introducing speed limit;
- Prohibit the use for certain types of traffic participants;
- Or any other solution providing traffic safety.

If, although all the aforementioned provisions have been complied with, the visibility at an intersection or point of access is reduced (due to *force majeure*, the situation at hand, existing surrounding buildings…) the solution to the problem of insufficient visibility should be sought among the following options:

- Changing the intersection type;
- Eliminating individual traffic directions;
- Eliminating individual intersection legs;
- Equipping the intersection with traffic lights;
- Introducing measures for slowing the traffic and placing mirrors;
- Introducing speed limit;
- Prohibit the use for certain types of traffic participants;
- ...

1.7.2.11 Dimensioning of the Roadway Structure in the Intersection Area

Certain deviations from layer of the roadway construction and its thickness, which are usual for sections of the open road, should be taken into account with regard to intersections/points of access.

Sudden braking and accelerations involving big masses occur in intersections, causing shear stress in layers of the roadway construction. Consequently, layers of the roadway construction (and their thickness) must be different than on sections of the open road.

Layers of the roadway construction in intersection areas are discussed in detail in the guideline *Dimensioning of Roadway Constructions*.

1.8 TRAFFIC SIGNS AND EQUIPMENT

Traffic signs in intersections and points of access shall be legally prescribed traffic signs, as specified in the Road Traffic Safety Act (Official Gazette of the RS no. 30/98) and the

Rules on Traffic Signs on Public Roads (Official Gazette of the SFRY nos. 48/81, 59/81, 17/85).

Data on traffic signs and equipment of an intersection or a point of access are an obligatory part of the intersection project.

Traffic signs on the MTD and the STD should be implemented in line with the traffic control at the intersection.

The selection of traffic signs at the intersection stems from the method for traffic flow management at the intersection (continuous, interrupted, combined) and visibility conditions (traffic signs II-1, II-2 or traffic signal lights).

Points of access for buildings and access (service) roads are not subject to the requirement specified in the previous paragraph.

In case of implementation of measures for slowing of traffic at the intersection, provisions of technical guidelines discussing measures for slowing of traffic shall be used.

Road crossings where the road crosses rails at the same level (railway, tram rail…) should be implemented in accordance with the applicable legislation.

1.9 PUBLIC LIGHTING

In case the intersection or point of access at grade envisages separate areas for pedestrians and cyclists, lighting of such intersections or points of access should be provided.

The lighting shall satisfy the following requirements:

- Lighting of the roadway ≥ 2 cd/m^2
- Lighting of the point of access (or the intersection) 3 - 5 cd/m^2
- Lighting of the pedestrian (or cyclist) crossing ≥ 5 cd/m^2

Public lighting poles should be placed in the distance equalling 3-4 times their height.

Conditions for implementation of public lighting are discussed in greater detail in the guideline *Public Lighting*.

1.10 UTILITY INFRASTRUCTURE

Solutions for existing utility infrastructure (underground and above ground) in the intersection or point of access area shall be a constituent part of the appropriate project documentation.

The project documentation shall envisage such solutions for utility infrastructure, which will enable its maintenance and reconstruction by intervening in the roadway to the smallest possible extent.

Any redirection of utility infrastructure should to the greatest possible extent take into account the following general principles:

- Solutions envisaged for shafts and facilities should be prepared so that traffic flows will be enabled under certain conditions during any maintenance of such facilities;
- The utility infrastructure network should pass outside the road surroundings or at a distance from the roadway;
- Distances between individual types of utility infrastructure should be in line with the applicable regulations;
- Shaft covers should be (if at all feasible) placed outside the roadway and only exceptionally on it;
- In case road shafts are planned on the roadway, they shall be located outside tyre routes.

2 SPLIT-LEVEL INTERSECTIONS AND ACCESS POINTS

2.1 INTRODUCTION

Split-level interchanges and junctions are designed at places of connection of roads of either the same or different category, where crossings at grade are not admitted due to the category of linking the roads to a network, or due to the importance of traffic flows.

A split-level interchange or junction is composed of road carriageways running through crossroads, entries, exits, and connecting ramps (only ramps in further text). As split-level interchanges and forks, due to execution of ramps in both horizontal and vertical alignment, predominantly extend over larger areas and at least at two height levels, their sight distance is never perfect, thus the entire structure of an interchange or a junction is unimportant for both traffic capacity and traffic safety.

However, areas of entries, exits, and interweaving, as well as partly the split-level interchange ramps themselves are special areas requiring specific driving techniques and a great drivers' attention. Therefore, in these Technical Specification for Public Roads (Guideline in further text) those areas are particularized and unified, whilst the rules of how they should be put together to split-level interchanges or junctions are indicated fundamentally, as each crossroads or interchange is actually a unique structure depending on many particularities of the location appointed.

The ramps themselves are generally provided with diminished elements in comparison with the roads on open routes, for both economy and their function of connecting and splitting the traffic flows. Namely, it is reasonable to reduce the vehicle speed and to achieve a greater homogeneity of the traffic flow, allowing drivers to carry out the required operations safer.

This Guideline is applicable to both construction and reconstruction of interchanges and junctions at places of connection of two motorways or expressways carried out by separating both traffic directions. Furthermore, it applies to all junctions where motorways or expressways are connected to roads of lower category.

To other roads such as 1st order main roads, urban rapid roads, etc., the present Guideline applies where this is required due to traffic volume, safety, or other reasons. In such cases the individual elements shall be adjusted to the intention or need. As a rule, lower or the lowest values indicated in the individual chapters of this Guideline shall be selected, or such examples are extra denoted.

To allow an easier decision, in Table 10 directives for application of split-level interchanges and junctions are presented. These directives are related to the road classification.

Table 10: Traffic characteristics of roads

Road ctg	Technical group	Typical features for road design and operation					
		Traffic type	$V_{dov(adm)}$	$V_{pot(tra)}$	Carriageway	Crossroads[2]	Feasible speed [3,4]
1	2	3	4	5	6	7	8
Out of settlements							
1	A	motor	130	80-100	separated directions[4]	split level	130 120 110 100
2	A	motor	90	60-80	two-way	split level	90 80
3	A	motor	110	70-90	separated directions	split level	110 100 90 80
4	B	mixed	90	50-70	two-way	at grade wid.	90 80 70 60

5	B	mixed	90	60-80	separated directions	at grade wid.	90 80 70 60
6	B	mixed	90	50-70	two-way	at grade wid.	90 80 70 60 50 40
7	B, C	tourist	70	Specif.	two-way	at grade equ.	70 60 50 40 30
8	B	mixed	70	40-60	two-way	at grade equ.	70 60 50 40 30
9	C	local	50	-	two-way	at grade min.	60 50 40 30
10	D	access	50	-	two-way	at grade without	not specified
In settlements							
11	A	motor	100	60-90	separated directions	split level	100 90 80
12	A	motor	90	50-70	two-way	split level	90 80 70 60
13	B	motor	80	50-60	separated directions	at grade wid.	80 70 60
14	B	mixed	70	40-50	two-way	at grade wid.	70 60 50 40
15	C	mixed	50	-	two-way	at grade equ.	50 40 30
16	D	mixed	50	-	two-way	at grade min.	not specified
17	D	residential	30	-	two-way	at grade without	not specified
18	D	residential	at a walking pace	-	-	-	not specified

LEGEND:

1 to be selected in view of the distances between centres of traffic potential (the greater the distance, the higher the v_{pot})

2 wid. = crossroads widening, equ. = complete traffic equipment, min. = minimum traffic equipment
without = without any traffic equipment – traffic sign only

3 to be selected in view of spatial conditions and continuity

4 lower V to be only selected where the environment impressions clearly affect the driver, and the speed limitation shall be obligatorily marked with a supplemental board "at rain"

2.2 KEY TERMS

Basic terms are presented in Fig. 37.

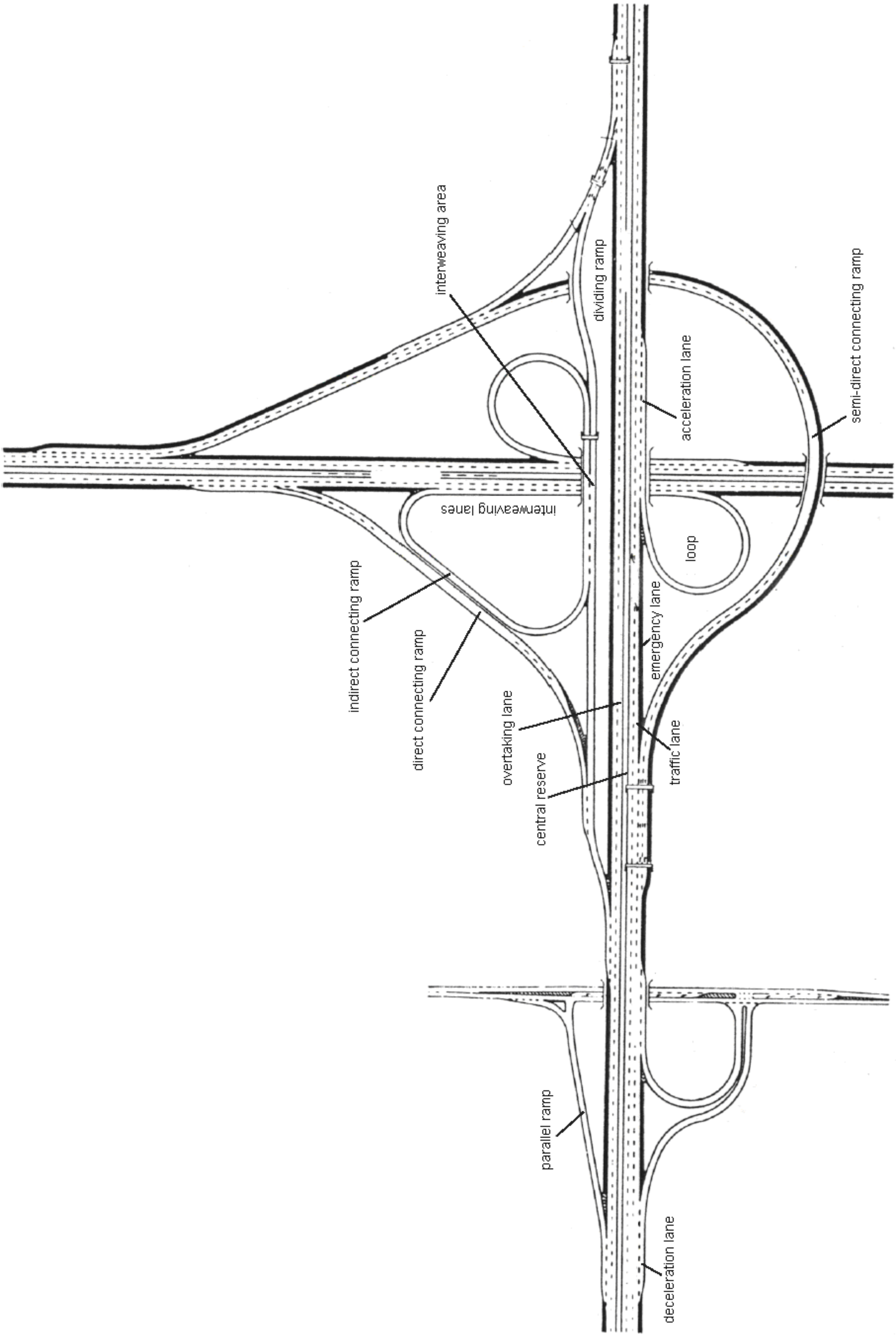


Figure 37: Basic terms

2.3 BASIC DIRECTIVES FOR DESIGN OF SPLIT-LEVEL INTERCHANGES AND JUNCTIONS

2.3.1 General

Split-level interchanges and junctions shall be so executed as to meet the following basic requirements:

- Adjustment of traffic junction to the categories of roads in a network to achieve uniform driving conditions, as well as uniform conditions of all the traffic functions on longer road sections;
- Ensuring safety of all the traffic operations before, at, and after a road junction;
- Traffic capacity of individual interchange or junction elements, as well as the total capacity of the entire split-level interchange or junction shall correspond to the traffic capacity of intersecting roads;
- In addition to ensuring the required safety and capacity of a crossroads, the economy of the interchange shall be justified.

2.3.2 Traffic satefy

A split-level interchange or junction can be considered as traffic safe, where its essential elements are identifiable, clear, and comprehensible in due time, thus they can be passed without any difficulties or dilemmas in view of driving correctness and safety.

Due to a high level of services offered by motorways, and to high speeds, as well as to increasing traffic density, the conditions indicated above are of extreme importance. As a rule, these conditions can be fulfilled in the following ways:

- The capability of an interchange or a junction of being identified can be achieved in such a way that it is repeatedly marked with distinctive and punctually placed vertical traffic signs. Points where traffic flows are split or united shall be explicit and well marked particularly by conducting individual elements. Moreover, they shall be additionally marked with directional boards and horizontal traffic signs.

- A sight distance of an interchange or a junction is ensured, if the individual elements of great traffic importance are provided with sufficient sight distances and a visual control field (control over the situation on other parts approaching the element foreseen for a traffic operation).

- Comprehensibility of a point of access or an interchange is achieved by a standardized execution of individual elements of a crossroads where several traffic flows are split, joined, or interwoven. The selection of the system of a split-level interchange or junction is of secondary importance.

Thus, a correct, and particularly a due drivers' reaction can only be achieved by proper and due announcement of such elements introducing an integral traffic sign system. Considering the foreseen speeds and the speed changes, the design shall also ensure sufficient distances between individual elements. In this place it shall be emphasized that a transition from smaller elements to larger ones requires smaller distances, and vice versa. The minimum elements, also enabling the minimum speeds, shall be preliminarily announced by the laying out method, although aesthetics of individual constituent elements might be affected. Such executions are indispensable to achieve comprehensibility, and can only be supplemented by the traffic equipment.

The sight distance of an interchange or a junction can be achieved by means of sufficient distances for a safe and continuous change of the speed, which is required between individual elements. Indeed, all the geometrical modifications of an interchange, such as reduction of traffic lane number, and separating islands, shall be clearly marked. In addition, it is of an extreme importance that the pavement is perfectly drained in all the areas where a change of the speed is foreseen.

On principle, in split-level interchanges, exits shall be located before entries. Interweaving operations should preferably be foreseen at dividing ramps; this shall be avoided on the road running through an interchange. It is also reasonable to increase or decrease the traffic lane number, depending on the foreseen traffic loading.

As traffic forecasts are often uncertain, particularly concerning the turning traffic-flows, this shall be considered, when conceiving split- level interchanges, by providing a possibility of executing additional lanes at least for turning flows.

Split-level interchanges and junctions shall be so designed as to balance the traffic and traffic-safety effects, as well as the construction costs.

2.3.3 Traffic capacity

As the traffic capacity of interchanges and junctions has still not been completely investigated, approximate critical values can be indicated for individual elements only; these values also depend on the entire traffic happening, traffic habits, and traffic anticipations in a broader area.

Therefore, in this chapter as well as in the subsequent ones where graphs for the traffic design of individual elements are presented, lower values shall be assumed, or it is required, if feasible in view of the given values, to increase dimensions of the individual elements by one degree.

Traffic capacity (at the service level D) for one traffic lane amounts to 1,800 vehicles per hour. When this value is attained or even exceeded, conflict situations or complete jams will occur at exits, entries, and places of interweaving.

For each conception of a split-level interchange or junction, prior to commencement of more detailed design, a traffic analysis based on a professionally approved methodology shall be preliminarily worked out.

2.3.4 Traffic economy

Due to spatial restrictions, distances between split-level interchanges, and economy it is not feasible to foresee the same elements for a split-level interchange ramp and for an open road. By introducing smaller elements the traffic capacity is generally not impaired, whilst the traffic safety is even improved.

2.3.5 Traffic conducting (with traffic equipment)

Increasing traffic volumes and speeds have a substantial influence over a correct traffic conducting. Traffic boards and way marks play the most important role in announcing a change of driving mode, and in due informing the drivers that they are approaching the area where they, or other drivers in the particular traffic flow, are going to change the driving mode.

The following traffic safety elements substantially depend on a correct traffic conducting: identification capability, sight distance, and comprehensibility of split-level interchanges and forks.

Boards serving to direct the traffic shall be harmonized with other traffic equipment elements.

The feasibility of a correct placing of boards to direct the traffic (before and at split-level interchanges and forks) also determines the minimum distances up to the next point of access or interchange, and has an essential influence over the selection of the system of interchanges and junctions. Therefore, the possibility of placing way marks shall already be considered at the conception stage of both classification and selection of split-level interchanges and junctions.

2.4 BASIC PARAMETERS

2.4.1 Input data

The following information and bases are required to conceive a split-level interchange or junction:

- information on actual and forecast properties of intersecting roads within a network;
- information on actual and forecast function of an interchange or a fork within a network;
- information on actual and forecast traffic flows, both in total and by individual foreseen directions at an interchange, including the traffic structure, and the information on peak traffic loading;
- information on location of an interchange or a fork such as: topography, urbanism, geological and soil-mechanical properties of the ground, water streams and ground water, present and foreseen use of land, underground and above ground public utilities, natural and cultural heritage, eventual special requirements with regard to the traffic conduction during construction, access to the land, etc.

2.4.2 Appointment of primary road

The appointment of the primary road at a split-level crossroads depends on the following:

- position of the interchange or the junction in the network;
- ranking of intersecting roads;
- traffic loading;
- turning traffic flows.

In case of a split-level junction of two motorways, the primary motorway is the one that is of a higher ranking in the particular network.

When turning traffic flows predominate at a certain interchange, the course of primary roads running through the interchange is adapted to such flows exceptionally only.

2.4.3 Design speed at crossroads

On principle, primary roads shall have the same elements both at and outside the interchange. In this way, the same speeds are enabled. In certain cases it is also possible to reduce the speed, if this is required for traffic safety reasons due to highly loaded exits, entries, and interweaving zones.

To assess the ramp elements at a split-level, interchange, lower values of design speed shall be assumed. To achieve the same driving conditions at different interchanges, the speeds indicated in figures and tables in the subsequent chapters of this Guideline shall be assumed for the individual types of ramps.

Entries from intersecting roads to the ramps shall be so carried out as to announce drivers unanimously that the driving conditions will change. Such a constructive execution shall be accentuated by designating the speed admissible at the ramps.

2.4.4 Distances between split-level interchanges and junctions

The planned road network specifies the distance between individual split-level intersections or junctions in dependence on individual primary and connecting roads of a broader area.

The minimum distance between successive interchanges or junctions results from the possibility of placing signs to direct the traffic, and from the wished or still admissible traffic flow quality between two consecutive split-level interchanges or junctions.

Minimum distances between two consecutive split-level interchanges, which still do not affect the rules for placing signs to direct the traffic, and the traffic quality, are indicated in Table 11, columns 1 and 2. Those values signify distances between entry and exit islands of two consecutive interchanges or junctions. If the distances indicated in columns 1 and 2 cannot be executed in certain cases, the value stated in the column 3 may exceptionally be assumed, however between maximum two adjoining interchanges or junctions.

In case that even this minimum distance cannot be realized, then the two adjoining interchanges or junctions act one on another in view of both traffic course and arrangement. If such an interaction can be afforded, and there are no other possible solutions to exclude one of the two interchanges or junctions thus creating a parallel road connection, it is allowed to introduce one of the systems shown in Fig. 39. When a special ramp for interweaving is foreseen, specifically shaped boards to direct the traffic are required. If shapes 4 and 5 presented in Fig. 38 are designed, full accesses to the primary road are abandoned. Foreseeing parallel roads shall compensate this.

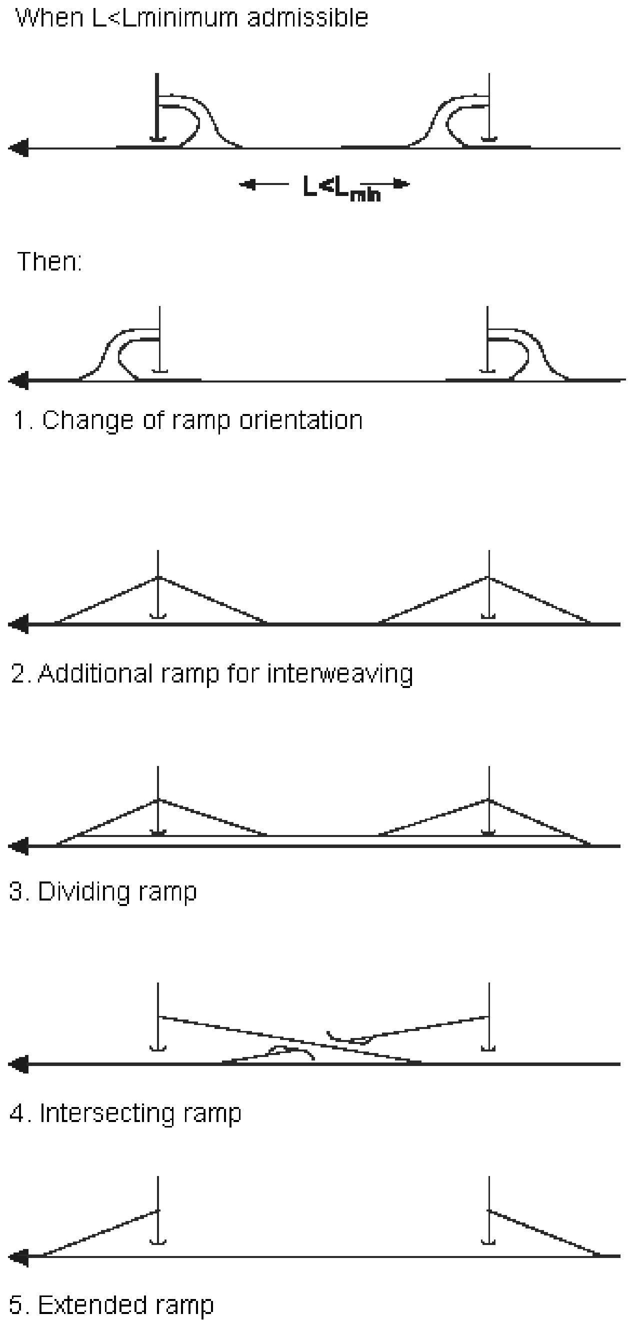


Figure 38: Auxiliary solutions for $L<L_{minimum\ admissible}$

Table 11: Minimum distances between split-level interchanges and forks

Ranking of split-level interchange or junction	Recommendable minimum distance [m]		Minimum admisible distance with only one announcing board
	heavy loaded section	less loaded section	
	1	**2**	**3**
fork of two motorways	2700 + Lu + Li *)	2700 + Lu + Li	600 + Lu + LI **)
interchange	2200 + Lu + Li	1700 + Lu + Li	800 + Lu + Li
*) deceleration lane length acceleration lane length **) feasible with traffic boards on portals only			

2.4.5 Position of a split-level interchange or junction with regard to the primary roads

2.4.5.1 General

In the interchange area, the minimum elements allowed for the open road must not be adopted for the primary road.

To ensure basic principles of designing split-level interchanges mentioned in chapter 2 particularly the following shall be considered:

2.4.5.2 Alignment

Entries and exits should be situated on stretched parts of the road;

Entries should not be located in sharp right curvatures due to unfavourable conditions (backward view in the side mirror);

If an exit from the left curvature cannot be avoided, the primary road course shall be accentuated. Therefore, the exit ramp shall be executed with a distinguishable right curvature, and in no way tangentially to the primary road left curve.

2.4.5.3 Vertical alignment

A good sight distance can be achieved by placing the decisive points of a split-level interchange or junction in a concave curve.

Longitudinal fall of intersecting roads should be as small as possible, however not smaller than it is indispensable to an effective drainage. Both traffic capacity and safety are getting worse by increasing the falls at the interchange. If the falls are substantial, some troubles with the ramp execution in view of the vertical alignment might occur in individual quadrants of the intersection.

Ascending exits and declining entries are favourable with regard to the driving dynamics and sight distance. However, attention shall be paid to ensuring the sight distance on the secondary road of the intersection.

In areas where a primary road crosses a valley on a high fill or a viaduct, the interchange location is unfavourable. In such cases it is most reasonable to place the access road onto the brink of the valley.

2.4.5.4 Maintenance of split-level interchanges and junctions

Maintenance of split-level interchanges and junctions is practically identical with the maintenance of intersecting roads. However, some difficulties in the accessibility to maintenance vehicles occur in case of split-level interchanges and junctions. Accesses to individual ramps as well as to the areas within the connecting ramps shall be so designed as to make the traffic in opposite direction on one-way ramps impossible. Junctions of access roads shall be carried out at clear places, and the accessibility to non-service vehicles shall be prevented.

2.5 SYSTEMS OF SPLIT-LEVEL INTERCHANGES AND JUNCTIONS

2.5.1 Bases to select a system of split-level interchanges and junctions

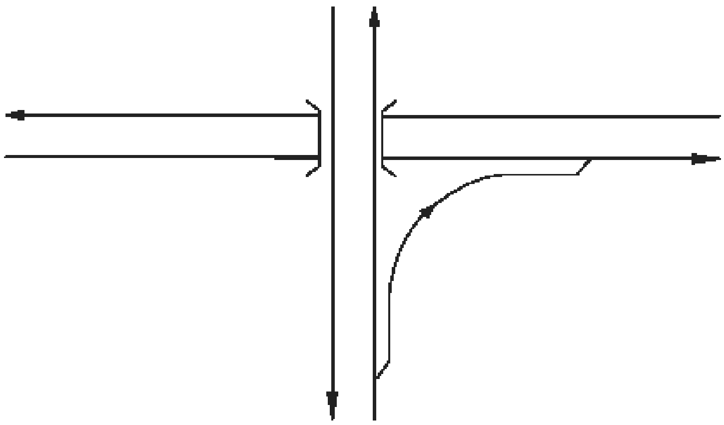
In addition to basic orientations and parameters of split-level interchanges and forks indicated in chapters 2 and 3, the following shall also be taken into consideration when selecting the system of a split-level interchange or fork:

- Roads intersected or connected at a split-level interchange shall be designed with regard to their ranking within the road network.
- Both exits and entries shall always be foreseen on the right side of the intersected roads. Exceptions are admissible between ramps within the interchanges, as well as in urban roads and expressways.
- For prevailing turning traffic flows at a split-level interchange more favourable ramps of the selected type of interchange shall be intended. Eventual seasonal i.e. daily, monthly, or annual traffic flows shall be considered.
- On intersecting roads, exits from these roads shall be situated before entries to these roads.
- As a rule, all traffic flows leaving a road and entering a split-level interchange shall run together. It is difficult to clearly mark several successive exits, and the traffic capacity is generally lower as well. Between more successive exits, between the ramps within split-level crossroads, at least the minimum required distances should be foreseen.
- All the traffic flows entering certain split-level interchange shall generally be united, and jointly conducted to the entry of a non-intersecting road. Exceptionally, several successive entries may be designed, if the dividing ramp is overloaded, or in case when uniting within a point of access requires special and expensive arrangements.
- As a rule, when ramps, or ramps and dividing ramps are united, the total number of lanes flowing together may be lessened by one lane only. Deviations from this rule are only admissible in exceptional cases, and such joining shall be carried out and marked very attentively.
- The execution of directing signs before and at a split-level interchange can essentially affect the selection of the type of such an access. Therefore, the systems of placing these traffic signs shall be verified in due time, and, if required, adapted already at an early design stage.

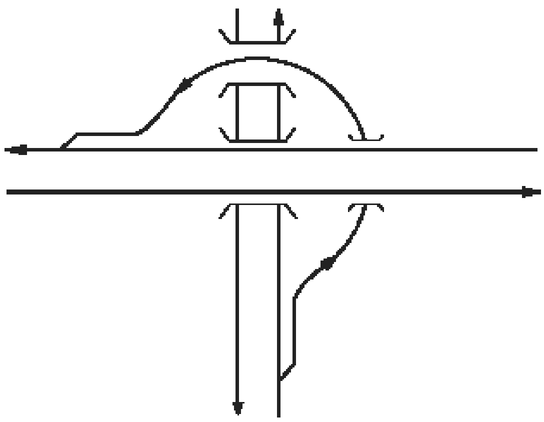
2.5.2 Types of ramps

The following three possibilities of conducting ramps at a split-level interchange or junction are available (refer to Fig 39):

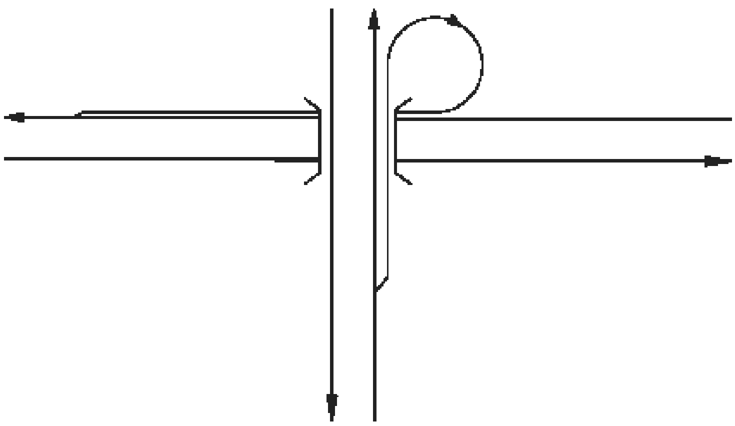
- a direct ramp
- a semi-direct ramp
- an indirect ramp



Direct ramp



Semi-direct ramp



Indirect ramp

Figure 39: Types of ramps of split-level interchanges or forks

The identification ability, a fluent course of the ramp alignment, and the traffic flow capacity are the best at direct ramps, and the worst at indirect ones.

2.5.3 Split-level interchanges and junctions

2.5.3.1 General

Split-level interchanges and junctions are used to join two roads of the same or similar rank, or of approximately the same traffic loading types (e.g. two motorways, a motorway and an expressway, a motorway and a 1st order main road being heavy loaded in view of the traffic).

Several basic types of split-level interchanges and junctions are known, differing one from the other particularly in ramp conducting. Reasonable variations of the basic types with regard to local conditions or traffic flows are admissible. However, attention shall be paid to an appropriate traffic conducting and the orientation by means of suitable traffic equipment, so that the drivers are acquainted with the modified driving conditions in due time. To achieve such goals, a correct execution of specific parts of a split-level interchange or junction is much more important than the type of a split-level interchange or junction itself.

2.5.3.2 Three-leg split-level interchanges and junctions

2.5.3.2.1 Trumpet

Considering the space consumption and investment costs, a trumpet is the most favourable type of three-leg split-level interchanges (the minimum consumption of space, one structure only).

Its weak point is an inner indirect ramp generally executed with the smallest element thus representing a substantial speed change, which affects negatively the identification ability, traffic flow capacity, and traffic safety. Such inner indirect ramp also determines the size of this type of this interchange.

Therefore, a trumpet is designed as a split-level interchange in such cases only, where the magnitude of the traffic flows in the A-C direction significantly differs from that in the B-C direction. In other words, in one of these directions, traffic flows are extremely intensive, whilst in the other one they are quite weak. A trumpet is orientated with regard to the intensity of the predominating traffic flows, thus both left and right execution of trumpets is known (Figs. 40, and 41).

For a due announcement of an inner indirect ramp it is very favourable to foresee a relatively smaller pre-curvature at the leg C, so that vehicles reduce their speed a bit at this location already.

The outer ramp embracing the inner one should preferably be designed as a basket-shaped curvature, which only touches the inner ramps. In this way more favourable elements can be achieved, and sufficient speeds ensured.

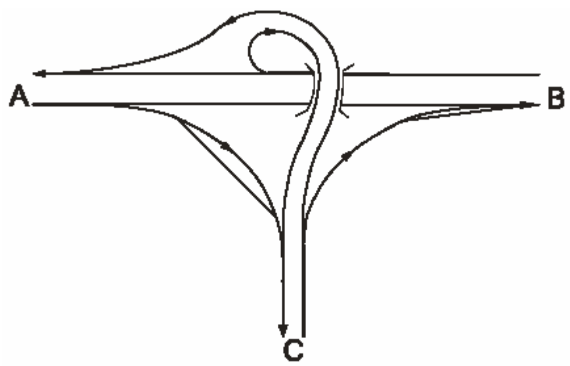


Figure 40: Left trumpet

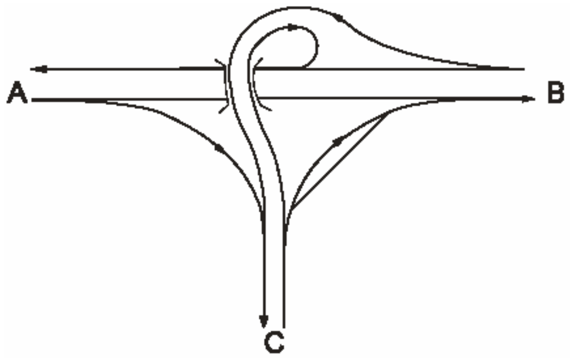


Figure 41: Right trumpet

The bulb interchange type represents a trumpet variation requiring more space, however improving driving conditions at the inner ramp. Such interchange type also requires two structures. Two alternatives of bulb interchanges can be distinguished: preferential direction B-C (Fig. 6), and preferential direction C-A (Fig. 7).

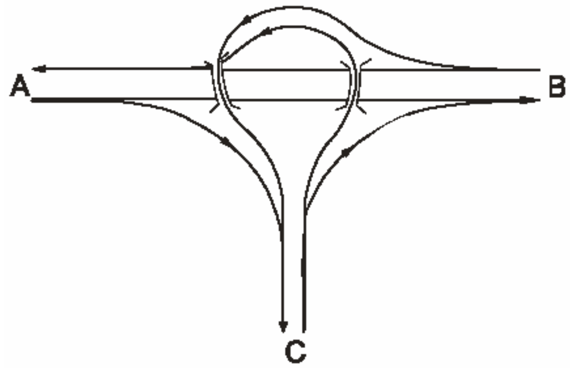


Figure 42: Bulb with preferential direction B-C

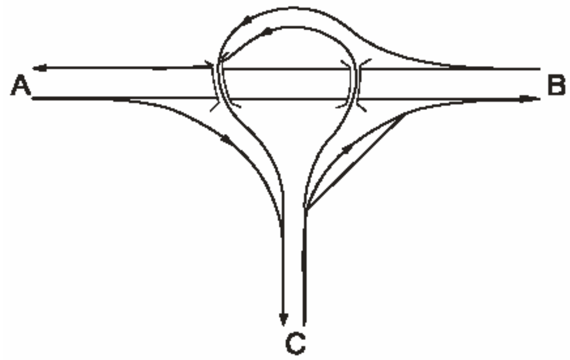


Figure 43: Bulb with preferential direction A-C

2.5.3.2.2 Triangle

At a triangle all vehicles turning left are directed by means of semi-direct ramps. Such a type requires three structures - bridges (Fig. 44), or a single two-storey structure - bridge (Fig. 45).

A triangle can be carried out with elements of any size allowing high (undiminished) speeds. However, the application of ramps is not recommendable for speeds of V≥80km/h, as exits shall be executed for major elements as well. At these exits the vehicle speed should not be too high, since an exit with acceleration lane to equalize the speed is a standard system for all the split-level interchanges and junctions.

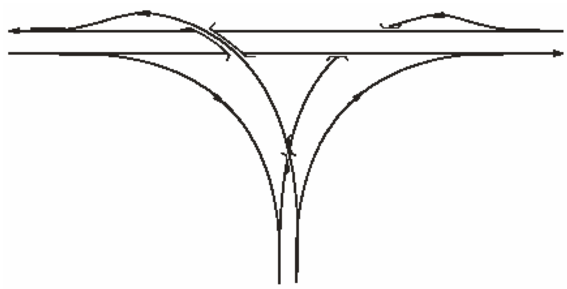


Figure 44: A triangle with three bridges

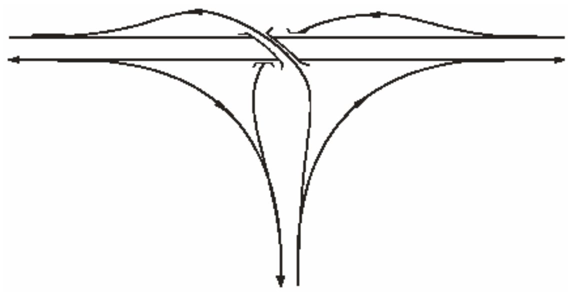


Figure 45: A triangle with a single two-storey bridge

2.5.3.2.3 Fork

A fork is a special triangle type, where, for some reason such as subordination of traffic flows, local particularities, etc., one turning direction is excluded. From a specifical point of view, the missing directions can be substituted out of the area of such split-level interchange as well (Fig. 46).

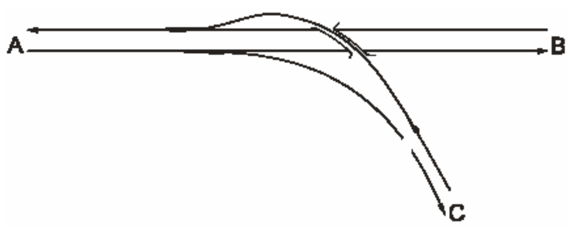


Figure 46: Fork

2.5.3.3 Four-leg split-level interchanges and junctions

2.5.3.3.1 Cloverleaf

At a split-level interchange or junction of a cloverleaf type (Fig. 47), all the vehicles turning left are conducted via indirect ramps. A single structure is required, the ramps are relatively short, the identification capability and comprehensibility of the interchange are simple, and the space consumption is relatively small in comparison with other types of four-leg split-level interchanges or junctions. An additional characteristic, and the major problem at the same time, is the need of traffic interweaving on both sides of both intersecting roads. The original cloverleaf has consisted of four symmetrical indirect ramps (refer to Fig. 47, quadrant III), and interweaving has been foreseen next to the traffic lanes. Such a solution has resulted in too short interweaving lanes thus causing major troubles concerning traffic capacity and safety. To solve these difficulties a series of solutions has been developed: shaping of inner ramps as indicated in quadrants II and IV, introduction of interweaving lanes and dividing ramps. Nowadays, those solutions are standard ones. By means of these improvements, the cloverleaf is the most economical and therefore the most frequently used four-leg interchange. It can always be designed when the magnitude of the interweaving traffic flows does not exceed 1500 vehicles per hour, on condition that sufficient interweaving ramps are foreseen for this traffic operation.

As a rule, dividing ramps shall be foreseen at cloverleaves. In the following cases, dividing ramps can be substituted by means of a special interweaving lane:

- no capacity problems in interweaving areas are expected;
- maximum admissible speeds on intersecting roads amount to 80 km/h to 100 km/h;
- placing signs to direct the traffic can be satisfactorily solved;
- minimum interweaving lane length of L ≥ 300m can be ensured.

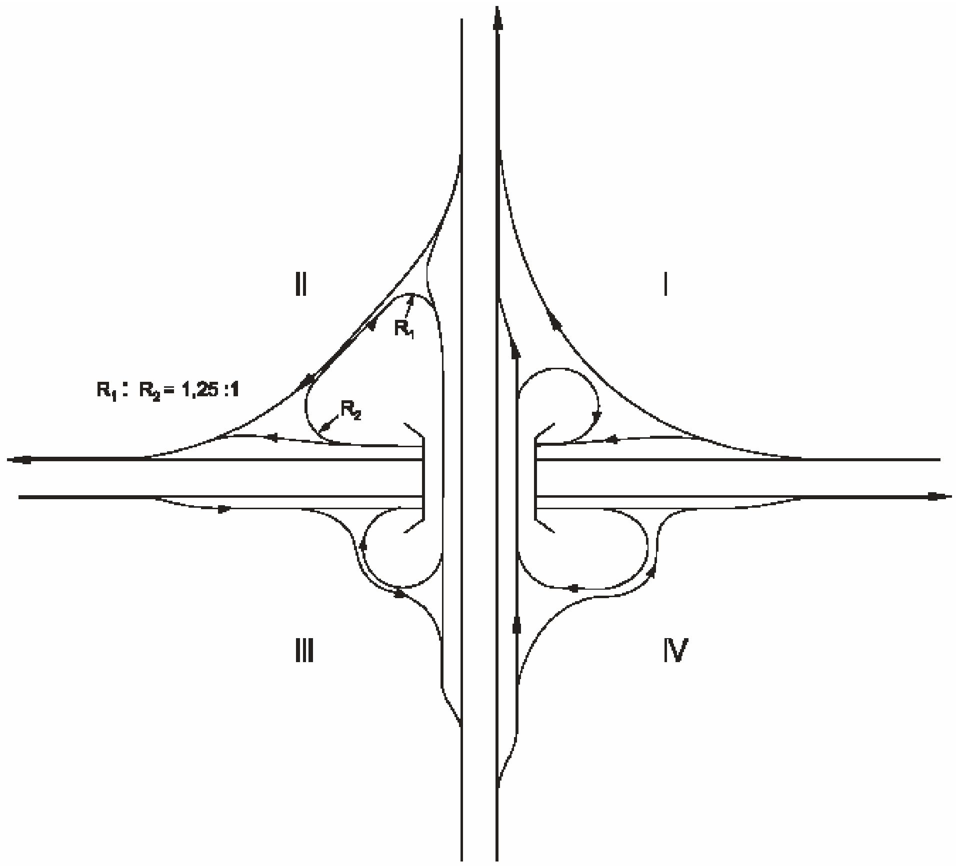


Figure 47: A cloverleaf with different ramp and dividing ramp conducting in individual quadrants

In the four quadrants in Fig. 47 different possibilities of execution of inner indirect ramps and dividing ramps are presented:

- Circular ramps in quadrants I and III enable a uniform drive over the entire ramp length, and give opportunity to introduce the greatest radii at the same area consumption. This ramp type may be introduced on condition that sufficient interweaving length is ensured.
- With an adapted (compressed) shape of the inner indirect ramp (quadrant II), the interweaving length at the dividing ramp can be increased. However, some problems with non-uniform driving conditions along the ramp can be noticed as a consequence of unequal radii of the ramp with an intermediate straight line. The ratio of radii shall not be greater than R1:R2=1.25:1. Unfortunately, a relatively small radius is indispensable at the entry to the dividing ramp, although the area consumption is the same as it applies to the circular ramp.

- A stretched form of the indirect ramp (quadrant IV) is recommendable in cases where a greater interweaving length on the dividing ramp, or a greater length of the
- ramp itself due to excessive longitudinal falls is the goal.
- Directly conducted ramps for vehicles turning right (quadrant I) allow high speeds, however larger areas are required.
- Ramps adapted to vehicles turning right (quadrants II, III, and IV) require less space, and, as a rule, shorter legs of the interchange. Adaptation of these ramps is more economical, but they allow lower speeds. When the adaptation method using arcs and counter-arcs at the ramp itself is introduced, certain problems with pavement drainage in twisting areas may occur.
- Non-parallel dividing ramps of larger curvatures adapted to other ramps (quadrants I and II) are more favourable than the partly non-parallel (quadrants I and IV, as well as II and III), or parallel dividing ramps (quadrants III and IV). At entries of other ramps, distances for interweaving become greater, and the shaping of the exit itself is more favourable. Exits of other ramps also increase the interweaving length at the dividing ramp. Directional traffic signs can be so placed as to increase their identification ability at smaller required length of the legs of a split-level interchange. In addition, a speed reduction is achieved by alignment twisting before the interweaving area.

Attention shall be paid to twisting of dividing ramp alignments. Namely, the latter are executed properly and harmonized in view of optics, as well as of the drive dynamics. A proper interweaving length, and a straight line being the most favourable geometrical element for interweaving, can be achieved in such a way that twisted adjustments are carried out at both ends between the ramps for vehicles turning right and the inner indirect ramp, whist the intermediate distance shall run in a straight line, parallel with the intersecting roads.

2.5.3.3.2 Cloverleaf modifications

As already mentioned in the previous chapter, vehicles turning left represent a difficulty at cloverleaves. Therefore, different modifications of the fundamental cloverleaf form have been developed for the case where one turing traffic flow is extremely intensive. Such modifications are shown in Figs. 48, and 49.

In figures 48 and 49, two modifications are presented for the case that turning traffic flows are extremely intensive in one direction, thus they are conducted by means of semi-direct ramps. In figure 48, conducting of a semi-direct ramp within a cloverleaf, winding other internal loops is shown. In Fig. 49, such a ramp is conducted past the other inner cloverleaf loops.

The aforementioned modifications are classical cloverleaf executions. In view of the traffic flows and modification particularities, numerous other modifications are feasible (refer to professional literature).

Within a cloverleaf, problems in the quadrants occur, where the dividing ramp directly passes over to the indirect inner ramp. In such cases, special arrangements shall be made such as: road marking, directional vertical signs, and more signs for gradual speed reduction. However, the best solution is to place a counter-arc onto the dividing ramp before the entry to the inner indirect ramp.

2.5.3.3.3 Special executions of four-leg interchanges and junctions

When, due to large turning arcs, even modified cloverleaf forms do not ensure sufficient capacity, a "windmill" (Fig. 50) can be used, conducting all the vehicles turning left, by means of semi-direct ramps. Such a system requires larger areas, five structures, and substantially higher construction costs.

When no other solution is feasible, a "Maltese cross" (Fig. 51) shall be used where all the turning vehicles are conducted directly. Such a split-level crossroads is the most unfavourable in view of both space consumption and construction costs.

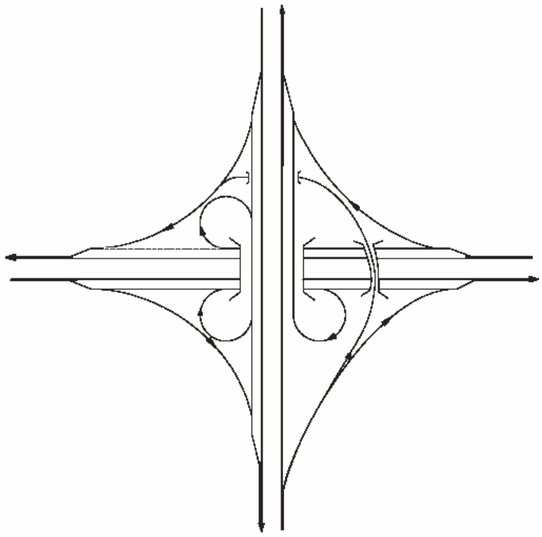


Figure 48: Modification of a cloverleaf by conducting certain vehicles turning left with a semi-direct ramp

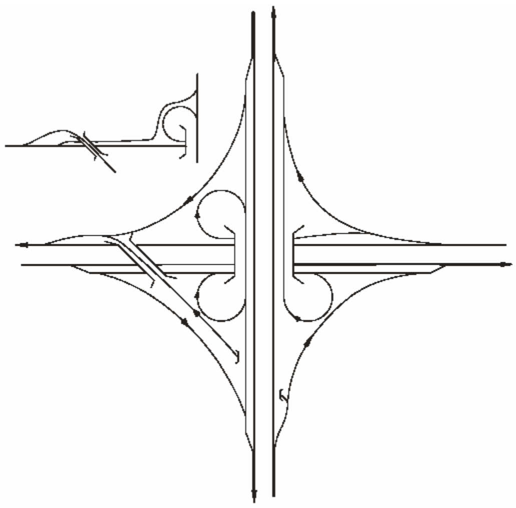


Figure 49: Modification of a cloverleaf by conducting certain vehicles turning left with a direct ramp

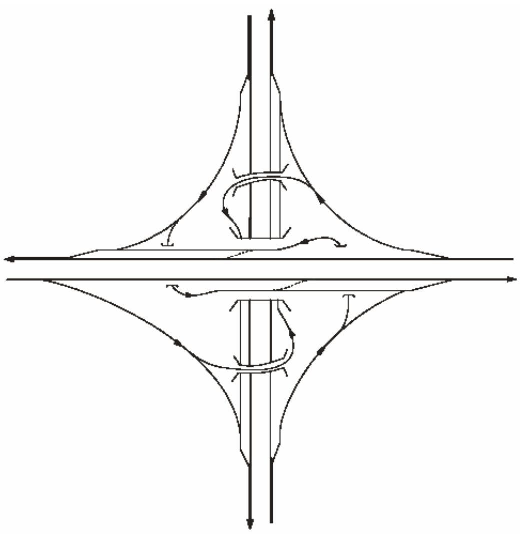


Figure 50: Windmill

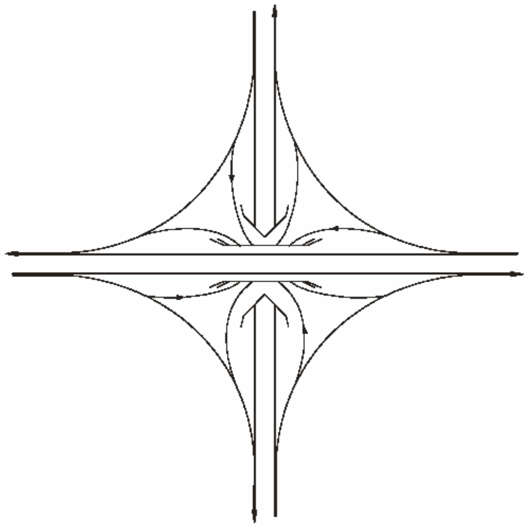


Figure 51: Maltese cross

In items 2.5.3.2 and 2.5.3.3, the basic and most frequent types of split-level crossings are indicated. With regard to specific traffic, field, town planning, and landscaping features, numerous modifications of these fundamental types have been developed; they can be found in the professional literature.

2.5.4 Split-level interchanges

Split-level interchanges are applicable to connect subordinate roads to primary roads.

To accomplish split-level interchanges, suitable systems have already been developed, which are approved and perfected in practice. They differ in conducting the ramps, and connecting to subordinate roads.

By their shape and length, ramps shall be so conducted as to allow a continuous speed change from the speed on a higher ranked road (motorway) up to the crossroads at grade with a subordinate road, where it shall be considered that the vehicles have to stop. Crossroads at grade shall be carried out in compliance with the Technical specifications (Guideline) for designing crossroads at grade.

An integral capacity of a crossroads at grade on a subordinate road is essential to the selection of the point of accesss type, as it shall be ensured that eventual traffic jams within a crossroads at grade will not cause jams on the higher ranked road.

A decision on the type of a split-level interchange depends on local conditions and features. Such interchange shall be selected, if possible, that the most intensive traffic flow at a split-level crossroads on the subordinate road is conducted as right turning vehicles.

2.5.4.1 Three-leg interchanges

As a rule, a trumpet type is designed for a three-leg split-level interchange. On principle, provisions indicated in 2.5.3.2.1 apply, only that smaller elements can be foreseen taking account of other functions. The difference is actually in the fact that the speed differences between primary and secondary roads are greater, thus the passing over of a secondary road to ramps shall be carried out by means of oppositely oriented radii already for the previous speed reduction.

In addition to the trumpet numerous specific solutions are designed also having split-level crossings and interweaving lanes on the subordinate road.

For shorter distances up to the neighbouring interchange or fork, an adapted semi-cloverleaf type is particularly suitable (Fig. 52).

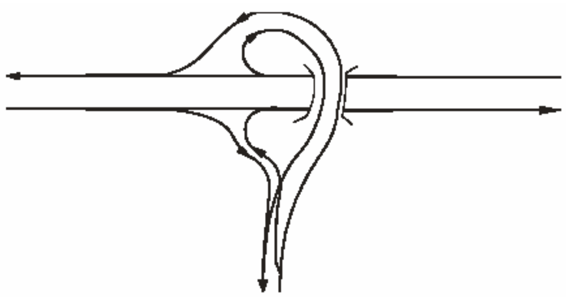


Figure 52: Interchange in a form of a semi-cloverleaf – adapted execution

2.5.4.2 Four-leg interchanges

For four-leg split-level interchanges semi-cloverleaves or rhombi are mainly used.

2.5.4.3 Semi-cloverleaf

In case of a semi-cloverleaf, both intersecting roads are linked to the ramps situated in two quadrants. Both position and shape of the ramps depend on local conditions, traffic-technical parameters, and vertical alignments of both roads. Mostly, such solutions are favourable in view of both traffic and space. In Figs. 53 – 56, the most frequent solutions are presented.

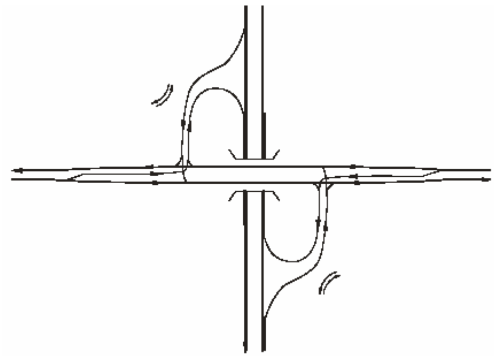


Figure 53: Unsymmetrical semi-cloverleaf with outer lanes for vehicles turning left

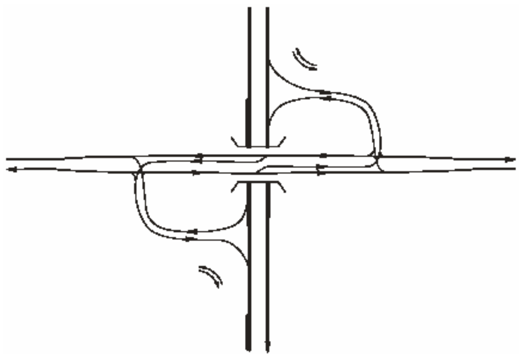


Figure 54: Unsymmetrical semi-cloverleaf with inner lanes for vehicles turning left

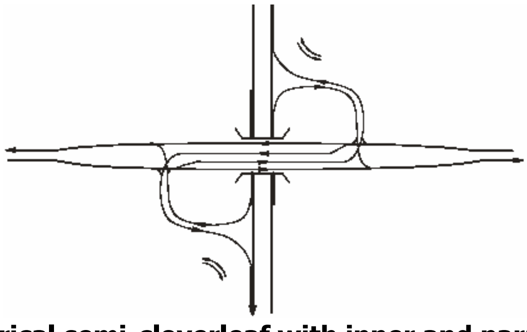


Figure 55: Unsymmetrical semi-cloverleaf with inner and parallel lanes for vehicles turning left

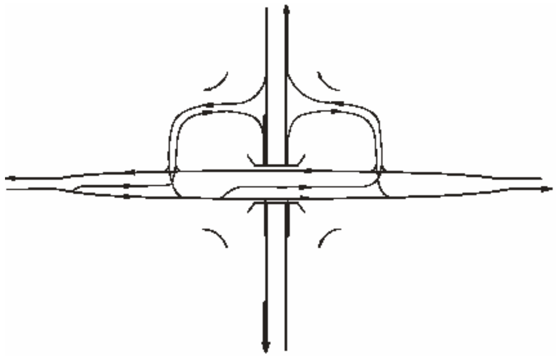


Figure 56: Symmetrical semi-cloverleaf

Classification of ramps in individual quadrants depends on the traffic flows (more intensive traffic flows should turn right on a road of lower ranking), whereas the ramp shape depends on the distance required between both points of access at grade on the subordinate road, or on vertical alignment conditions, or on the necessary placing of left turning lanes. Between both points of access, vehicles turning left can be disposed in different ways, all in accordance with the Guideline dealing with crossroads at grade.

2.5.4.3.1 Rhombus

In rhombi, both intersecting roads are linked to one-way ramps in all the four quadrants. Due to an insignificant space consumption, to short distances required in the direction of the subordinate road, to a good orientation on the subordinate road, as well as to sufficient traffic capacity, rhombi are very favourable solutions for substantially loaded interchanges in limited spatial conditions such as urbanized areas.

In Figs. 57 – 60, basic rhombus systems are indicated. It is almost a rule that split-level crossroads on a road of lower ranking shall be equipped with traffic lights.

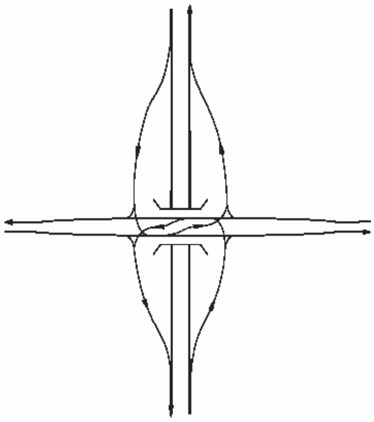


Figure 57: Rhombus with inner consecutive lanes for vehicles turning left

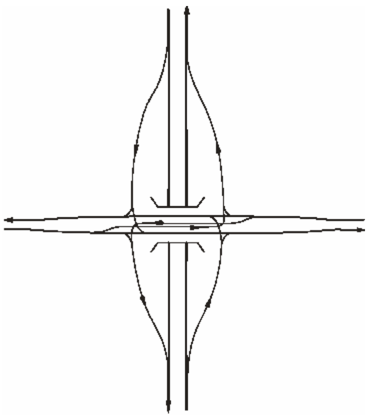


Figure 58: Rhombus with inner parallel lanes for vehicles turning left

Traffic capacity of both crossroads at grade on a subordinate road is decisive to appoint the distance between those crossroads, thus this distance is an essential element of this type of a split-level junction. For higher traffic loading where more traffic lanes in one direction are required at crossroads at grade, the widths on the road of lower ranking become substantial, and the orientation at entries to individual lanes is poor.

The rhombus shapes shown in Figs. 59 and 60 ensure a better traffic volume. The shape indicated in Fig. 59 requires a roundabout. The shape presented in Fig. 60, where both crossroads at grade are united in a single one, requires traffic lights to be foreseen at that crossroads, whilst all the vehicles turning right may drive without stop.

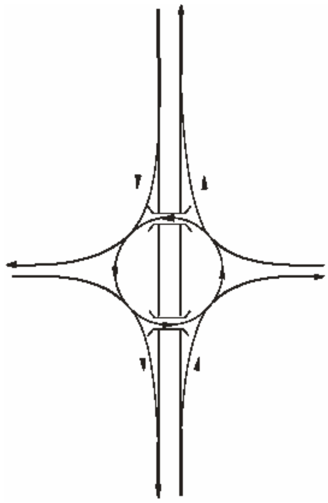


Figure 59: Rhombus with roundabout

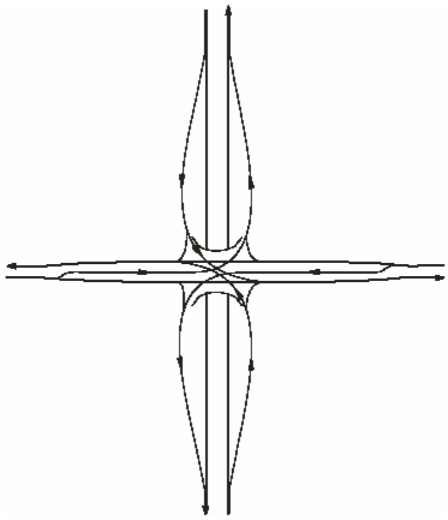


Figure 60: Rhombus with outer lanes for vehicles turning left

2.6 DESIGN

2.6.1 General

Individual traffic lanes splitting or uniting at a split-level interchange or junction, shall be, if possible, conducted by unchanged horizontal alignment and vertical alignment elements. If this is not possible, or it is technically and economically unacceptable, traffic lanes of the subordinate road shall be adapted first of all.

2.6.2 Ramps

2.6.2.1 Groups and types of ramps

The following two groups of ramps are distinguished:

- ramps linking linking together two motorways (split-level – split-level)
- ramps linking together a motorway and a subordinate road (split-level – at grade).

The division of ramps by types is indicated in 2.6..2.1.

With regard to the method of their conducting, ramps can be divided in freely conducted ramps, and adapted ramps.

Table 12: Minimum elements for ramp design

ELEMENT	Designation	minimum elements for design values Vr [km/h]					
		30	40	50	60	70	80
minimum radius	R [m]	25	45	75	120	175	250
maximum longitudinal slope	rise +s [%]	5,0					
	fall -s [%]	6,0					
radius of convex curvature	Rconvex [m]	500	1000	1500	2000	2800	4000
radius of concave curvature	Rconcave [m]	250	500	750	1000	1400	2000
Minimum cross fall	q [%]	2,5					
Maximum cross fall	qk [%]	7,0 (8,0)					
minimum fall of ramp twisting	Δ [%]	0,1 + a a= distance between twisting axis and ramp edge					
min. stopping sight distance	Lz [m]	25	30	40	60	85	115

In Fig. 61, types of both groups of ramps are shown, including approximate design speeds.

In Table 12, elements for design of both horizontal and vertical alignment in view of the design speed are indicated.

2.6.2.2 Design elements of ramp horizontal and vertical alignment

2.6.2.2.1 Bases

For both groups, and by individual types, elements for designing both horizontal and vertical alignment are indicated in Table 12 with regard to design speeds (V_{des} = 30-80 km/h).

In Fig. 61, recommended design speeds for different ramp groups and types are indicated.

The ramp design cannot fully consider the characteristics, which apply to an open road alignment (designing both horizontal and vertical alignment in space). Only the design criterion with regard to sufficient sight distance shall be preserved. It is often necessary to design ramps wilfully to emphasize the minimum elements, which cannot be avoided in split-level interchanges and junctions.

The minimum horizontal and vertical alignment elements are only foreseen for split-level interchanges and junctions. For elements at grade, provisions dealing with the design of crossroads at grade apply.

The ramp length depends on the alignment conditions, sufficient spatial and time distances between individual points (exits, entries, interweaving), vertical traffic signs, traffic division, etc.

The greatest lengths of parallel ramps should not exceed 200 to 300 m in order to avoid the impression of a multiple lane road.

Exit ramps, before being connected to a road of lower ranking, shall be so conducted as to ensure the sight distance in a length of at least 50 m. In opposite case, suitable traffic signs for a crossroads at grade on a subordinate road shall be already placed before, i.e. on the ramp itself.

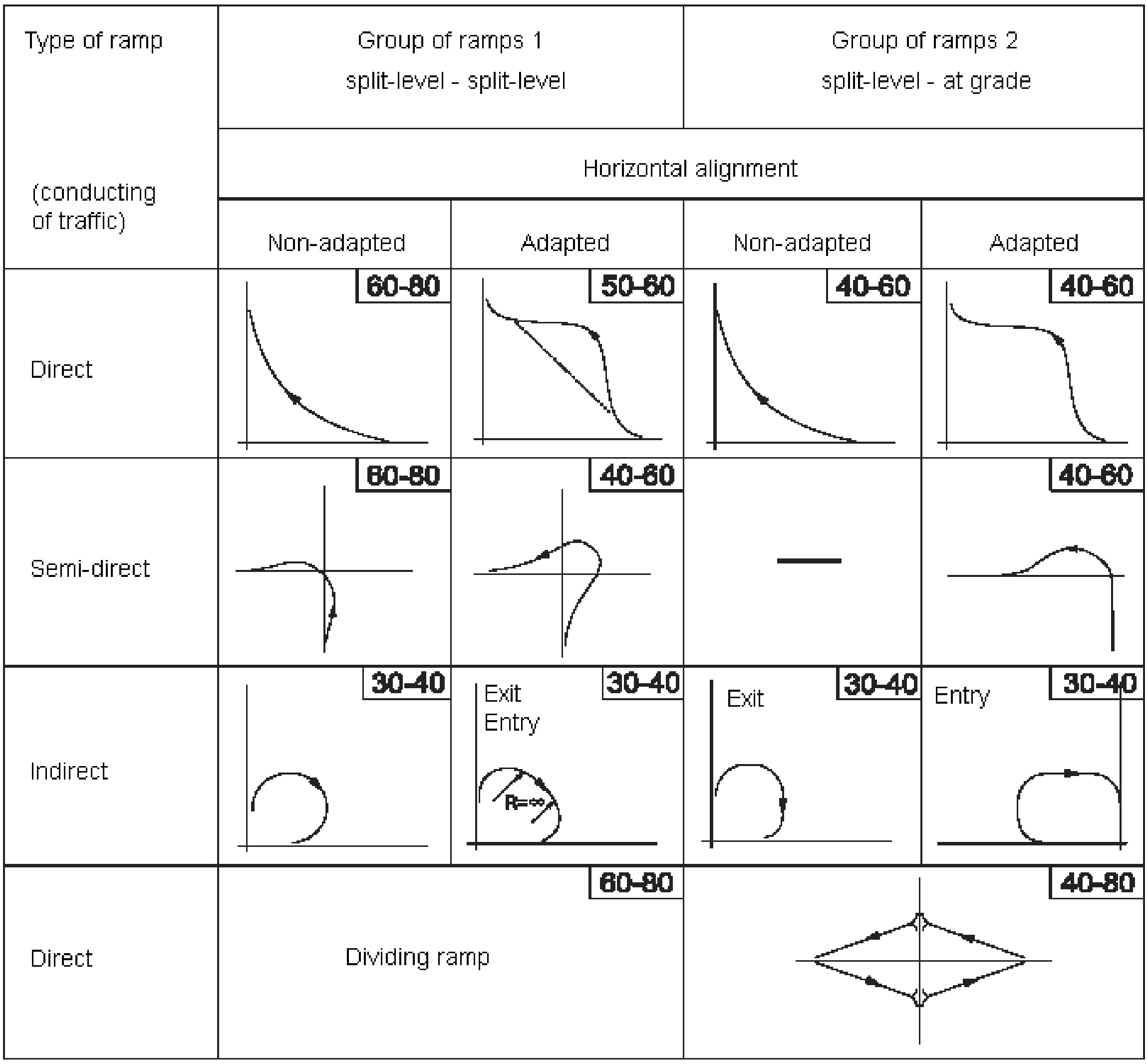


Figure 61: Types of ramps and recommended design speeds [km/h]

2.6.2.2.2 Alignment

A straight line can be used as a road alignment element without any restrictions.

Minimum radii for certain design speeds shall be taken from Table 12, or from the graph q=f(R) in Fig. 62.

For all the transitions between horizontal alignment elements of different curvature, a transition curve in a form of a clothoid shall be used, generally in the range of $R/3 < A < R$.

To enable a correct twisting of a ramp carriageway, transition curves of A=R shall be often selected for radii of R=30-60 m.

To achieve sufficient and due identification ability of the dividing triangular island, as well as a correct speed reduction on exits, the angle of fracture of the exit ramp to the main direction shall amount to 12° minimum. To meet this requirement, in dividing and parallel ramps a multiple twist of the ramp shall be executed as shown in Fig. 63 a-c. When such a twist is impossible, a parallel or dividing ramp shall be so shifted as to achieve the angle of fracture at least 6° (Fig. 63). In such cases, weaving-out on the ramp itself shall be carried out according to types IR1 and IR3 (Fig. 32). When twisted dividing and parallel ramps are executed, weaving-out shall be foreseen according to types IR2 and IR4 (Fig. 63).

Traffic capacity of an entry can be increased, when already before the weaving-in location such condition is attained as to allow vehicles to increase their speed (road alignment elements, sight distance of both entry and the road of higher ranking). This can be achieved in such a way that, in addition to other sight distance conditions, a weaving-in at the smallest possible angle to the main direction is foreseen (3-5°).

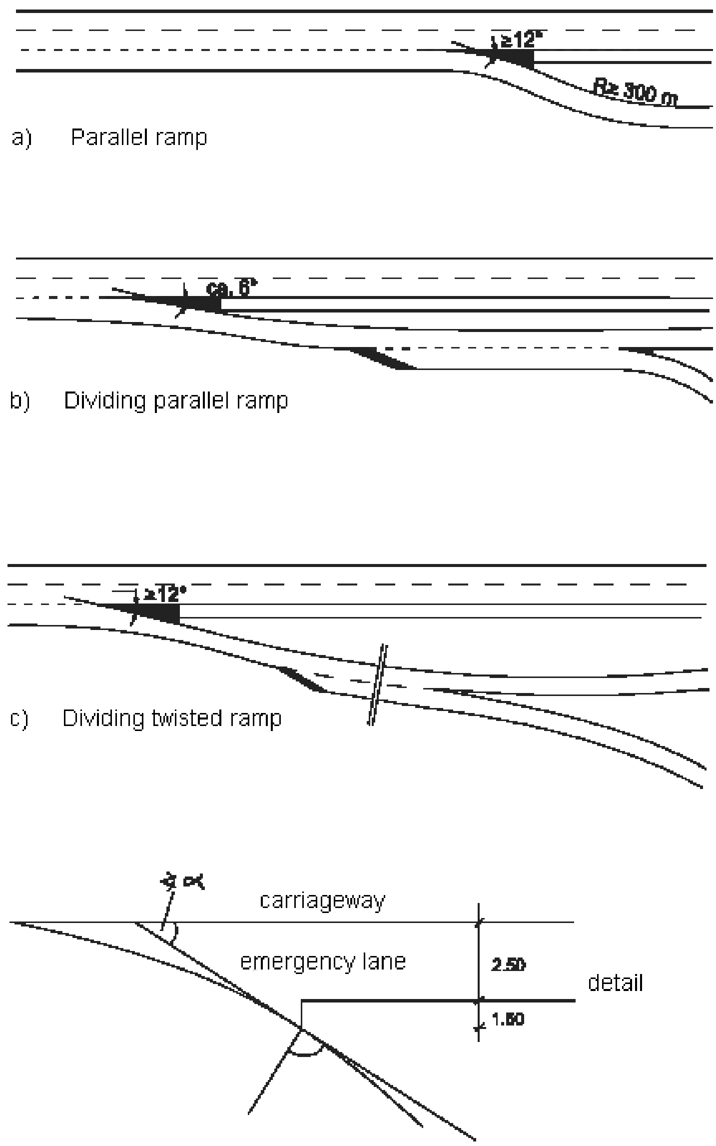


Figure 62: Twist of parallel and dividing ramps

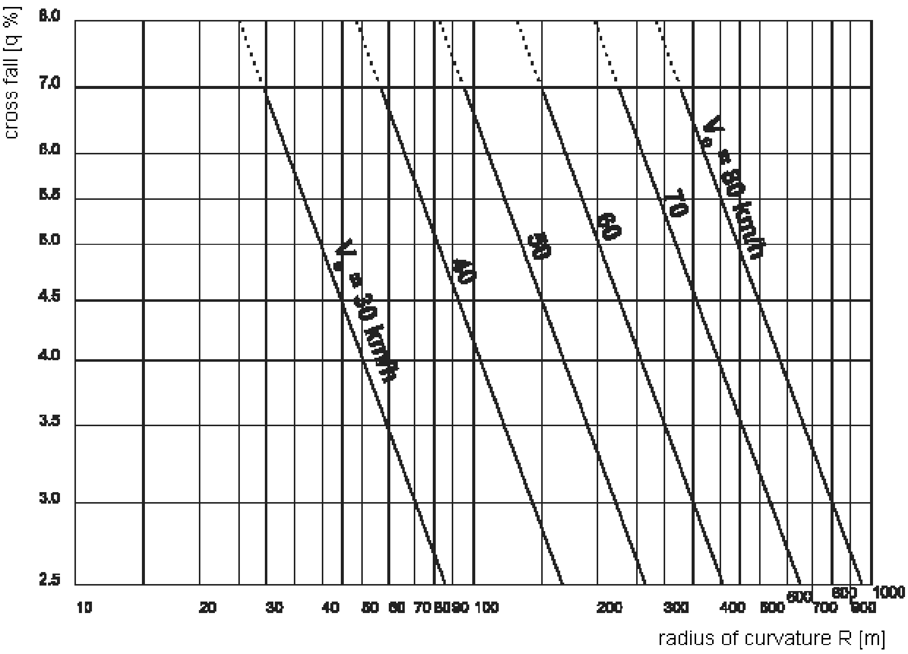


Figure 63:q=f(R)

2.6.2.2.3 Vertical alignment

The greatest longitudinal slopes of ramps for individual types of ramps, as well as the design speeds, shall be taken from the Table 12. At greater longitudinal slopes of main directions of an interchange or a junction these values can be exceeded up to the maximum value s_{max} = 10% at individual ramps, but only in cases where the considered ramp is conducted stretched in horizontal alignment. However, attention shall be paid to sufficient twisting length, so that the resultants of the falls remain within admissible limits.

To meet the minimum requirements in view of ramp drainage, the minimum longitudinal slope of the ramp shall be equal to, or greater than the slope of the twisting ramp.

Twisting shall be carried out around the ramp axis to be selected, with regard to the normal cross-section of the ramp, as indicated in Fig. 64. The ramp axis selected in such a way ensures, in view of horizontal and vertical alignment, correct conducting of ramps onto and from main directions of a split-level interchange or junction. Moreover, twisting around this axis ensures proper conducting of ramps from and onto the main roads of a split-level interchange or junction.

The size of radii of vertical curvatures shall be taken from Table 3. Those radii can also be smaller, on condition that the requirements of sufficient sight distance for the braking distance at the foreseen design speed are met.

2.6.2.3 Cross-section elements

2.6.2.3.1 Normal cross-section

2.6.2.3.1.1 Group of ramps 1 (split-level – split-level)

The cross-section NPP1 is used when this is permitted by both length and traffic loading of a ramp (graph in Fig. 65). Independently on the ramp length such cross-section is foreseen in loops, except in three-leg interchanges and junctions, as well as at connection with dividing ramps.

The ramp length is the distance between both dividing islands of entry and exit, or between splitting and uniting of the ramps in the junction area where traffic conditions remain unchanged. This criterion also applies to interweaving lanes.

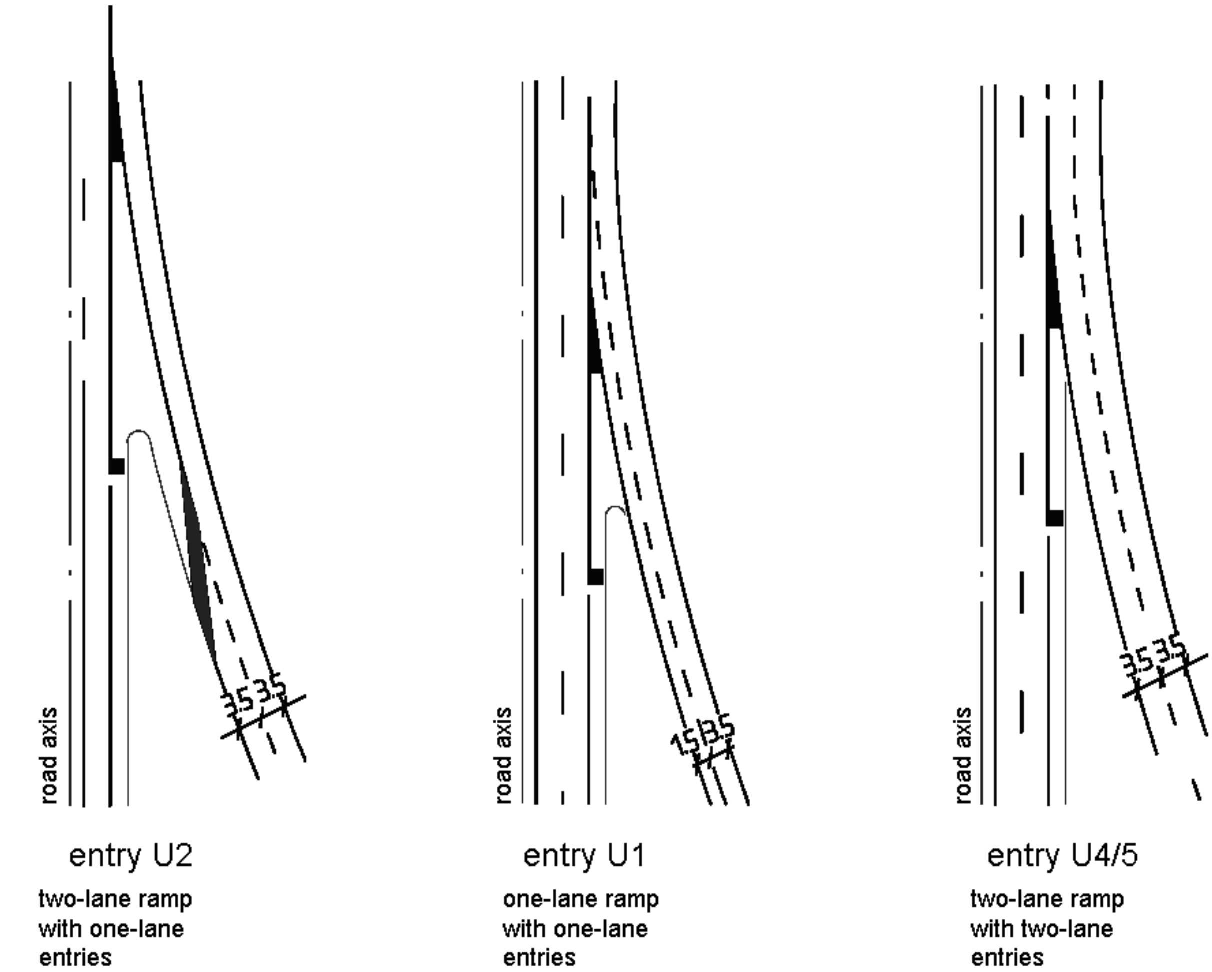


Figure 64: Position of axis on the split-level crossroads ramp

The type NPP2 shall be foreseen when this is required by the length and traffic loading respectively (refer to graph in Fig. 65). In this way, possibility of overtaking is achieved at a greater length of the ramp.

The type NPP3 shall be foreseen in case of traffic loading exceeding 1,200 vehicles per hour on the considered section of the ramp.

For dividing ramps it is recommended to foresee the types NPP2 or NPP3. Interweaving lanes are always added to the basic cross-section of a ramp. Where no sufficient space is available to execute a full two-lane ramp cross-section with an interweaving lane, one-lane ramp with an interweaving lane shall be designed.

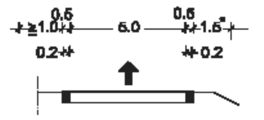
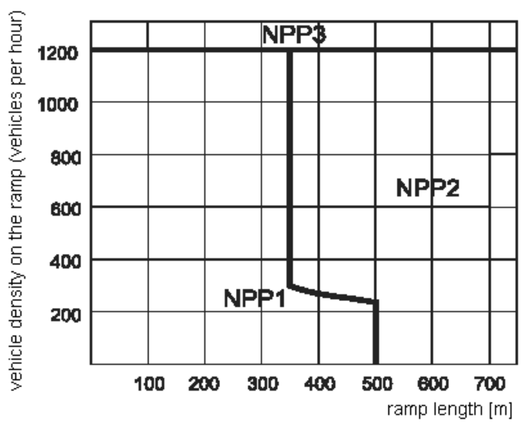
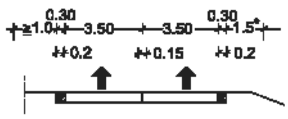
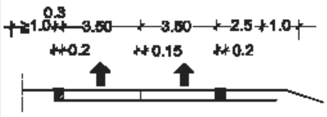
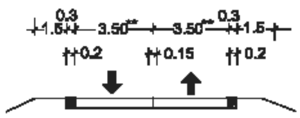
At a three-leg split-level interchange or junction of roads of the same ranking (a star), ramps running directly between main directions shall be constructed. Their cross-section shall be such of the main direction, or NPP2 and NPP3.

At exits from and entries into main directions the same cross-sections as on the other ramp parts shall be carried out. Narrowing required for traffic operations shall be executed by means of road marking.

When the main directions of a junction are carried out with cross-section elements, which level is lower than that required for NPP2 and NPP3, the same cross-section shall be designed for continuous ramps as well.

2.6.2.3.1.2 Group of ramps 2 (split-level – at grade)

For this type of ramps cross-sections NPP1, NPP2, and NPP4 shall be used. In cases where special central reserves are foreseen on two-way ramps, the latter can be of different cross-sections composed of the elements of the NPP2 cross-section. Points of access to a subordinate road shall be designed in compliance with the technical specifications for crossroads at grade. Both exits from and entries into main directions shall be designed according to types NPP1 or NPP2. The cross-section NPP2 is suitable especially in cases where more than one lane is required for the connection to a road of lower ranking (distribution lanes at a crossroads at grade). In this way, the jam effect on the priority road is prevented at the point of access at grade.

Cross-section	Description	cross-section elements (M)	cross-section applicability
NPP1	one-lane cross-section		
NPP2	two-lane cross-section		
NPP3	two-lane cross-section with emergency lane		
NPP4	two-lane cross-section with co unter-traffic		for ramps shorter than 125 m a dividing island is recommended

* 1.0 m in cuts

** for R < 130 m, in compliance with item 5.2.3.4, where widening of carriageways is required

Figure 65: Ramp normal cross-section

Where a one-lane cross-section is sufficient, the NPP1 can be selected for each direction with a central reserve. When the parallel traffic course is longer than 125 m, a more economical cross-section NPP4 shall be selected. When a central reserve is designed, it is admitted to provide each traffic lane with its own vertical alignment. However, attention shall be paid to master the difference by means of the central reserve (dewatering and cross-fall of the central reserve).

2.6.2.3.2 Ramp cross-fall

Ramps shall be executed at one-sided cross-fall, including marginal strips, and emergency lanes. To achieve proper drainage, the minimum cross-fall shall amount to 2.5%, whereas the maximum one in curvatures shall be 7% (8%). Cross-falls for individual radii can be read from the graph indicated in Fig. 65. At ramps, shaping of individual edges in the sense of the vertical alignment is extremely sensitive. Therefore, a counter-cross-fall of 2.5% can be foreseen at curvatures of R>1,000m, if this is more favourable to the edge design.

For combined one-way curvatures of greater radii, a greater cross-fall can be designed (with regard to the graph), if this is favourable to conduct the ramp edges. Such a principle also applies to a straight line between two one-way curvatures. The cross-section of the ramp shall generally be the same as that of the road, or of the ramp to which it is connected. In special cases, which shall be economically justified, the difference between these cross-falls may amount to 5% maximum.

2.6.2.3.3 Cross-fall twisting

Between ramp areas, cross-fall twisting shall be carried out by a different degree or direction of curvatures.

The minimum slope of the twisting ramp is indicated in Table 12. As a rule, twisting shall be performed at the transition curve length.

For both exits and entries one may exceptionally omit the rule that parallel lanes shall be inclined in the same way as the main directions. When twisting, for the vertical alignment or other reasons, is indispensable to both exits and entries, a wedged surface of slope of 5% maximum at the triangle side can be foreseen between the main direction and deceleration or acceleration lane at the beginning of the dividing island. In this way, twisting of the exit or entry can be extended up to the end of the transition to the deceleration or acceleration lane.

2.6.2.3.4 Widening of ramps in curvatures

For ramps of types NPP1, NPP2, and NPP3, where the traffic runs in one direction only, no widening in curvature is necessary. For the type NPP4 (two-way traffic), widening shall be foreseen by introducing radii of R≤130m, all in compliance with the design regulations for roads out of settlements.

2.6.2.3.5 Adding or taking-away of lanes

A change of the traffic lane number shall be carried out at a suitbale length. Optical effects in case of a curved ramp shall be avoided (without counter-cirvatures). A favourable course is ensured, when the following expression applies to the greater radius in the width modification area:

$$R < \frac{L_z^2}{4 \cdot i}$$

L_z (m) lenght of width modification

i (m) width modificaton

Pavement edges can be aligned independently of the road axis, or they can be calculated assuming the basic values L_z indicated in Table 3.

2.6.3 Exits

2.6.3.1 Exit design

Exits shall be uniformly designed in accordance with standardized types. Exits at ramps may be designed a bit less complex than those from main directions.

To the exit design, in addition to the traffic operations of reducing the speed and exiting the main direction, two properties are essential as well, namely identification capability and traffic capacity. Therefore, exits shall generally be designed with parallel deceleration lanes.

An emergency lane in the deceleration lane area is foreseen exceptionally only; however, the shoulder extending up to the safety barrier shall be sufficiently wide to allow vehicles to stop without any substantial obstacles for the exiting traffic.

In the area of the deceleration lane, as well as of the exit itself, a durable road marking shall be executed.

2.6.3.2 Types of exits

2.6.3.2.1 Types of exits from main direction

The selection of the exit type depends on the exit ramp cross-section. The types of exits are indicated in Fig. 66.

- A one-lane exit ramp with a single deceleration lane shall be designed in compliance with the I1 type. The exit ramp cross-section is NPP1.
- A two-lane exit with a single deceleration lane shall be designed according to the I2 type, if the exit ramp is of NPP2 type. The traffic capacity of such a type can be very high, particularly if the two-way exit in the main direction is timely and correctly marked. To achieve better capacity it is favourable to design the exit opening not too much curved, thus allowing higher speeds, and achieving greater optical safety. The alignment elements shall ensure the same design speed as on the main road, or the speed on the main road shall be reduced before the exit.
- The I3 type represents a solution for a two-lane exit ramp according to the NPP3 cross-section with a double deceleration lane. It shall only be foreseen when the exiting traffic is very intensive, i.e. its volume exceed the main direction traffic volume. Such type of exit urgently requires marking by means of portals.
- The I4 exit type represents a solution, where a two-lane exit ramp of NPP3 cross-section is used, and where the main direction consists of three or four lanes, thus, after the exit, the number of lanes can be reduced by one taking account of the traffic loading. One lane of the main direction passes over directly to the turning ramp. To this lane, a deceleration lane is added on the right side flowing into the second lane of the two-lane turning ramp. Marking with portals suitably supplemented by means of road marking (arrows) shall be carried out in the main direction.
- In I2, I3, and I4 types, exit ramps shall be executed as one motorway direction, if the latter passes over to the other direction without any exit (three-leg motorway junctions I5).
- The exit type I5 is an alternative of the exit type I4. This type is recommendable in cases of extremely significant traffic flows turning right, and it relieves the extreme right lane prior to the exit. Directing traffic signs on portals are mandatory. A weak point of this type of exit is an aggravated orientation, therefore it is recommended to foresee a directing board with inner illumination. A wide (0.5m) interrupted line representing a continuation of the dividing island should not be shorter than 150 m. In this way, vehicles, which have positioned themselves wrongly, are still allowed to continue their driving direction.

2.6.3.2.2 Types of exits from ramps

The type of exit from a ramp depends on the required cross-sections of ramps both before and after the particular exit. The minimum distance between successive exits from a ramp (distance between the dividing island and the beginning of the closure surface of the subsequent exit) amounts to 180 m for IR1 and IR2 types, whereas to 260 m for IR3 and IR4 types (interweaving). The types of exits from ramps are shown in Fig. 32.

- The IR1 type with a single-lane exit from a single-lane ramp shall be foreseen, if both ramps are carried out with the NPP1 cross-section. In the deceleration lane area the NPP2 can also be executed, when the required widening and narrowing of the main ramp can be carried out optically favourable.
- The IR2 type is a simple fork used in longer ramps (an exceeding of the distance requires a two-lane cross-section), or when this execution is favourable to conducting the ramp alignment (e.g. in twisted dividing ramps).

- The IR3 type represents a one-lane exit from a two-lane ramp. It shall be foreseen in cases where a short and less loaded ramp (NPP1) branches off from a long or highly loaded main continuous ramp with a normal cross-section NPP2 or NPP3.
- The IR4 type represents a two-lane exit from a two-lane ramp. It is designed in cases where the turning traffic is heavier than the traffic remaining in the original direction. The exit is shaped as a fork.

Recommendations for placing traffic marking:

- for IR2, IR3, and IR4 types, traffic marking/signs on portals are foreseen;
- for IR2, and IR4 types (forks), additional road marking (arrows) are required;
- for IR1 and IR3 types, directional signs placed after the dividing island (detail A) can be introduced.

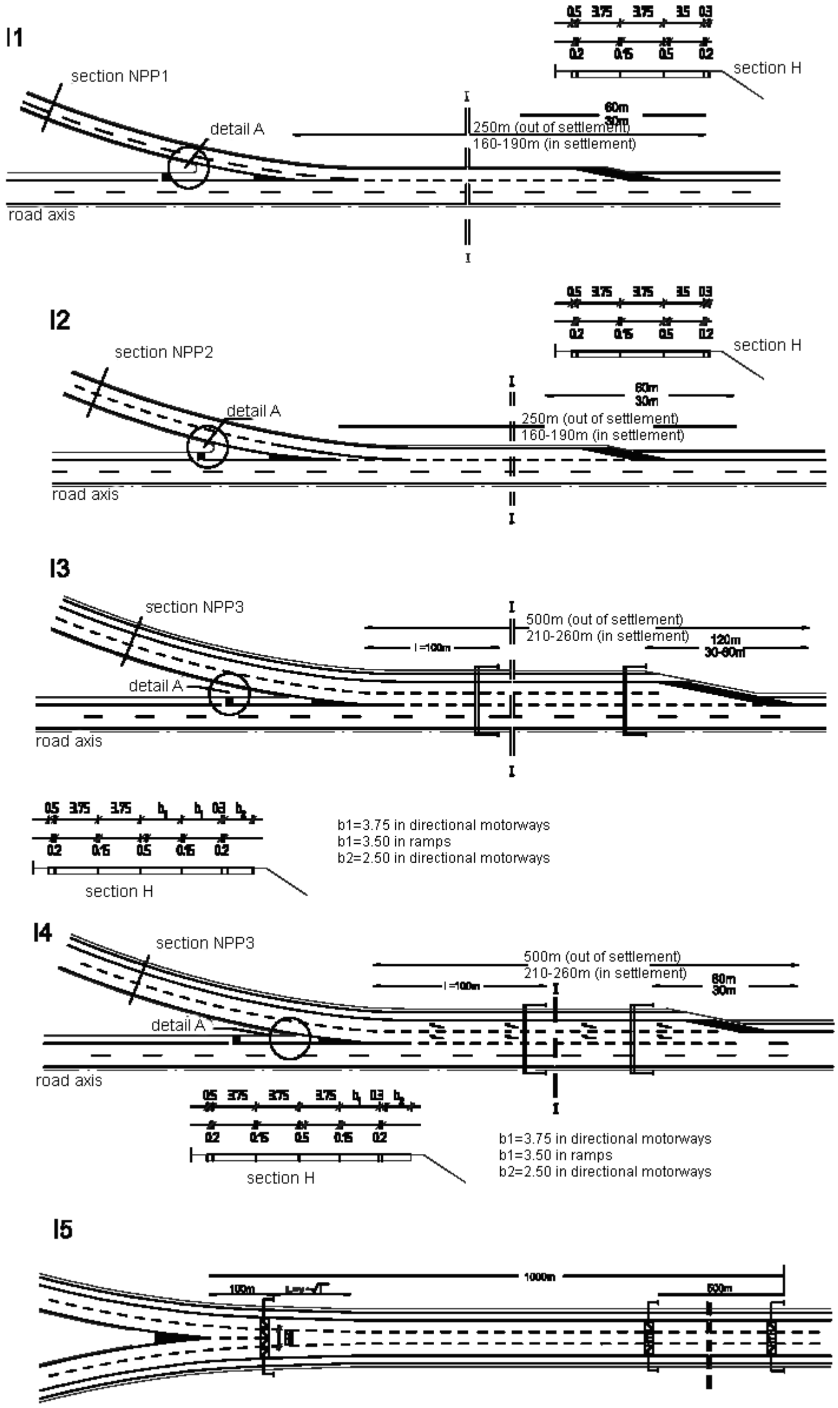


Figure 66: Types of exits from main direction

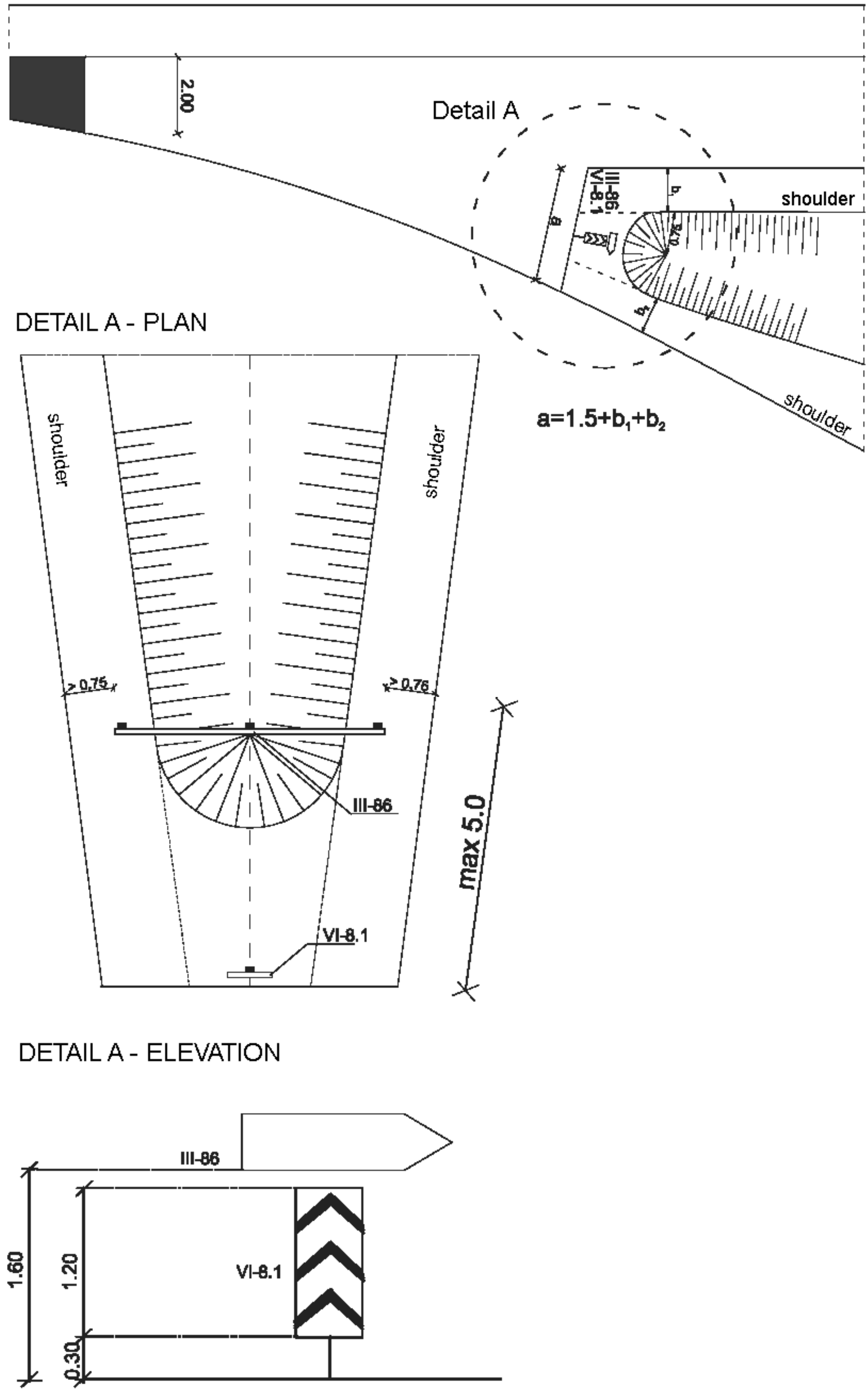


Figure 67: Types of exits from main direction – detail A

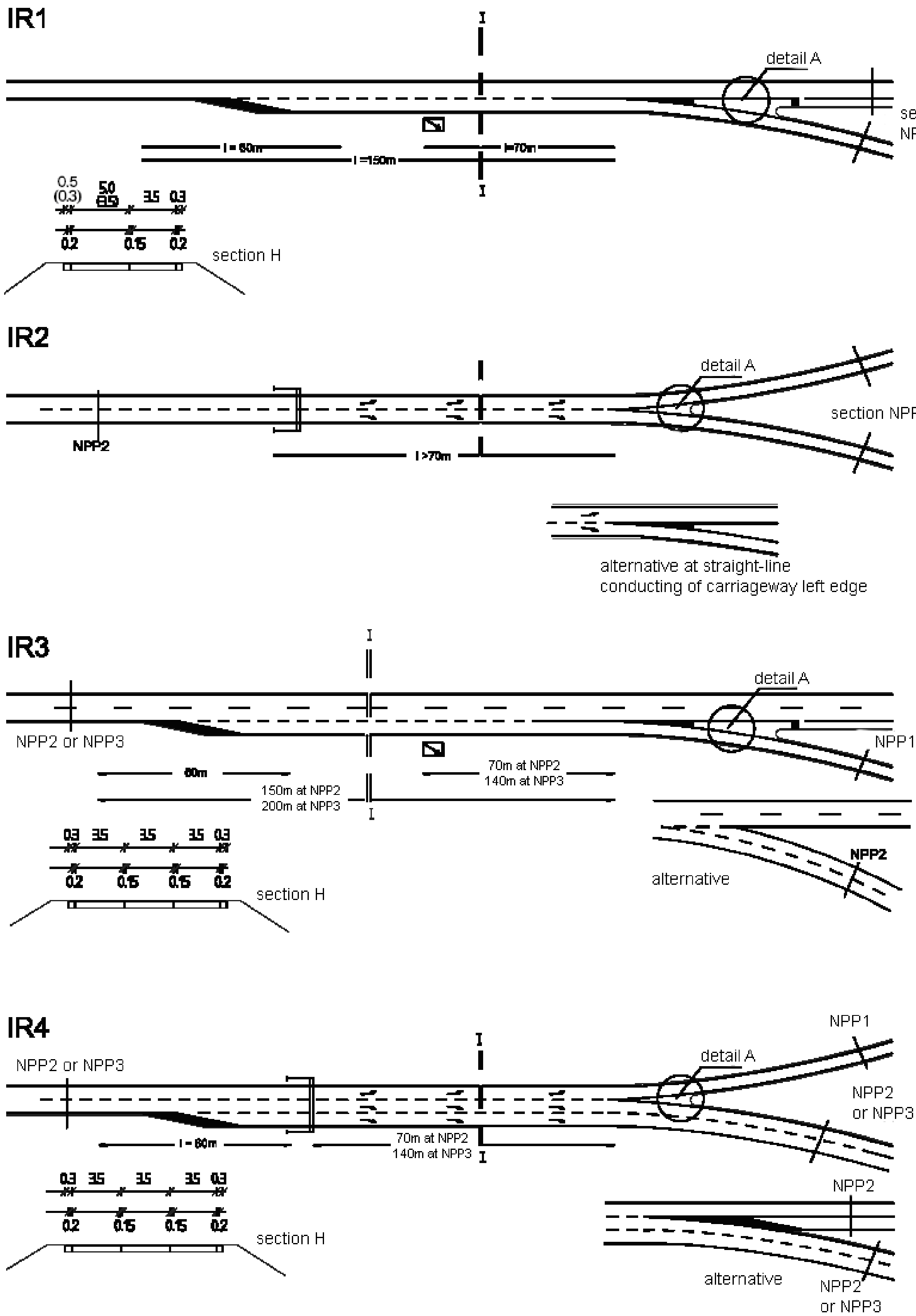


Figure 68: Types of exits from ramps

2.6.3.3 Deceleration lane design

Deceleration lane lengths depend on the lengths required for speed reduction (drive dynamics), as well as on the lengths necessary to carry out the traffic manoeuvre of weaving out. From researches performed abroad it is evident that the calculations generally provide insufficient lengths, and that they signify an inadmissible simplification of relatively complicated and heterogeneous topic, which can only be comprehended by statistical processing of observations of the integral traffic operation. This results in a length of deceleration lanes of 250 m for one-lane exits and 500 m for two-lane exits respectively.

In special cases (substantial longitudinal falls) it is reasonable to perform the length control following the dynamical formulae, however only taking account of the lengths greater than those indicated in the passage above and in Fig. 68.

FORMULA:

$$L_z = L_1 + L_2$$

$$L_1 = \frac{V_0}{3,6} \cdot t_r$$

$$L_2 = \frac{1}{3,6^2 \cdot g} \int_{V_1}^{V_2} \frac{V}{f_T(V) + \frac{s}{100} + u(V)} \, dv$$

$$V_2 = V_0 = V_1 = V_{zasn} \text{ or } = V_{proj}$$

where:

L_z	[m]	stopping distance
L_1	[m]	vehicle driving distance in time t_r
L_2	[m]	distance at the stage of vehicle stopping from the moment, when the driver applies the brake, up to the final speed
V	[km/h]	speed
V_0	[km/h]	initial speed
V_1	[km/h]	vehicle speed after completion of braking (final speed)
V_2	[km/h]	vehicle speed just before beginning of braking (initial speed), V_2= 90%V_0
t_r	[s]	reaction time: t_r=2.0 s for technical group A, and t_r=1.5 s for technical groups B, and C
g	[m/s²]	gravitational acceleration
f_T	[-]	coefficient of friction in tangential direction (admissible maximum value $f_{T\,adm}$)
s	[%]	road alignment longitudinal fall
u	[-]	coefficient of air resistance (dynamical air resistance)

$$u = 0,461 \cdot 10^{-4} \left(\frac{V}{3,6}\right)^2$$

To acceleration and deceleration lengths calculated in this way a length to perform the manoeuvre, and a length to change the LZ width from Table 12 shall be added. The calculation of the manoeuvring length shall take account of the vehicle speed as it on the main road. According to assumptions mentioned in the literature vehicles should carry out the manoeuvre in three (3) seconds.

In case of execution of I1 and I2 types deceleration lanes can also be longer than 250 m, if the main direction consists of more than two lanes, or, if the percentage of lorries in the traffic composition is substantial. However, the deceleration lane length shall generally amount to more than 500 m. The accomplishment of the widening for additional traffic lanes can also be shorter than the lengths indicated in Fig. 30, when this is reasonable because of the limiting factors (structure). Such reduction must not exceed a half of the normal length. The beginning of the widening shall be clearly marked (detail A in Fig. 64), which contributes to higher capacity, and better safety of the traffic course.

The deceleration lane width shall be equal to the main direction traffic lane width. If the traffic lanes in the main direction are 3.75 m wide, the deceleration lane width may amount to 3.50 m. For road marking it is not necessary to foresee additional widths.

2.6.3.4 Dividing island design

Dividing islands at exits shall be attentively designed to achieve the identification capability and safety of the latter. The exit itself shall be therefore marked with suitable directional boards visible at night as well. Moreover, smaller radii shall also be marked, if they appear immediately after the particular exit, or when no sufficient guarantee for a due identification ability is given by the ramp alignment and by the ramp course itself. Before the dividing island, a closure surface shall be foreseen, which shall be included in the preceding road marking. The point of the island shall be 1.5 m wide. It shall only be rounded off, if the execution with raised kerbs is foreseen. The surface for the island point shall be at the same height as the pavement, if feasible.

2.6.4 Entries

2.6.4.1 Entry design

For the design of entries in the main direction and to the ramps within the junction area it is essential to achieve the smallest possible speed differences thus better safety and higher capacity. Therefore, acceleration lanes shall be foreseen at all entries.

2.6.4.2 Types of entries

2.6.4.2.1 Types of entries to main directions

Types of entries particularly depend on the normal cross-sections of both main direction and entry ramps. The types of entries are shown in Fig. 69.

The admissible traffic loading on an entry ramp with regard to the traffic loading of the main direction, and to different speed ratios, can be read from the diagram in Fig. 70.

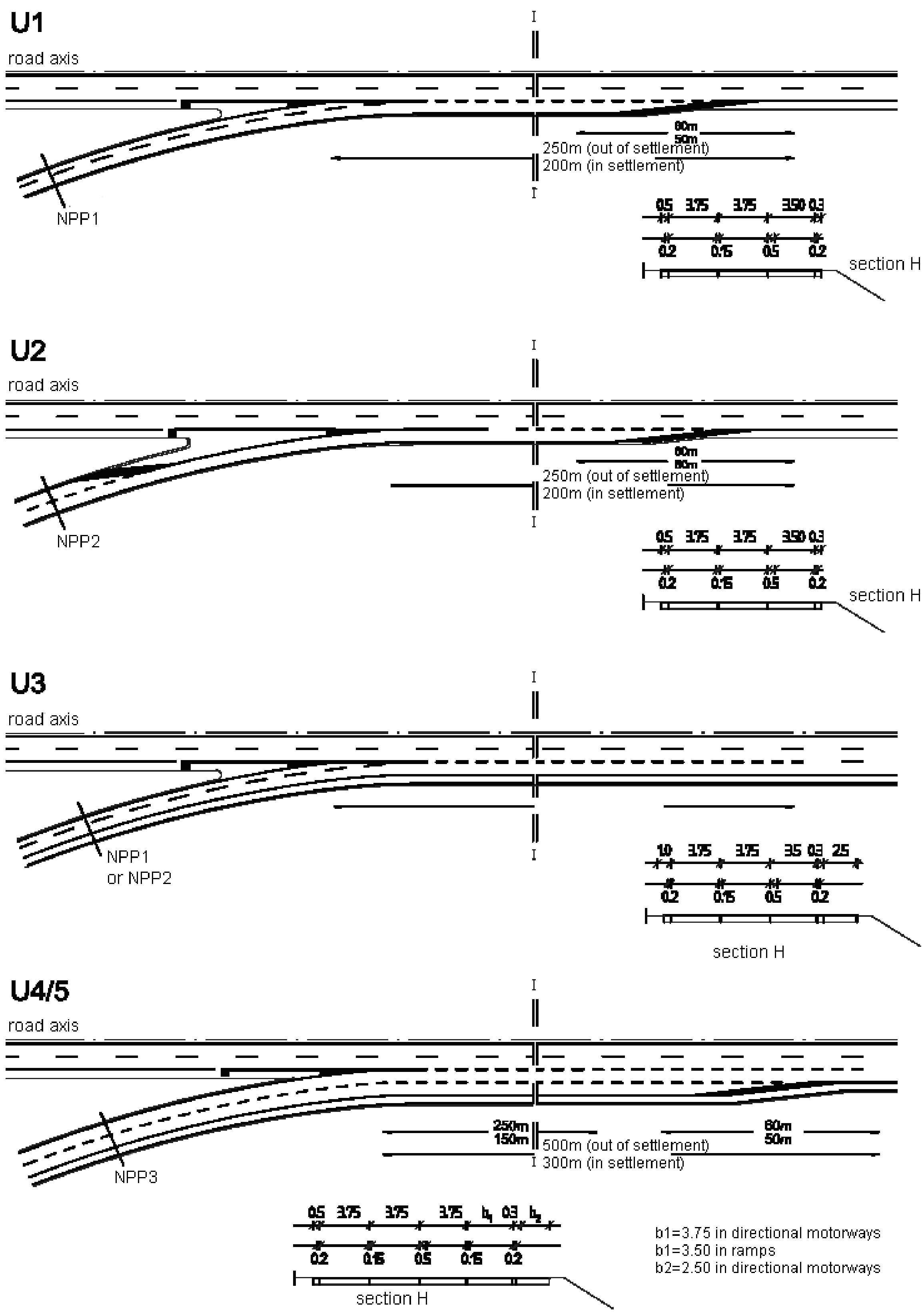


Figure 69: Types of entries to main direction

The U1 type represents an entry with a one-lane ramp and one-lane acceleration lane. The one-lane ramp of NPP 1 cross-section of 5.00 m width can be narrowed, by means of a closure surface located before the dividing island of the entry, to the acceleration ramp traffic lane width, which should be equal to that in the main direction.

The admissible traffic loading of entries is can be read from the diagram in Fig. 71.

The U2 type represents an entry with a one-lane acceleration lane, and a two-lane entry ramp with the NPP2 cross-section. However, this ramp is narrowed to a one-lane ramp, and the latter is extended to the acceleration lane. This width reduction is carried out by means of a closure surface on the left lane of the two-lane ramp, so that a one-lane weaving-in is achieved. In ramps, which sight distance is insufficient on a part of the entry, and where the length of the prescribed closure surface is not enough for a due identification ability of the narrowing, the closure surface shall be lengthened.

The U3 type represents a one-lane entry with summing up the traffic lanes in the main direction. It shall be foreseen, where the entry ramp is executed with NPP1 or NPP2 cross-section, and where no weaving-in is feasible on the one-lane acceleration ramp due to the traffic volume in the main direction.

The U4 and U5 types represent an execution with a two-lane ramp of NPP3 cross-section, and with double acceleration lanes. The left traffic lane of the entry ramp is added to the main direction, whilst the right one merges in the acceleration lane – U5 type. In cases where a three-lane road is not necessary, the third, added lane may be cancelled, however not before than 500 m after the termination of the U4 type acceleration lane. The end of the additional lane shall be marked in due course.

If a two-lane entry ramp passes over directly to the main direction (three-leg motorway junction), the ramp shall be carried out as one-way motorway.

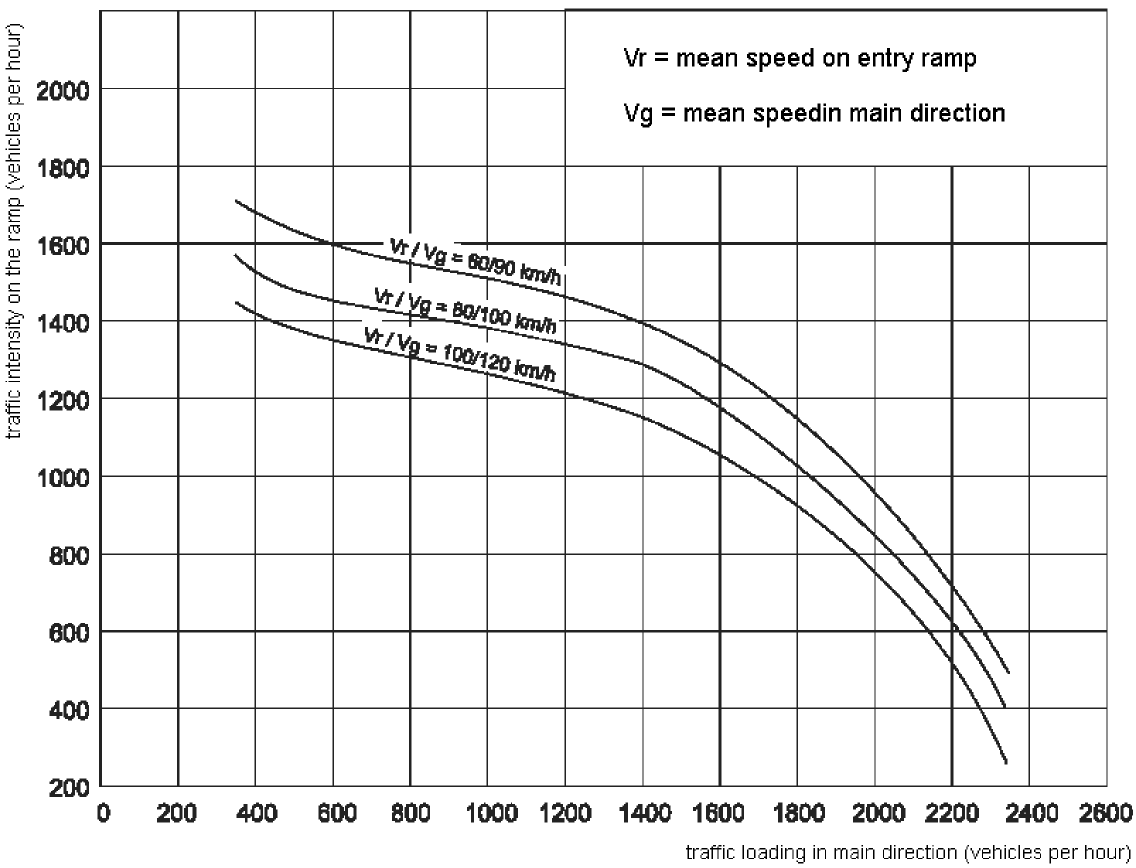


Figure 70: Admissible loading of entries

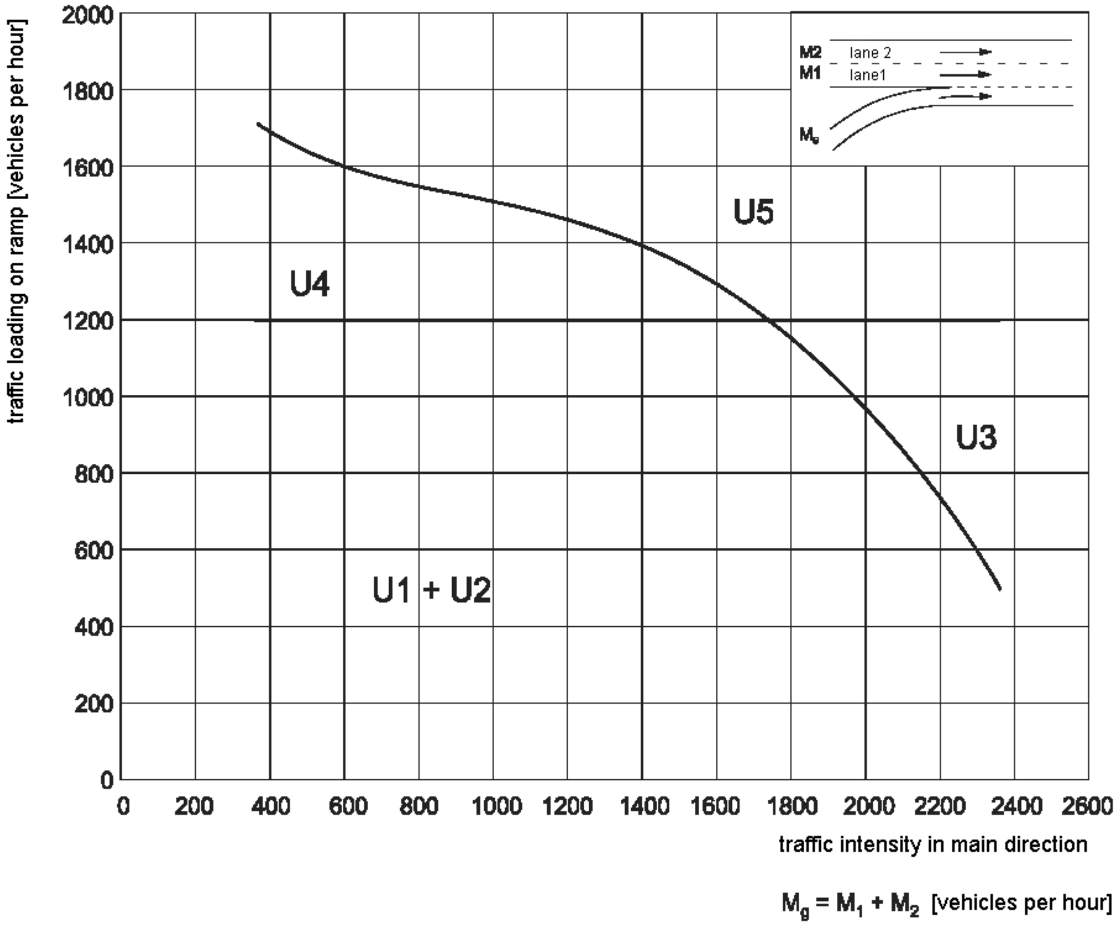


Figure 71: Applicability of entry ramp types

2.6.4.2.2 Consecutive entries

Where, in special cases, more consecutive entry ramps are conducted one by one towards the main direction, the ZU entry types shown in Fig. 72 shall be introduced.

In the crossroads area, such ramps shall be united and led concentrated, i.e. by means of one entry, to the main direction.

The ZU1 type shall be used, if both entry ramps are executed with NPP1 or NPP2 cross-sections, and if the traffic loading in the main direction, as well as on entry ramps meet the requirements of the graph indicated in Fig. 70.

The ZU1 and ZU3 types shall be applied, if either of entry ramps is carried out with the NPP3 cross-section.

Entry details shall be designed as it applies to the types of single entries. To achieve higher traffic capacity and better safety of entries, higher values as those indicated in Fig. 72 should be aimed.

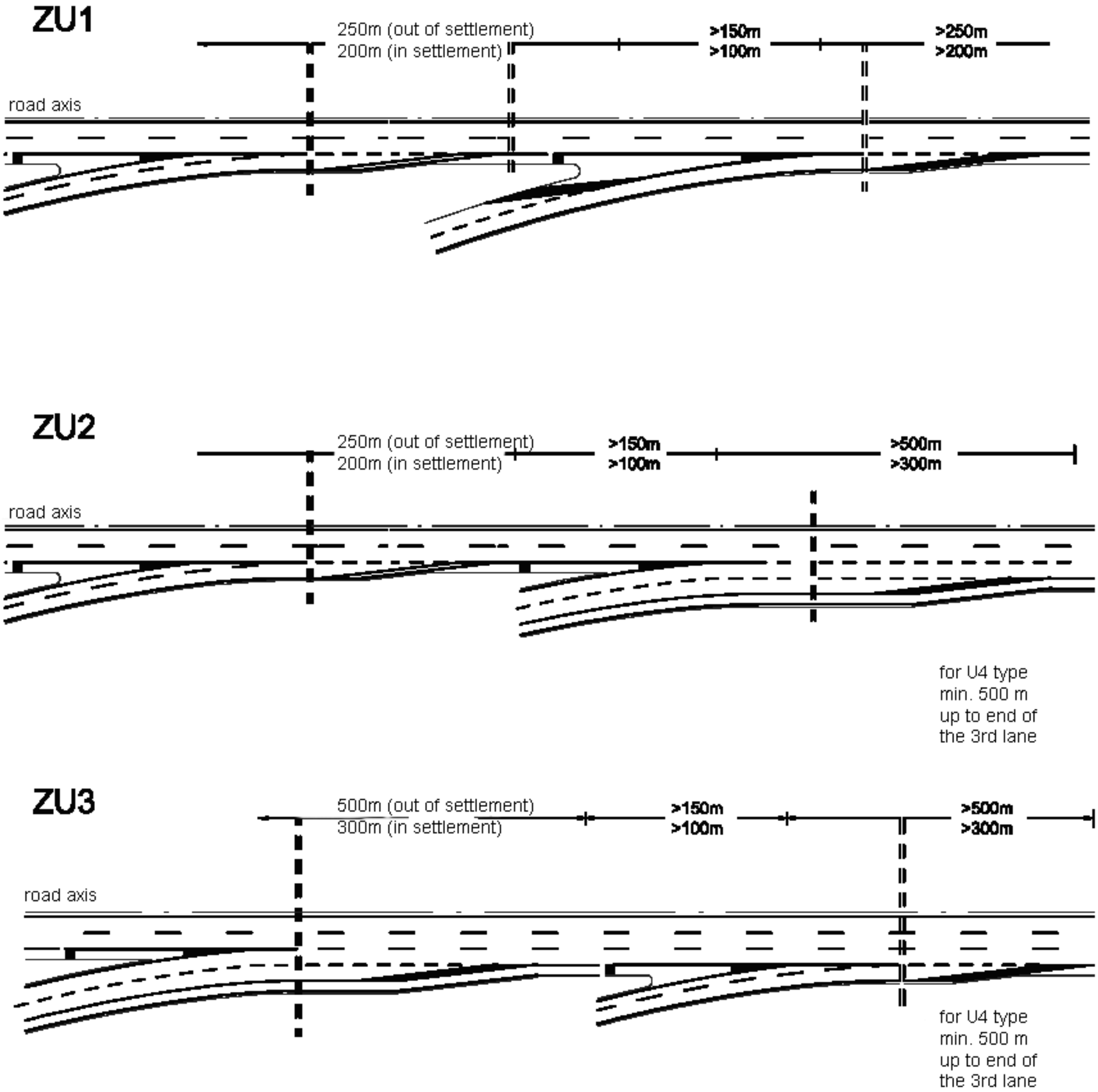


Figure 72: Consecutive entries

2.6.4.2.3 Types of entries onto ramps

For the design of these types of entries, cross-sections of ramps before and after the particular entry are decisive. Executions with acceleration lanes, or such where lanes of both ramps are summed up (uniting of ramps), are possible. Distance between two successive entries shall not be lower than the values indicated in Fig 73

The UR1 type is an execution with a one-lane entry ramp, and a single acceleration lane. It shall be foreseen, when the traffic running on the entry dies not exceed the conditions for the U1 type of the entry to the main direction.

The UR2 type represents a solution by summing up the two ramps, where the latter are executed according to NPP1 or NPP2 types, and where a two-lane ramp of type NPP2 is required after the particular entry due to either length or traffic loading.

The UR3 type is used, when a ramp of NPP1 or NPP2 type should be connected to a two-lane ramp of NPP2 or NPP3 type, and if the weaving-in traffic is of a subordinate character.

A direct or tangential connecting of entries to the main direction shall be avoided.

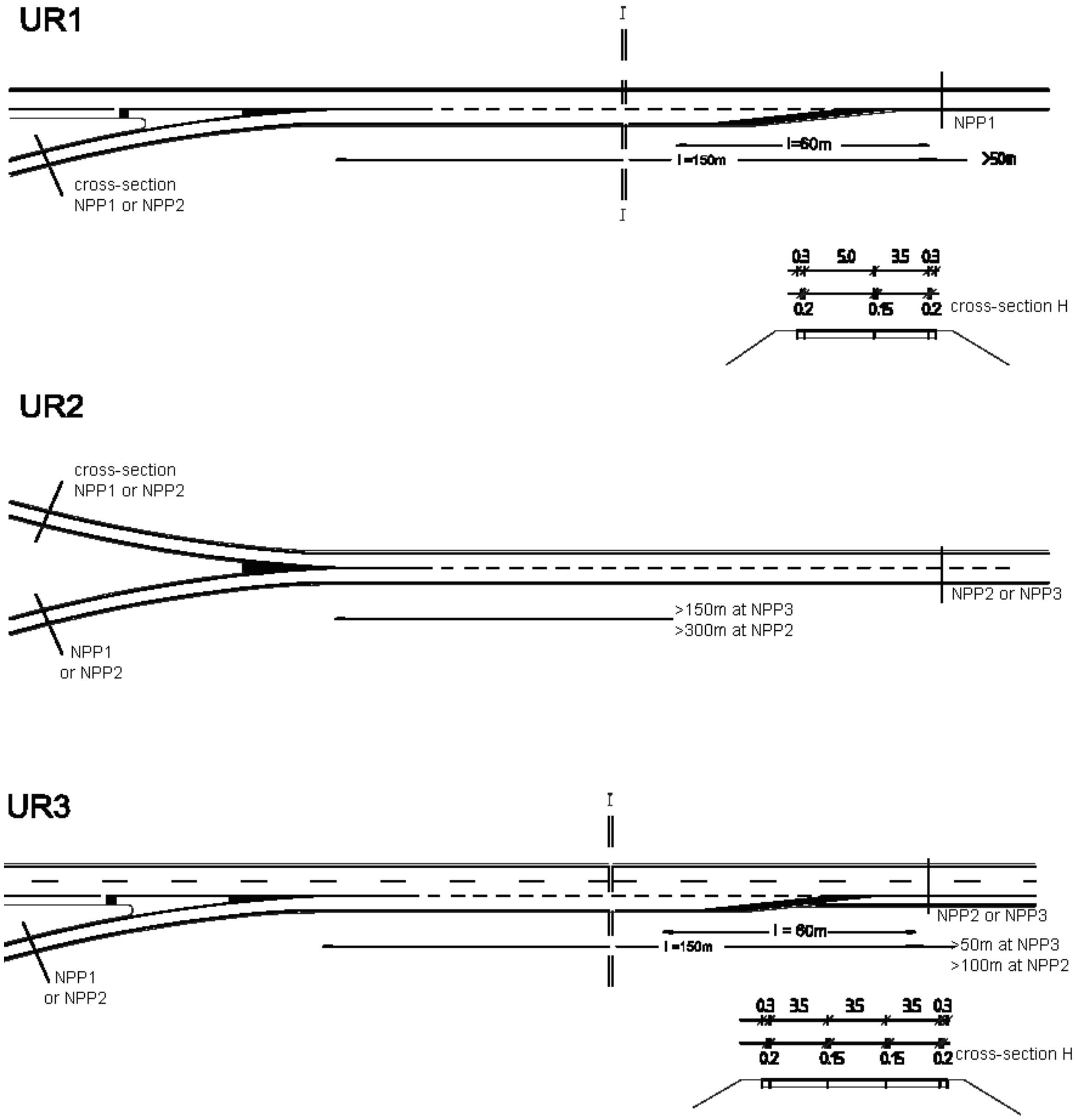


Figure 73: Types of entries onto ramps

2.6.4.3 Acceleration lane design

To the acceleration lane design the same rules, considerations, and forms as for the deceleration lane lengths (item 2.6.3.3) apply.

The lengths of acceleration lanes, as well as the execution of different types of entries are shown in Figures 69, 70, and 71.

Acceleration lanes are of the same width as the traffic lanes, along which they run. Road marking does not influence the cross-section width.

2.6.4.4 Dividing island design

At entries, dividing islands must not be filled up with visual obstacles such as structures, traffic signs, etc. By conducting the edges of the entry and the closure surface, a dividing island shall be so designed as to achieve a due identification capability of the entry, and observing of traffic on the motorway in the side mirror as son as possible. The dividing island measures 1.50 m in width. It shall only be rounded off (by r = 0.75 m), when it is carried out with raised kerbs.

2.6.5 Interweaving lanes

2.6.5.1 Interweaving lanes along main direction

Interweaving lanes along the main direction may be foreseen exceptionally only: in cases where, due to an insufficient distance between two consecutive points of access the problem cannot be solved in no other way, or in case of cloverleaves where turning traffic flows are insignificant in comparison with those in main directions, etc. In such cases it shall be verified, whether the required traffic operations can be signalled timely and sufficiently, as well as if, due to interweaving, disturbances to traffic flow capacity and safety occur in the main direction.

Where such lanes are shorter than 500 m, vehicle speed in the main direction shall be reduced to 80 – 100 km/h. Stopping lanes at the interweaving lanes are not required, however, shoulders reaching up to the safety barrier shall be foreseen. Their width shall amount to 2.0 m, which satisfies indispensable needs.

2.6.5.2 Interweaving lanes along ramps

Interweaving lanes at ramps are generally foreseen in case of cloverleaves. The execution is indicated in Fig. 74.

After the point where an interweaving lane is connected to the dividing ramp, a length of 50 – 80 m for a parallel drive of interweaving vehicles shall be foreseen (uninterrupted line). Then, a pure interweaving length of 250 m minimum follows. In this way, a total interweaving length of at least 300 m is achieved. Such an execution ensures sufficient quality of the traffic flow up to a total volume of 1,900 vehicles per hour. Values to be introduced for an assessment of the traffic flow quality are indicated in Fig. 75.

Where either the length or the traffic loading requires a dividing ramp of NPP2 or NPP3 cross-sections, then an interweaving lane shall be attached to this ramp as shown in Fig. 38. In case that the entire width is not available for any restrictions, the interweaving lane is preferential comparing to the two-lane dividing ramp

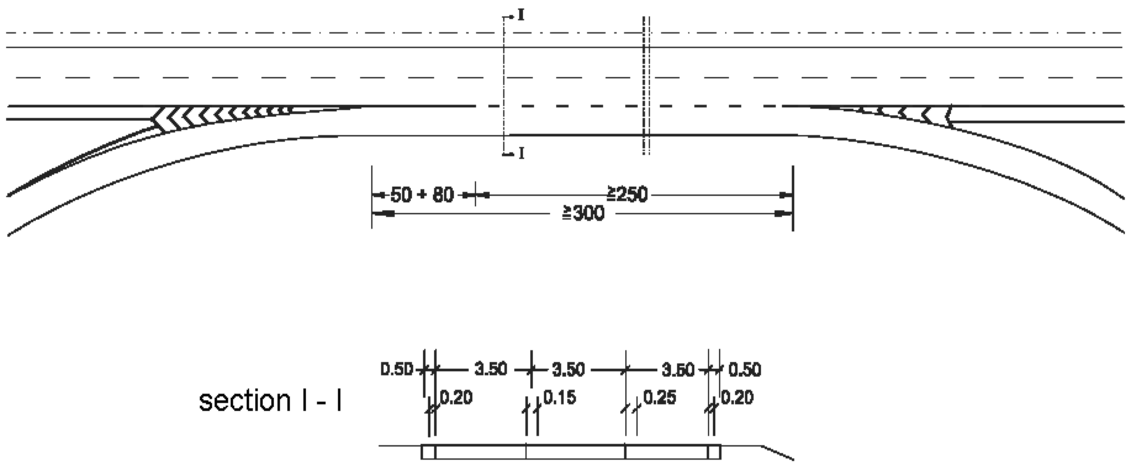


Figure 74: Execution of interweaving lanes at ramps

2.6.6 Points of access of ramps to subordinate roads

Points of access of ramps to a subordinate road shall be carried out in compliance with the rules, which apply to crossroads at grade. Special variations of execution only occur in case of proximity of two points of access, which shall be mutually combined. The following examples show proposals of execution of characteristic points of access (Figs. 75 – 80).

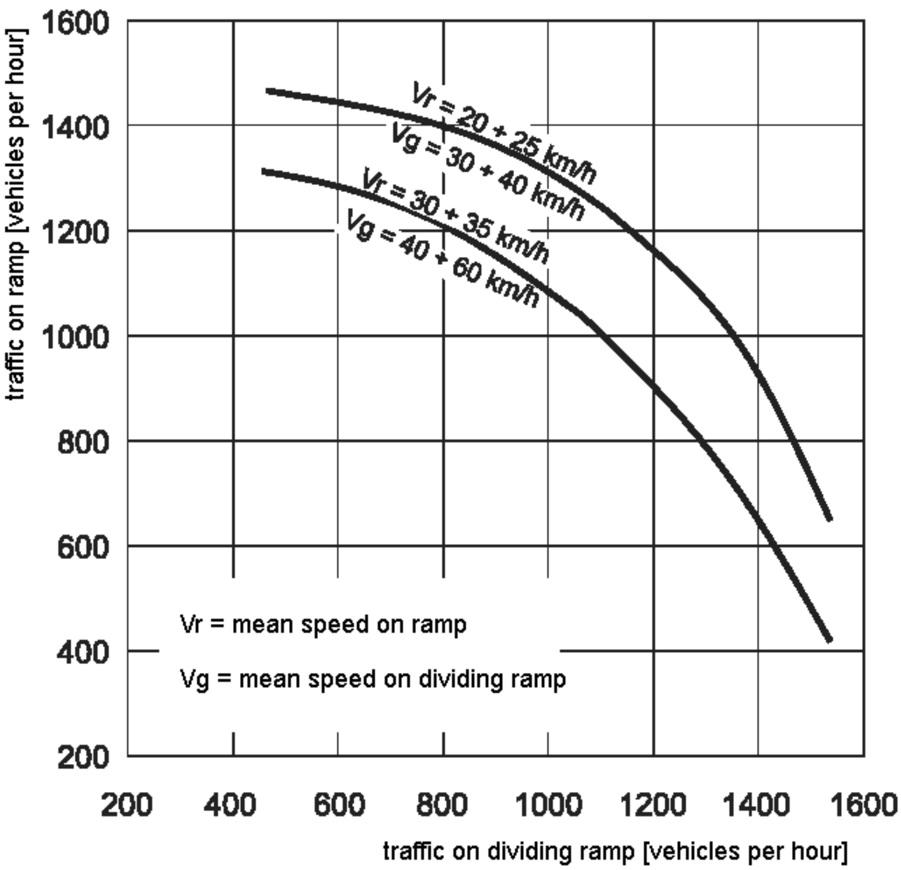


Figure 75: Traffic flow quality on the interweaving lane as a function of traffic flow intensity

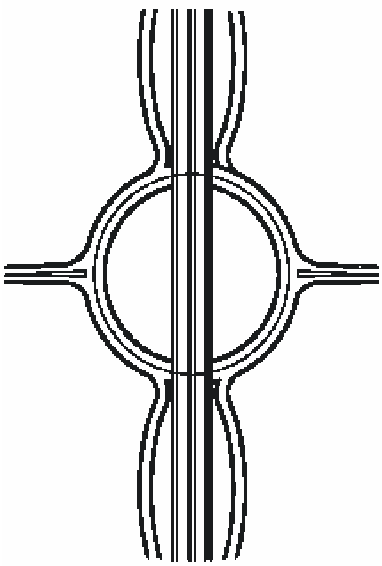


Figure 76: Execution of points of access at a roundabout (refer also to Fig. 59)

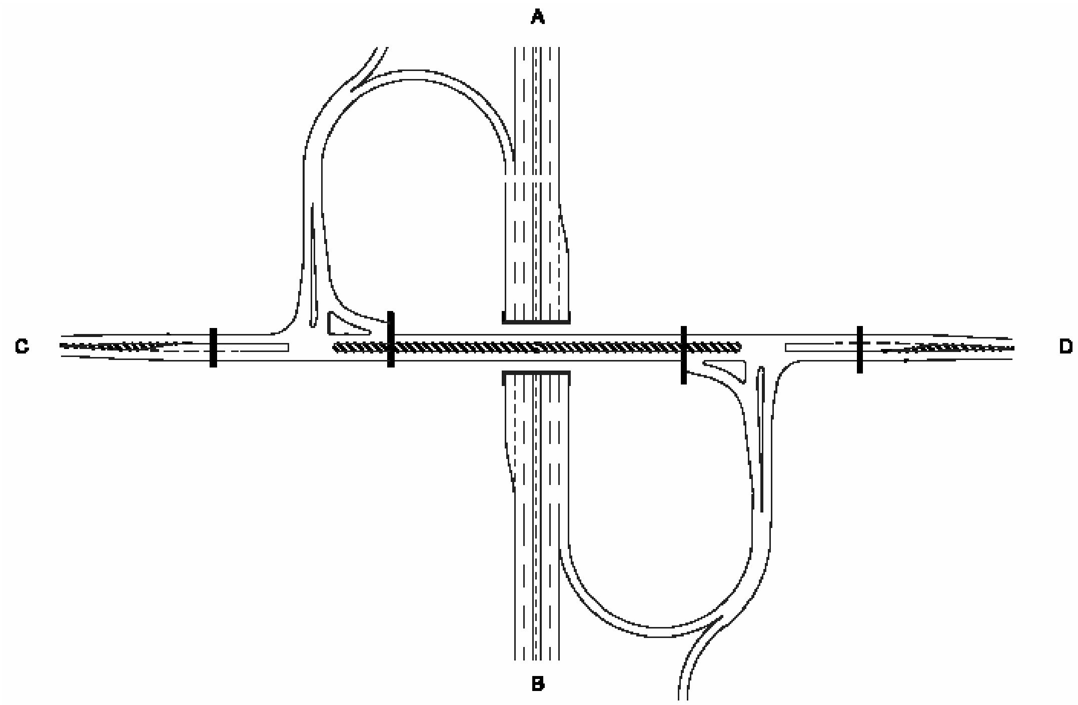


Figure 77: Execution of points of access on a subordinate road (road of lower ranking) at an unsymmetrical semi-cloverleaf, with outer lanes for vehicles turning left (refer also to Fig. 53)

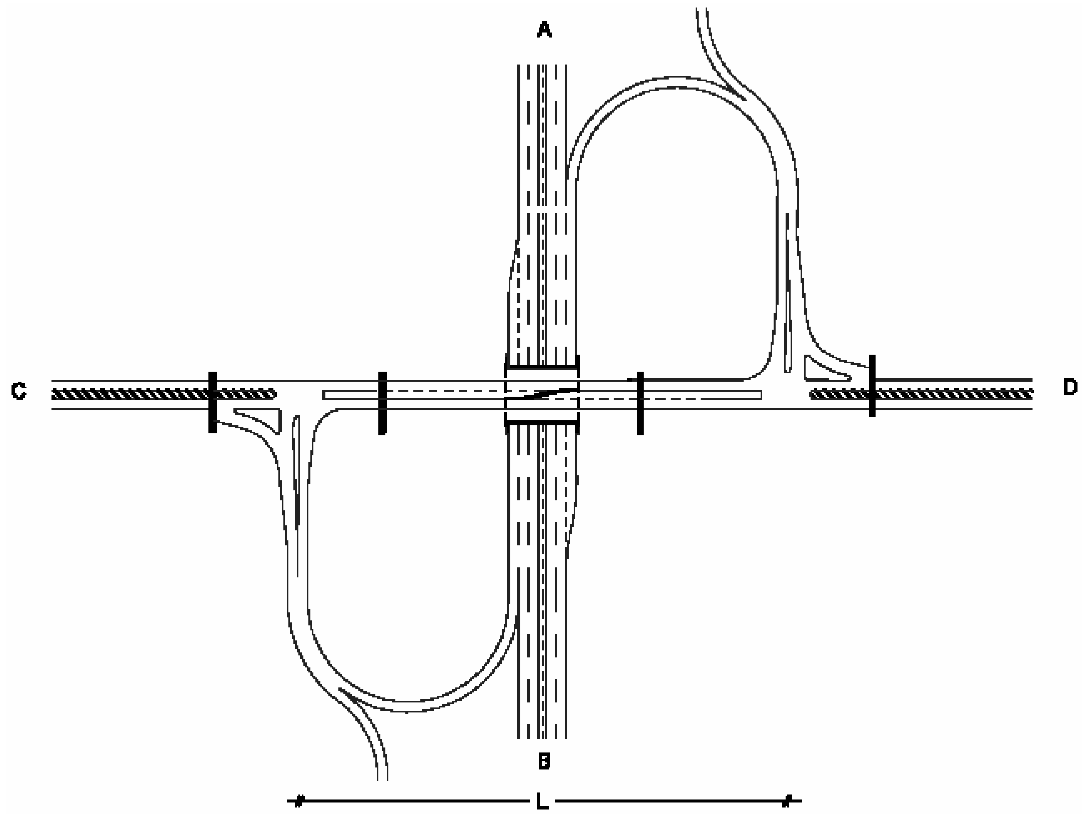


Figure 78: Execution of points of access on a subordinate road at an unsymmetrical semi-cloverleaf, with inner lanes for vehicles turning left; these lanes can be either successive or parallel (refer also to Figs. 18 and 19). The distance between crossroads depends on the required lengths of left - turning lanes.

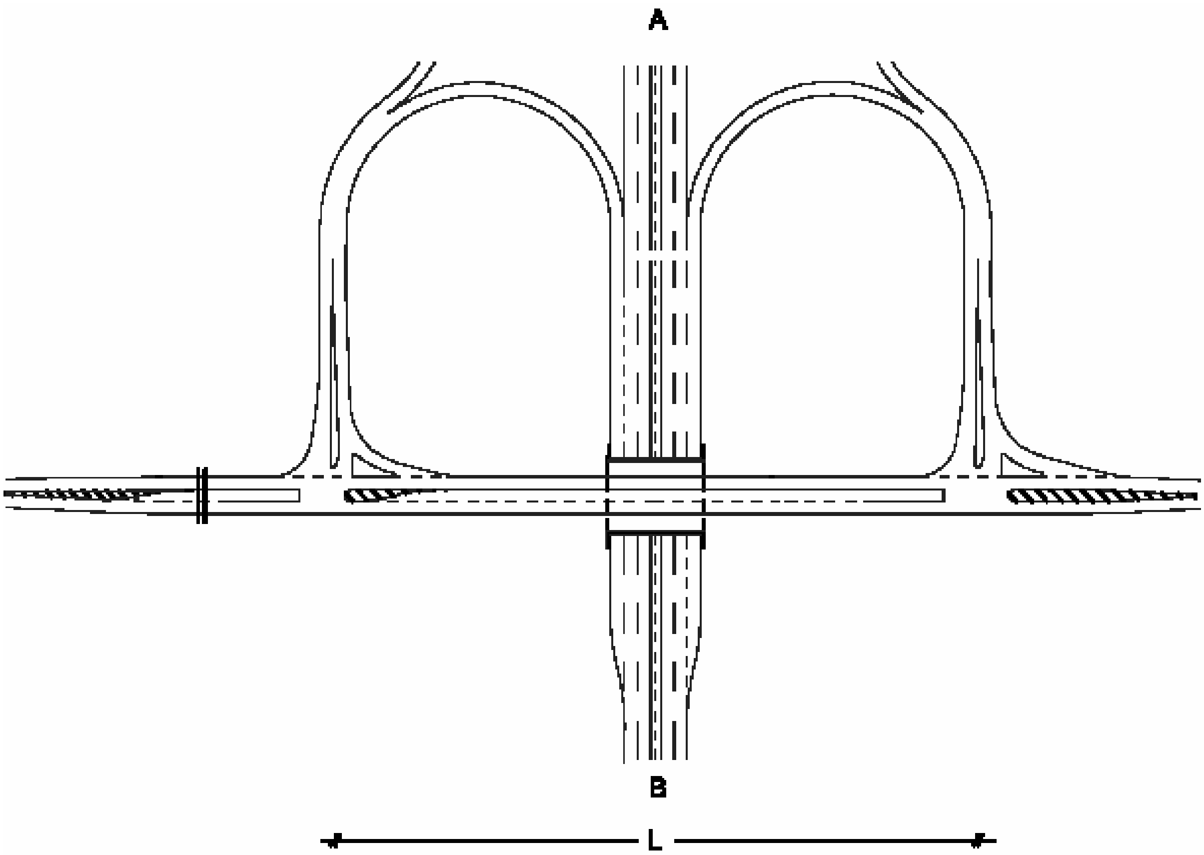


Figure 79: Execution of points of access on a subordinate road at a symmetrical semi-cloverleaf (refer also to Fig. 56)

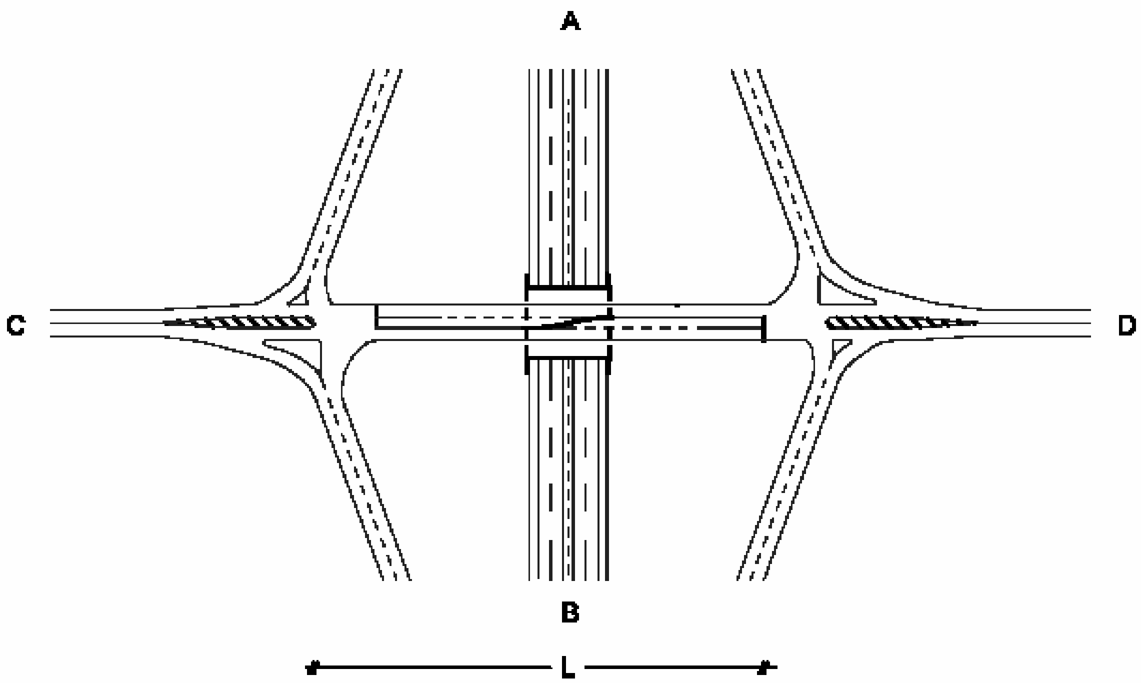


Figure 80: Execution of points of access at a rhombus with inner lanes for vehicles turning left. These lanes can be either successive or parallel (refer also to Figs. 21 and 22). In place of canalized crossroads, roundabouts can be foreseen.

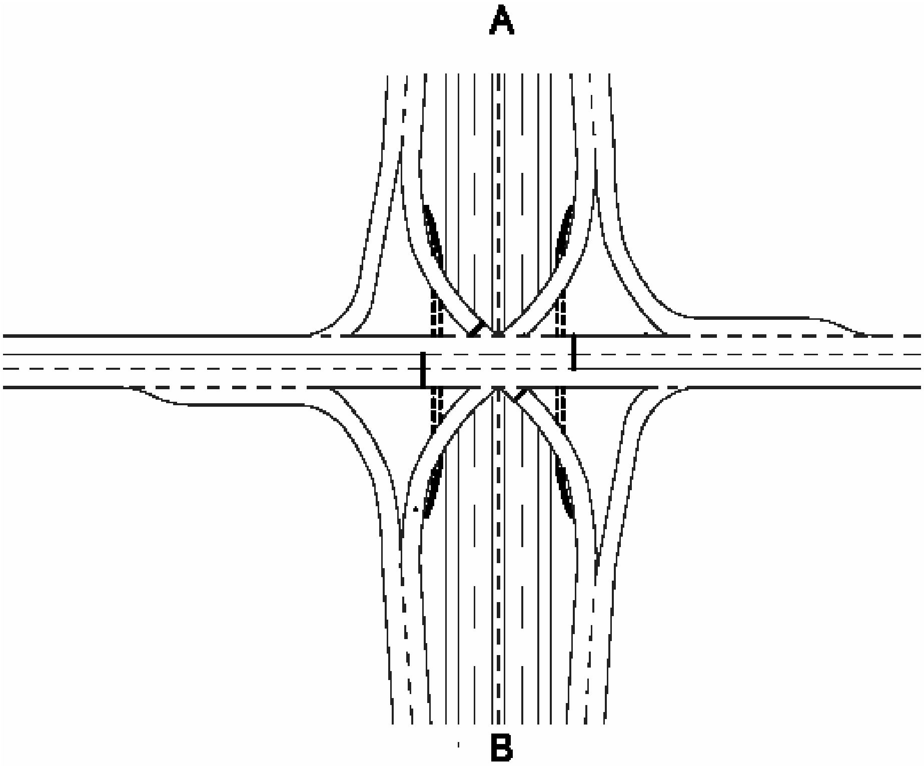


Figure 81: Execution of points of access at a rhombus with outer lanes for vehicles turning left (refer also to Fig. 60)

2.6.7 Sight distances

2.6.7.1 General

In split-level interchanges and junctions all the requirements in view of the sight distance apply particularly to the individual constituent parts: entries, exits, interweaving lanes, and minimum elements suddenly appearing on ramps due to restricting conditions.

Basically, the Rulebook for road design, and its provisions relating to sight distances, shall be considered.

At entries, all the traffic signs, and the entries themselves shall be visible from a distance of at least 180 m. At dividing points within the ramps this distance may be reduced to 100 m.

On the ramp alignments special attention shall be paid to minimum horizontal and vertical elements. The latter shall be recognizable at sufficient distance, so that the drivers can adjust the driving mode. In case of small radii it is optically favourable, if the further course of the ramp after the particular minimum element is visible as well.

On the complete ramp at least the stopping sight distance shall be ensured.

In the entry area, the entering sight distance shall be ensured from the entry island to the acceleration lane end. This sight distance is a safety sight distance. To achieve the highest possible capacity of an entry, the approaching sight distance shall be ensured.

For the control of the upper sight distances, a height of 1.0 m is assumed as the height of the eyes of motorcar drivers. For vehicles, the height of 2.0 m shall be considered.

In the areas of points of access of ramps to a non-preferential road (crossroads at grade), the respective regulations for sight distances shall apply.

2.6.7.2 Entering sight distance

The entering sight distance shall be ensured to a driver, who is forced, for any reason, to stop his vehicle at the entry point or anywhere on the acceleration lane, in order to enter the preferential traffic lane or dividing ramp without any danger, and to equalize the speed with the speeds of vehicles driving on the traffic lane to which he is entering. Whenever possible, the entering sight distance shall be also ensured by a view in the side mirror. A sight distance control shall be performed for motorcars.

The sight distance chord in dependence on the vehicle speed in the main direction or on the ramp can be read from the graph indicated in Fig. 82.

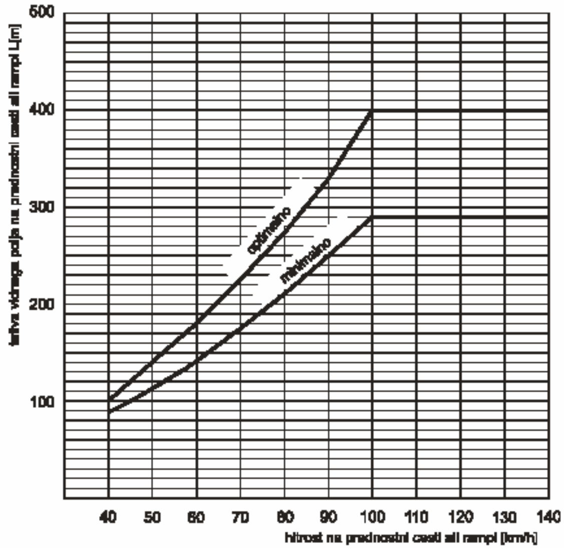


Figure 82: Chords of entering sight distance

When an entry is exceptionally situated at right curvature of either the main direction or the ramp, the field of vision for sufficient entering sight distances extends out of road profile. In Fig. 83, the ratio of the curvature radius of the main direction to the required height of segment is indicated, which ensures he required entering sight distance.

Special attention shall be paid to the entering sight distance at locations of convex vertical curvatures.

When a sufficient entering sight distance cannot be ensured for whatever reason, the speed in the main direction or on the ramp shall be limited by means of traffic signs.

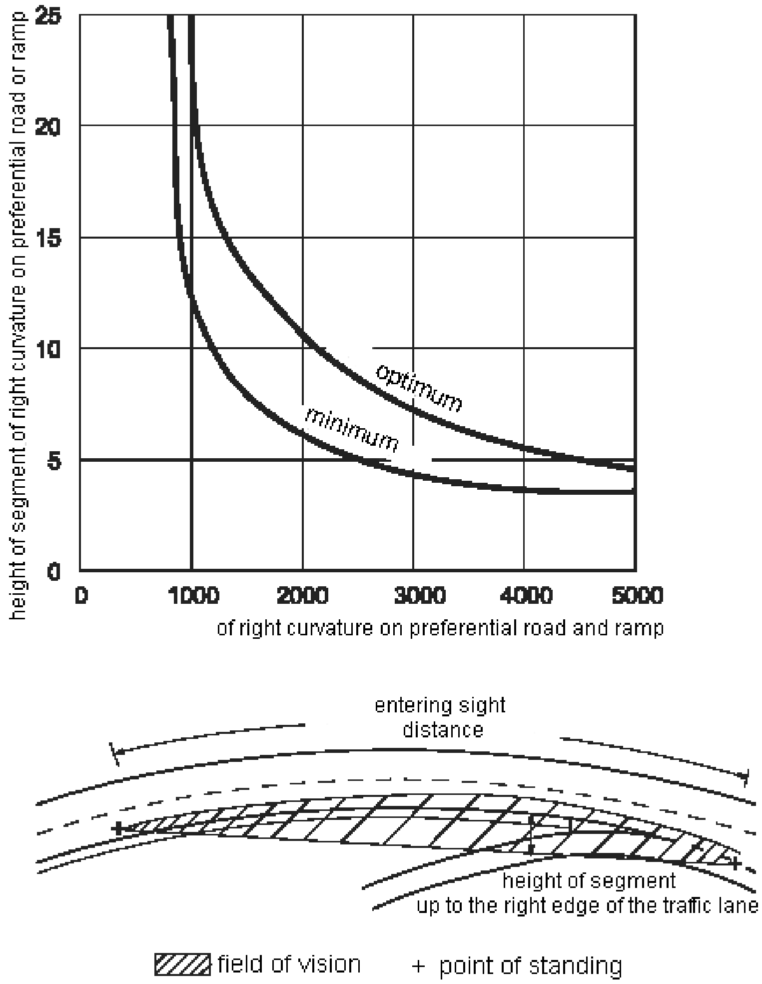


Figure 83: Required radii and heights of segments to ensure entering sight distance at right curvatures

2.6.7.3 Approaching sight distance

An approaching sight distance is a distance to be available to a vehicle approaching the entry to the main direction or the ramp. With regard to both horizontal alignment and vertical alignment course, it can be given either by a direct view on the main direction or the ramp, or, at a parallel course, by dint of the left side mirror on vehicles approaching the entry.

An approaching sight distance performs the following functions:

- it allows a vehicle approaching the entry to perceive, in due course, the preferential road or ramp, as well as the entering location;
- it enables an entering vehicle to assess, in due time, the traffic situation in the main direction or ramp, and to adjust the driving mode, especially the speed;
- it enables placing vertical traffic signs, and executing road marking on the pavement.

The required field of vision for the approaching sight distance is evident from the Fig. 48. This figure also indicated the minimum admissible field of vision.

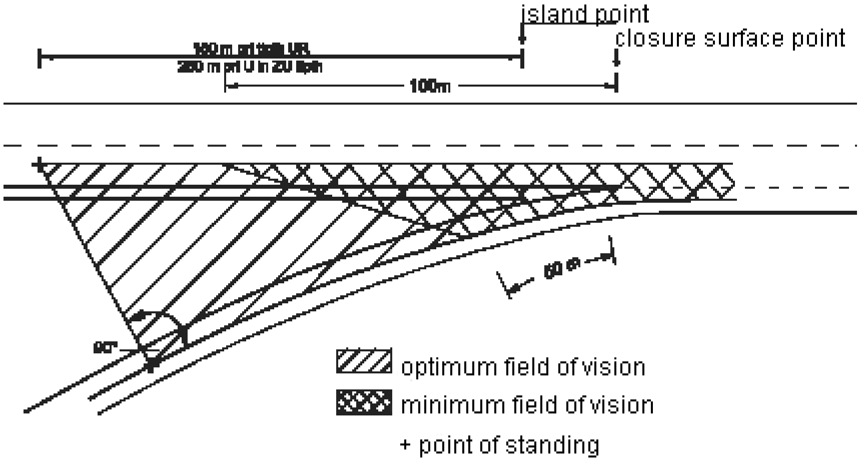


Figure 84: Optimum and minimum field of vision for approaching sight distance

When driving from an entry ramp onto a preferential road, a view at an angle of 90° shall be aspired. If this is not feasible, the point, behind which the sight distance shall be ensured, shall be moved towards the dividing island of the entry. When the angle to the point in the main direction exceeds 130°, the course of the entry ramp shall be modified in such a way that, first, the latter runs parallel with the main direction at the required length, and then, it is connected to the main direction at an angle of 3 to 5°. In this way, the approaching sight distance is ensured in the side mirror of a vehicle.

Minimum distances shall only be designed in cases, where other solutions are economically unjustified.

2.6.8 Split-level interchanges on two-lane roads

On two-lane roads of very intensive traffic flows and, usually, of high speeds as well, it is reasonable, in view of the traffic loading, to foresee a split-level interchange, if it can be reliably proven that no type of crossroads at grade is feasible.

When split-level interchanges are foreseen on two-lane roads, in addition to the right turning lanes, branching and connecting lanes shall be carried out as well, if the entries are located on an ascending section, or when they are connected to a preferential road of higher ranking at a very sharp angle. The lengths of such lanes shall amount to at least 150 m for speeds of v≥70km/h, and 250 m for speeds of v≥90km/h respectively.

To meet the traffic safety requirements it is particularly important to examine the overtaking conditions very closely. Namely, research works show that it is reasonable to prescribe and mark where overtaking is permitted, and where not in the split-level interchange area.

2.7 EQUIPMENT

2.7.1 Principles

Information on the equipment of a split-level interchange or junction are an indispensable constituent part of the crossroads design, as the driving behaviour required for traffic capacity and safety cannot be ensured solely by a suitable selection of elements of a split-level interchange or junction.

Taking account of the principles of the traffic technics, namely that design, construction, and use of the road traffic should be considered as a whole, a traffic equipment design shall be worked out parallel to the interchange or junction design.

2.7.2 Marking to direct the traffic

2.7.2.1 General

Traffic directional boards at a split-level interchange or fork shall ensure a due directing of the driver with regard to the geometrical characteristics of an interchange or a fork.

Both adding and taking away of traffic lanes represent peculiarities in the field of traffic directing.

Boards shall be placed at sufficient distance from the announced situation; they shall also comprise the information on this distance (additional board).

Boards with signs to direct the traffic are not urgently necessary for dividing the traffic flows, on condition that the reduction of the traffic lane number is indicated by means of arrows on safety posts. On interweaving lanes longer than 500 m, boards shall be placed (adding the traffic lanes).

2.7.2.2 Adding traffic lanes

Adding of traffic lanes shall be marked with boards when an interweaving traffic lane runs at the main direction lane at a length of at least 500 m.

2.7.2.3 End of traffic lane

Where a multiple-lane road is narrowed by one traffic lane, boards shall be placed indicating the beginning of the narrowing, and an additional board indicating the distance up to this narrowing shall be provided as well.

2.7.2.4 Lighting of split-level interchanges and junctions

Lighting of split-level crossroads shall only be foreseen, when a crossroads is situated in an urban area, and when such roads are united at the crossroads, which are already equipped with adequate lighting.

2.7.2.5 Landscaping of split-level interchanges and junctions

At all the stages of a split-level crossroads design, appropriate landscaping shall be considered as well, and impacts the split-level interchange of fork on the cultural landscape of broader area shall be verified.

2.7.2.6 Drainage of split-level interchanges and junctions

Due to special conditions resulting from speed changes, frequent drive direction changes, changing the traffic lanes, accelerating, and braking, it is of particular importance that the elements of an interchange are so designed as to prevent occurrence of aquaplaning.

Drainage of slopes of cuts and fills, as well as of areas close to the fills, and particularly of surfaces within individual ramps of split-level interchanges and junctions shall be carried out according to drainage principles applying to open road sections. Basically, the simpler the drainage type, the most effective and the most suitable for maintenance it is. Usually, for very different geometrical situations occurring at split-level interchanges and junctions, almost all known drainage systems shall be combined.

3 ROUNDABOUTS

3.1 AREA OF APPLICATION

This guideline defines the policies regarding project-technical design of roundabouts on public roads.

It covers the use of roundabouts, the method for acquiring data for calculating the capacity, the method for calculation and dimensioning, the impacts of individual construction elements in traffic, the influence of cyclists and pedestrians on the throughput of a roundabout as well as traffic elements of roundabouts, representing a comprehensive whole.

This guideline deals only with those types of roundabouts which are most common in practice:

- roundabouts with outer diameter (inscribed circle diameter) of less than 100 m,
- roundabouts not controlled by traffic lights,
- roundabouts with maximum three lanes in circular flow.

Roundabouts with mountable central island, roundabouts with drivable central island (double roundabouts) and roundabouts with outer diameter exceeding 100 m are not dealt with in this guideline.

3.2 DEFINITIONS

Roundabout is a channellised circular intersection with non-mountable, partly mountable or drivable central island and a circulatory roadway tying three or more legs over which the traffic streams counter clockwise.

Single-lane roundabout is a roundabout with a single incoming/outgoing lane and a single-lane roadway.

Multi-lane roundabout is a roundabout with one or more lanes at entries/exits, with part of the circulatory roadway or the entire circulatory roadway shaped as a multi-lane roadway.

Circulatory roadway is a circulatory roadway driven by vehicles around the central island counter clockwise. The vehicles entering the roundabout yield to the vehicles in the circular flow.

Central island is a raised physical obstacle of circular or oval shape, placed in the centre of the roundabout. It prevents straight-through driving and limits the roundabout on the inner side.

Mountable part of the central island (apron) is that portion of the central island, which together with the circulatory roadway enables long vehicles to drive through the roundabout. It is distinguished from the circulatory roadway by material used and colour.

Outer diameter (inscribed circle diameter) is the diameter of the outer (largest) circle of the roundabout, i.e. the diameter between the outer edges of the circulatory roadway.

Inner diameter

is the diameter of the central island, i.e. between the inner edges of the circulatory roadway.

Roundabout legs are the incoming roads or lanes on both sides of a raised island or the island marked only by ground markings designated for pedestrians, which lead the contrary or same directional traffic (entry - exit) to/from the roundabout.

Entry is the area of the roundabout where the incoming lane enters the roundabout and is separated from it by the yield line (separation line). The entry can be funnel-shaped (flared) or with parallel edges. In this area vehicles have to slow down or stop until there is sufficient gap between vehicles in the circular flow, allowing them to enter the roundabout.

Exit is the area where vehicles exit the roundabout.

Number of lanes The number of lanes at the point where every leg enters the roundabout and the number of lanes within the roundabout are the basic parameters used for calculating the throughput of a roundabout.

The number of entry lanes and the lanes within the circulatory roadway provides the basis for the basic classification of roundabouts - single-lane and multi-lane.

If a circular segment - section of circular flow between two successive approaches - or the entire circulatory roadway is double- or multi-lane, the roundabout is referred to as double- or multi-lane.

Incoming traffic flow comprises vehicles entering the roundabout (Fig. 85).

Outgoing traffic flow comprises vehicles exiting the roundabout (Fig. 85).

Circular traffic flow or circling traffic flow comprises vehicles circling on the lanes around the central island (Fig. 85).

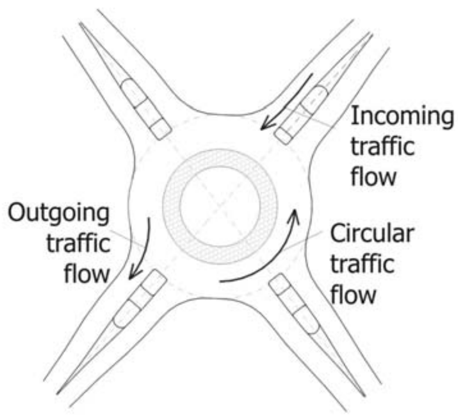


Figure 85: Roundabout flows

Waiting bay is the area between the inner edge of the marked pedestrian or bicycle crossing and the outer edge of the circulatory roadway. It is used by vehicles waiting for an acceptable critical gap between vehicles travelling in the circular flow.

Entry radius is the radius of the right edge of the roadway at the entry to the roundabout, directing vehicles towards the roadway.

Exit radius is the radius of the right edge of the roadway at the exit from the roundabout, directing vehicles from the roadway.

Splitter island - pedestrian refuge is a raised element of a roundabout, separating the incoming and outgoing traffic, navigating vehicles to properly enter and exit the roundabout and ensuring greater traffic safety for pedestrians and cyclists crossing a roundabout leg.

The shape of the splitter island depends on the size of the roundabout (triangular or drop-like).

Entry width (e) is the width of the funnel-shaped entry (Fig. 86); it is measured at a right angle, from the entry radius to the intersection between the extended right edge of the pedestrian refuge and ground markings indicating the outer edge of circulatory roadway.

Width of the lane (v) is the width of the approach lane before the roundabout (Fig. 86).

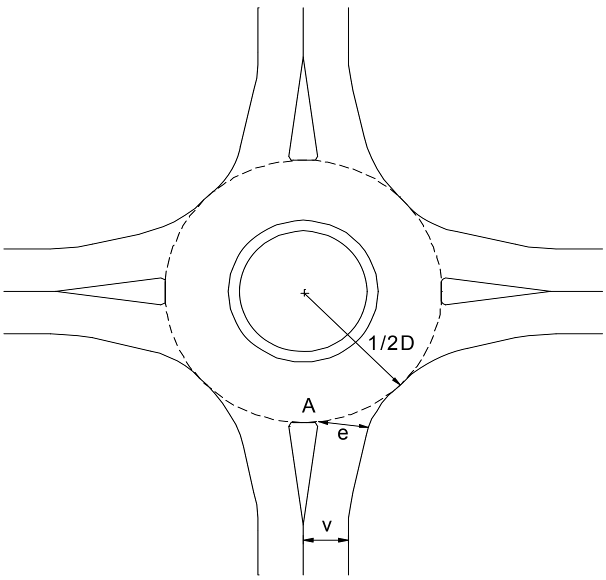


Figure 86 The entry width (e) and the width of the approach lane (v)

Average effective flare length (l') is the average length of the widened section at the entry to the roundabout (Fig. 2.3). If there is no flare at the entry, the right edge of the roadway at the entry follows the GFD line, while the entry width is the same as the width of the roadway. BA is the line perpendicular to the entry curve and has the length e. The length of the BD line is e-v and that of the BC line (e-v)/2. The average effective flare length is CF, its distance from the right edge of the roadway being (e-v)/2. The CF value (distance), which equals l', is called the average effective flare length.

Sharpness (rate) of flare is defined by the relationship S=1.6(e-v)/l' (Fig. 2.3). It is a measure of the rate at which extra width is developed in the entry flare - from v do e - along the average effective flare length l'**.**

Large values correspond to short severe flares. Small values represent long gradual flares.

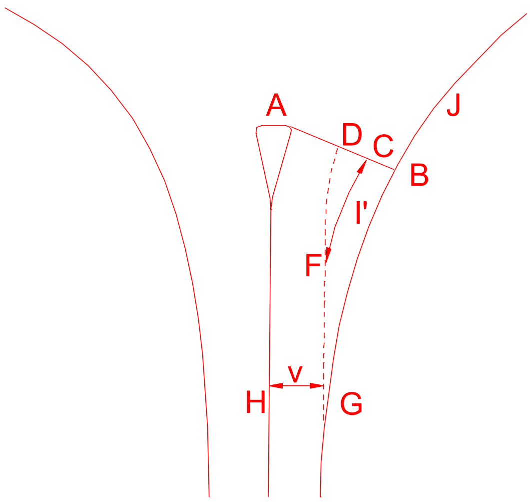


Figure 87: Average effective flare length

Entry angle (Φ) is the angle determined by the tangents on the central line of the incoming lane and the circulatory roadway at the point where the central line of the incoming lane intersects with the outer radius of the roundabout or at the point where the extension of the first tangent intersects with the median line of the circulatory roadway.

In practice there may be two examples, depending on the length of the circular segment between two successive entries.

First example: great length of the circular segment (Fig. 88)

The BC line is a tangent to the EF curve (the median line of the roadway at the entry) at the point where the EF curve intersects with the outer radius of the roundabout. The angle Φ is the angle between BC and the tangent to the median line of the circulatory roadway at the point where BC intersects with A'D'.

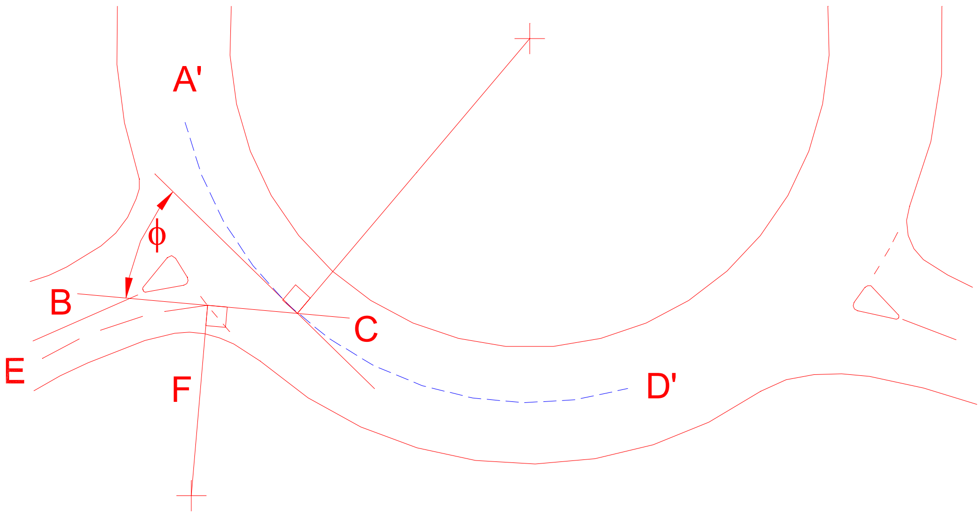


Figure 88: Great length of the circular segment

Second example: small length of the circular segment (Fig. 89)

The BC line is identical as in the case of great length of the circular segment. The GH line is the tangent to the JK curve, which is the median line of the roadway at the exit. The GH tangent is at the point where the median line of the roadway at the exit intersects with the outer radius of the roundabout. L is the point of intersection between BC and GH. BLH forms the angle 2Φ. Half angle is the angle Φ.

The basic elements of a roundabout are presented in Figure 90.

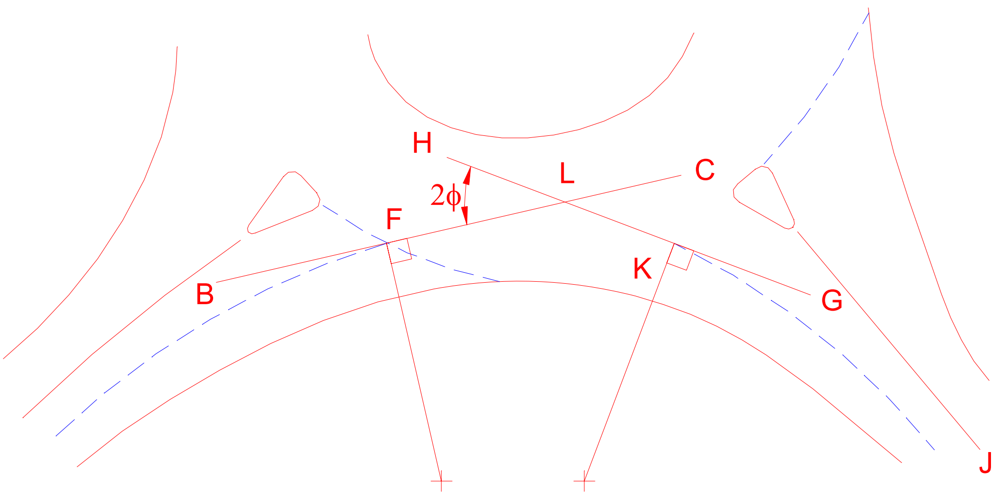


Figure 89: Small length of the circular segment

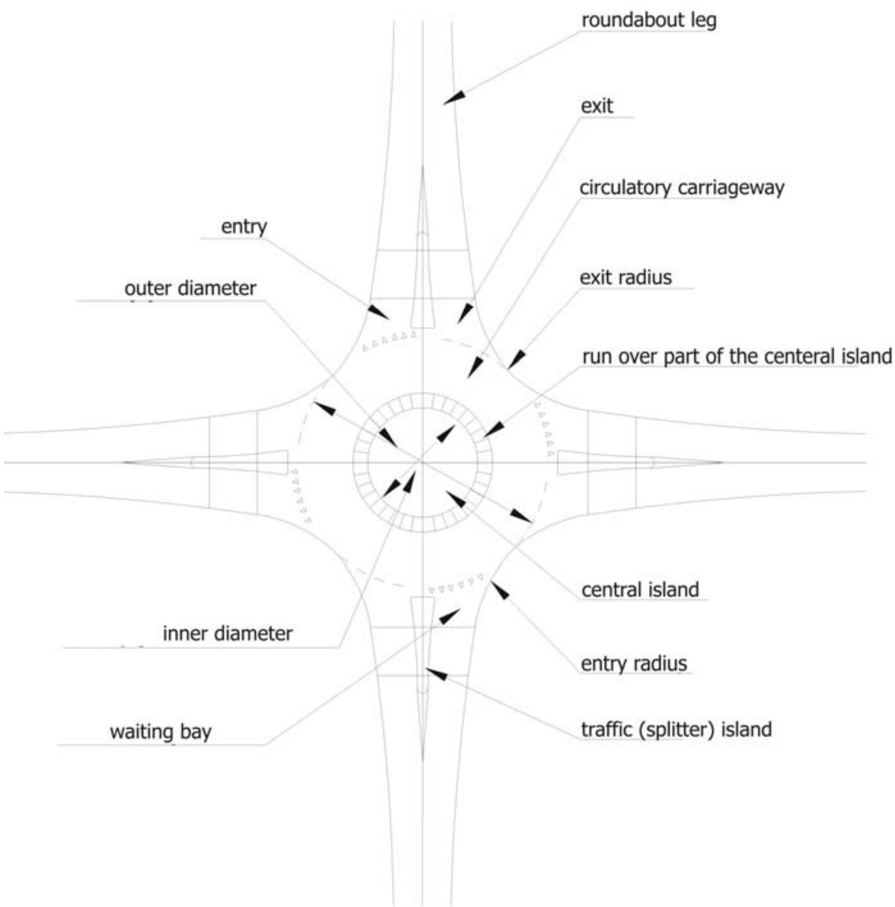


Figure 90: Basic elements of a roundabout

3.3 MARKINGS, ACRONYMS AND SYMBOLS

Q_C	circular traffic flow before an entry (*PCE/h*)
Q_E	entry traffic flow (*PCE/h*)
F, f_C	geometry dependent factors
e	entry width (*m*)
v	lane width prior to entry (*m*)
l′	flare length (*m*)
D	outer diameter of the roundabout (*m*)
R	entry radius (*m*)
F	entry angle (°)
L	entry capacity [PCE/h]
M_K	traffic volume of circulatory roadway (at the y point of conflict) [PCE/h]
M_A	exit traffic volume [EOV/h]
a	entry geometric factor
b	factor - the number of lanes within the circle
C	factor - the number of lanes at entry
FB	circulatory roadway width
φ	half central angle between the points of conflict
T	the length of the splitter island [m]
W	the width of the splitter island [m]
Z	approach width [m]

α half acute angle of the splitter island [°]

A volume at entry [%]

M_E traffic flow volume at entry

L approach capacity

3.4 CHARACTERISTICS OF ROUNDABOUTS

3.4.1 Special features of roundabouts

Special features of roundabouts which distinguish them from classic crossroads at grade are

- roundabouts are crossroads with a combination of continuous and interrupted traffic flow,
- vehicles entering a roundabout yield to the vehicles in the circular flow (the "Yield to the Right Rule" does not apply in roundabouts),
- the vehicle entering a roundabout does not stop if the roundabout is free, but enters the circular flow at reduced speed,
- small roundabouts in urban areas enable only low speed traffic with front vehicle wheels turned at a large angle,
- pedestrians and cyclists in roundabouts are subject to the same rules as in classic crossroads,
- reverse driving is prohibited (and unnecessary) in roundabouts,
- long vehicles are allowed to use also the non-asphalted (paved) part of the circulatory roadway (mountable part of the central island); small vehicles have no need for this.

3.4.2 Advantages and disadvantages

The advantages of roundabouts in comparison to classic crossings at grade are mainly the following:

- great traffic safety (less points of conflict than in the case of classic crossings at grade, elimination of points of conflict at intersection, impossible to drive through a roundabout without reducing speed, etc.);
- the possibility of high traffic volume;
- shorter queues (continuous traffic);
- less noise and emission of toxic gases;
- less space needed (as for crossings at grade with separate lanes for turning vehicles;
- at equal capacity);
- good crossing solution in case the traffic flow on the main and side traffic route is approximately equal;
- good solution for multi-ways crossroads (five or more);
- less severe consequences of traffic accidents (no head-on collision and collision at a right angle);
- smaller maintenance expenses (compared to traffic light controlled crossroads);
- good traffic calming solution in urban areas;
- aesthetic value.

The disadvantages of the roundabouts are the following:

- the more lanes are within a roundabout, the poorer is traffic safety (contrary to classic crossings at grade);
- successive roundabouts do not enable synchronisation ("green wave");

- problems with the lack of space for central island in built-up areas;
- roundabout traffic cannot be directed by traffic police;
- roundabouts are not recommended in front of institutions for the blind and sight- and hearing-impaired, old people's homes, hospitals and health centres as well as all other locations where non-motorised traffic participants due to temporary or permanent disadvantages cannot safely cross the road without light signalling devices;
- large roundabouts are not recommended in front of kindergartens and schools as well as other locations where there are many children;
- problems occur in the event of dense bicycle and pedestrian traffic crossing one or more legs of a single-lane roundabout;
- poor solution in the case of a strong flow of vehicles turning left;
- subsequent installation of traffic lights does not significantly influence the capacity.

In view of the above the suitability of constructing a roundabout has to be considered on a case by case basis. Roundabouts are thus suitable and recommended mainly at the following crossings:

- shaped like an X, Y, K (acute crossing angle);
- with a greater number of legs (five or more);
- if specially exposed to traffic accidents with grave consequences;
- if involving too high entry speed;
- where the conditions of driving change (e.g. at end points of fast road sections, at entry points to urban areas, at motorway exits);
- in the case of too high speed at the main traffic route, which disables safe entry of vehicles from a side traffic route;
- where there is no basis for traffic lights, but the traffic exceeds the capacity of crossroads not controlled by traffic lights;
- as traffic calming measure.

3.4.3 Traffic safety in roundabouts

3.4.3.1 Motor vehicle traffic

From the point of view of traffic safety the main advantage of single-lane roundabouts (compared to classic three- or four-ways crossroads) is the elimination of the conflict surface and points of conflict of the first (crossing), second (weaving) and third (accession, bifurcation) order (Fig. 91).

In theory, a classic four-ways crossroads has 32 points of conflict (16 crossings, 8 bifurcations and 8 mergings), while a single-lane four-leg roundabout has only 8 points of conflict of lower order (4 bifurcations and 4 mergings).

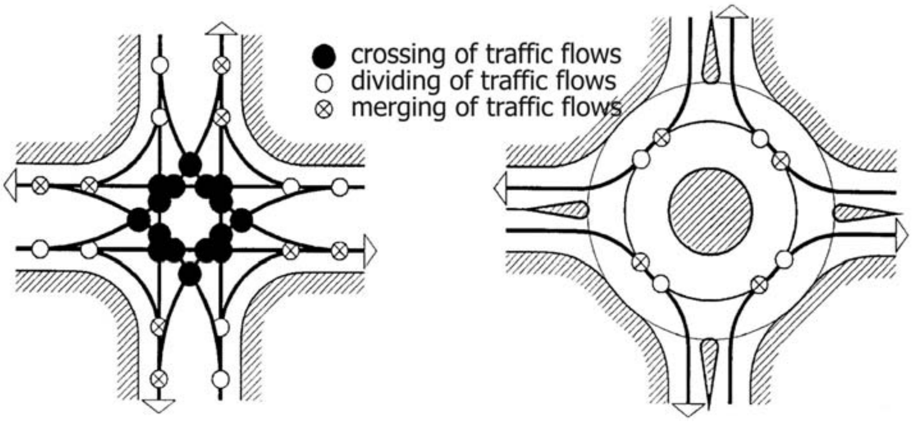


Figure 91: Points of conflict in a classic four-ways classic crossroads and four-leg roundabout

If the circulatory roadway consists of two lanes, the number of points of conflict increases by the number of conflict points of weaving, which is theoretically the same as the number of approach roads, yet still less than 32. The traffic safety level deteriorates quickly by introducing additional lanes (three or more).

From the practical aspect double- or multi-lane roundabouts do not involve only points of conflict but also sections of conflict, since nothing specifies where a driver should change lanes within a roundabout (Fig. 92). This is (in addition to usually higher permitted speed) also one of the main technical reasons as a result of which large roundabouts are less safe than small ones. The reason thus lies in the basic characteristic of large roundabouts.

Moreover there are a few types of accidents that occur in roundabouts, but not in classic crossroads (Fig. 93).

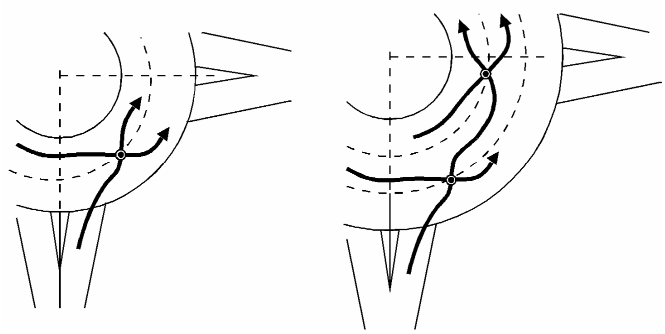
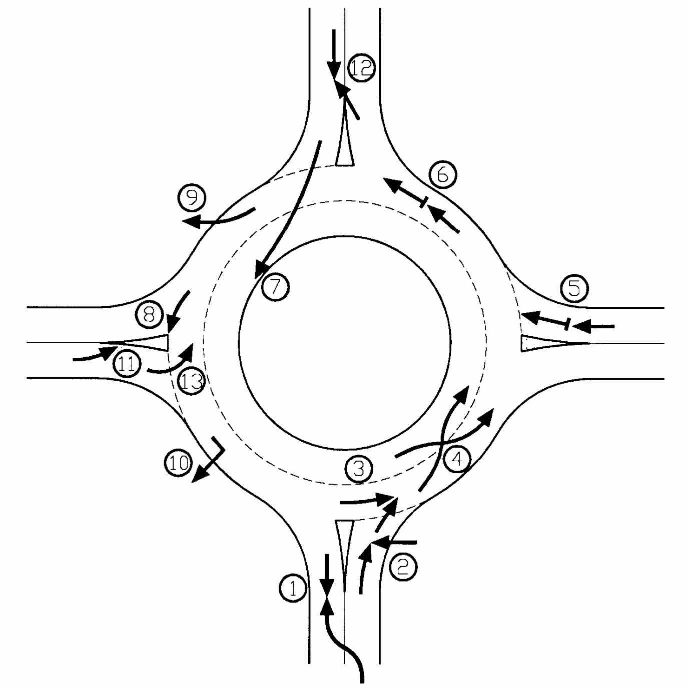


Figure 92: Point of conflict of weaving and the section of conflict



1. overtaking before the crossing
2. collision with a pedestrian/cyclist
3. collision at entry
4. collision while changing the lane
5. rear-end collision upon entry
6. rear-end collision upon exit
7. collision with the central island
8. collision with the splitter island at exit
9. skid from the roundabout

10. turnover
11. collision with the splitter island at entry
12. skidding at exit
13. driving in the opposite direction

Figure 93: Types of traffic accidents in a double-lane roundabout

Also, the consequences of traffic accidents in roundabouts are significantly different from those in classic crossroads. Above all, they are less grave and usually do not result in death and severe bodily injuries. This is due to the fact that there are no head-on collisions in roundabouts, which cause the most serious consequences. In roundabouts the vehicles are usually involved in lateral collisions, at an acute angle, or in rear-end collision.

The collisions between motor vehicles and cyclists (pedestrians) who are crossing a roundabout leg are the same as in the case of classic crossroads, only the consequences are somewhat less grave (on account of lower speed at entry and exit).

3.4.3.2 Pedestrians and cyclists

Traffic safety of pedestrians and cyclists depends mainly on proper vertical and horizontal signalisation and splitter islands as well as the method applied for controlling bicycle traffic in the roundabout zone.

In principle, there are two ways for routing bicycle traffic in the roundabout zone (Fig. 94):

- parallel routing of bicycle traffic (along the outer edge of the circulatory roadway) and
- independent routing (parallel to kerbs or in the form of a concentric circle)

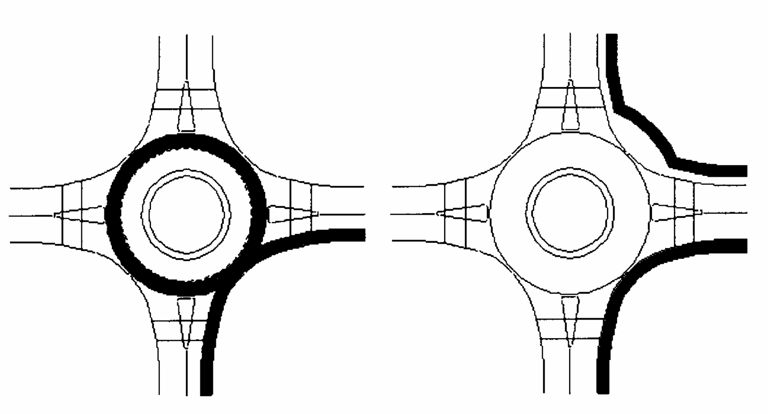


Figure 94: Two possible ways of routing bicycle traffic in the roundabout zone

Routing bicycle traffic in the roundabout zone using the independent method is safer. All crossings of motor traffic and pedestrians or cyclists have to be at a right angle, as a result of which the sight field of the crossing participants is of most correct shape. This also results in the fact that the only points of conflict are at crossings over the roundabout legs and even there the pedestrians and cyclists are (partly) protected by islands.

Routing bicycle traffic parallely is somewhat less safe (the exceptions being roundabouts with very low motor traffic volume), since a cyclist is in direct contact with the motorised traffic participants, i.e. on the same surface. To provide for better protection of cyclists, it is recommended that in such cases raised elements are installed in the extended area of the splitter islands.

In roundabouts outside urban areas cyclists have to be routed independently - separately, while in roundabouts in urban areas this method is recommended and the parallel method should be used only if the maximum permitted speed is 40 km/h and in restricted traffic zones.

When before a roundabout in an urban area, cyclists travel on the roadway, they should be provided a separate path in the roundabout zone.

One of the two methods of routing bicycle traffic in the roundabout zone in urban areas is chosen based on the volume and structure of motor traffic, the volume of bicycle flow and the position of the roundabout in the urban road network.

3.4.3.3 Measures for ensuring a safe roundabout in terms of traffic

After checking if the location and the position of the roundabout in the urban road network are suitable, the following has to be considered as much as possible, when a roundabout is designed:

leg alignment should be as perpendicular to the roundabout as possible (speed reduction, sight field of proper shape, etc.) Suitable entry of a vehicle into the circular flow is achieved by selecting the adequate entry radius (speed at entry to the roundabout is directly related to the entry radius). If the approach is tangential to the roundabout, the rule based on which vehicles in the circular flow have priority over the vehicles at the entry is not sensible, the speed at entry is high, sight is not provided to vehicles entering the roundabout and rear-end collisions may occur. Tangential alignment of outgoing lanes from the roundabout requires a lot of wheel turning and results in a large covered area (Fig. 95).

Therefore, the legs should be aligned as perpendicularly to the roundabout as possible. If possible, the extended axis of the roundabout legs should intersect at one point - the centre of the roundabout.

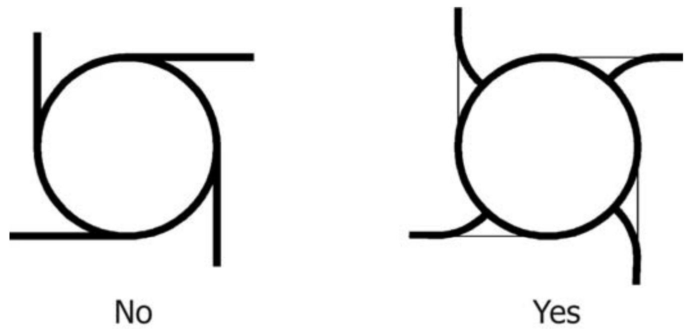


Figure 95: Roundabout leg alignment

the width of entry to the roundabout and flare length; the most dangerous manoeuvre in a roundabout is the entry, which is carried out on a relatively small area. For this reason its shape is very important, both for traffic safety (driving at minimum speed and shorter queuing until a gap enables a vehicle to enter the circular flow) and capacity (queuing time);

deflection of the path of a vehicle through a roundabout (Fig. 96) is one of the elements with the strongest impact on the traffic safety of a roundabout. The curvature has to be shaped like a double S curve, comprised of three radii, the size of which has to be mutually co-ordinated. The tighter the curves, the lower the speed at entry and the greater the traffic safety of the roundabout. The deflection can be influenced in two ways:

- by changing the size of the central island (more favourable, yet in practice often infeasible),
- by the shape of splitter islands (less favourable, but more frequently feasible).

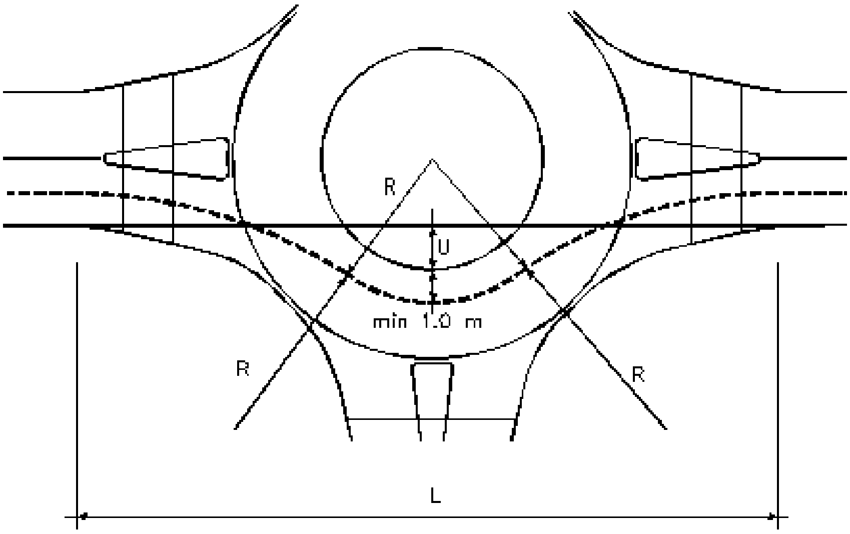


Figure 96: Deflection of the path of a vehicle through a roundabout

As the outer edge of the lane at the entry and exit from the roundabout is designed, the general rules for designing road axis and edges have to be complied with**.**

entry and exit radii; the size of exit radii depends on the size of the roundabout, the number of lanes within the circular flow and the shape of the central island (cone or funnel).

The size of the exit radii has to be always greater than that of entry radii, only exceptionally it may be equal.

In the case of small single-lane roundabouts (8m ≤ Rn ≤ 14.5 m) and medium-sized roundabouts (14.5 m ≤ Rn ≤ 21 m) with cone-shaped central islands the exit radius should be 12 m or 15 m.

In the case of large single-lane roundabouts (21 m ≤ Rn ≤ 31 m) with cone-shaped central islands the exit radius should be 15 m.

In the case of large single-lane roundabouts (21 m ≤ Rn ≤ 31 m) with funnel-shaped central islands the exit radius may be from 15 m to 18 m.

In the case of large multi-lane roundabouts with funnel-shaped central islands the exit radius may be from 12 m to 21 m, depending on the size of the roundabout and the desired speed (30 or 40 km/h).

pedestrian and cyclist crossings have to be placed outside the roundabout by the length of one to two vehicles (waiting bay). The length of that area depends on the size of the roundabout and the size (length) of the central island.

The minimum length of the waiting bay should be 4.5 m and the maximum 10 m. These values correspond to one or two passenger vehicles or one long vehicle.

As the waiting bay is provided, the traffic safety of non-motorised traffic participants improves and the throughput of the roundabout increases, since cyclists and pedestrians represent a lesser obstacle to the vehicles entering the circular flow;

splitter islands should be adjusted to the size of the roundabout: in the case of large roundabouts splitter islands should be shaped like a triangle and in the case of small roundabouts of a drop-like shape (Fig. 97).

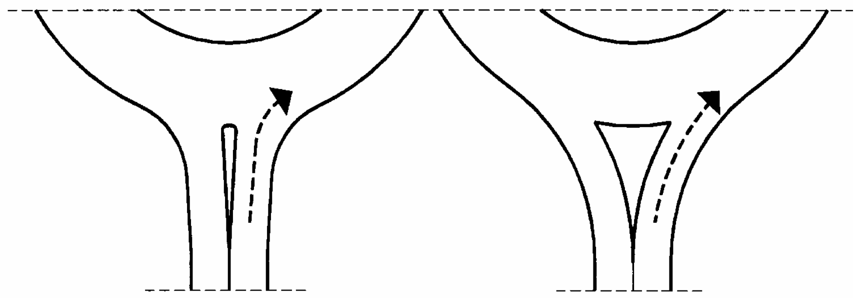


Figure 97: The shape of a splitter island depending on the size of the roundabout (small roundabout = drop, large roundabout = triangle)

drainage of a roundabout; the outward cross fall of the circular lane is more common, since it is more easily provided between the points of access and the circular lane and the drainage is simpler also. The weaknesses of the outward (negative) cross fall are reflected by decreased tyre-ground (roadway) adhesion coefficient (rain, slippery ice, etc.), as it is not sufficient for assuming the centrifugal force affecting the vehicle in the circular flow.

In view of the above, the stability of a vehicle in large roundabouts (which enable driving in the circular flow at high speed) has to be checked in such cases. The inward cross fall of a circular lane is (from the technical aspect) more correct, yet proper implementation of access point drainage and screwing is much more demanding.

the drive over part of the central island has to be provided so as to avert vehicles from driving over it (course grain material, paved), and at the same time enable long vehicle to navigate the roundabout.

It is included only in small and medium-sized roundabouts, 1 - 2 m wide (depending on the size of the inner radius).

It is reasonable to raise the contact line between the central island and the circular roadway (2-3 cm).

illumination of the roundabout conditions the traffic safety of a roundabout at night. In the case of roundabouts it is important that all entries are lit and, if possible, also the central island is illuminated.

speed control of driving through the roundabout is the main piece of information based on which traffic safety level is estimated. Lower speed of motor traffic leads to calmer traffic flow, in which case more attention can be devoted to other traffic participants, while at the same time the possibility of traffic accidents resulting in grave consequences is reduced.

The criterion to be complied with is that at flat transition (half of a circle) speed should be below 30 km/h or 35 km/h. Control should be provided by elements shown in Figure 3.6 and two equations stated below in this chapter.

Prior to control, two elements have to be specified.

The first element is the length L between the start of curvature (deflection) at entry and the end of curvature at exit. L depends on the size of curvature radii and the outer radius of the roundabout.

The second element is U (deflection), which represents the distance between the edge of the central island and the right edge of the roadway at exit (measured at the start of the curvature).

Greater U (greater central island radius) has a greater impact on speed control than the length L (in the case of tighter curvature). In order to achieve the same impact the L has to be decreased much more than U increased (approximate ratio equals 8).

At the same time, the passability by long vehicles is more improved due to greater curvature (deflection) radii than in the case of smaller central island radius, which does not lead to speed reduction impact for passenger vehicles in the circular flow. Greater curvature (deflection) radii lead to greater throughput at the exit and thus faster outgoing traffic.

The radius of the driveline deflection equals:

$$R = \frac{(0.25 * L)^2 + (0.5 * (U + 2))^2}{U + 2}$$

Good solutions are those which result in the R value between 22 and 23 m.

In the case of small driveline deflection radius, the connection between the speed of passing through the roundabout and the driveline radius is the following:

$$V = 7.4 * \sqrt{R}$$

with V [km/h] and R [m].

In the case of good solutions the speed at which a roundabout is driven is 30 km/h. If in small roundabouts the result is higher than 35 km/h, project elements have to be corrected. After each change of a project element, the effect of that change has to be re-examined.

If any of the above stated measures for ensuring a safe roundabout cannot be implemented, the deviation from such measure has to be specifically justified.

3.4.3.4 Underpasses and overpasses as a measure aimed at improving traffic safety of pedestrians and cyclists

In roundabouts with two or more incoming lanes (high capacity - large roundabout - high expected speed), a grade crossing for pedestrians and cyclists is not recommended.

In such cases it has to be checked and grounds provided proving that it is reasonable to design an underpass or overpass, depending on the volume and structure of motor traffic, the number and structure of pedestrians and the position of the roundabout in the road network.

The other possibility is the introduction of light warning signs.

It is not reasonable to install traffic lights at pedestrian crossings of new roundabouts.

3.5 ROUNDABOUT CATEGORIES

3.5.1 Classification of roundabouts according to location and size

In general, roundabouts may be divided by location and size into the following groups:

Type of a roundabout	Outer diameter [m]	Approximate capacity [veh./day]
Mini urban	14 - 25	10,000
Small urban	22 - 35	15,000
Medium-sized urban	30 - 40	20,000
Medium-sized (single-lane) rural	35 - 45	22,000
Medium-sized (double-lane) rural	40 - 70	-
Large rural	> 70	-

Note: Capacities are only approximate values for four-leg roundabouts with equal distribution of traffic flows. The table includes only informative values; when concrete problems are being solved, every roundabout has to be examined in terms of the actual traffic flows and used project-technical elements.

<u>Urban roundabouts:</u>

Mini roundabout

Installation in dense urban areas with the aim of traffic calming. The expected speed of vehicles is up to 25 km/h. Cyclists are routed using the parallel method (along the outer edge of the circulatory roadway). Due to small dimensions of mini roundabouts the splitter islands are preconstructed and of the size smaller than the minimum permitted for small and medium-sized roundabouts. In comparison to a classic crossroads not controlled by traffic lights a mini roundabout as a rule has higher capacity and provides considerably greater safety of traffic participants at low costs.

Designing of such roundabouts requires a special approach.

Mini roundabouts are not dealt with in this guideline.

Small roundabout

These roundabouts are usually installed only in urban areas. The expected speed at small roundabouts is below 30 km/h. In the case of most busy small roundabouts it is recommended that raised bicycle paths are provided. Such roundabouts are often placed at entries to smaller settlements, since besides warning the drivers that the driving conditions are about to change, they also offer unlimited possibilities of landscaping and architectonic design.

Medium-sized roundabout

In principle, they are installed at more busy intersections in urban environment. Project-technical elements have to be selected so as to ensure that the speed of vehicles does not exceed 40 km/h. Great stress is laid on the routing of pedestrian and bicycle traffic, separated from the roadway by elevation. Splitter islands enable sufficient space for protecting the cyclists between lanes at entry/exit.

<u>Rural roundabouts:</u>

Medium-sized roundabout

They are installed outside urban centres, where the number of expected pedestrians and cyclists is low. They are designed so as to enable maximum throughput of approaches given adequate traffic safety (maximum speed is 40 km/h).

Medium-sized double-lane roundabout

In principal, they are installed outside urban centres where the traffic is heavy.

Large roundabouts

These are installed exceptionally, usually at motorway approaches to a town. Designing of these roundabouts requires a special approach. The bicycle and pedestrian traffic is managed separately and is not included in the roundabouts of this type.

Large roundabouts are not dealt with in this guideline.

3.5.2 Categorisation of roundabouts by purpose

Roundabouts are divided into three basic types by purpose:

- roundabouts calming traffic

installed in urban and transitional areas

- roundabouts restricting traffic

installed in urban areas with the aim of restricting traffic and by suitable geometric elements ensuring maximum permissible or prescribed capacity

- roundabouts aimed to provide maximum capacity at acceptable safety level

only outside urban areas.

3.5.3 Categorisation of roundabouts by the number of legs

Roundabouts are divided by the number of legs as follows:

- three-leg,

- four-leg,
- five- or more leg, etc.

3.5.4 Categorisation of roundabouts by the number of lanes

Roundabouts are divided by the number of lanes within a circulatory roadway as follows:

- single-lane roundabouts,
- double-lane roundabouts,
- multi-lane roundabouts.

The number of lanes within a circulatory roadway has to be at least equal to the number of a roundabout incoming and outgoing lanes.

The number of lanes within the circular flow is limited to three maximum.

A good compromise between the throughput and safety of a roundabout are two lanes within a circular flow.

3.5.5 Categorisation of roundabouts by individual approach alignment

- **At grade**

In case the legs of the roundabout are aligned at grade, there are two ways of routing approaches:

- approaches routed into the roundabout and
- approaches routed past the roundabout (directly) (Fig 4.3)

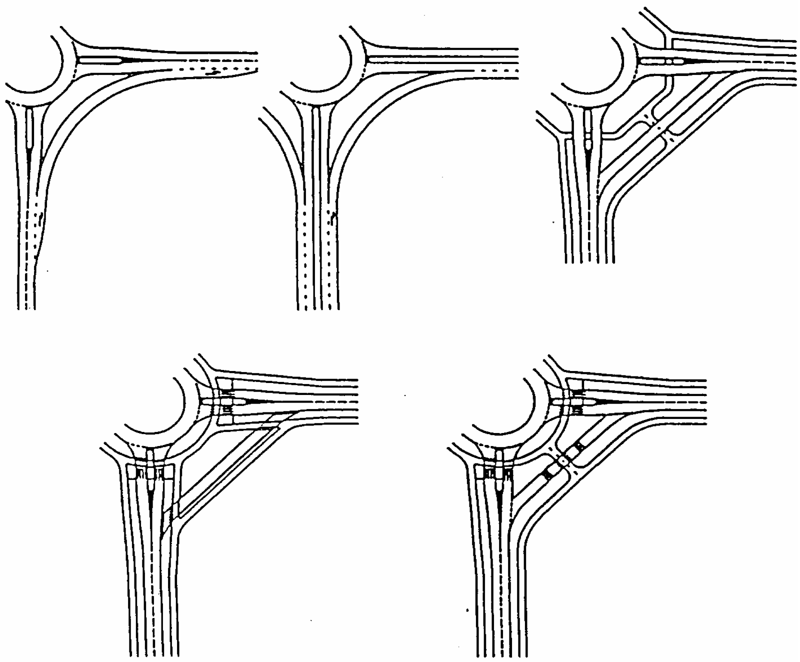


Figure 98: Approaches routed past the roundabout (directly)

3.5.5.1 Grade separated

In the case of off-grade alignment of roundabout legs (e.g. instead of a diamond) two main types of roundabouts are distinguished:

- one large (Fig. 99)
- two small (Fig. 100)

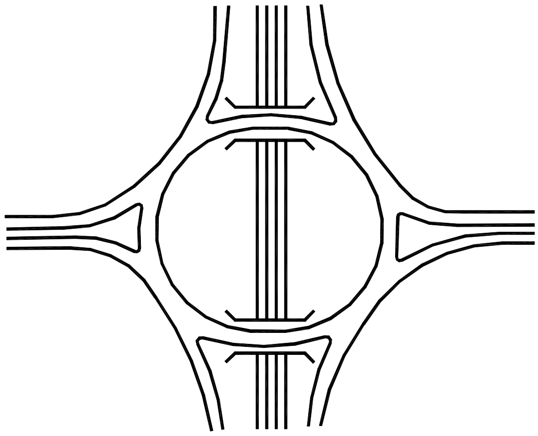


Figure 99: One large

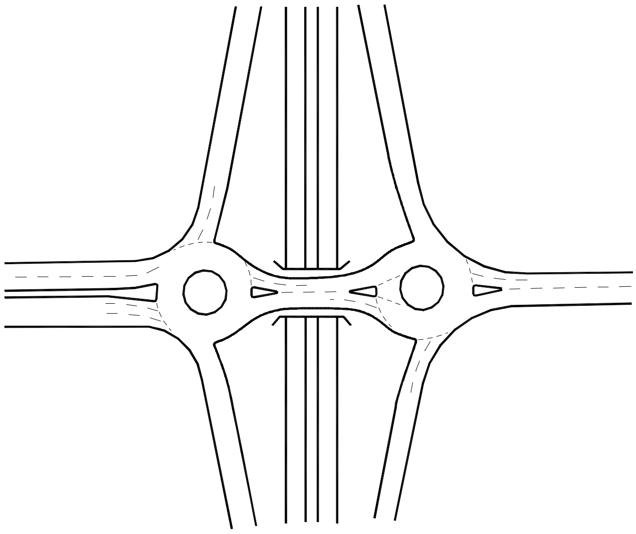


Figure 100: Two small

3.6 ROUNDABOUT CAPACITY

3.6.1 General

The throughput of every new or reconstructed roundabout has to be checked.

It can be calculated in two ways.

The first is iterative (a recommended shape - dimension - of roundabout that was selected based on spatial, urban planning and/or other criteria is checked). Based on the capacity calculation the dimensions of project elements may be changed, until the calculation results indicate sufficient throughput at the end of the planning period.

The second calculation method is to seek optimal project elements, taking into account the known traffic volume, so as to ensure sufficient throughput. This is followed by spatial, urban planning and/or other verification.

As the throughput of a new roundabout is to be determined, the expected traffic volume at the end of the planning period has to be considered. The calculations have to be made for peak volume, expressed in percentage of average daily traffic. The percentage is specified based on known data about the changes in traffic volume in the relevant area.

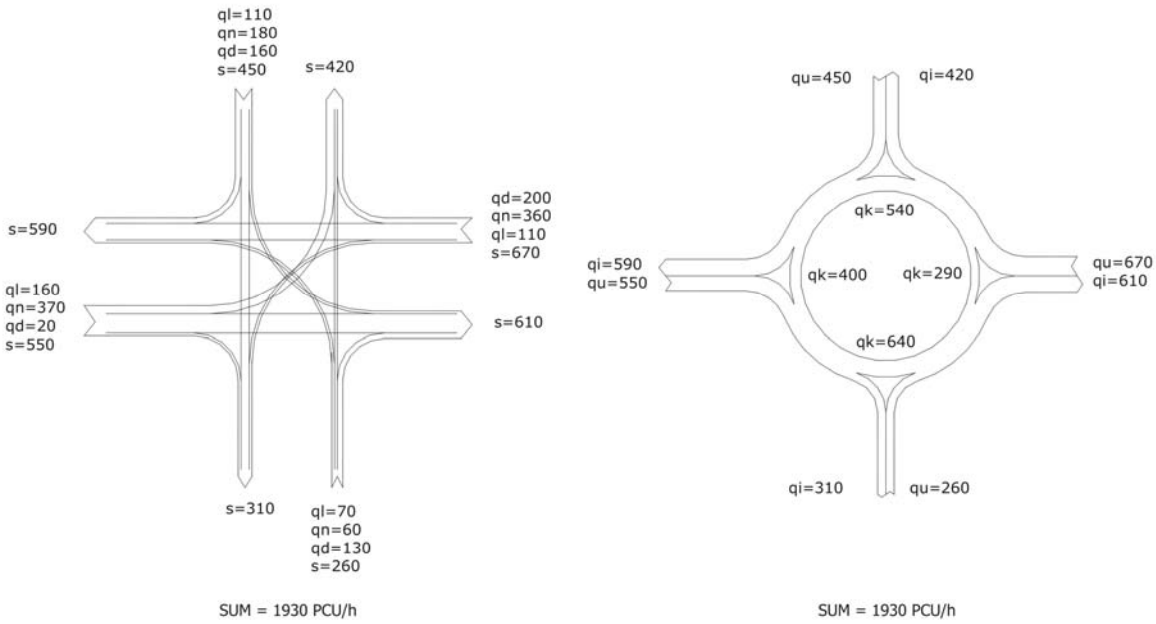


Figure 101: Example of converting the traffic volume of a classic four-ways crossroads to that of a four-leg roundabout

In the event the existing crossroads is reconstructed into a roundabout, the calculation of throughput has to be made for two or more peak levels (at least for the morning and afternoon peak hour volumes). Also in this case the planned increase in traffic volume until the end of the planning period has to be considered.

Unlike new roundabouts the reconstruction of a traditional (classic) crossroads into a roundabout requires also the conversion of traffic volume from that of a classic crossroads to that of a roundabout (Fig. 5.1).

3.6.2 The notion of the roundabout capacity

The roundabout capacity C tells us how many vehicles drive through a roundabout within a given time unit.

It is calculated as the sum of throughput of all entries Q_{Ei} into the roundabout.

$$C = \sum_{1}^{n} Q_{Ei}$$, n - the number of entries

The throughput of the entry Q_E determines how many vehicles enter the roundabout through one entry within a given time unit.

$$Q_E = f\,(Q_C, \text{geometry}),$$

where Q_C is the circular traffic flow.

The results of the comparative research of the existing roundabouts in Slovenia showed that the Australian and Austrian (Swiss) methods were in almost all cases the closest to the actual throughput values.

The results of the calculation using the German method were in all instances smaller than the actual values of throughput at entries to the roundabouts (even by more than 50%), which is why we do not recommend this method.

The results obtained by applying the English method fall somewhere between the Swiss, Australian and German method, which is why in view of the parameters used for the calculation of capacity this method is suitable for setting optimal geometric elements of roundabouts. If the English method is used, a comparative calculation using the Austrian or Australian method has to be made.

The most suitable for calibration to the Slovene circumstances are the Austrian and Australian method. One of these two methods should be selected based on the size of the roundabout and/or availability of a suitable computer tool for the calculation:

- In the case of more complex roundabouts, where in addition to the calculation of capacity the delays, the number of stops and the queue length are calculated as well, the calculation is made using the non-linear Australian method. The use of computer programmes is recommended.
- For small and medium-sized roundabouts the Austrian calculation method is sufficient.

The methods are described in greater detail below.

3.6.3 Austrian method

Before deciding on the adequacy of a roundabout location an estimate has to be made about the suitability of the roundabout implementation using the diagram included in Figure 5.2.

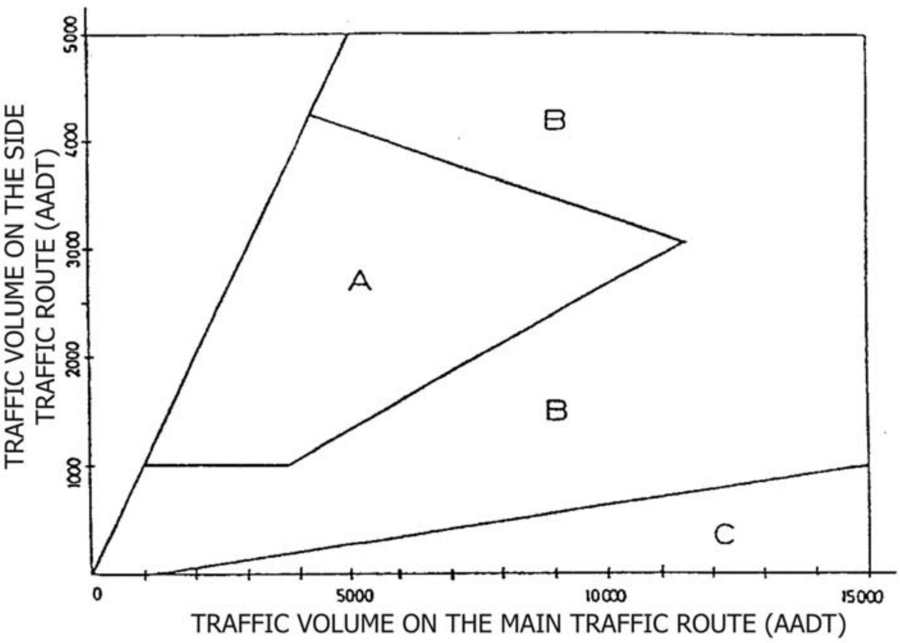


Figure 102: Area where roundabout implementation is adequate

3.6.3.1 5.3.1 Establishing the capacity using the calibrated Austrian method

Since the capacity of a roundabout depends on the capacity of entries to the circulatory roadway, the capacity of each entry has to be established. The following equation is used for establishing entry capacity:

$$L = 1500 - 8/9 * (b * M_K + a * M_A) \text{ [PCE/h]}$$

Zone A: Recommended implementation of the roundabout

Zone B: Adequacy of the implementation of the roundabout has to be checked:
- compared to a classic crossing at grade (lower area)
- compared to an off-grade crossing (upper area)

Zone C: Recommended implementation of classic or roundabout crossing at grade

where:

L entry capacity [PCE/h]

M_K circulating flow

(at the y point of conflict) [PCE/h]

M_A exiting volume [PCE/h]

a entry geometric factor

b factor - the number of lanes within the circle

Geometric factor a is determined in relation to the distance B between the points of conflict x and y (Fig. 103). In the case of a single-lane entry to a roundabout the distance B is calculated as follows (Fig. 5.3):

$$B = \frac{(D - FB) * \pi * \varphi}{180} \quad [m]$$

where:

D outer diameter of the roundabout [m]

FB the width of the circulatory roadway [m]

φ half central angle between the points of conflict [°]

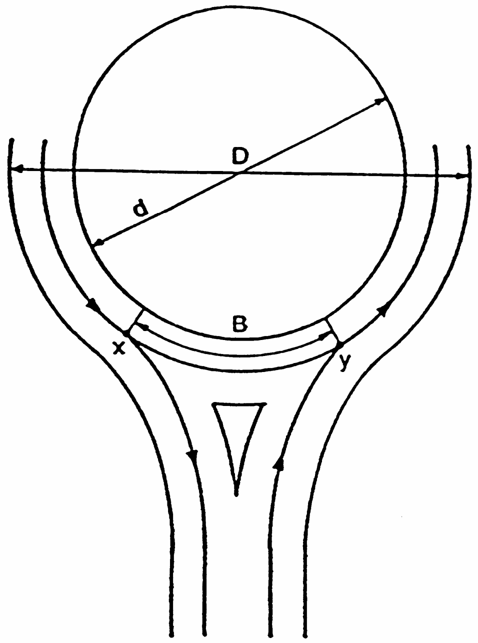


Figure 103: Relevant distance B between the points of conflict x and y

The central angle between the points of conflict depends on the geometric design of the roundabout (Fig. 104):

$$\sin \varphi = \frac{B'}{(D - FB)} \quad [rad]$$

$$B' = \frac{(T + FB/2 + Z/2 * \sin \alpha) * W}{T} \quad [m]$$

where:

T the length of the splitter island [m]

W the width of the splitter island [m]

Z the entry width [m]

α half acute angle of the splitter island [°]

$$tg\alpha = \frac{W}{2T} \quad [rad]$$

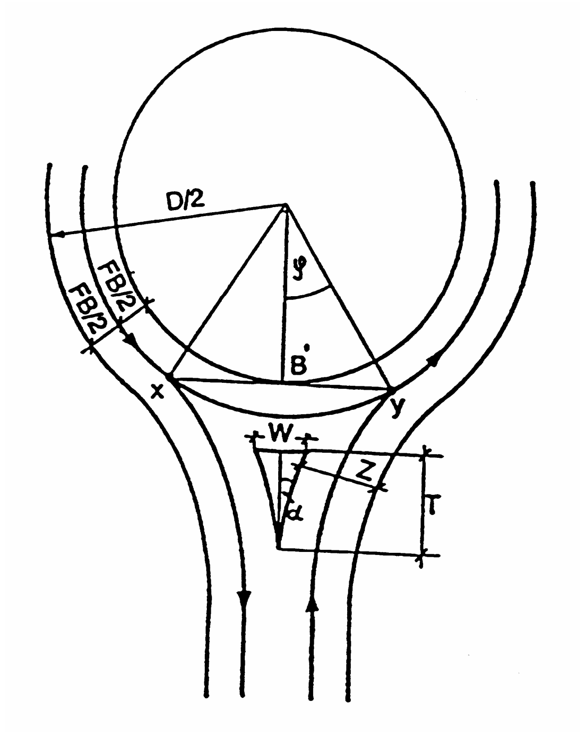


Figure 104: Geometric design of a roundabout

In the case of multi-lane entries or a greater number of lanes within the circular flow the calculation procedure is identical, with the relevant minimum distance B between the points of conflict (Fig. 105).

Based on the research about navigate them we believe that the parameter a need not be calibrated for the Slovene conditions.

The factor b reflects the influence of the number of entry lanes. The stated b coefficient values are calibrated according to Slovene conditions (in the brackets the coefficients used in Switzerland and Austria are given).

single-lane b = 0.90 - 1.0 (0.9 – 1.0)

double-lane b = 0.80 - 0.84 (0.6 – 0.8)

three-lane b = 0.55 - 0.65 (0.5 – 0.6)

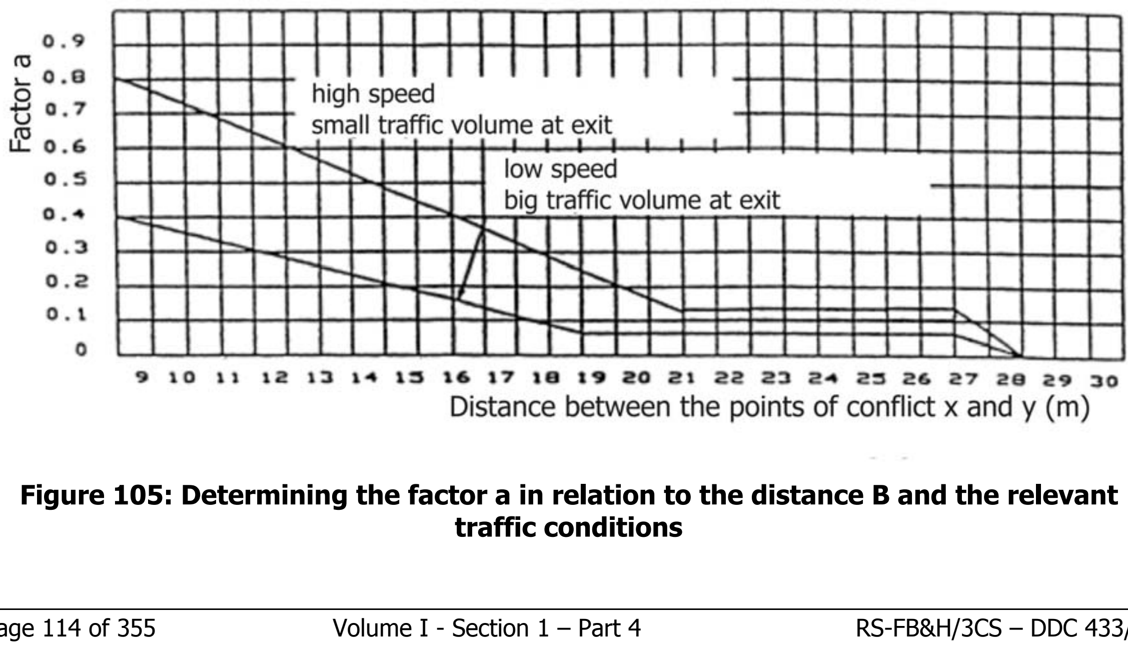


Figure 105: Determining the factor a in relation to the distance B and the relevant traffic conditions

3.6.3.2 Establishing the volume at entry

By establishing the volume at entry it is determined to what extent the calculated entry capacity has been exhausted according to the actual and projected traffic volume. It is calculated using the following formula:

$$A = \frac{c * M_E}{L} * 100 \quad [\%]$$

where:

A entry volume level [%]

M_E entering flow [veh/h]

L entry capacity [veh/h]

c factor - the number of entry lanes [-]

The coefficient c describes the influence of the number of lanes in a roundabout. The Slovene calibrated values are stated. In the brackets the Austrian and Swiss values are given:

single-lane entry c = 0.90 -1.0 (1.0)

double-lane entry c = 0.50-0.65 (0.6–0.7)

three-lane entry c = * (0.5)

* in Slovenia there is no such roundabout, which is why the calibration was not made. We propose that the basic parameter c is used.

It can be seen from the calibrated values of b and c coefficients that their values for various types of roundabouts are not constant, only the upper and lower values exist.

In the case of single-lane roundabouts the recommended parameter value is b= 1.0 for small roundabouts, b = 0.95 for medium-sized roundabouts and close to 0.90 for large roundabouts.

Similar applies also to roundabouts with double- or three-lane circulatory roadway. Small roundabouts are approaching the upper limit and large the lower limit. Thus, for medium-sized to large roundabouts the most suitable coefficient is b = 0.63 and for very large roundabouts b=0.58.

The entry volume level should not (taking into account also maximum hourly peak volumes) exceed 90% of the maximum hourly traffic volume.

3.6.4 Australian method

The Australian method or the so-called Jacobs calculation deals with the throughput of the entry to a roundabout in relation to the circular flow using the exponent function. Thus, the results obtained for small circular flow are somewhat higher than for linear dependencies.

The general formula for determining the entry traffic throughput is:

$$L = \frac{(1 - p * t_0) * e^{-p*(t_a - t_0)}}{1 - e^{-p*t_f}}$$

where:

L entry traffic throughput [PCE/h]

q_p traffic volume on the circulatory roadway [PCE/h]

t_0 minimum time gap in circular traffic flow [s]

t_f minimum time gap (gross time gap between vehicles in side traffic flow (at entry)) [s]

t_a border time gap in circular flow still enabling one vehicle to enter the circular flow [s]

p $p = q_p/3600$

The Australian method of the entry throughput calculation is based on the time gap theory. The number of empty gaps (time gaps) in the main circular traffic flow which vehicles enter from the non-priority entry traffic flow is calculated.

Calibrated Slovene factors for small roundabouts:

t_o = 4 sec

t_a = 2.5 – 2.6 sec

t_f = 2 sec (one circular lane)

= 0 sec (two circular lanes)

Calibrated factors for medium-sized roundabouts:

t_o = 3 - 4 sec

t_a = 2.3 – 2.5 sec

t_f = 0 sec (two circular lanes)

Calibrated factors for large roundabouts:

t_o = 2 sec

t_a = 1.2 sec

t_f = 0 sec (two circular lanes)

The method is suitable for calculating the capacity of more complex roundabouts with higher volume, especially if integrated in a computer model.

It is recommended that the degree of saturation of the roundabout in the entire planned period is below 0.8 - 0.9.

3.6.5 Estimate of the roundabout entry throughput

Based on the results acquired by the traffic count analysis at roundabouts in Slovenia a graph was prepared showing the throughput of entries to roundabouts.

Figure 106 demonstrates the throughput of entries to roundabouts with a single entry lane and one circular lane (1-1), with a single entry lane and two circular lanes (1-2), with a single entry lane and three circular lanes (1-3) and with two entry lanes and three circular lanes (2-3).

It is recommended that the graph is used for a preliminary estimate of individual entry throughput, as a means of help for determining the size and the basic parameters (number of lanes) of a roundabout.

3.6.6 Delays in roundabouts

Delays in roundabouts are divided into geometric delay and queue delay.

The first indicates the delay of a vehicle on account of longer path and reduced speed while driving in the roundabout, while the second represents the delay caused by queuing to enter the circular traffic.

The mid queuing time of vehicles at entry into the roundabout can be estimated by means of the chart included in Figure 107, which is based on German research.

Mid queuing time in excess of 45 seconds is not dealt with. The reserve volume is calculated as the difference between the capacity and the actual traffic flow volume.

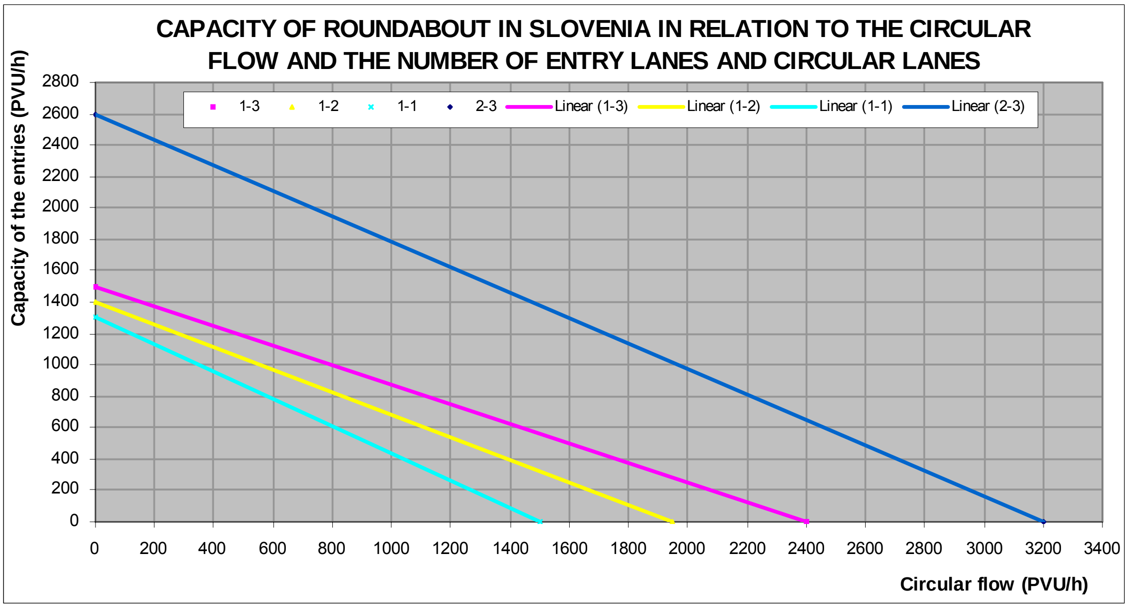


Figure 106: Capacity of entries of roundabouts

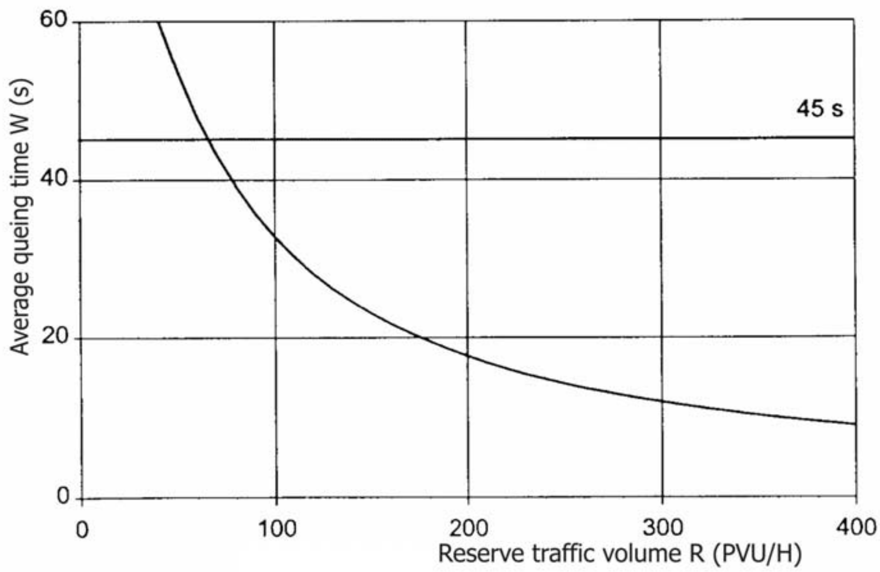


Figure 107: Chart for determining mid queuing time

3.6.7 The influence of bicycle and pedestrian traffic on the roundabout capacity

Bicycle and pedestrian traffic decrease the capacity of a roundabout. If the volume of bicycle and/or pedestrian traffic is high, the influence of this traffic on the roundabout capacity has to be checked.

The analyses of the impact of pedestrians and cyclists has to be prepared if the volume of bicycle and/or pedestrian traffic is high (residential zones, schools, sports centres, etc.). This applies especially to single-lane roundabouts and roundabouts with a single-lane entry.

In single-lane roundabouts there may be problems with entering and exiting a roundabout due to strong pedestrian and/or bicycle flow. The vehicles at entries to/exits from a roundabout have to yield to pedestrians/cyclists. This results in hindered (interrupted) flows and jams (Fig. 108).

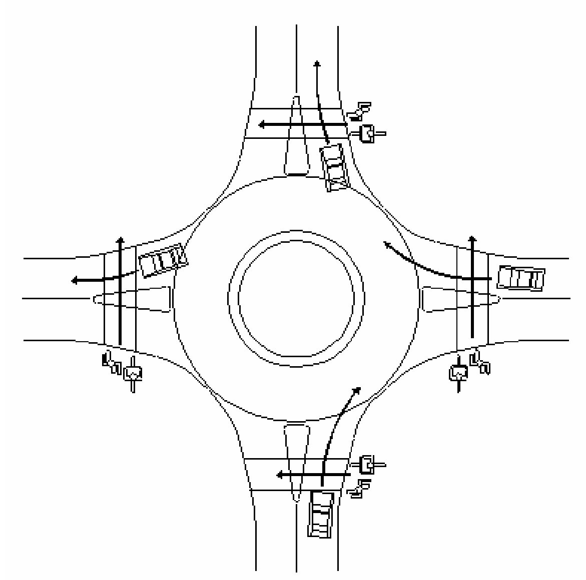


Figure 108: Hindered roundabout flows

If the motor vehicle flow is directed towards the entry, it is questionable whether the minimum capacity will be achieved.

If the vehicle flow is directed towards the exit, the maximum capacity is exceeded.

In case the vehicle queue at exit from a roundabout is so long that it extends to the entry before that exit, problems occur with entrance to the roundabout (and minimum capacity provision is questionable).

The moment when the roundabout becomes fully blocked (Fig. 109) depends on how the flows are divided at other entries.

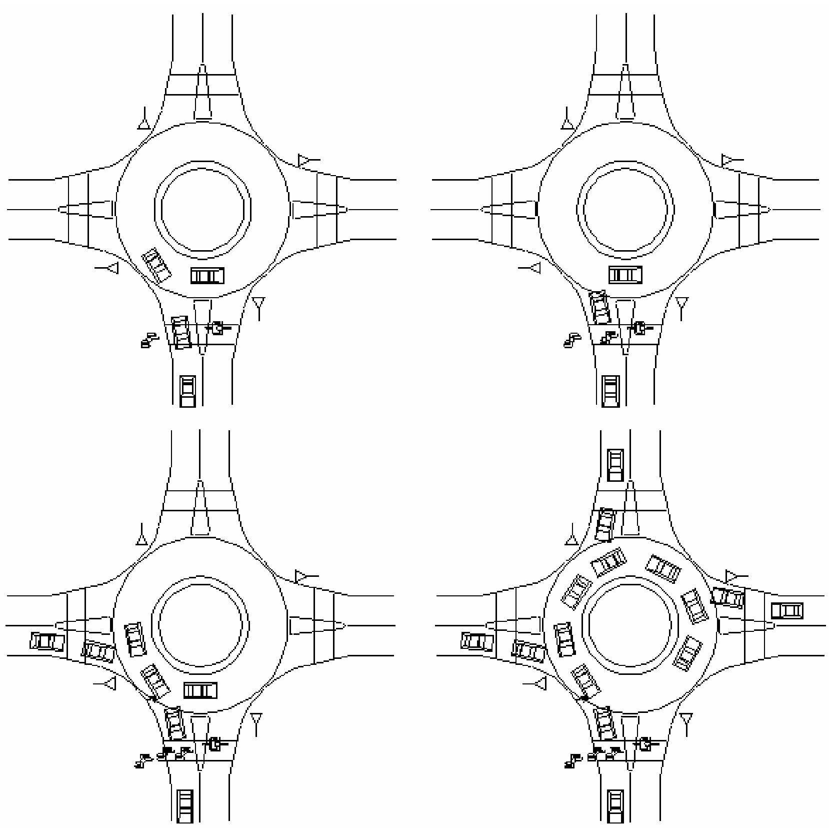


Figure 109: Roundabout blockage

At a single-lane roundabout with a waiting bay that can accommodate one vehicle three situations are possible:

- gaps between individual units of the cross flow allow the vehicles to pass, so there are no vehicles waiting in the waiting bay;
- gaps between individual units of the cross flow still allow the vehicles to pass, even though vehicles have to wait in the waiting bay;
- gaps between individual units of the cross flow are too small, the waiting bay is occupied and all subsequent vehicles wait on the circulatory roadway.

Below the document presents the methods for calculating the reduction in the roundabout entry capacity as a result of pedestrian/bicycle flow.

- **Determining the impact of pedestrians using the German method**

By means of a chart included in Figure 110 the reduction factor f_p is specified, which depends on the expected number of pedestrians.

The impact on the capacity is set for every individual entry separately.

If the traffic flow volume of a roundabout exceeds 900 PCE/h, the cross pedestrian flow does not have any additional negative impact on the capacity.

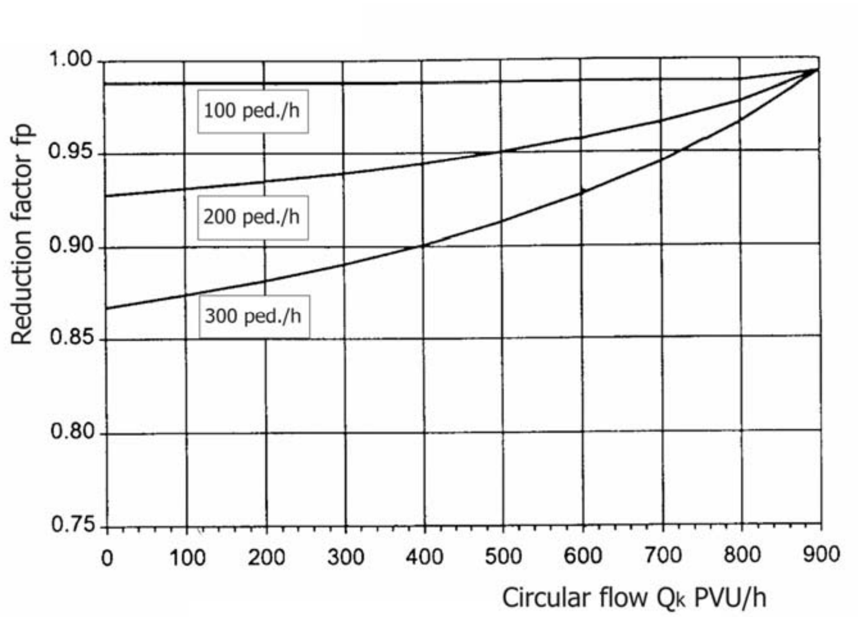


Figure 110: Reduction factor f_p

3.6.7.1 The impact of bicycle and pedestrian traffic on the throughput of a roundabout entry - findings of Slovene research

The findings stated in the continuation of the document are the result of traffic count and observation of traffic flows in Slovene roundabouts of different sizes.

- **The entry throughput is influenced more by the time during which the entry traffic flow is obstructed by pedestrians and cyclists than by the number of pedestrians and cyclists.**

If the traffic count showed that a pedestrian crossing is crossed, for instance, by 150 pedestrians and 25 cyclists, this information does not help much to establish the influence of pedestrians and cyclists on the roundabout entry throughput, as we do not know the structure of bicycle and pedestrian traffic. The fundamental difference is if pedestrians and cyclists cross the pedestrian crossing one by one or in a platoon. The information that a pedestrian crossing was occupied for 10 minutes within one hour tells us more. This means that the entering vehicles were able to enter the roundabout without interruption for 50 minutes within one hour, assuming that the cyclists and pedestrians are the only obstacle preventing vehicles from entering the roundabout without interruption.

- **The influence of bicycle and pedestrian traffic on the entry throughput decreases as the circular flow increases and at a certain level of the circular flow diminishes.**

In theory, the greatest influence of pedestrians and cyclists on the roundabout entry throughput is noticeable at the circular flow of 0 PCE/h. In this case every pedestrian or cyclist that crosses the roundabout entry reduces the entry throughput. When the circular flow increases, the entering vehicles encounter an additional disruption, representing an obstacle in addition to the pedestrians and cyclists at entry. As the circular flow continues to increase, the influence of pedestrian and cyclists on the roundabout entry throughput diminishes, when the circular flow reaches a certain point. From this point onward only the vehicles in the circular flow present an obstacle affecting the roundabout entry throughput.

- **In spite of higher bicycle and pedestrian traffic volume its influence on the roundabout entry throughput is diminished in the event of high circular flow volume.**

Based on the traffic count it was impossible to accurately establish at which circular flow volume the impact of pedestrians and cyclists on the entry throughput is diminished.

However, the following applies: If a pedestrian crossing is within one hour crossed by, for instance, 100 pedestrians, their impact is diminished at a smaller circular flow volume than if a crossing is within one hour crossed by 200 pedestrians.

Pedestrians crossing over a crossing at a time a vehicle is in the circular flow hindering an entering vehicle, do not additionally decrease the roundabout entry throughput.

In the case of such circular flow there are less pedestrians among one hundred that additionally obstruct the traffic within one hour than among two hundred.

Therefore, the impact of 100 pedestrians on the entry throughput is diminished at a lower circular flow volume than that of 200 pedestrians.

- **If the volume of bicycle and pedestrian traffic is equal, its impact on the roundabout entry throughput differs in the case of single-, double- or three-lane roundabouts.**

The traffic count and the observance of the traffic flows showed that if a crossing is crossed by, for instance, 100 pedestrians per hour, this has a different effect on the roundabout entry throughput in the case of single-, double- or three-lane roundabouts, given equal circular flow volume in all three types of roundabouts.

The graphs below show how pedestrians and cyclist reduce the roundabout entry throughput in addition to the circular flow. The graphs demonstrate how 50, 100 and 150 pedestrians per hour decrease the roundabout entry throughput in addition to the circular flow.

50 pedestrians per hour in the graph denote the time needed by 50 pedestrians for crossing the roundabout entry.

These pedestrians cross the roundabout entry at random and individually.

The average time needed for a single pedestrian to cross the roundabout entry is calculated by measuring the time needed by several pedestrians to cross an existing roundabout which is then divided by the number of pedestrians.

Naturally, this time depends also on the roundabout entry width crossed by the pedestrians. The time needed by 50, 100 or more pedestrians per hour is the multiple of that average time.

If one pedestrian needs 5 seconds to cross the roundabout entry, 50 pedestrians need 250 seconds.

If a platoon of 15 pedestrians - from the time the first pedestrian steps on the pedestrian crossing until the time the last pedestrian from the platoon crosses over - needs, for instance, 10 seconds, the platoon of these 15 pedestrians is represented by two pedestrians in the graph.

These pedestrians hindered entry traffic only for 10 seconds, which equals the period traffic would be interrupted by two pedestrians crossing the roundabout entry separately.

The number of pedestrians crossing over a crossing within one hour is calculated by measuring the overall time during which the crossing was within one hour occupied by pedestrians and cyclists and dividing it by the average time needed by one pedestrian for crossing the roundabout entry.

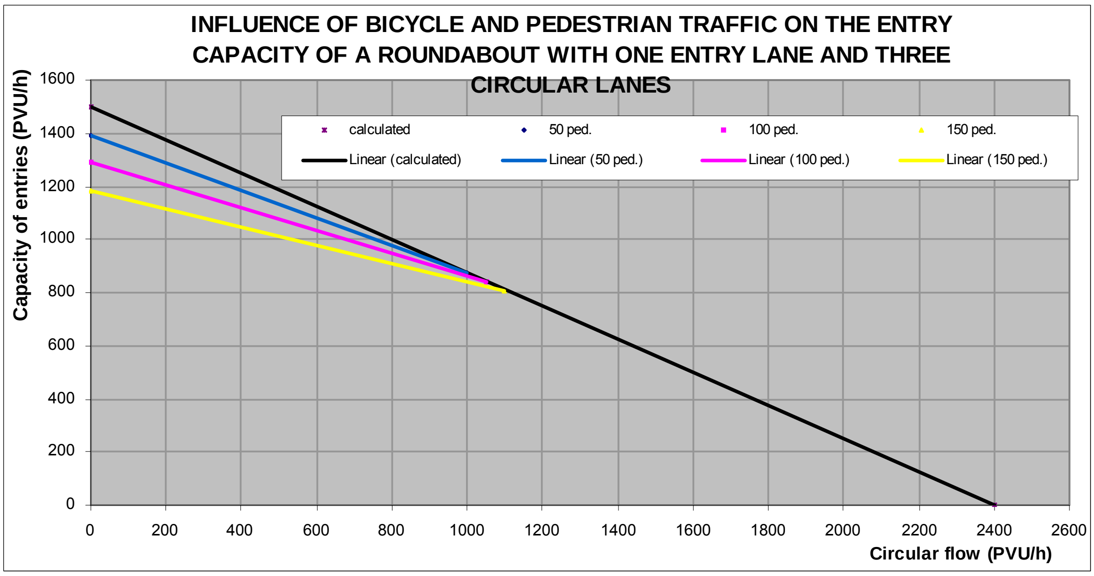


Figure 111: The influence of the bicycle and pedestrian traffic on the roundabout entry throughput in the case of a roundabout with a single entry lane and three circular nes.

Figure 111 shows the influence of the bicycle and pedestrian traffic on the roundabout entry throughput in the case of a roundabout with a single entry lane and three circular lanes.

The "calculated" straight line represents the roundabout entry throughput in relation to the circular flow. The straight line "50 pedestrians" indicates the roundabout entry throughput in relation to the circular flow assuming that within one hour the roundabout entry will be crossed by 50 pedestrians.

Similar relation is shown using the straight lines "100 pedestrians" and "150 pedestrians".

Figure 12 shows the influence of the bicycle and pedestrian traffic on the roundabout entry throughput in the case of a roundabout with a single entry lane and one circular lane. The "calculated" straight line represents the roundabout entry throughput in relation to the circular flow.

The straight line "50 pedestrians" represents the roundabout entry throughput in relation to the circular flow assuming that within one hour the roundabout entry will be crossed by 50 pedestrians. Similar relation is shown using the straight lines "100 pedestrians" and "150 pedestrians".

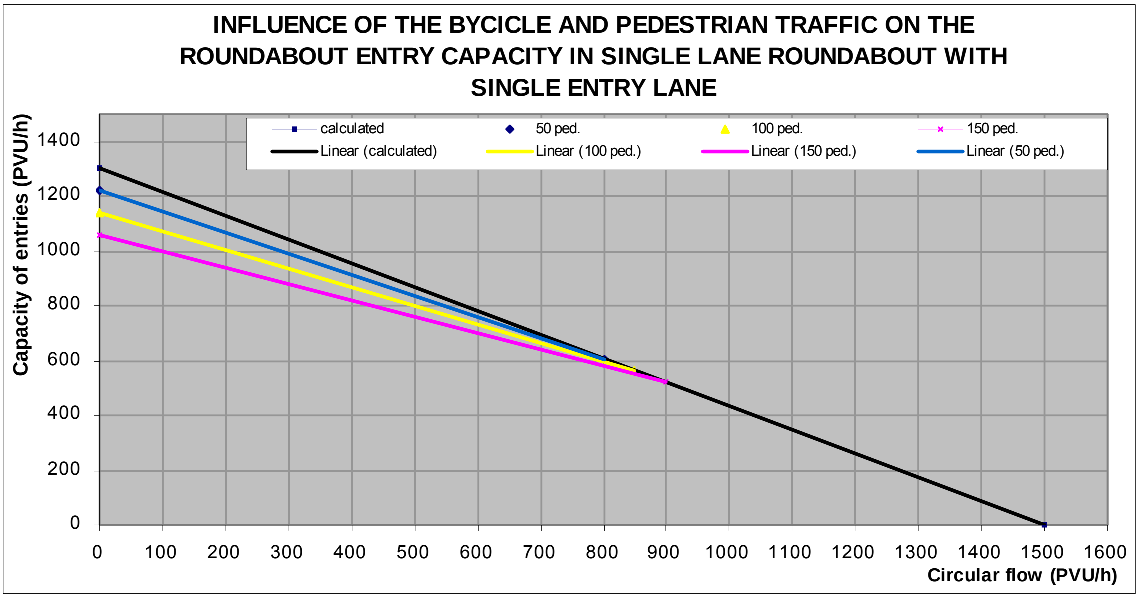


Figure 112:The influence of the bicycle and pedestrian traffic on the roundabout entry throughput in the case of a roundabout with a single entry lane and one circular lane.

Figure 113 shows the influence of the bicycle and pedestrian traffic on the roundabout entry throughput in the case of a roundabout with a single entry lane and two circular lanes. The calculation principle is the same as for single-lane roundabouts and roundabouts with three circular lanes.

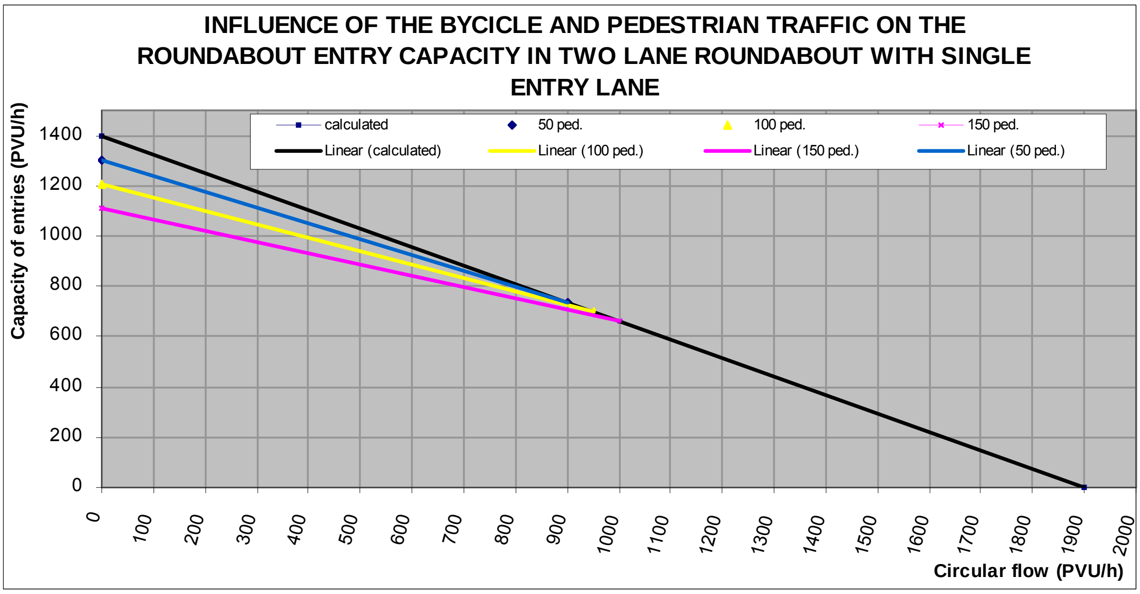


Figure 113: The influence of the bicycle and pedestrian traffic on the roundabout entry throughput in the case of roundabout with a single entry lane and two circular lanes.

3.6.7.2 The influence of cyclists in the circulatory roadway according to the Dutch method

If the bicycle traffic is routed over the circulatory roadway (parallel routing of bicycle traffic), the influence of the bicycle flow can be determined using the Dutch method as follows:

$C_{entry} = (1440 - I_{circular} - 0.5 * I_{exit}) * (1 - I_{bicycles}/800)$

where:
C_{entry} entry capacity [PCE/h]
$I_{circular}$ circular flow volume [PCE/h]
I_{exit} circular flow volume at roundabout exit [PCE/h]
$I_{bicycles}$ bicycle traffic flow volume [cyclists/h]

3.7 DETERMINING PROJECT-TECHNICAL ELEMENTS OF A ROUNDABOUT

Every crossroads is specific, which is why the project-technical elements can be presented only within certain recommended limits, which are the result of traffic-technical or safety aspects.

A designer has to choose the optimal element values for specific traffic and spatial conditions from within the recommended limits.

Table 13: Limit and recommended values of individual geometric elements

element	symbol	unit	limit dimensions	recommended dimensions
entry width	*e*	*m*	3.6 - 16.5	4.0 - 15.0
(approach) lane width	*v*	*m*	2.75 - 12.5	3.0 - 7.3
flare length	*l′*	*m*	12 - 100	30.0 - 50.0
diameter	*D*	*m*	27 - 172.0	27 - 100.0
entry angle	*Φ*	°	0.0 - 77.0	10 - 60
entry radius	*R*	*m*	6.0 - 100	8.0 - 45.0
circular lane width	*u*	*m*	4.5 - 25	5.4 - 16.2
sharpness of flare	*S*	/	0 - 2.9	0 - 2.9

The values included in Table 13 were obtained by empirical method, which is why every deviation from these values has to be well considered, as it may have unfavourable consequences primarily as regards roundabout safety. Also, table 6.1 does not contain the values applying to mini roundabouts.

To provide for geometrically optimum roundabout the influence of individual changes on the entry throughput and safety has to be observed.

The English calculation method is very suitable for observing changes of entry throughput.

This method is based on the observation of a driver's behaviour in circular traffic. Due to specific English method of driving the quantitative results obtained by this method cannot be transposed into our environment, but this method is nevertheless quite suitable for qualitative comparison of selected variants. It is recommended only for geometric optimisation of selected variants.

For the final calculation of the actual throughput the Swiss, German or Australian method (for more complex roundabouts) are more suitable.

3.7.1 Selection of the outer diameter (D) and the circular lane width

The selection of the outer diameter is affected mainly by the location of the future roundabout. In residential areas a roundabout is mainly designed to calm the traffic given sufficient throughput, while at major roads its main task is to provide throughput while ensuring sufficient safety of traffic participants (Table 6.2).

Table 14: Categorisation by size and location

Type of roundabout	outer diameter [m]	approximate capacity [veh./day]
mini urban	14 - 25	10,000
small urban	22 - 35	15,000
medium-sized urban	30 - 40	20,000
medium-sized (single-lane) rural	35 - 45	22,000
medium-sized (double-lane) rural	40 - 70	-
large rural	> 70	-

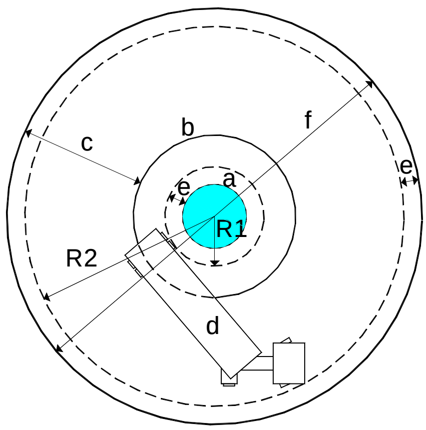
Note: Capacities are only approximate values for four-leg roundabouts with equal distribution of traffic flows. The table includes only informative values; when concrete problems are being solved, every roundabout has to be examined in terms of the actual traffic flows and applied project-technical elements.

The outer diameter *D* and the circular lane width are interrelated. First, the number of lanes within the circulatory flow has to be specified. For traffic safety reasons only two lanes are recommended.

The recommended values for the lane width (5.4 - 16.2 *m*) presented in Table 15 apply to one circular lane at lower speed and to several lanes at higher speed.

The pasability by a relevant vehicle has to be checked for all roundabouts.

To provide for the passability by a relevant vehicle - articulated vehicle - of a small and medium-sized roundabout (R_z=14-18 m) the main design elements have to be in a certain ratio and of the prescribed minimum size (Figure 114).



a central island
b central island + the mountable part of the central island
d relevant vehicle
e safety distance (within which there must not be any physical obstacles) 1.0 m
f outer diameter of the roundabout

Figure 114

Central island diameter [m]	R1 [m]	R2 [m]	Minimum outer diameter of the roundabout [m]
6.0	4.0	13.4	28.8
8.0	5.0	13.9	29.8
10.0	6.0	14.4	30.8
12.0	7.0	15.0	32.0
14.0	8.0	15.6	33.2
16.0	9.0	16.3	34.6
18.0	10.0	17.0	36.0

If the relevant vehicle is a truck with a trailer, the use of the following values is required under certain conditions, depending on the size of the roundabout (Table 15).

Table 15

<table>
<tr><td colspan="2">outer diameter [m]</td><td>27 - 35</td><td>35 - 45</td></tr>
<tr><td colspan="2">circular lane width [m]</td><td>6.5 - 8.0</td><td>5.75 - 6.5</td></tr>
<tr><td rowspan="4">required conditions</td><td>lane width at entry [m]</td><td>3.25 - 3.5</td><td>3.5 - 4.0</td></tr>
<tr><td>lane width at exit [m]</td><td>3.5 - 3.75</td><td>3.5 - 4.25</td></tr>
<tr><td>entry radius [m]</td><td>10 - 12</td><td>12 - 14</td></tr>
<tr><td>exit radius [m]</td><td>12 - 14</td><td>14 - 16</td></tr>
</table>

Special attention has to be paid to small roundabouts through which the public passenger transport routes pass. In such cases it is sensible to introduce a special lane for public passenger transport.

The speed at which vehicles navigate a roundabout can be controlled also by other parameters as described later in the document.

3.7.2 Alignment of approaches to the roundabout

For safety reasons the approaches to the roundabout are aligned as perpendicularly to the roundabout as possible (Figure 6.2), since tangential alignment results in too high speed at entry, difficult entry to the roundabout and rear-end collision upon entry.

The conditions for good entry of a vehicle to a roundabout are created by proper selection of the entry radius *R*, entry width *e* and flare length *l'*.

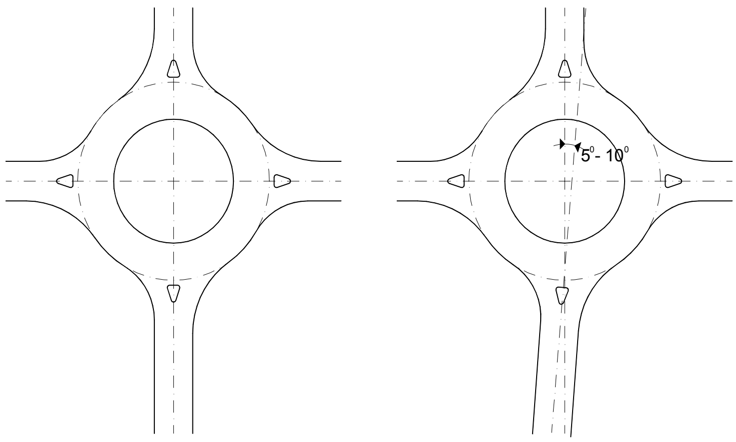


Figure 115: Optimal (left) and permissible (right) alignment of approach to a roundabout

3.7.3 Width of the approach lane before the roundabout (v)

The width of the approach lane before the roundabout is an important element which significantly influences the entry throughput.

In the case of reconstructions the approach lane width is conditioned by the lane width prior to reconstruction.

Slovene regulations specify minimum approach lane width of 2.75 *m*, while the limit and recommended values are given in Table 16.

3.7.4 Entry width (e) and the entry flare length (l')

The most critical manoeuvre in a roundabout is the entry, which is why it is very important that this small area is optimally designed.

It is described by two elements:

- entry width *e*,
- entry flare length *l'*.

The entry flare length *l'* is defined as the length of the median line connecting the curve of a normally wide entry and the flare curve.

Greater values of the recommended entry width *e* in Table 16 indicate a higher number of lanes.

3.7.5 Entry radius R in entry angle Φ

These two elements do not have a significant impact on the throughput, but they are important for providing traffic safety at entry to a roundabout and in circular flow.

The size of the entry radius depends on the size of the roundabout.

Foreign experience shows that the optimal entry angle is 30°.

3.7.6 Roundabout exit width

One of the main assumptions made as the entry throughput is calculated is that traffic leaves the roundabout without interruption.

In order to achieve that the exit has to be wide enough. The recommended and limit values are given in Table 15.

3.7.7 Exit radius

As for exit width similar applies to exit radius. Exit radius should ensure proper exit throughput and safety at exit speed. Exit radius should be larger or equal to entry radius, but absolutely not smaller.

3.7.8 Splitter island dimensions

In the case of large roundabouts splitter islands are recommended to be shaped like a triangle and in small roundabouts like a drop.

Minimum triangular splitter island dimensions depend on the size of the roundabout and the entry radius and are (due to the size of the roundabout) not difficult to comply with.

Minimum dimensions of a drop-like splitter island depend on the type of traffic participants crossing the splitter island (pedestrians and cyclists or pedestrians only).

It is recommended that the splitter island is, at the wider part, where it is crossed by the bicycle path, at least 2 m wide (length of a men's bicycle + safety distance), while the minimum width at the point where traffic signs keep right (II-47) and the sign indicating a traffic island (VI-8) are installed should be at least 1.0 m (Fig. 116).

It is recommended that the splitter island is, at the wider part, where it is crossed by the bicycle path, at least 2 m wide (length of a baby carriage and the person driving it + safety distance), while the minimum width at the point where traffic signs *keep right* (II-

47) and the sign indicating a traffic island (VI-8) are installed should be at least 1.0 m (Fig. 117).

All line intersections should be rounded at least with an 0.5 m radius.

In roundabouts where cyclists are directed over the circular lane (parallel routing), the width of the splitter island may be less than 2.0 m at the widest part.

The same applies for roundabouts without cyclists. In such cases the splitter island is designed of other materials and segment form.

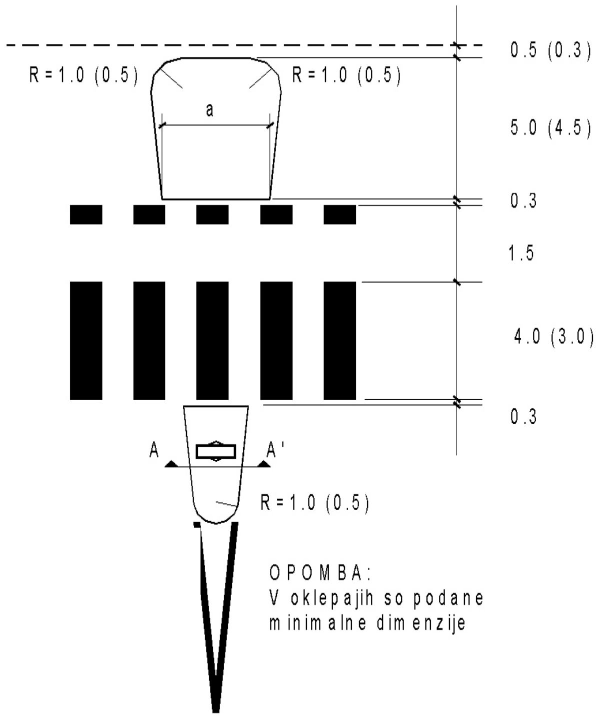


Figure 116: Minimum dimensions of a splitter island

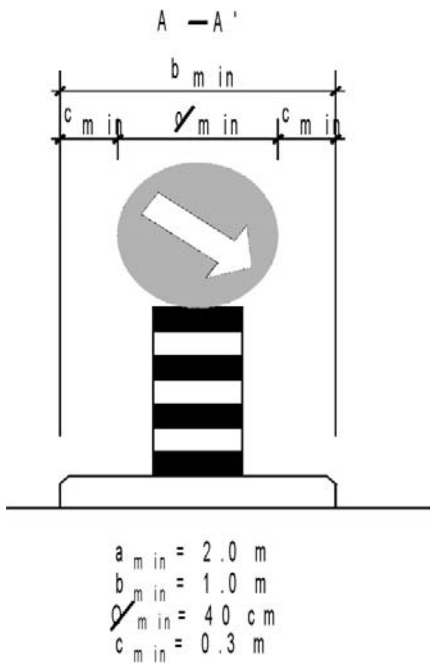


Figure 117: Minimum dimensions of a splitter island

3.8 HORIZONTAL AND VERTICAL ALIGNMENT OF A ROUNDABOUT

3.8.1 Horizontal alignment

Horizontal alignment refers to road alignment in broader and narrow sense.

Alignment in a broader sense denotes the elements of the horizontal route of the road at the longer section before and after the roundabout.

In narrow sense, alignment refers to the last element of the horizontal route of the road before the roundabout and the first element of the horizontal route of the road after the roundabout.

- **Road axis route at the longer section**

By decreasing the radius of consecutive arcs before a roundabout the speed is gradually reduced before a roundabout, which prevents the possibility of too late detection of the roundabout by drivers and rear-end collisions.

The straight, being an element at a longer section before the roundabout is not prohibited, but is not recommended and should in principle be used only in the case of reconstructions of the existing classic crossroads or in urban areas where the road axis route is predetermined due to surrounding buildings (Figure 118).

In such cases public lighting requires special attention.

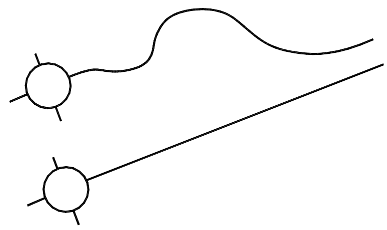


Figure 118: The axis route at the longer section before the roundabout

3.8.1.1 The road axis route in the roundabout area

It is recommended that the last and the first element directly before and after a roundabout is a straight, although this is not necessary.

The straight in principle provides for rectangular leg approach to a roundabout, which is favourable from the point of view of traffic safety.

It is also desirable that the extensions of roundabout leg axes intersect at a single point. It is best if this intersection is in the centre of the roundabout. It is somewhat less favourable is this intersection is left of the arc centre (from the entry point of view). In such cases the maximum permitted deviation is less than 15^{o}. The worst case is when the intersection is right of the roundabout centre, since it results in increased maximum possible entry speed.

The sizes of preceding and subsequent arcs depend on the planned speed limit.

3.8.2 Vertical alignment

As roundabouts are designed, special attention has to be paid to vertical alignment, i.e. longitudinal falls of crossing roads, vertical curvature elements and cross falls of the circular lane.

Limit values of the above-mentioned elements are specified based on the driving dynamics rules, psychological and physical rules and especially construction possibilities and requirements. The latter include particularly the driving dynamics requirements and efficient drainage of the roundabout area.

General principles for aligning routes of crossing roads in the scope of vertical plane projection are as follows:

The roads accessing the roundabout must not be routed through the roundabout so that a crest would develop reducing the sight distance at roundabout entry. The approach grades should break at ≤4%, otherwise the curvature should be provided at at least R500.

The radius of the vertical curvature cannot extend to the circular lane.

The entire area restricted by the outer radius of a roundabout (or the outer edge of the pedestrian walkway, in the event the roundabout includes cyclists and pedestrians) has to be on a single plane.

It is impermissible that this plane is broken across the central island.

Maximum gradient of the above-mentioned plane can exceptionally be 2.5%, while special attention has to be devoted to drainage (minimum gradient of the roadway in such case equals 0.5%).

- **Conditions applying to approach grades**

Maximum longitudinal fall of the approach grades of a roundabout should not exceed s_{max} = 3% directly before the vertical curvature. If the slope of the approach grades is directly before the vertical curvature more than s_{max}, it has to be reduced to s = 3%.

Such radius of the vertical curvature rounding the new break is selected which is higher or at least equal to r_{min} and it is does not fall within the area of the vertical curvature of the roundabout approach.

Minimum longitudinal fall of the approach grades of a roundabout is determined by drainage devices. Also in the roundabout area the approach grades should not be characterised by the longitudinal fall of the road edge below 0.5%, even though level sections are also possible. The latter require that the roadway is surrounded by perforated (inlet) kerbs.

3.8.3 Condition applying to vertical curvature of roundabout approach

In the event of roundabout approaches on the upward or downward gradient a platform has to be provided directly before the entry with a longitudinal inclination of ±3.5% maximum.

The length of the platform is minimum 6 m or more in the case of strong traffic flows and a high number of trucks. In such cases it is desirable that the vertical curvature starts only after 12 m, measured from ground signalisation which indicates non-priority.

The longitudinal fall at the platform at a 6 m distance (or 12 m) must not exceed ±3.5%. If there is a vertical curvature at this location, the tangent gradient is measured.

To other segments of vertical alignment of approaches to a roundabout the same conditions apply as to classic crossings at grade.

3.8.3.1 Cross fall of a circulatory roadway

The cross fall of a circulatory roadway has to provide mainly:

- adequate drainage and
- enable connecting changes in inclinations at transitions between approach lanes and the circular lane.

We distinguish between two cross falls of a roundabout:

- outward cross fall (negative) and
- inward cross fall (positive).

Outward cross fall of a circulatory roadway

This is the most common method of vertical alignment of a roundabout (Figure 7.3). This is the simplest way to provide suitable drainage and unproblematic transition between approach lanes and the circular lane. The cross fall should not exceed -2.5%.

The combination of the outward cross fall and geometric elements enabling too high speed can result in a dangerous roundabout.

The weaknesses of an outward inclined circulatory roadway are apparent mainly in bad weather conditions, when due to the combination of the negative cross fall and the decreased friction coefficient between the tyres and the ground, a vehicle starts skidding outward already at low speed.

In addition, a drive through a curve with a negative cross fall unfavourably impacts the driver's and passenger's comfort (transverse force acts contrary than expected).

In the event classical crossroads are reconstructed into small and medium-sized roundabouts such method of vertical alignment is usually cheaper, as in principle the previous drainage method may be used.

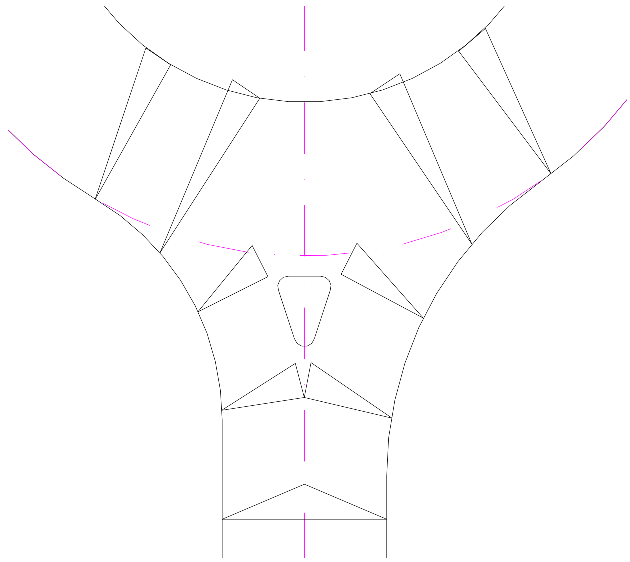


Figure 119: Outward cross fall

Inward cross fall of a circulatory roadway

From the traffic-technical point of view the inward cross fall (Figure 120) is the correct cross fall in a circular curve. Irregardless of the above fact it is used less frequently, as the correct drainage and approach connection are much more demanding.

As the direction of the cross fall changes at entries and exits, it has to be ensured that the change does not exceed 5%. The change in cross fall is provided by vertical radius.

A great deal of attention has to paid to the location of road gullies. The critical points for water stagnation (the so-called water pockets) are the entries, exits and the inner lane of the circulatory roadway.

As the circulatory roadway is inclined towards the centre of the roundabout, the following errors may occur:

- non-connecting approach screwing,
- water pockets at entries to and exits from a roundabout,
- water stagnation at the inner circular lane.

As the outer edge of the lane at the entry and exit from the roundabout is designed, the general rules for designing road axis and edges have to be complied with.

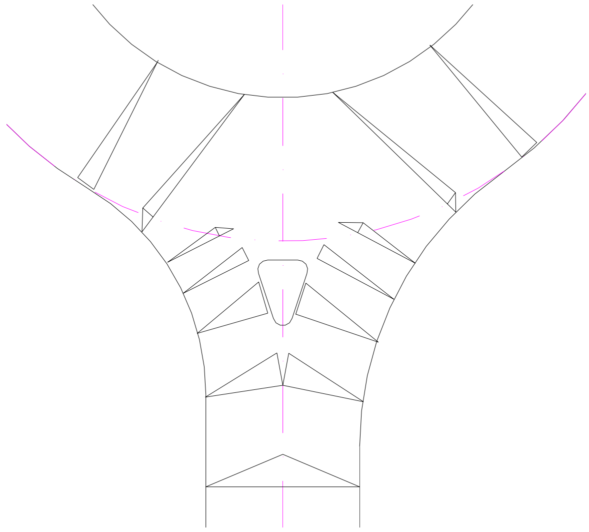


Figure 120: Inward cross fall

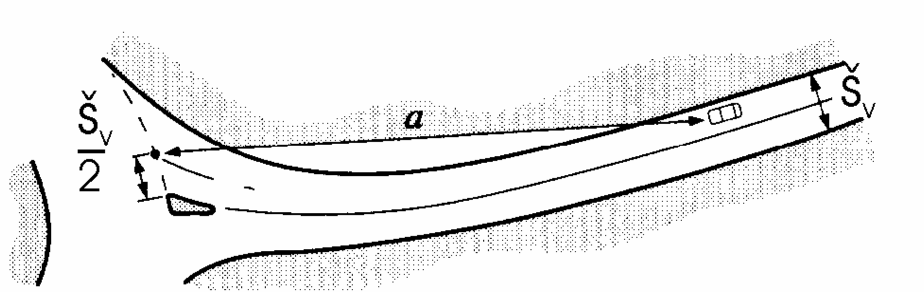
3.9 SIGHT DISTANCE

The main rules regarding sight distance in roundabouts that need to be complied with are:

- in urban roundabouts a driver may have sight of the opposite roundabout exit, but not necessarily,
- in rural roundabouts a driver must not have sight of the opposite roundabout exit, which can be achieved by elevating the central island.

The above-mentioned rules are sensibly applied regardless of the number of roundabout legs and the number of lanes within the circulatory roadway.

The sight distance values applying to roundabouts are given in Table 17. Approach sight distance at roundabout entry is presented in Table 18. It is measured to the yield line as shown in Figure 121.



KEY:

▭	position of the vehicle (in the middle of the lane)
a	recommended sight distance needed for stopping according to the planned entry speed

Figure 121:. Approach sight distance

If sufficient sight distance criterion is not met, the drivers have to be warned thereof by extra traffic signs.

Table 16: Stopping sight distance

Stopping sight distance [m]		
V_R [km/h]	40	50*
recommended	50	70
minimum	40	50

* only in the case of large roundabouts in rural areas or at motorways

3.9.1 The height of the sight line and obstacles

The sight field at entry to the left and across the central island should be provided as in Figure 122. Sight distance should be provided from the height of a driver's sight line 1.1 m to the height of an obstacle 1.1 m, while the sight field should extend to 2.0 m above the roadway surface.

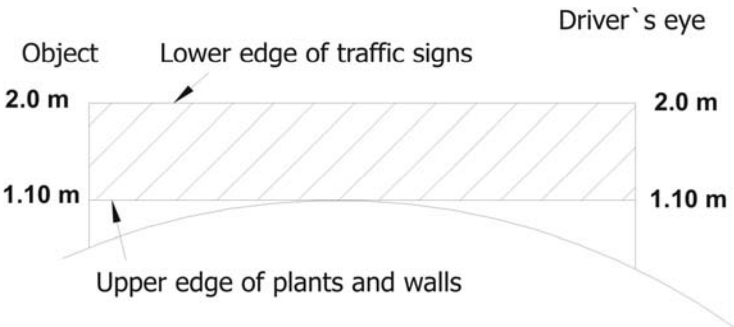


Figure 122: Sight distance at entry to the left

Remaining sight distance should be provided as shown in Figure 123. Sight distance should be provided from the driver's eye height (between 1.1 m and 2.0 m) to the height of an obstacle between 0.1 m and 2.0 m, measured from the roadway surface.

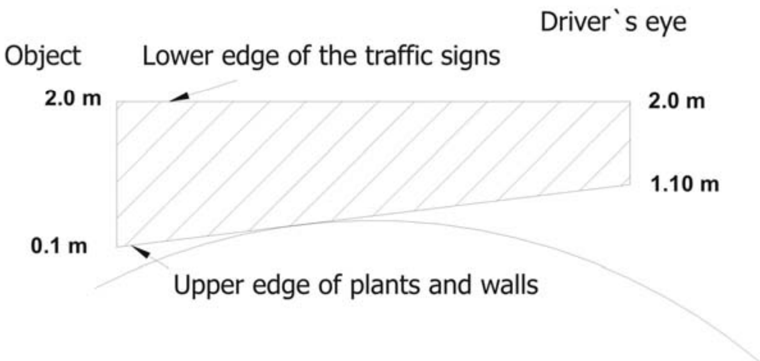


Figure 123: Remaining sight distance

Traffic signs in this area should not be installed less than 2.0 m high, measured from the surface of the roadway to the lower rim of the sign.

3.9.2 Sight distance to the left

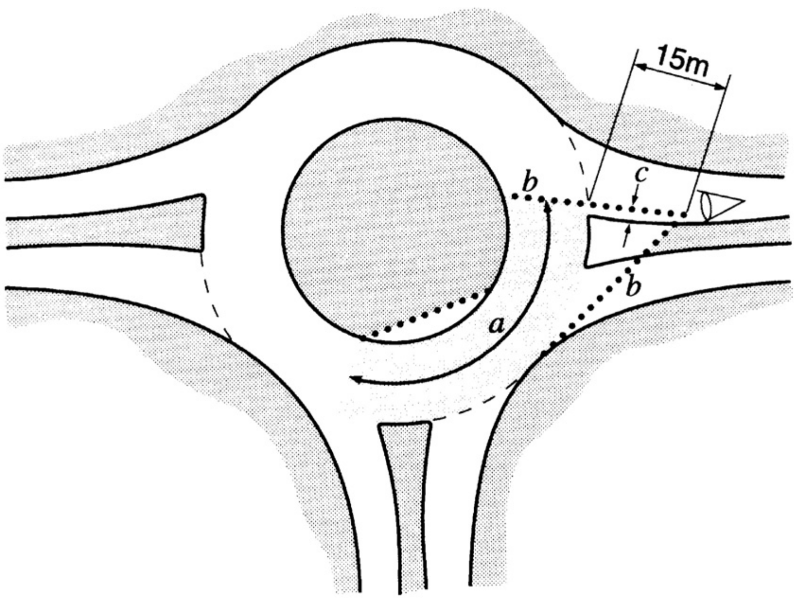
Drivers of all vehicles approaching the ground markings indicating the edge of the circulatory roadway have to be provided sight of the entire width of the circulatory roadway, from the yield line to their left at a stopping distance measured along the circulatory roadway axis (Table 17).

Table 17: Sight distance to the left

Diameter of the roundabout [m]	Sight distance [m]
< 40	-
40-60	40
60-100	50

Sight distance to the left is checked from the centre of the lane (in the case of a double-lane entry from the left one) at a distance of 15 m from the yield line, as shown in Figure 124.

It always has to be checked whether the constructions and devices as well as traffic signs or other permanent or temporary facilities next to the road limit sight distance.



KEY:

a sight distance related to circulatory speed given in Table 18

b sight field border

c half width of non-flared lane

Figure 124: Sight distance to the left needed for entering a roundabout

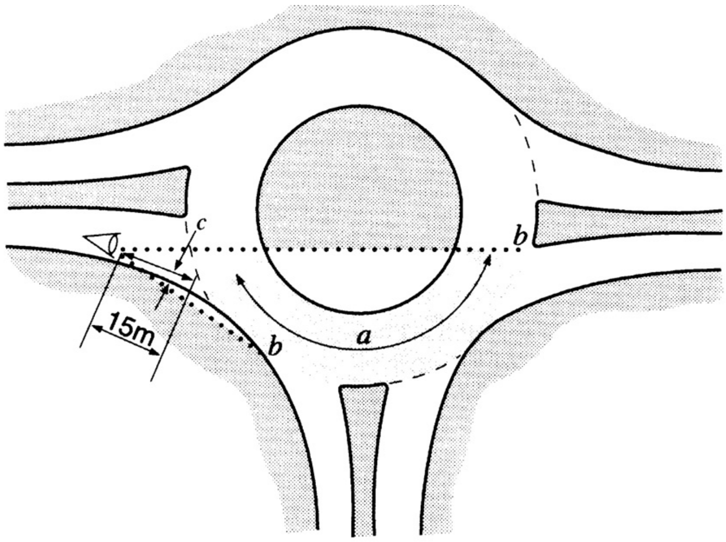
In some cases (small roundabouts without substance in the central island) excessive approach sight distance at entry or between two consecutive entries may cause too high speed at roundabout entry.

In such events it is reasonable to limit the excessive sight distance by selectively adding plants to the central island.

3.9.3 Approach sight distance at entry

Drivers of all vehicles approaching the yield line have to be provided sight of the entire width of the circulatory roadway before them, measured along the median line of the circulatory roadway, which corresponds to the size of a roundabout as shown in Table 18.

Sight distance should be checked from the centre of the right lane at a distance of 15 m from the yield line, as shown in Figure 125.



KEY:

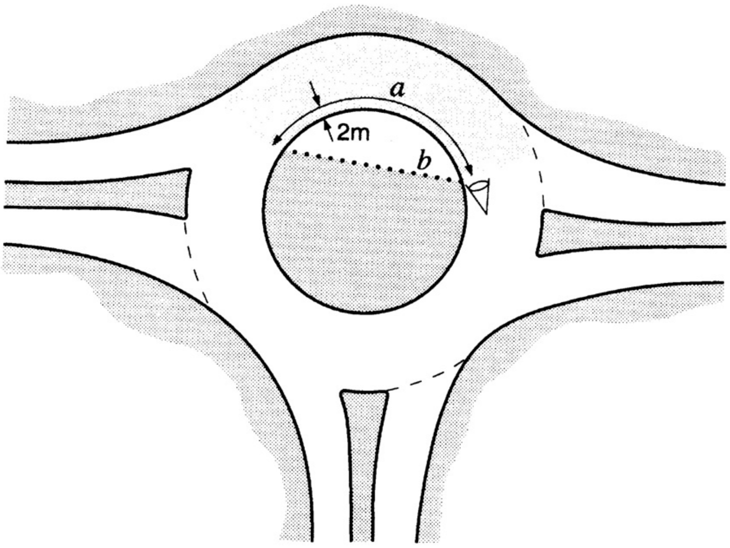
a sight distance related to circulatory speed, given in Table 18
b sight field border
c half width of non-flared lane

Figure 125: Approach sight distance at roundabout entry

3.9.4 Sight distance on circulatory roadway

Vehicles on the circulatory roadway have to be provided sight of the entire width of the circulatory roadway before them, at a distance corresponding to the size of the roundabout (Table 16).

This sight distance has to be checked for 2 metres outside the edge of the central island as shown in Figure 126.



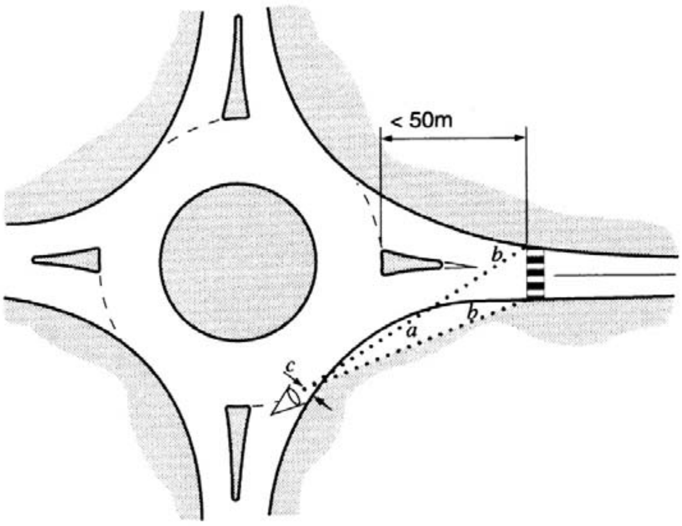
KEY:
a sight distance related to circulatory speed, given in Table 18
b sight field border

Figure 126: Sight distance on circulatory roadway

3.9.5 Sight distance to pedestrian crossings

When approaching a roundabout, the vehicles approaching a pedestrian crossing have to be provided such sight distance to the pedestrian crossing that they can safely stop the vehicle, driving at a speed permitted at roundabout entry.

In small and medium-sized roundabouts the drivers that are directly before the yield line should be provided sight of the entire width of the pedestrian crossing on the immediate downstream exit (if the pedestrian crossing is up to 50 metres away from the roundabout) (Figure 8.7).



KEY:
a minimum area over which unobstructed sight has to be provided if the pedestrian crossing is less than 50 metres away from the roundabout from the observance point
b sight field border
c lane half-width

Figure 127: Sight distance from the entry to the pedestrian crossing on the immediate downstream exit

3.9.6 Visibility obstructions

Traffic signs, dense and high softscape (plants, trees) and other raised elements and objects may be within the sight field only if they do not obstruct visibility.

Trees, public lighting poles, overpasses, etc. may be within the sight field only if their width is 55 cm maximum.

Wherever possible, the pedestrian walkways should be outside the sight field also. If this is not possible, pedestrian traffic should have the least possible effect on the deterioration of visibility conditions.

3.9.7 Sight distance on raised roundabout legs

When a roundabout is above the main traffic route, the sight distance condition has to be met at the entry from the slip road. Already in the initial designing phase the sight distance has to be checked by examining whether the planned overpass rail, walls or traffic signs and direction signs will obstruct the sight distance on entry to a roundabout.

Insufficient sight distance on entry may cause jams (braking at entries) and poorer traffic safety. It is important that the yield line is clearly visible to the drivers of approaching vehicles and that it is not hidden by a convex curve.

3.10 TRAFFIC EQUIPMENT

3.10.1 Splitter islands - pedestrian refuge

The raised splitter island at roundabout entry is obligatory, unless in the case of mini roundabouts, as it is of utmost importance for safe routing of motor vehicles, pedestrians and cyclists.

Also in mini roundabouts, if at all possible, the typical elevated elements should be used to physically separate the roundabout entry and exit.

The splitter island lines should be adjusted to the lines of the incoming, outgoing and circular lane of the roundabout. The intersection of these lines should be rounded at least with a radius of 0.5 m.

3.10.2 Pedestrian and bicycle crossings

Pedestrian and bicycle crossings ensure traffic safety and comfort of pedestrians and cyclists while crossing roundabout legs.

The crossings have to be designed in such a way that they attract the maximum possible number of pedestrians (who would otherwise cross the road at random).

Pedestrians have to be provided sight of the approaching vehicles during crossing.

As regards the pedestrian sight distance special attention has to be paid to roundabouts comprising bus stops. Buses, stopped at bus stops must not obstruct the pedestrians' or drivers' sight distance.

Pedestrian crossings have to be installed somewhat apart from the roundabout exits (by the length of one to two passenger vehicles), which results in a conflict between pedestrian and driver requirements. If a pedestrian crossing is too far from the roundabout exit, the pedestrians will not use it. In such cases incorrect crossing of roundabout legs has to be prevented by physical means (bushes, fences, etc.). If a pedestrian crossing is too close to a roundabout, there is the possibility of vehicles queuing at entry, with the queue extending to the circulatory roadway, which hinders traffic on that roadway.

Every case has to be treated separately and thoroughly. The following has to be taken into account: the speed of vehicles, the volume of pedestrian/bicycle and vehicle flows, the size of the roundabout and the length of the pedestrian crossing.

3.10.3 Mountable part of the central island

The mountable part of the central island is that portion of the central island which together with the circulatory roadway enables long vehicles to drive through the roundabout when, due to the smallness of a roundabout or the width of the circulatory roadway, this would not be possible without the mountable part of the central island.

The mountable part of the central island is thus provided only in the case of small and medium-sized roundabouts.

In the case of mini roundabouts the mountable part of the central island cannot be provided, while for large (multi-lane) roundabouts it is unnecessary.

The mountable part of the central island is usually from 1.0 to 2.0 m wide, depending on the surface covered by the relevant vehicle while driving through the roundabout (full circle).

The mountable part of the central island has to be designed in the manner and using the materials which dissuade the drivers of short vehicles from using it, so that it is used only by those vehicles which cannot pass through the roundabout without it.

This can be achieved by sufficient outward inclination of the plane (approx. 5%) and rough surface, e.g. paving.

3.10.4 Kerb colour and shape

The kerbs of splitter islands have to be well visible. They are either white or black-and-white.

On the inner side of the circulatory roadway the kerbs with a lesser gradient have to be installed, when the inner circular lane is followed by the mountable part of the central island (Figure 128). The gradient of such kerb should be less than or equal to 1.25:1, which prevents the tyres of long vehicles from becoming damaged as they drive over the kerb. The kerb is recommended to be 2.0-3.0 cm high.

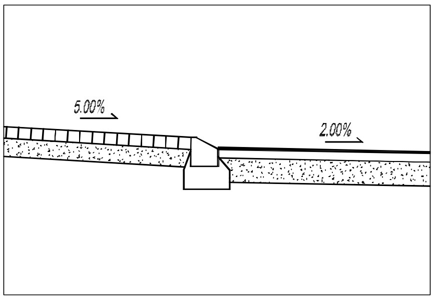


Figure 128: The kerb between the circular lane and the mountable part of the central island

In the case of very small roundabouts a connecting transition is recommended between the inner circular lane and the mountable (paved) part of the central island due to less tyre wear (Figure 129).

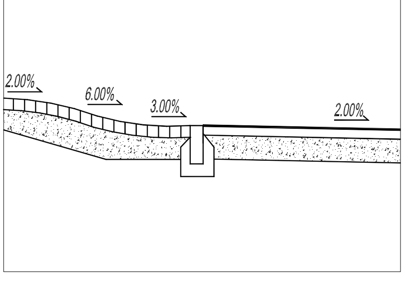


Figure 129: A connecting transition between the inner circular lane and the mountable (paved) part of the central island.

3.10.5 Roundabout illumination

To meet the traffic safety conditions roundabouts have to be properly lit at night. The entries and the central island of the roundabout have to be illuminated (Figure 130).

Splitter islands are suitable for holding lighting poles only if they are big enough and do not reduce visibility.

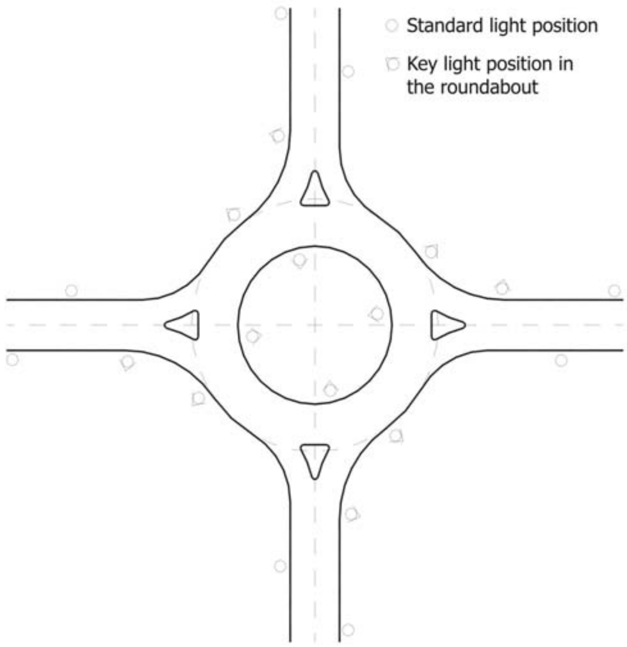


Figure 130: Recommended positioning of lights in a roundabout

The lighting poles should be placed in a circle along the roundabout circumference. They should be distributed evenly with equal distance between the light and the centre of the island. Every approach or entry should be lit for at least 60 metres before the roundabout. The colour of the light and the height of the lights should be uniform in the entire roundabout area, but no less than on approaches.

The lighting of the roundabout should be equal to that of the approaches.

3.11 TRAFFIC SIGNS

3.11.1 Vertical signing and ground marking

Roundabouts are equipped by traffic signs and equipment prescribed in the existing legislation.

Every roundabout should in principle be equipped with at least the following traffic signs:

- *proceed right only* sign (II-45.1) at the non-mountable part of the central island in the extension of the median line of the entry lane,
- *yield* sign (II-1) and roundabout *ahead* sign (II-48) on a joint pole at the roundabout entry, directly before the wide broken cross line (V-10) or (V-10.1),
- *give way triangle* marking (V-39) on the roadway before the wide broken cross line,
- *keep right* sign (II-47) and the sign indicating a traffic island (VI-8) on a joint pole on the outer part of the splitter island (at the top of the island facing forward),
- the sign indicating a traffic island (VI-8.1) on the inner part of the splitter island (in medium-sized and large roundabouts).

A roundabout has to be equipped with traffic control signs depending on its purpose (intersection of streets, local roads, national roads), as follows:

- on the inner side of the splitter island
- street name sign,
- direction arrow (III-86) or direction sign (III-87) and the direction arrow above the lane at portal (III-90.1) for more than two traffic destinations,

in the area upstream to the roundabout:

- *speed limit* (II-30) at adequate distance from the roundabout, where the speed on rural roads has to be reduced,
- *roundabout ahead* sign (I-30) exceptionally on roads in urban areas, if a roundabout is not equipped with the advance direction sign (III-84),
- advance direction sign (III-84) at adequate distance from the roundabout.

Every roundabout should in principle be equipped with at least the following roadway markings:

- broken wide cross line (V-10 or V-10.1), which is usually before the pedestrian or bicycle crossing and may be painted also after the crossing with a give-way triangle (V-39),
- short broken line (V-4) denoting the outer edge of the roundabout,
- broken centre line (V-2) separating traffic lanes in circular flow,
- field before the island for separating traffic flows (V-33),
- pedestrian crossing (V-16) and bicycle crossing (V-17 and V-17.1), when there are pedestrians and cyclists in the roundabout,
- yield line (V-1) of prescribed width before the splitter island in the area on the approach to the roundabout.

In individual cases, when this is required for traffic safety, the roundabouts have to be equipped also with safety fences and delineators.

3.11.2 Traffic light installation at roundabouts

Traffic lights are installed at roundabouts only exceptionally in the following cases:

- if the existing roundabouts are *overloaded* and cannot be reconstructed,
- if *railway traffic intersects* with a roundabout,
- in order to *improve traffic safety* of a very high pedestrian and cyclists flow, if an off grade solution cannot be provided,
- in the case of *changed traffic conditions* in urban areas which occurred after a roundabout was constructed.

In overloaded roundabouts the traffic lights do not result in higher capacity, but enable "artificial" gaps and greater throughput. Traffic lights prevent that all vehicles approaching the roundabout entry would have to stop on account of yield rule while entering the roundabout.

If the railway traffic intersects with the central island or one of the roundabout legs (Figure 10.1), traffic light installation is one of the possible solutions (the other being elevation of the roundabout).

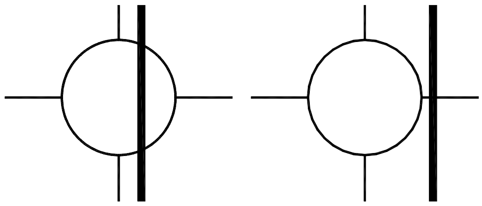


Figure 131: Railway traffic intersects with the central island or one of the roundabout legs

Traffic safety of pedestrian and bicycle flow in large roundabouts can be improved in two ways. By routing pedestrian and bicycle traffic off grade or by introducing traffic lights.

Installing traffic lights in a roundabout is one of the possible solutions also in the case of changed traffic conditions which may occur after a roundabout has been constructed. Due to changed traffic conditions a predominant (main) traffic route may be formed in a roundabout, as a result of which one of the main criteria for introducing a roundabout is eliminated (approximately the same traffic flow volume at the main and side traffic route).

In such cases traffic lights may be installed or one of the following two possibilities applied:

- a lane for driving by the roundabout may be introduced (if the main traffic route is turns right) or
- the main traffic route may be elevated (if the main traffic route turns left or runs straight ahead),

however, both solutions are costlier than traffic lights.

Traffic light installation at roundabouts may be simultaneous or progressive.

3.12 OTHER EQUIPMENT

3.12.1 Landscaping

When the area surrounding a roundabout is designed, the competent experts, especially landscape architects have to participate to incorporate the landscaping of such area into the landscape architectural plans. The design has to take into account the maintenance. When the maintenance responsibility is assumed by a third party, e.g. local organisations arranging landscaped areas and greens, the maintenance standards and rules have to be agreed in advance. If a third party wishes to change the roundabout area landscaping conditions in any way (e.g. by planting tall plants), they may do so only based on prior approval of the competent institutions. Such plants must not influence the sight distance or traffic safety (luxurious treetops, cones, fruit, leaves, etc.).

Regardless of aesthetics, landscaping of the roundabout area may also bring practical advantages from the point of view of traffic engineering. By adjusting the land (e.g. planting the central island) the approaching vehicles may be more evidently warned about the nearby roundabout. By obstructing the view of the opposite side of a roundabout to that of the approach, it is possible to avoid the drivers' confusion and perplexity caused by the sight of the traffic streaming through the entire roundabout.

Planting of the central island represents a good background for traffic signs and direction signs at the central island, while it visually aligns various vertical characteristics and prevents disorderly appearance.

Careful planning of the area where a certain sight distance is required (on the outer edge of the central island) may include the planting of low species of plants, while nearer to the central island higher and denser species of bushes and pruned trees may be planted. Special planting, which is perhaps more suitable in urban environment, usually requires more effort and investments.

In rural areas the limitations regarding planting have to be observed, i.e. indigenous plant species and the surrounding landscape.

On flat, open grassy areas landscaping is as a rule limited to earthscaping. Possible plantings are checked based on design projects in accordance with the landscape architecture plans.

In general, it is not suitable to plant high plants on the central island of a roundabout with a diameter of less than 10 m (including the mountable part of the central island), since due to the required sight distance only a very small area is available for planting in the centre of the island.

The splitter islands are planted only if they are large. Prior to that the conditions of vertical signalisation and sight distance have to be met. Only then, they are planted with greenery and other plants (the remaining available area).

In urban environment the height of the central island is not prescribed and can be decided by the designers. At rural road sections involving higher speed, the height of the central island has to warn the driver that they are approaching a roundabout or an obstacle on the road. The central island has to be landscaped (planted) in such a way that at night it blocks the lights of the contrary directional vehicles and at the same time provides the prescribed sight distance of adjacent entries.

3.12.2 Fountains, monuments and other objects in the central island

Fountains, monuments, sculptures and other objects may be placed in the central island, provided that the sight distance and visibility of the traffic signalisation are not reduced.

When such structures are installed, care should be taken that the conditions of sight distance and visibility of the traffic signalisation are fully complied with.

Signs, boards and other objects or devices for visual or audio informing and advertising must not be erected in the central island of a roundabout.

4 RAILROADS CROSSINGS

4.1 AREA OF APPLICATION

The guidelines for designing road-railway crossings describe spatial, construction, traffic, technical and safety conditions.

4.2 DEFINITION OF TERMS

The terms used in the guidelines for designing road-railway crossings have the following meaning:

Level crossing is an intersection of a railway and public road or non-categorised road used for road traffic on one level (hereinafter: LCr).

Road signal is a traffic light signal warning about the approaching train or the lowering of arms of (half-)barriers. It is indented to protect LCr.

(Half-)barriers are barriers or (half-)barriers consisting of a mechanism and arm, which closes the roadway when in the lower horizontal position.

Split barriers are the barriers which separately and with a delay close first the right and then the left half of the roadway facing the road vehicles approaching the LCr.

AADT of trains and road vehicles a*verage annual daily traffic*

Danger zone of the LCr is the part of the road between the line representing the minimum distance between the stable objects/devices from the closest rail which equals 3 meters or from the axis of the closest track on the approach to the LCr (warning cross, mechanism of (half-)barriers, etc.) which equals 3.75 m, and the line of the danger zone, which is 2 metres away from the last rail or 2.75 m from the axis of the last track on the departure from the LCr (Figure 132).

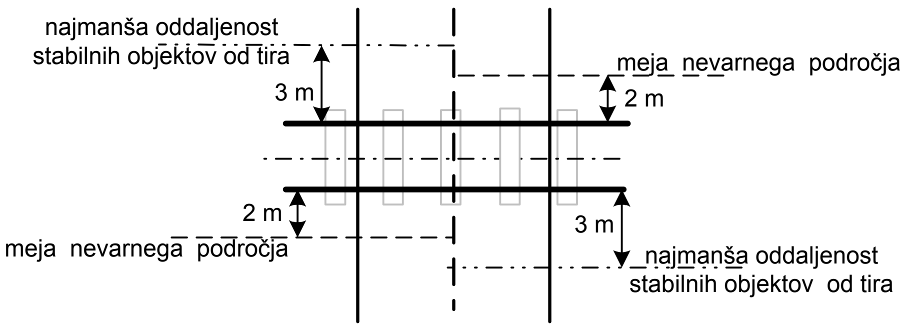


Figure 132

Translation of figure text

najmanjša oddaljenost stabilnih objektov od tira	minimum distance between stable objects and the rail
meja nevarnega področja	line of the danger zone
meja nevarnega področja	line of the danger zone
najmanjša oddaljenost stabilnih objektov od tira	minimum distance between stable objects and the rail

Switch-on point is a point on the track or rail, as far from the LCr as necessary to enable the entire process of switching on the LCr protection system. It is equipped with the devices for the detection of railway vehicles, i.e. their wheels. In the case of automatic devices for protecting LCr the LCr protection system is switched on, as a railway vehicle is approaching.

Approach zone is, in the case of LCr protected by automatic devices, that part of the track or rail between the switch-on point and the LCr on which the train is approaching the LCr.

Departure zone is, in the case of LCr protected by automatic devices, that part of the track or rail between the switch-on point and the LCr on which the train is departing from the LCr.

Switch-off point is that point on the track or rail which is, in the case of LCr protected by automatic devices, located directly at the LCr or the intersection of a road and railway, equipped with a device(s) for the detection of railway vehicles which automatically switches off the protection system, once the train passes it.

Signal interlocking devices are railway devices designed according to specifically prescribed rules and standards applying to signalling-technical safety ("Fail safe" system). This means that every foreseeable critical irregularity has to be reflected so that it cannot endanger traffic safety and, as a rule, cause a traffic halt.

Other expressions used herein have the same meaning as defined in:

- regulations on public roads;
- regulations on road traffic safety;
- regulations on railway traffic safety;
- regulations on railway traffic.

4.3 SPATIAL CONDITIONS

4.3.1 Methods for limiting the number of LCrs

The number of LCrs has to be limited to a minimum, which is achieved mainly by:

- cancellation of LCrs;
- arrangement of connecting roads between LCrs and road traffic assignments (rerouting) to a common LCr, which provides greater safety at crossing;
- restricted construction of new LCrs;
- spatial planning;
- construction of off-Level crossings (overpasses - underpasses).

4.3.2 Setting minimum distance between neighbouring LCrs

In accordance with the previous Item herein the distance between the existing LCrs has to be increased so that it equals at least:

- 1000 meters at rail sections with maximum permitted rail speed up to and including 100 km/h;
- 1500 meters at rail sections with maximum permitted rail speed up to and including 120 km/h;
- 2000 meters at rail sections with maximum permitted rail speed exceeding 120 km/h.

Exceptionally, the distance between two neighbouring LCrs referred to in the previous paragraph of this Item can be smaller, if the construction of connecting paths is considerably difficult or if their length exceeds 4 km, measured from the LCr from one to the other side of the track, namely:

- 700 meters at rail sections with maximum permitted rail speed up to and including 100 km/h;
- 1,000 meters at rail sections with maximum permitted rail speed up to and including 120 km/h;
- 1,500 meters at rail sections with maximum permitted rail speed exceeding 120 km/h.

4.3.3 Setting minimum distance between neighbouring LCrs reserved for pedestrians

The distance between a LCr designed for various road traffic participants and a LCr reserved for pedestrians, or between an off-Level crossing and a LCr reserved for pedestrians, or between two neighbouring LCrs reserved for pedestrians must not be less than:

- 500 metres at main tracks and
- 250 metres at regional tracks.

4.3.4 Conditions for constructing substitute connecting roads

When substitute connecting roads are constructed, the width and the connecting road category have to be equal to that of the road assigned to another crossing.

In the case of new constructions and assignments the roads of higher category must not be assigned to a LCr located on a road of lower category.

4.3.5 Prohibitions and conditions for constructing new LCrs

New LCrs must not be constructed on the main track, unless they represent substitute LCrs, which have to be protected.

On regional tracks only protected LCrs may be constructed, provided that:

- the railway traffic does not exceed 70 trains AADT;
- the maximum permitted rail speed is not more than 120 km/h;
- no other protected LCr or off-Level crossing is anywhere at a distance of up to 2,000 metres;
- the road traffic density does not represent an increase in the AADT by more than 2,500 motor vehicles or that this is not anticipated in the period of 5 years;
- no off-Level crossing is planned to be constructed in such area;
- the protection system of the LCr for each train will not be switched on for more than 90 seconds;
- the investment intervention, i.e. construction of a protected LCr is economically justified according to the Decree on the Uniform Methodology for Preparing Investment Public Procurement Programmes (Official Gazette of the RS, no. 82/98).

Only a temporary LCr, protected for the duration and for the purpose of repair works, facility construction, reconstruction, etc., may be constructed on tracks. Such LCr has to be protected in the manner and for the period specified by the Commission referred to in Article 109 of the Safety of Railway Transport Act (hereinafter: the SRTA). Such a LCr has to be removed immediately after the conclusion of works for which it was set up, unless the Commission appointed based on the regulation governing railway traffic safety decides otherwise.

4.4 CONSTRUCTION CONDITIONS

4.4.1 Setting the LCr construction area

From the point of view of construction a LCr is considered a roadway that crosses a track and expands for 3 meters from the axis of the far most rails on both sides of the LCr over the entire width of the roadway.

4.4.2 Setting LCr maintenance conditions

A LCr has to be constructed and maintained in such a manner that both railway and road traffic run safely and smoothly and so that the crossing by motor vehicles at prescribed speed is unhindered on the entire width of the roadway, including any bicycle paths, pavements, shoulders and facilities providing for drainage of rain water.

4.4.3 Distance of road crossroads from LCr

Road crossroads have to be so far from the track that the length of the road crossing the railway track is - from the line representing the minimum distance between stable objects/devices and the rail, i.e. (half-)barrier on the exit side of the LCr, to the "yield" traffic sign or the "stop" sign - at least 25 metres.

The provision of the previous paragraph is not applied in the event of a one-way road directing traffic from the crossroads to the LCr.

4.4.4 Setting construction characteristics of roads at LCr

Construction characteristics of the roadway at LCr have to comply with the road design rules within the meaning of levelled road route, and in addition:

- the roadway has to be levelled with the upper rail edge at least between both lines representing the minimum distance between stable objects/devices and the rail on both sides of the track;
- at least for 20 metres from the LCr the road must not be characterised by a longitudinal Level of more than 3%.

4.4.5 Setting the angle of the road-railway crossing

Road-railway crossing has to be at a right angle.

Notwithstanding the first paragraph hereunder such angle may be 90°±15° in the event of a protected LCr.

If the terrain configuration does not allow for the angle referred to in the previous paragraph or if the construction or reconstruction of such LCr leads to disproportionately high expenses, the angle between the road axis and the railway axis at a protected LCr may be less than 75 degrees, but minimum 60 degrees.

4.4.6 Setting the width of the roadway across the track

The width of the roadway at the LCr must not be less than 3 meters at least between the lines representing the minimum distance between stable objects/devices and the rail on both sides of the track.

The roadway of a road at LCr whose width according to the previous paragraph hereunder does not exceed 6 meters, must have on the right side, at least for 20 metres along both sides of the track from the line representing the minimum distance between stable objects/devices and the rail, a passing bay facing the road vehicles of such width that together with the width of the roadway it equals at least 6 metres.

The width of the roadway at LCr must not, according to the first and second paragraph hereunder, be less than the width of the existing road before and after the LCr.

4.4.7 Other construction regulations applying to a LCr

Construction conditions applying to a LCr that are not specified herein are stipulated in the regulations on the design, construction and maintenance of the lower and upper railway track structure and Signal interlocking devices.

4.5 ROAD TRAFFIC CONDITIONS

4.5.1 Setting the LCr area in terms of road traffic

In terms of road traffic the LCr area is the area stretching from the first traffic sign denoting the approach to the road-railway crossing to the line representing the minimum distance between stable objects/devices and the rail on the departure from the LCr or (half-)barrier on the departure from the LCr.

4.5.2 Markings on the roadway before a LCr

On stabilised roadways (asphalt, cement concrete) the carriageways have to be on the approach to the LCr at least for 50 metres before the LCr separated by a continuous no-passing line. If this is not possible due to the road parameters, the length may be shorter, but no less than 25 metres.

On both sides of the LCr, protected only by (half-)barriers, with maximum permitted rail speed over 120 km/h, the carriageways have to be separated by a no-passing line starting at least 50 metres before the crossing. If possible under the circumstances and required due to traffic safety, traffic calming measures may be imposed in the area of the approach to the LCr in accordance with the road regulations.

The road running along the track from which the road that crosses the railway bifurcates, the distance from the crossing being less than 25 metres, has to be equipped with traffic signs warning about the nearby road-railway crossing and a supplementary sign indicating the direction or the direction and the distance from the LCr.

4.5.3 Setting the minimum distance of a road crossroads from a LCr

If on a road that crosses a railway track there is a road crossroads closer than specified in Item 1.3.3 herein, the traffic at the road crossroads has to be arranged so that the road crossing the railway track is designated as major regardless of the category of crossing roads.

4.5.4 Dependency conditions traffic lights - devices at a LCr

If the road crossroads at which traffic is controlled by light signalling devices- traffic lights is less than 50 metres from the LCr, protected by automatic devices, the following conditions have to be met:

- such technical dependency has to be provided between traffic lights and automatic devices protecting the LCr that at the latest when the LCr protection system is switched on the prohibition of traffic is signalled to road traffic participants approaching the LCr, while the road traffic participants located in the LCr area are enabled the fastest possible departure from the LCr area;
- in the event of failure or when the traffic lights are turned off, the traffic arrangement has to be such as specified in the previous Item (1.4.3).

The technical solution for an individual LCr is according to the previous paragraph hereunder determined in design terms jointly by the road manager and the railway infrastructure manager.

4.5.5 Setting the road traffic density criteria

Road traffic at the LCr is:

- occasional (seasonal) - AADT equals up to 25 vehicles;
- light - AADT is between 25 and 250 vehicles;
- medium - AADT is between 250 and 2,500 vehicles;
- heavy - AADT is between 2,500 and 7,000 vehicles;
- very heavy - AADT equals 7,000 or more vehicles.

4.6 RAILWAY TRAFFIC CONDITIONS

4.6.1 Setting the railway traffic density criteria

Rail line traffic is estimated as very dense if on average more than 70 trains in 24 hours (AADT) are recorded on annual basis.

4.6.2 Setting the minimum distance from the LCr after the railway signal

The distance between the main railway signal and the protected LCr following it has to be more than 50 metres (travelled way or safety area).

4.6.3 Setting the conditions for two close LCr systems with control signals

Between the railway control signal or the auxiliary control signal and the pertaining LCr on the track there must be no other LCr that is not controlled by that signal.

If a control signal controls two successive LCrs, this has to be marked on the mast of the control signal.

4.6.4 Functioning of a LCr in the event of train stoppage at a Level crossing

If the location of the planned train stoppage on the track in the LCr departure area is such that the longest train with its rear would extend over the road-railway crossing, the LCr protection system has to be switched on for as long as this area is occupied.

4.7 TECHNICAL CONDITIONS

4.7.1 Road signal

4.7.1.1 The purpose and description of the road signal

When the protection system is switched on, the road signal announces the approach of a railway vehicle and the lowering of arms of (half-)barriers into the lower (horizontal) position. It consists of the basic triangular plate, representing the basic traffic sign denoting danger in the form of an equilateral triangle, with a set of lights with visors installed one next to the other on the lower side as well as a mast and a base in the ground.

The lights of the road signal are turned off, when the LCr protection system is switched off, however, when the protection system is switched on, they flash alternately at 60 blinks per minute, with equal on and off period.

The size, shape, colour, colorimetric and photometric characteristics of the basic triangle of the road signal have to comply with the regulations on road traffic signs. The mast and the back of the basic triangle of the road signal with the fastening construction have to be grey matt. The shapes, dimensions and the method of installing the road signal are presented in Attachment I, which is a constituent part of this guideline.

The radius of the lights on the basic triangular plate of the road signal with 900 mm sides has to be 200 mm and on a triangular plate with 1,200 mm sides 300 mm, while the light beam angle has to more than 100°.

4.7.1.2 Intensity of the light flux emitted by the road signal light

The intensity of the light flux has to be specified in the technical regulation and must not be less than prescribed for light traffic signs controlling vehicles in road traffic.

4.7.1.3 Determining the road signal position

Road signals are erected before LCrs by to the right side of the roadway facing the vehicles on both sides of the LCr. This represents basic protection.

Road signals have to be well visible continuously along the road axis crossing the LCr, at a distance equalling at least the stopping distance, but not at the distance of less than 50 metres.

4.7.1.4 Microlocation conditions for installing a road signal

The horizontal distance between the outer edge of the roadway or the edge of the extra width or the hard shoulder for emergency stop and the closest side of the traffic sign on roads outside towns has to be 0.75 metre and on urban roads at least 0.30 metre, if the road is kerbed. The axis of the road signal mast must not be more than 2 metres away from the edge of the roadway or from the edge of the extra width or the hard shoulder for emergency stop.

The lower side of the basic triangular plate of the road signal has to be 2.25 metres above the roadway surface. The base of the signal may be 150 mm above the terrain level maximum.

If a LCr is in addition to road signals protected also by (half-)barriers, such a signal has to be erected 1 to 1.5 metres before the (half-)barrier.

If a road signal is placed on the pavement or next to a bicycle path or route, such spot has to be selected, taking into account the provisions of this Item, that the road signal does not obstruct the pedestrian or bicycle traffic profile.

4.7.1.5 Examples of road signal positioning on the left side of the road

A road signal has to be erected also on the left side of the road facing road vehicles, if:

- the prescribed visibility of the road signal on the right side of the road cannot be provided;
- also on the left side of the road traffic signs facing road vehicles are installed indicating the approaching LCr;
- the Level crossing is protected also by spit barriers;
- in the case of (half-)barriers there is a pavement and/or bicycle path or route on the left side of the roadway, or:
- this is required by other local circumstances.

4.7.1.6 Installing road signals on feeder roads

The road signal has to be placed also on the right side of the roadways of approach and feeder roads leading to the road on which a LCr is located, if the axes of such road are less than 10 metres away from the nearest rail. Such road signal has to be equipped with a supplementary sign indicating the direction it applies to. The size, shape, colorimetric and photometric characteristics of the supplementary sign have to comply with the provisions of the Rules on Traffic Signs and Equipment on Public Roads; if an object to which the sign refers is in immediate vicinity of the sign, the distance need not be stated.

If a road signal is positioned on the approach or feeder road which does not lead directly and only to the LCr and applies only to vehicles turning in a certain direction, the light of every such signal may contain an arrow indicating the direction to which the road sign applies, in addition to the supplementary sign.

4.7.1.7 Road signals equipped with bells

At least one road signal on each side of the track has to be equipped with devices emitting audible signals with bells.

Bells are turned on immediately as the protection system is switched on.

Bells are turned off:

- in the case of LCrs protected only by traffic light-audible signals the signals are turned off immediately as the protection system is switched off;
- in the case of LCrs protected only by traffic light-audible signals and (half-)barriers, when the arms of (half-)barriers reach the lower position.

4.7.2 Barriers and half-barriers

4.7.2.1 The purpose and description of barriers and half-barriers

Barriers and half-barriers (hereinafter: (half-)barriers) consist of an arm and a mechanism. The mechanisms can be electro-mechanical or electro-hydraulic. They lower and raise the arm of the (half-)barrier. When down (the arm is in the lower horizontal position), half-barriers from both sides of the track close only the right half of the roadway facing the road vehicles, while barriers extend across the full width of roadway.

4.7.3 Raised and lowered position of (half-)barriers

When raised, a (half-)barrier is in the upper (vertical) position.

The lateral distance between the outer edge of the roadway or the extra width and the most exposed part of the (half-)barrier mechanism as the arm is in the vertical position must not be less than 0.75 metre and more than 2 metres.

When the arm closes also the pavement and/or bicycle path, the distance from the edge of that part of traffic area to the most exposed part of the (half-)barrier mechanism as the arm is in the vertical (raised) position must not be less than 0.20 metre from the pavement edge or 0.25 metre from the cycling path edge.

4.7.3.1 Provisions regarding the position of lowered (half-)barriers

When closed (lower horizontal position) a (half-)barrier has to be 0.9 to 1.2 metres above the roadway, as shown in Figure 2 of Attachment II, which is a constituent part of this guideline.

Space has to be provided for the counterweights of the arms, so that they do not represent an obstacle to the road traffic participants.

4.7.3.2 Provisions regarding the position of raised (half-)barriers with arms

The upper surface of the (half-)barrier mechanism base has to be above the level of the roadway or pavement, but no more than 0.1 metre.

The most exposed part of the (half-)barrier in lowered or raised position must not extend over the line representing the minimum distance between stable objects/devices and the rail. Exceptionally, such distance may be smaller, if this is without any doubt required by the local conditions, but it must not be less than 3.25 metres from the axis of the closest rail.

4.7.3.3 Purpose and appearance of (half-)barrier arm

The arms of (half-)barriers have to be made of light materials and attached to the mechanism in such a manner that, in the event of a collision, the arm and mechanism as well as the vehicle suffer as little damage as possible and so that they do not represent great physical resistance.

The arm of an automatic (half-)barrier has to be electrically controlled for breakage.

The mechanisms of (half-)barriers have to be engineered in such a manner that the arms of (half-)barriers are to hold back in uppermost or lowermost position.

On the side facing the approaching road traffic participants the arms of the (half-)barriers have to be over the entire length coated with a reflective substance possessing equal light-reflective characteristics as type 2 light-reflective material, in red and white colour alternately. The red and white coloured fields are at a right angle to the arm axis. The colour, colorimetric and photometric characteristics have to comply with the regulations governing traffic signs.

The arms of the (half-)barriers that are not coated with a light-reflective substance referred to in the previous paragraph hereunder have to be equipped with three red reflex reflectors positioned over full length. There may be two lights on the arms, which are, when protection system is switched on and the arms start to lower, constantly lit or flashing, and turn off when the arms of the (half-)barriers reach the uppermost position. The lights have to be facing the road and be shielded towards the track.

The position of reflex reflectors and lights is shown in Figure 1 in Attachment II, which is a constituent part of this guideline.

4.7.3.4 Equipment of the (half-)barrier arm

The reflex reflectors have to be rectangular, with the height and length ratio of 1:2 and the surface of at least 40 cm^2. The lights on the arms of (half-)barriers have to be rectangular, with the height and length ratio of 3:4 and the surface of 40 cm^2.

4.8 SAFETY CONDITIONS

4.8.1 Introductory provisions

4.8.1.1 Conditions of safe crossing of a track at LCr

The road traffic participants, complying with traffic rules and signalisation, have to be ensured safe crossing at a LCr.

The road traffic participants have to be by means of road traffic signs in due time warned about the danger of approaching an unprotected or protected LCr.

The speed limit regulated by traffic signs on the road crossing an unprotected LCr has to be no 50 km/h maximum.

4.8.1.2 Classification of protected and unprotected LCrs

LCrs can be either protected or unprotected.

Unprotected LCrs are the crossings marked only with the warning cross.

Protected LCrs are those equipped with technical means preventing the road traffic participants from crossing a railway track (arms of (half-)barriers) or announcing the arrival of a train and/or prohibiting the road traffic participants from crossing the railway track (road signals), when a train is approaching the LCr or driving across it.

4.8.1.3 Obligation to protect LCr

Regardless of the speed of trains, a LCr has to be protected:

- if the road traffic is medium or dense;
- if the rail line traffic is very frequent;
- if it is not possible to provide a sight area at unprotected LCr;
- if a LCr cannot be eliminated, assigned or an off-Level crossing constructed or when this is economically unjustified;

- on roads with regular public passenger bus lines;
- on the main national road of category 2 and on regional road of category 1;
- on double- or multi rail tracks.

LCrs on industrial rails are not subject to the provisions of the previous paragraph hereunder, with the exception of the third and fifth indent. When traffic on industrial rails is arranged in such a way that trains stop before the LCr or traffic is controlled by authorised railway employees, the third and fifth indent of the first paragraph need not be complied with.

4.8.1.4 Maximum period switched on a protection system of the LCr

If in spite of the fact that all traffic and technical-technological conditions for protection are met, it is impossible to ensure that the total period during which protection system is switched on lasts less than 5 minutes, another solution has to be sought in compliance with this guideline.

4.8.2 Local traffic safety conditions

4.8.2.1 Crossing area (zone)

That part of the road between the point, where a driver of a road vehicle has to start slowing down, if this is necessary to ensure that the vehicle safely stops in front of the warning cross, road signal or (half-)barrier, and the point, where the front of the longest road vehicle passes the crossing area so that its rear, most exposed part is past the danger zone line or the (half-)barrier line on the departure from the LCr, is called the crossing zone (Cp) (Figure 133).

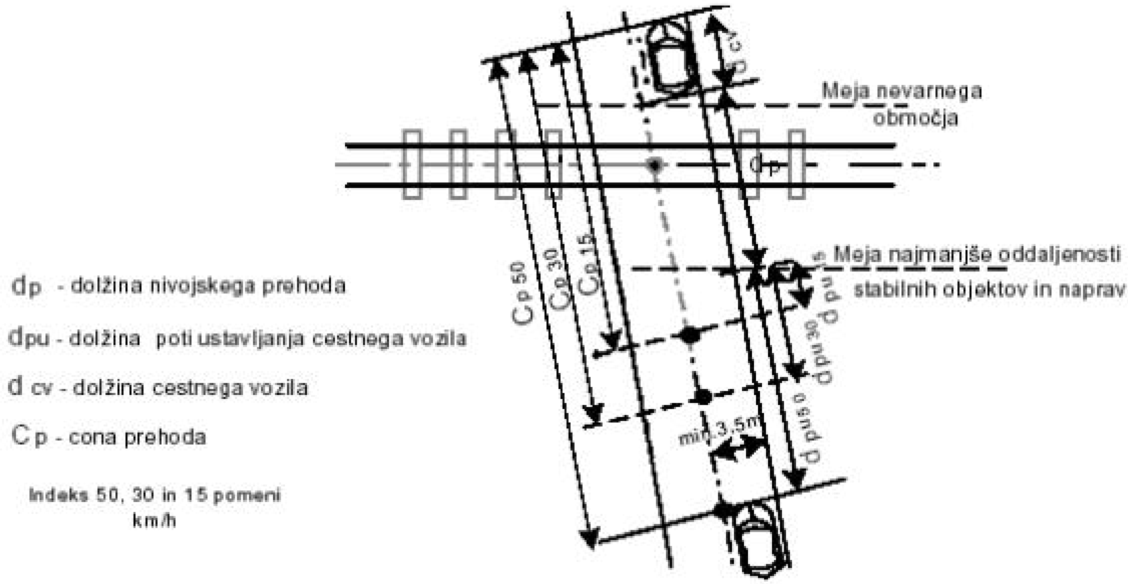


Figure 133 Translation of figure tekst

Meja nevarnega območja	Line of the danger zone
Meja najmanjše oddaljenosti stabilnih objektov in naprav	Line representing the minimum distance between stable objects/devices
dolžina nivojskega prehoda	length of the Level crossing
dolžina poti ustavljanja cestnega vozila	stopping distance of the road vehicle
dolžina cestnega vozila	length of the road vehicle
cona prehoda	crossing zone
Indeks 50, 30 in 15 pomeni km/h	Index 50, 30 and 15 refers to km/h

The crossing zone (C_p) is the sum of the stopping distance of a road vehicle (d_{pu}), the length of the longest road vehicle (d_{cv}) and the length of LCr (d_p):

$$C_p = d_{pu} + d_p + d_{cv} \text{ [m]}$$

The time needed by a road vehicle for driving across the crossing zone is the LCr clearance time. The LCr clearance time (t_{zp}) is the quotient of the crossing zone length and maximum permitted speed of road vehicles from the point from which the stopping distance is calculated. It equals:

$$t_{zp} = C_p \text{ [m]} / v_{cv} \text{ [m/s] [s]}$$

The values of the stopping distance (d_{pu}) depending on the speed of road vehicles at longitudinal Level of 0 to ±7% are given in the table below:

Road vehicle speed	Stopping distance
[km/h]	[m]
50	41
30	22
15	10

In the case of a longitudinal Level of more than 7%, 5 metres have to be added to the stopping distance in the event of a fall and 5 metres subtracted in the event of a rise (expect at speed up to 10 km/h).

The crossing length (d_p) in the case of an unprotected LCr is the shortest distance between:

- the invisible line, perpendicular to the right edge of the roadway from the position of the road traffic sign - warning cross on the approach to the LCr and the LCr danger zone line in the case of a crossing at a right angle (Figure 1 of Attachment IV, which is a constituent part of this guideline) or
- the invisible line perpendicular to the right edge of the roadway from the intersection between the danger zone line and the right edge of the roadway in the case of a crossing at an acute angle (Figure 2 of Attachment IV, which is a constituent part of this guideline) or
- the invisible line, perpendicular to the right edge of the roadway from the intersection of the danger zone line and the invisible line parallel to the right edge of the lane at a distance of minimum 3.5 metres or the left edge of the lane (Figure 3 of Attachment IV, which is a constituent part of this guideline) in the case of a crossing at an obtuse angle on the departure from the LCr.
- The crossing length (d_p) in the case of a protected LCr is the shortest distance between:
- the invisible line, perpendicular to the right edge of the roadway from the position of the road signal at the right edge of the roadway in the case of protected LCr on the approach to the LCr and the LCr danger zone line, protected by half-barriers in the case of a road-railway crossing at a right angle (Figure 1 of Attachment IV, which is a constituent part of this guideline) or
- the invisible line perpendicular to the right edge of the roadway from the intersection between the danger zone line and the right edge of the roadway in the case of a road-railway crossing at an acute angle protected by half-barriers (Figure 2 of Attachment IV, which is a constituent part of this guideline) or

- the invisible line, perpendicular to the right edge of the roadway from the intersection between the danger zone line and the invisible line parallel to the right edge of the roadway at a distance of minimum 3.5 metres or the left edge of the lane (Figure 3 of Attachment IV, which is a constituent part of this guideline) in the case of a crossing at an obtuse angle protected by half-barriers or (half-)barrier closing the right side of the roadway (barrier or split barrier) on the departure from the LCr.

4.8.2.2 The path and time of a railway vehicle approach to a LCr

The path of a railway vehicle approach to a LCr is the path from the visibility point on the track to the LCr in the case of an unprotected LCr or from the switch-on point on the track to the LCr in the case of a LCr protected by automatic devices.

The time of a railway vehicle approach ($t_{pžv}$) to the LCr is the time required by a railway vehicle, driving at maximum permitted rail speed, to pass the path of a railway vehicle approach to a LCr, increased by 6 seconds for safety reasons.

4.9 UNPROTECTED LEVEL CROSSINGS

4.9.1 General provisions

4.9.1.1 Marking of unprotected crossings and elements of sight area

Unprotected LCrs have to be marked by traffic signs according to the Rules on Traffic Signs and Equipment on Public Roads. Sight area has to be provided.

The traffic sign - warning cross at a LCr has to be installed at least so far from the nearest rail that the invisible line from the position of the traffic sign perpendicular to the right edge of the roadway intersects the road axis at the line representing the minimum distance between stable objects/devices and the rail (see Attachment IV, which is a constituent part of this guideline).

The sight area is the area stretching from the visibility point on the road before the LCr to the vertical axis of the crossing at 1 to 2.5 metres above roadway level, when road traffic participants have unobstructed view to the visibility point on the track from both sides of the LCr at the height of at least 1.5 to 4 metres above the upper rail edge (URE) of a one-rail track across the LCr (see Attachment III, which is a constituent part of this guideline).

The visibility point is that point on the road from which a road traffic participant, when approaching a LCr, has for the first time a view all the way to the visibility point on the track.

The visibility point is that point on the track at least as far from the LCr that a road traffic participant has to be able to notice the approaching railway vehicle from the visibility point so as to stop their vehicle before the LCr. The visibility point is set by a calculation of a railway vehicle approach path.

The vertical axis of the LCr is at the intersection of the track axis and the road axis.

The contents of the third to sixth paragraphs are graphically presented in a sketch (Figure 134)

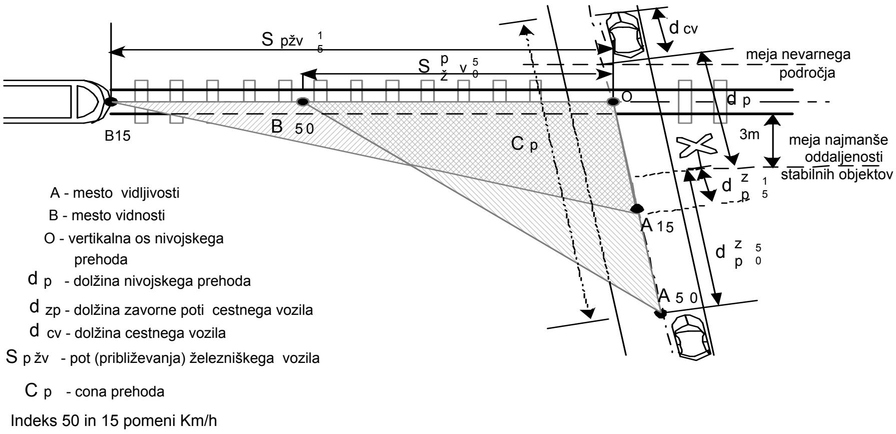


Figure 134

meja nevarnega področja	line of the danger zone
meja najmanjše oddaljenosti stabilnih objektov	the line representing the minimum distance of stable objects
A - mesto vidljivosti	A - sight point
B - mesto vidnosti	B - visibility point
O - vertikalna os nivojskega prehoda	O - vertical axis of the Level crossing
d_p - dolžina nivojskega prehoda	d_p - length of the Level crossing
d_{zp} - dolžina zavorne poti cestnega vozila	d_{zp} - braking distance of a road vehicle
d_{cv} - dolžina cestnega vozila	d_{cv} - length of a road vehicle
$S_{pžv}$ - pot (približevanja) železniškega vozila	$S_{pžv}$ - path of a railway vehicle (approach)
C_p - cona prehoda	C_p - crossing zone
Indeks 50 in 15 pomeni Km/h	Index 50 and 15 refers to Km/h

4.9.1.2 Formulas for calculating the approach time and path

In the case of an unprotected LCr the approach time of a railway vehicle (t_p) has to be at least 6 seconds longer than the time needed for road vehicles to leave the LCr (t_{zp}).

The path of a railway vehicle approach to the LCr ($s_{pžv}$) is the product of maximum permitted rail speed of railway vehicles ($v_{žvmaks}$) and the railway vehicle approach time (t_p). It equals:

$$s_{pžv} = v_{žvmaks}\ [m/s] \times t_p\ [s]\ [m]$$

4.9.1.3 Speed limit according to sight

For an unprotected LCr it is established, based on a view from the sight point on the road, if adequate sight to the visibility point on the track is provided, taking into account the maximum rail speed of the train, in the event a road vehicle travels at 15 km/h.

If the sight area referred to in the first paragraph hereunder is provided, it is checked also if it is provided in the event a road vehicle travels at 30 km/h or 50 km/h.

If under the first and second paragraph hereunder the track sight is established to be inadequate, a suitable sign has to be erected on the road before the Level crossing - "speed limit" (II-30).

Traffic mirrors may be used to provide for greater sight area.

4.9.1.4 Conditions for providing safe crossing of a LCr in the event a road vehicle stops at the warning cross

To provide safe crossing of an unprotected LCr by a road vehicle in case a vehicle has to come to a full stop in front of the warning cross, the sight point has to be at such distance from the point of stoppage (which is in this case also the visibility point) that the time of a railway vehicle approach, taking into account the additional 6 seconds for safety reasons, is longer then the time needed for the longest vehicle to pass the crossing zone at a speed of 5 km/h.

4.9.1.5 Sight area at a LCr reserved for pedestrians

In the case of an unsecured LCr reserved for pedestrians, the sight area is suitable if, when crossing the track, from the line representing the minimum distance between stable objects/devices and the rail, the pedestrians have a view of the track at such distance that, complying with the road traffic regulations, they may cross the Level crossing or stop before it without hazard.

4.9.1.6 Signals on track denoting approach to a LCr

In the case of unprotected LCrs permanent signals have to be provided on major and regional tracks 500 metres before the Level crossings, warning the train about the approach to such crossings.

4.9.1.7 Protection of a LCr by locked barrier

Unprotected LCrs on rural paths and forest trails recording occasional seasonal traffic that do not provide the sight area may be protected by a locked plank across the full width of the roadway. Upon the request of the user the key is handled by an authorised person in the manner prescribed for a particular crossing by the manager of the LCr.

Local users have to be acquainted with the method in a locally specific manner.

4.10 PROTECTED LEVEL CROSSINGS

4.10.1 General provisions

4.10.1.1 Types of protection

LCrs are protected by:

- mechanic devices, operated by an authorised railway employee;
- automatic devices with road signals;
- automatic devices with road signals and (half-)barriers.

4.10.1.2 Signal interlocking devices for protecting LCrs

Automatic devices for protecting LCrs must have a status of Signal interlocking devices as specified in the technical regulations and must ensure traffic protection in all traffic-technological situations on the road and track, traffic areas and in relation thereto for traffic on both rails in both directions.

The methods of informing the operators of railway vehicles and the train personnel and their conduct in the event of a critical irregularity recorded in the functioning of devices that protect the LCr have to be stipulated in railway traffic regulations.

4.10.1.3 General description of automatic protective devices

Automatic devices for protection of a LCr are those devices which are switched on by the train itself as it is at a certain distance within the approach zone before the LCr, at the switch-on point, and switched off after the train passes the road-railway crossing at the switch-off point. The protection system can also be switched on by directing the paths in the traffic area and switched off automatically as the switch-off point is passed.

As the automatic devices for the protection of LCrs are designed, the circumstances at the LCr have to be estimated and the times calculated which ensure timely switch-on of the protection system before the train arrives to the LCr, considering maximum permitted rail speed.

4.10.1.4 Automatic switch-off of the protection system of a LCr without train drive

The automatically switched-on protection system of a LCr is switched off in the following ways:

- by train, as it fully passes the switch-off point;
- by issuance of an order to the automatic device for the protection of a LCr at the pertaining traffic control point;
- automatically, at least 300 seconds (5 minutes) after the time the protection system was switched on, if prior to that the train does not pass the switch-off point.
- The automatic switch-off of the protection system of a LCr without train drive referred to in the third indent of the previous paragraph hereunder has to be disabled:
- if the train is planned to stop in the approach zone, especially if a train stop or the main signal are within this zone, and only for the period during which the train stands still at the stop or in front of the signal, or
- if the automatic device for protecting the LCr enables the protection system to be switched off by issuance of an order at the pertaining traffic control point.

4.10.1.5 Power supply sources for the devices protecting a LCr

Automatic devices have to be primarily supplied a permanent power source from the public network or indirectly from the power supply of other Signal interlocking devices. In addition, they must have their own, back-up source of energy supply, which enables proper functioning for at least 8 hours after the primary power supply failure.

4.10.1.6 Advance bell-ringing

Advance bell-ringing is intended to warn the road traffic participants that a train is approaching the LCr or that the arms of the (half-)barriers will start lowering. In the case of automatic devices for the protection of a LCr the advance bell-ringing is signalised by light and audible signal, while in the event of mechanical devices for the protection of a LCr it is signalised by an audible signal, which may be complemented also by a light signal.

The duration of advance bell-ringing must in no case be shorter than 15 seconds.

4.10.1.7 Gravity-based lowering of (half-)barrier arms in the event of a secondary power supply failure

In the case of automatic devices providing protection of a LCr by road signals and (half-)barriers the arms of the (half-)barriers have to automatically lower by means of gravity to the horizontal position in the event of a secondary power supply failure.

4.10.1.8 Signalising the approach to the LCr on the track

Approach to a protected LCr has to be signalised on both sides by permanent signals, placed at least at a braking distance, taking into account the permitted deviations.

4.10.1.9 Operating conditions on two-rail tracks

At LCrs protected by road signals and (half-)barriers on two-rail tracks the arms of (half-)barriers that started to rise have to be raised completely, in the event the protection system is switched off as one train passes on one rail and immediately switched on due to another train on the second rail. After they are raised completely, the entire process of switching on the protection system has to start anew, including the advance bell-ringing. On account of the arms of (half-)barriers being raised, the duration of protection is 8 seconds longer - the time needed for raising the arms. If the (half-)barriers are in the lower position, they have to stay there also as the second train approaches.

4.10.1.10 Arrangement of pedestrian and bicycle areas

In the case of a LCr protected only by road signals or by road signals and (half-)barriers traffic areas have to be provided for pedestrians and cyclists on the rights side of the roadway in the direction facing the road vehicles, especially in densely built-up areas, in the vicinity of schools and kindergartens.

The locations referred to in the first paragraph hereunder may be equipped with additional road signals and/or suitably designed fences which prevent pedestrians from directly crossing the track (zigzag fences). The devices have to be adjusted for the disabled using wheelchairs.

4.10.2 Level crossings protected by mechanical barriers, operated by an authorised railway employee

4.10.2.1 Lowering of mechanical barriers prior to train arrival

At a LCr protected by mechanical barriers operated (lowered and raised) by an authorised railway employee on the site, the arms of the barriers have to be lowered at least 3 minutes prior to the expected train arrival.

At a LCr protected by mechanical barriers operated by an authorised railway employee from a remote location which does not provide a suitable view of the LCr, the arms of the barriers have to be start being lowered at least 5 minutes prior to the arrival of a train at such a LCr.

A LCr protected by mechanical barriers operated by an authorised railway employee from a remote location which does not provide a suitable view of the LCr has to be equipped with at least an advance bell-ringing device, which gives an audible warning to the road users by intermittent bell-ringing, i.e. the bell is stricken with a small hammer, indicating that the arms of the barriers will start being lowered (advance bell-ringing period), namely:

- at least 15 audible signals or 15 hammer strikes in 20 seconds for a LCr 17 up to metres long;
- at least 20 audible signals or 20 hammer strikes in 25 seconds for a LCr more than 17 metres long.

4.10.2.2 Operating method of road signals in the case of mechanical barriers

LCrs protected by mechanical barriers may also be protected by road signals which have to be switched on as the bell-ringing starts, before the arms of the barriers are lowered, and switched off as the arms of the barriers again reach the uppermost (vertical) position.

4.10.3 Level crossings protected by automatic devices only with road signals (without (half-)barriers)

4.10.3.1 Installing a road signal at a crossing at an acute angle

A road signal has to be installed at a LCr comprised of a road-railway crossing at an acute angle at least so far from the nearest rail that the invisible line from the position of the road signal perpendicular to the right edge of the roadway intersects the road axis at the line representing the minimum distance from stable objects/devices (identical to the positioning of the warning cross - see Figure 2 in Attachment IV, which is a constituent part of this guideline).

4.10.3.2 Switching road signal lights on and off

The lights of the road signals are turned on immediately as the protection system is switched on.

The lights of the road signals are turned off, when the rear of the train passes the switch-off point.

4.10.3.3 The time when the protection system is switched on before train arrival and the approach time of a railway vehicle to a LCr

At a LCr protected only by road signals the protection system has to be switched on for at least 21 seconds (advance bell-ringing 15 sec + 6 sec) before the train arrives at the LCr or at least for so long that the time of the train approach to the LCr is 6 seconds longer than the time needed for clearance of the danger zone by the longest characteristic road vehicle or pedestrian in the crossing area at the lowest speed (see Item 5.4.3).

The approach time of a railway vehicle (t_p) is the period from the time the protection system is automatically switched on until the time of railway vehicle arrives at the LCr.

4.10.4 Level crossings protected by automatic devices with road signals and (half-)barriers

4.10.4.1 Switching road signal lights on and off, raising and lowering of arms of (half-) barriers

In the case of automatic devices for the protection of LCrs by road signals and (half-)barriers the road signal lights are turned on immediately as the protection system is switched on.

The arms of the (half-)barriers start being lowered as soon as the advance bell-ringing time passes and the lowering may last for 8 to 12 seconds, usually 10 seconds.

The arms of the (half-)barriers start being raised as soon as the train passes the switch-off point and the raising may last for 6 to 8 seconds, usually 7 seconds.

The road signal lights are turned off when the rear of the train leaves the road-railway crossing area and all the arms of the (half-)barriers are raised to vertical position.

4.10.4.2 The time when protection system is switched on before train arrival

At a LCr up to 15 metres long, protected by road signals and (half-)barriers, the protection system has to be switched on:

- on one-rail tracks at least 31 seconds before the train arrival, taking into account light and audible signals lasting for 15 seconds, which warn the road traffic participants that the arms of the (half-)barriers are being lowered (advance bell-ringing), lowering of the arms of (half-)barriers, which lasts for 10 seconds, and additional 6 seconds for safety purposes;
- on two-rail tracks at least 39 seconds before the train arrival at a LCr, taking into account light and audible signals lasting for 15 seconds, which warn the road traffic participants that the arms of the (half-)barriers are being lowered (advance bell-ringing), lowering of the arms of (half-)barriers, which lasts for 10 seconds, additional 6 seconds for safety purposes and 8 seconds due to peculiarities on two-rail tracks as two trains drive over adjacent rails;
- at LCrs protected by barriers, at least 35 seconds before the train arrival.
- At a LCr protected by split (half-)barriers the delay time until the arms of the (half-)barriers start being lowered on departure from the LCr has to be considered.

At a LCr protected by split (half-)barriers the second pair of (half-)barrier arms on the departure from the LCr has to start being lowered with a delay, taking into account the time referred to in the first paragraph hereunder and, additionally, the time needed for the slowest vehicle to pass from the first (half-)barrier on the approach to the LCr to the second (half-)barrier on the departure from the LCr.

4.10.4.3 The approach time of a railway vehicle to a LCr and the formula for calculating the distance from switch-on points on the track

In any case the protection system of a LCr by full lowering of (half-)barriers has to be switched on soon enough to enable the most exposed rear part of the longest road vehicle to safely pass the danger zone in the crossing area at the lowest speed and to pass the second pair of the (half-)barriers while departing from the LCr. Likewise, the protection system of a LCr by full lowering of (half-)barriers has to be switched on soon enough for the pedestrians to safely and in due time leave the danger zone in the crossing area and depart from the LCr by passing the second pair of (half-)barriers.

The approach time of a railway vehicle to the LCr protected by road signals and (half-)barriers (t_p) must not be shorter than 31 seconds on one-rail tracks and 39 seconds on two-rail and parallel tracks.

The approach time of a railway vehicle to a LCr protected by road signals and (half-)barriers (t_p) at the maximum permitted rail speed must not be shorter than the time needed by road participants (road vehicles, pedestrians) to leave the danger zone.

1. Calculation of the approach time (t_p) for pedestrians;

$$t_p = \frac{d_p}{v_p} + 6s$$

d_p – length of the Level crossing,

v_p – speed of pedestrians (1.2 m/s).

2. Calculation of the approach time (t_p) for vehicles standing in front of the LCr;

$$t_p = \frac{d_p + d_{cv}}{v_{cv5km/h}} \times 3.6 + 6s$$

d_{cv} – maximum length of road vehicles (18.75 m),

$v_{cv5km/h}$ – average speed of road vehicles driving across the crossing area (5 km/h).

3. Calculation of the approach time (t_p) for vehicles at minimum speed of 15 km/h;

$$t_p = \frac{d_p + d_{cv} + d_{pu}}{v_{cv15km/h}} \times 3.6 + 6s$$

d_{pu} – stopping distance of road vehicles at the speed of 15 km/h,

$v_{cv15km/h}$ – minimum speed of road vehicles (15 km/h).

In the case of two-rail and parallel tracks additional 8 seconds are added.

Of the three (time) values the highest is considered. If such value is less than 31 seconds on a one-rail track or less than 39 seconds on a two-rail or parallel track, the approach time of a railway vehicle (t_p) is 31 and 39 seconds respectively. If, however, such value is higher (more than 31 or 39 seconds - depending on the track), the highest value is considered. The switch-on point is calculated based on the highest value.

The distance of the switch-on point (L_{vm}) on the track in the area on the approach to the LCr is calculated as follows:

1. At a LCr with remote control; as a product of the approach time of a railway vehicle to the LCr (t_p) and the maximum railway speed ($v_{žvmaks}$), using the formula:

   $$L_{vm} = v_{žvmaks}\,[m/s] \times t_p\,[s]$$

2. At a LCr with control signals; control signals are placed at the braking distance before the LCr (set in the Rules on the Signalling-Safety Devices). The distance of the switch-on point from the control signal, calculated using the formula 2x $v_{žvmaks}$[m]; $v_{žvmaks}$, is expressed in km/h. If the maximum railway vehicle speed is less than 50 km/h, the switch-on point is placed 100 m before the control signal.

If the railway vehicle approach time $t_p = \frac{L_{vm}}{v_{žvmaks}}$ is shorter than the time needed by the road participants to leave the danger zone, the control signal is relocated accordingly, but to the extreme point than specified in the Rules on the Signalling-Safety Devices.

4.10.4.4 Setting conditions for obligatory use of (half-)barriers

The use of (half-)barriers is obligatory:

- for protection of LCr on double- or multi-rail tracks;
- on tracks with maximum permitted rail speed above 100 km/h;
- at crossings with roads with roadway width of 7 metres or more;
- at crossings with roads with two or more carriageways;
- at crossings where the road traffic is dense and/or railway traffic very frequent.

If the roadway at the protected LCr is less than 6 metres wide, the barriers have to extend across the full width of the roadway.

4.10.4.5 Maximum permitted distance of two tracks or rails at a single LCr

LCrs at double- or multi-rail or parallel tracks, which are less than 22 metres apart, including the danger zone, have to be protected by a single device, which is switched on for trains driving on the rails from all directions.

4.10.5 Level crossings at electrified tracks

4.10.5.1 The purpose and contents of the inscription on the marking of the height profile

Before a LCr on electrified tracks height profiles have to be marked so as to avoid unauthorised approach to the line conductor. The marking of the height profile consists of a wire levelled with the roadway, a warning sign "ATTENTION" High Voltage Danger of Death" above the road axis and a warning sign indicating danger of electricity - red zigzag arrow (see Attachment V, which is a constituent part of this guideline and shows the warning sign).

LCrs reserved for pedestrians and/or cyclists need not be equipped with a height profile.

4.10.5.2 Location of the height profile

A height profile has to be placed 4.5 metres high parallely to the roadway and perpendicular to the road axis across the entire road width, including the shoulders and pavements.

The height profile marking has to be at least 8 metres from the closest rail, measured by the road axis, while the distance between two markings of height profiles on both sides of the track must not be less than 20 metres.

4.11 TRANSITIONAL AND FINAL PROVISIONS

4.11.1 Transitional period for meeting the requirements regarding the distance between the existing LCrs

The distance between the existing LCrs may be smaller than specified in Items 4.2.2 and 4.2.3 herein:

- until the first reconstruction of the road that crosses such a LCr;
- until the construction of connecting roads enabling assignment;
- until the construction of an off-Level crossing near the LCr;
- no later than within 10 years of the date this guideline enters into force.

The prescribed minimum distance between LCrs has to be provided by the railway infrastructure manager, the road manager and the competent state authorities and commissions appointed by such authorities.

4.11.2 Transitional period for meeting the requirements regarding the angles at which the roads cross the existing LCrs

The prescribed minimum angle referred to in Item 4.3.5 herein has to be provided at the existing LCrs:

- upon the first reconstruction of the road or
- upon the reconstruction of the protection devices or
- no later than within one year, if an extraordinary event is recorded at the LCr, which is the result of inadequate sight of the track on account of too acute crossing angle or
- no later than within one year, if within such period three instances of endangerment of traffic safety are recorded due to too acute crossing angle or
- if the LCr is located on the road leading to the towns frequented by visitors in tourist or school buses, but no later than within 10 years of the date this guideline enters into force.

4.11.3 Transitional period for providing the width of roadway crossing the track

The conditions referred to in Item 1.3.6 herein have to be met within the five years of the date this guideline enters into force.

Notwithstanding the first paragraph hereunder the conditions specified in Item 1.3.6 herein have to be met:

- upon the first reconstruction of the road or

- no later than within one year if an extraordinary event is recorded at the LCr, which is the result of the fact that vehicles cannot meet in the LCr area or cannot in due time leave the track on account of the given traffic situation, or
- no later than within one year, if within such period three instances of endangerment of traffic safety are recorded due to disabled timely clearance of vehicles from the track in a given existing traffic situation, or
- the LCr is located on the road leading to cultural and historical facilities or tourist sights etc. and used within the scope of special routes of tourist or school buses.
- **Transitional period for providing the distance of road crossroads from a LCr**

The conditions laid down in Items 4.3.3 and 4.4.3 hereunder have to be met for the existing LCrs no later than by the first reconstruction of any road that is crossed near the LCr or at the LCr.

Notwithstanding the previous paragraph hereunder the conditions specified in Items 4.3.3 and 4.4.3 herein have to be met immediately, if:

- an extraordinary event is recorded at the LCr due to disabled LCr danger zone clearance on account of the given traffic situation in the nearby crossroads, or
- within one year three instances of endangerment of traffic safety are recorded due to disabled LCr danger zone clearance on account of the given traffic situation in the nearby crossroads, or
- the LCr is located on the road leading to cultural and historical facilities or tourist sights etc. and used within the scope of special routes of tourist or school buses.

4.11.4 Transitional period for providing LCr protection

The conditions referred to in Items 3.1.3 and 5.1.4 herein have to be complied with within ten years of the date this guideline enters into force at the latest. The railway infrastructure manager and the road manager have to jointly prepare the programme of requirements and priorities for protecting a LCr within one year at the latest.

4.11.5 Establishing the adequacy of sight areas and measures

The conditions referred to in Item 4.1.3 hereunder are established by a commission appointed based on the railway traffic safety regulations within three years of the date this guideline enters into force, while the implementation must follow within 8 years of the same date at the latest.

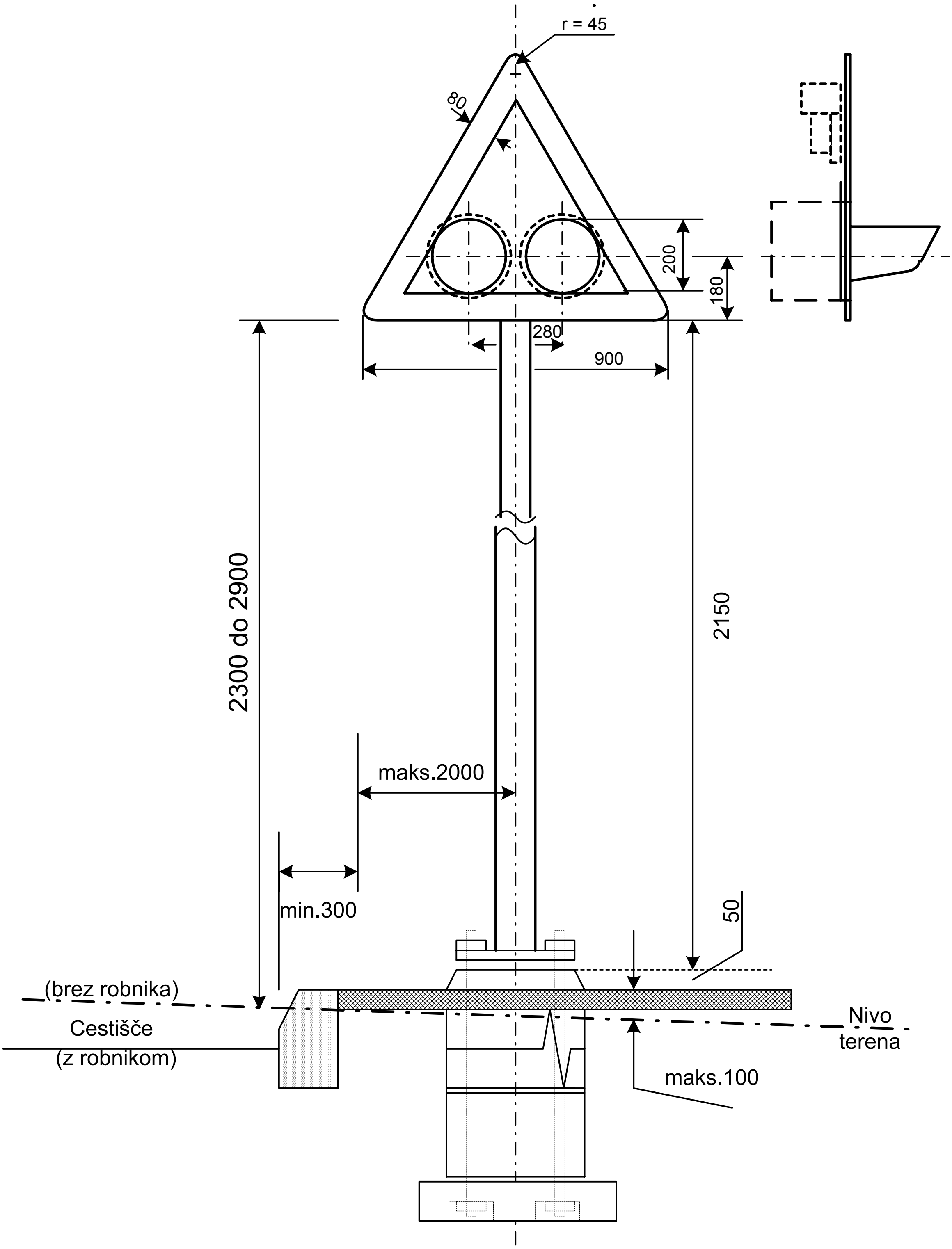
4.11.6 Detailed regulations governing the implementation, design and construction of Signal interlocking devices

Detailed technical contents of the conditions for providing LCr protection are specified in the Rules on Conditions for Designing, Setting up and the Maintenance of the Signal interlocking Devices as well as technical specifications and specifications of system requirements.

4.11.7 Replacement of mechanical devices for protecting LCr

Mechanical devices for protecting LCr, managed by the authorised railway employee from a remote location, have to be replaced by a more suitable solution (elimination, off-level crossing, automatic protective device) within five years of the date this guideline enters into force.

ATTACHMENT I: Road signalisation



Translation of figure tekst

2300 do 2900	2300 to 2900
maks. 2000	max. 2000
min. 300	min. 300
(brez robnika)	(without kerb)
Cestišče (z robnikom)	Roadway (with kerb)
maks. 100	max. 100
Nivo terena	Terrain level

ATTACHMENT II: Barriers and half- barriers

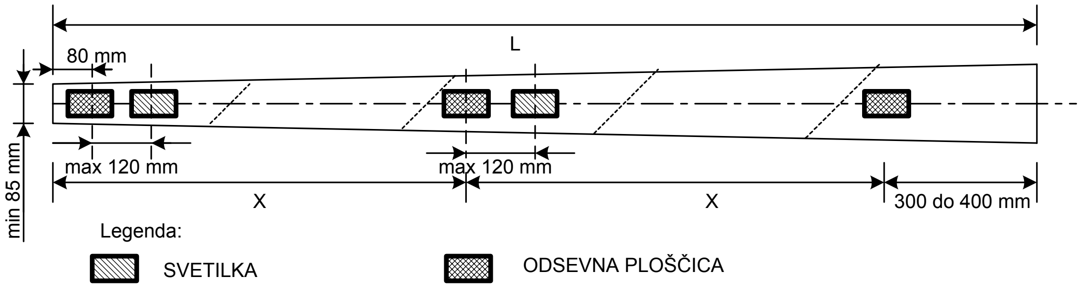


Figure 1

Translation of figure text

SVETILKA	LIGHT
ODSEVNA PLOŠČICA	REFLEX REFLECTOR
300 do 400 mm	300 to 400 mm

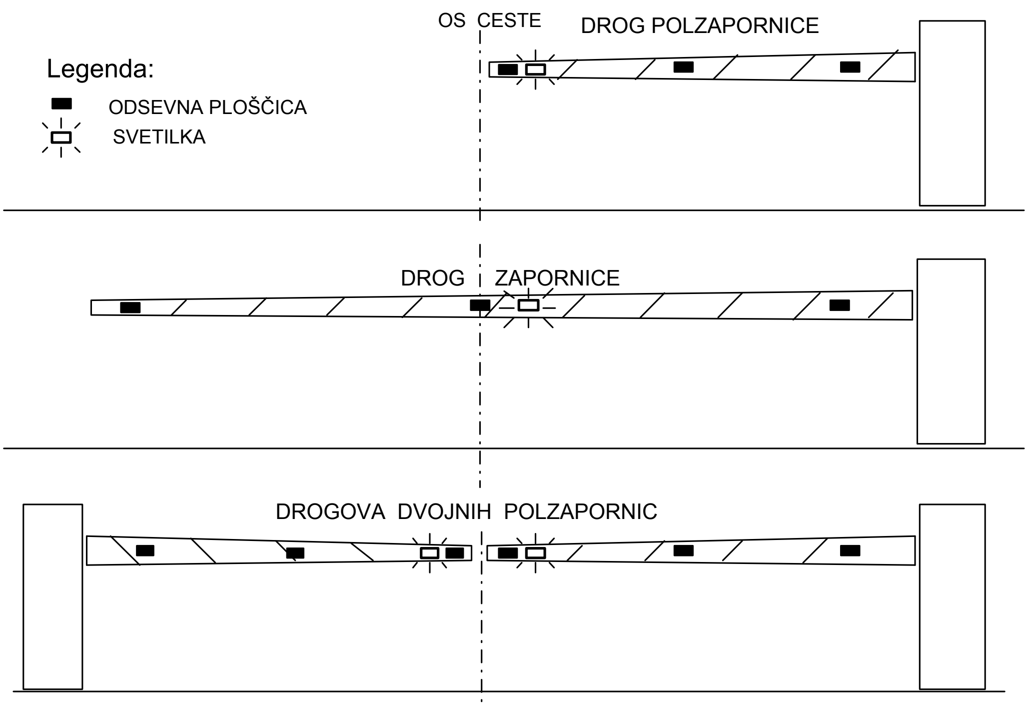


Figure 2

OS CESTE	ROAD AXIS
DROG POLZAPORNICE	ARM OF THE HALF-BARRIER
DROG ZAPORNICE	ARM OF THE BARRIER
DROGOVA DVOJNIH ZAPORNIC	ARMS OF DOUBLE BARRIERS
Legenda:	Legend:
ODSEVNA PLOŠČICA	REFLEX REFLECTOR
SVETILKA	LIGHT

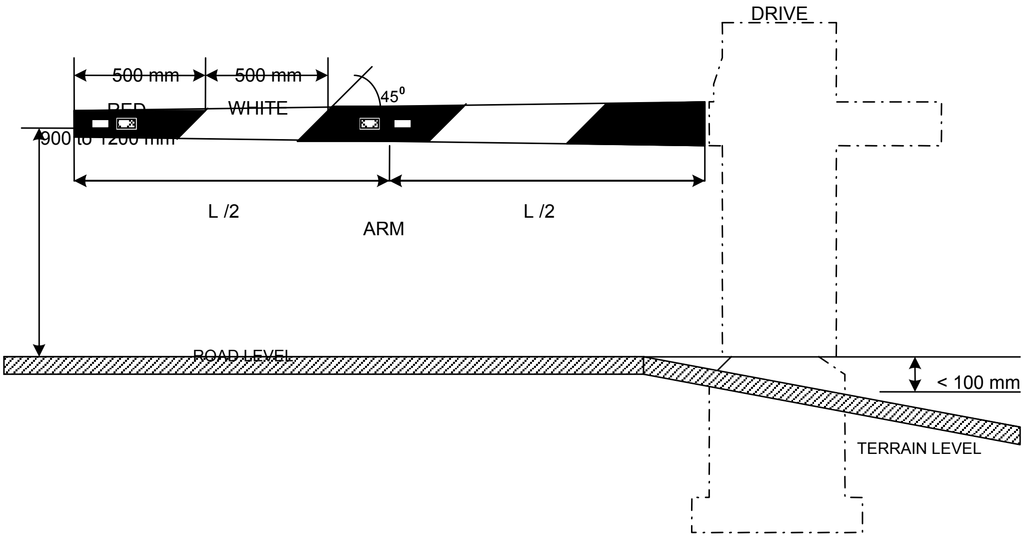

DRIVE
500 mm
500 mm
45°
RED
WHITE
900 to 1200 mm
L /2
L /2
ARM
ROAD LEVEL
< 100 mm
TERRAIN LEVEL

Figure 3

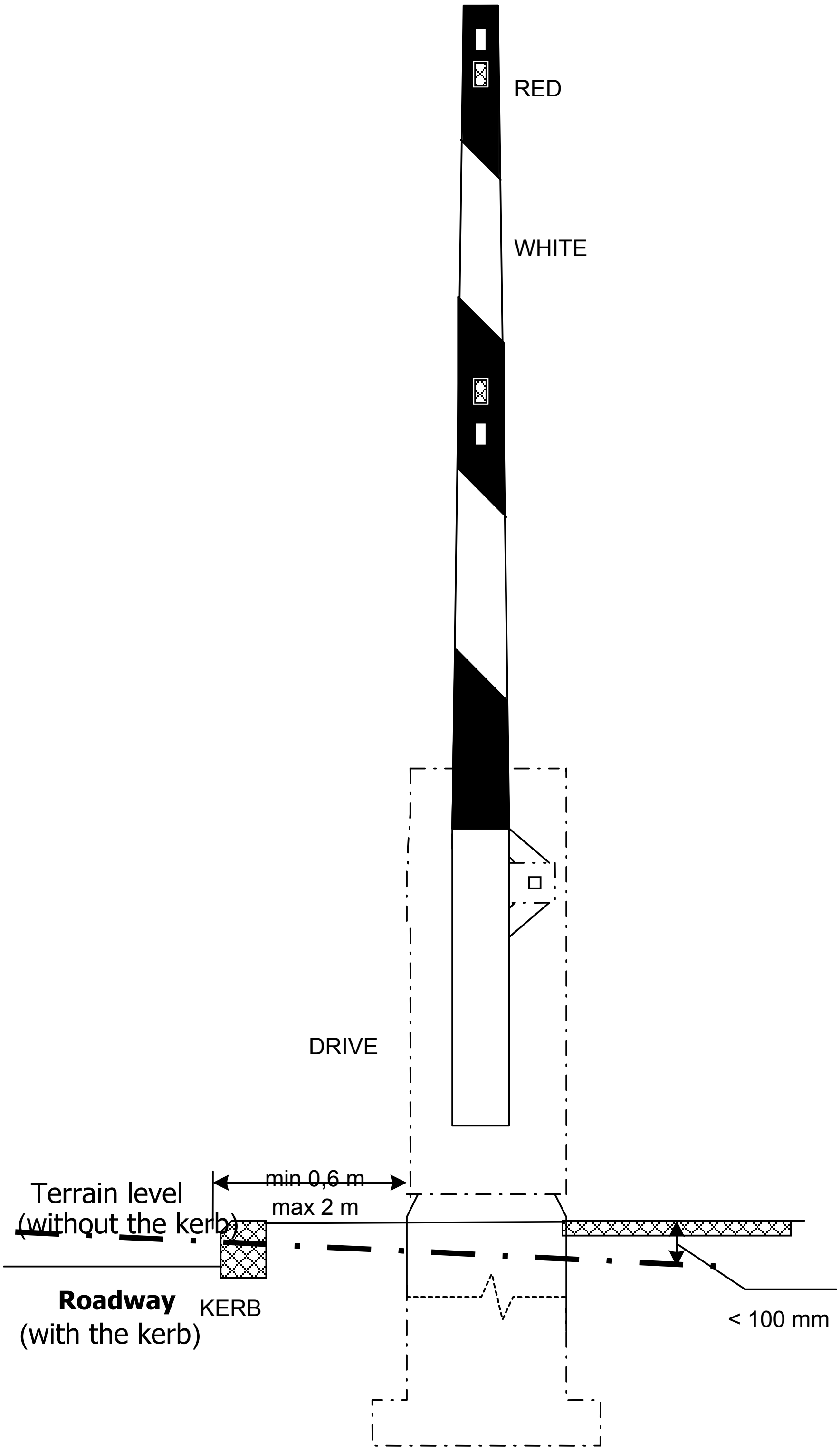
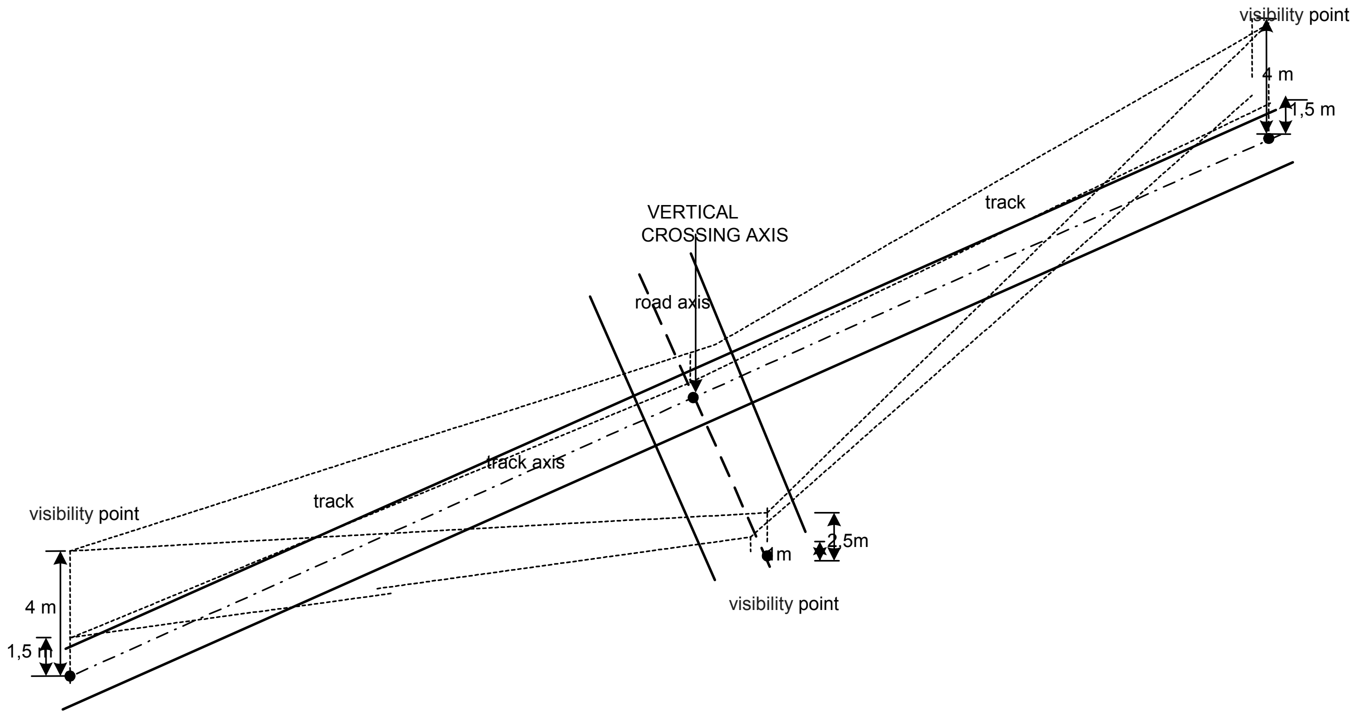
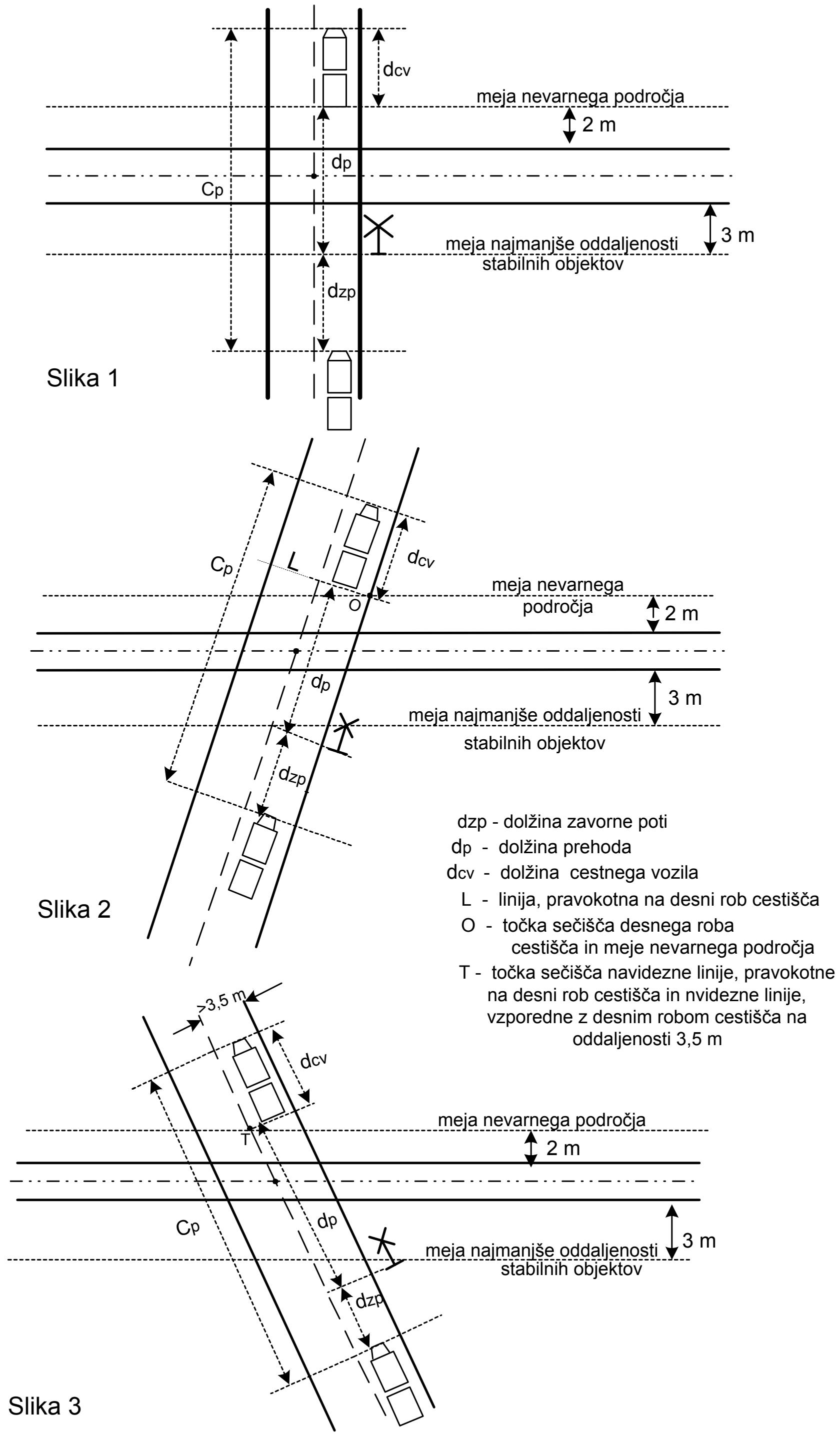

RED
WHITE
DRIVE
min 0,6 m
max 2 m
Terrain level
(without the kerb)
Roadway
(with the kerb)
KERB
< 100 mm

Figure 4

ATTACHMENT III: Visibility area



ATTACHMENT IV: Lines of danger zones



Translation of figure text

meja nevarnega področja	line of the danger zone
meja najmanjše oddaljenosti stabilnih objektov	the line representing the minimum distance of stable objects
Slika 1	Figure 1
meja nevarnega področja	line of the danger zone
meja najmanjše oddaljenosti stabilnih objektov	the line representing the minimum distance of stable objects
Slika 2	Figure 2
dzp - dolžina zavorne poti	dzp - braking distance

dp - dolžina prehoda	dp - the length of the crossing
L - linija, pravokotna na desni rob cestišča	L - line perpendicular to the right edge of the roadway
O - točka sečišča desnega roba cestišča in meje nevarnega področja	O - point of intersection between the right edge of the roadway and the line of the danger zone
T - točka sečišča navidezne linije, pravokotne na desni rob cestišča in navidezne linije, vzporedne z desnim robom cestišča na oddaljenosti 3,5 m	T - point of intersection between the invisible line perpendicular to the right edge of the roadway and the invisible line parallel to the right edge of the roadway at a distance of 3.5 m
meja nevarnega področja	line of the danger zone
meja najmanjše oddaljenosti stabilnih objektov	the line representing the minimum distance of stable objects
Slika 3	Figure 3

ATTACHMENT V: The sign table of dangerous high voltage

Translation of figure text

POZOR!	ATTENTION!
Visoka napetost	High Voltage
Smrtno nevarno	Danger of Death

5 PASSING –BY AND TURNING AREAS

5.1 AREA OF APPLICATION

This guideline defines the policies regarding project-technical design of passing bays and turning sites on public roads in the Federation of Bosnia and Herzegovina.

The technical guideline covers the use of passing bays and turning sites on public roads, the types and forms of passing bays and turning sites and project-technical elements of passing bays and turning sites.

5.2 DEFINITIONS OF TERMS

Passing bay is a specially marked area next to the roadway, which enables two vehicles to meet since they cannot meet on the roadway as it is too narrow.

Local public roads and streets in settlements and towns represent a mutually dependent traffic network of a municipality or a town, connected with the regional or major road network.

Major public roads are the roads connecting the entire or the major part of the territory of Bosnia and Herzegovina, the Federation, integrating it into the European road network, while at the same time they comprise a mutually dependent traffic network.

Relevant vehicle is a motor vehicle whose dimensions are relevant for setting project-technical road elements and other traffic areas and areas designated for motor vehicles outside the roadway.

Non-categorised road is every traffic surface not categorised as a public road.

The area of a point of access is specified by points at individual branches of a categorised road, where due to the design of the point of access the cross section of the road starts to be changed in any way (ground floor, longitudinally or transversally), and at the access branch until the access is finalised, which is at least as wide as the road surroundings of the categorised road.

Turning site is a special traffic area designed for turning of motor vehicles, especially passenger vehicles, trucks and buses.

Point of access is a junction (joint) between a public road and all areas from which vehicles directly enter and exit traffic on a public road. It is part of the road connecting that particular road with a public road of the same or lower category, non-categorised road or access to a facility or land. A point of access is a constituent part of a road covering the area to the edge of the road surroundings, which is 2.0 m from the outer edge of the ultimate point of the road body cross section with draining devices and the slope of the road body or from the protective fence set up along the body of a motorway.

Traffic arrangement (method of traffic management) is the method in which traffic runs, determined for a road or part of it or for a settlement or part of it by the road manager. Traffic arrangement comprises the determination of priority directions as well as the traffic management system and method, the limitations of road use of the use of its parts by traffic type, speed limitations and specification of measures for calming traffic, arrangement of stand still traffic, setting the restricted traffic zones, limited speed zones and pedestrian zones, specification of other obligations of road traffic participants. Traffic arrangement has to be marked with prescribed traffic signs.

Traffic areas outside the roadway include rest areas, parking lots, bus stops or turning points, gas stations, traffic weighing and supervising premises and facilities, etc.

Regional public roads connect settlements and localities within one or more districts, they integrate the entire district area and create a mutually dependent traffic network of one or more districts hooked up to the major road network.

Hairpin bends are road curves changing the direction of a drive at a high angle, comprised of small circular curves.

5.3 MARKINGS, ACRONYMS AND SYMBOLS

b	basic width of the roadway [m]
b_{iz}	expansion of the roadway in the passing bay area [m]
b_f	width of the roadway at the start of the turning site [m]
D	inter-axis distance and the length of the front overhang of the vehicle [m]
l_p	the length of the transition [m]
L_{iz}	the length of the passing bay [m]
l_s	total length of the passing bay [m]
R	radius of the arc [m]
$š_{voz}$	width of the vehicle [m]

5.4 PASSING BAYS

Passing bays are specially marked areas next to the roadway, which enable two vehicles to meet since they cannot meet on the roadway as it is too narrow.

5.4.1 Location of passing bays

Passing bays have to be provided on one-lane two-way roadways, where two relevant standard vehicles or one relevant vehicle and another vehicle cannot meet safely and without difficulties.

Passing bays are usually designed so that they are intended for vehicles driving downwards and only exceptionally for vehicles driving upwards.

Passing bays cannot be more than 300 m apart and the distance between them has to be adjusted to the visibility of the route and traffic volume on the road.

In order to provide for maximum effect of a passing bay, minimum decrease in throughput and impact on environment, the passing bay has to be designed taking into account the following:

- topographically suitable sites have to be selected for the location of a passing bay,
- straight and non-inclined sections are suitable for passing bay location,
- passing bays cannot be located in the area of apices of vertical curves,
- the passing bay has to be as long as possible, at least of the length enabling one relevant standard vehicle to be set aside,
- in the passing bay area the roadway has to be suitably expanded, so that the traffic profile of the vehicles coming from the opposite direction is undisturbed.

5.4.2 Dimensions of a passing bay

For a meeting of two trucks the passing bay is designed as shown in Figure 135, and the relevant dimensions are given in Table 18.

The markings on Figure 135 and in Table 18 have the following meaning:

b	basic width of the roadway (m)
b_{iz}	expansion of the roadway in the passing bay area (m)
L_p	the length of the transition (m)
L_{iz}	the length of the passing bay (m)
L_s	total length of the passing bay (m)

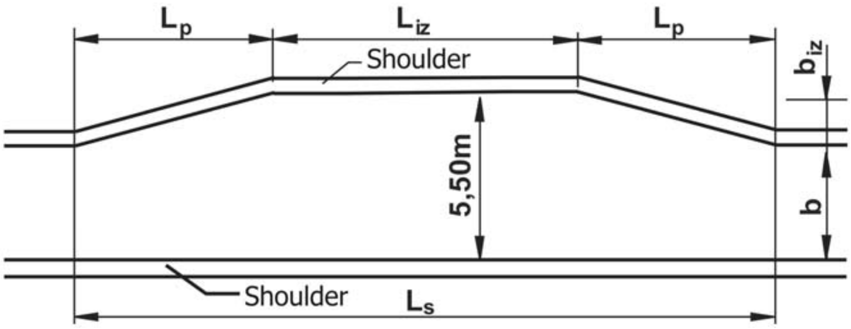


Figure 135: Dimensions of the passing bay enabling two trucks to meet

Table 18: Dimensions of the passing bay enabling two trucks to meet

Type of the passing bay	Width (m)		Distance (m)		
	b	b_{iz}	L_{iz}	L_p	L_s
1	3.00	2.50	10	10	30
2	3.50	2.00	10	7	24
3	4.00	1.50	10	5	20
4	4.75	0.75	10	3	16

5.4.3 Implementation of passing bays

The cross fall on the passing bay equals the cross fall on the roadway or 2.5% minimum, whereas at the curve it equals the cross fall of the curve.

Within a one-lane hairpin bend intended for two-way traffic the passing bay has to be designed as part of the hairpin bend, thus a sufficient expansion has to be made, enabling the vehicle waiting at the passing bay not to extend to the lane of the vehicle coming from the opposite direction.

5.5 TURNING SITES

Turning sites are special traffic areas designed for turning of motor vehicles, especially passenger vehicles, trucks and buses.

5.5.1 Location of turning sites

Turning sites are provided at the end of every accessible road (cul-de-sac), if there is no other possibility for turning a motor vehicle within reasonable distance. For buses turning sites are engineered at the end of public passenger transport routes. The turning bow (turning site) is suitable especially for turning longer vehicles. While planning the turning sites the guideline for expanding the roadway at the curve and the guideline for forming hairpin bends have to be followed. In the case of long approach roads, intermediate turning sites are needed, if there are no crossings, junctions with other roads or other possibilities for turning vehicles.

5.5.2 Types of turning sites

There are two basic types of turning sites (shown in Figures 136 and 137):

- the turning site at the roadway extension representing the so-called symmetrical turning site (bow or rectangular turning site),
- the turning site next to the roadway extension representing the so-called non-symmetrical turning site (bow or rectangular turning site),

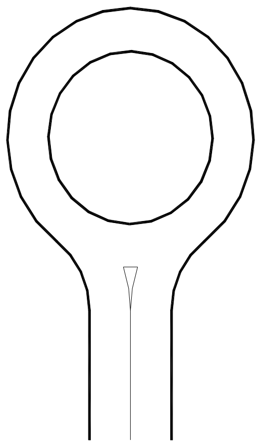


Figure 136: Turning site at the roadway extension (symmetrical turning site)

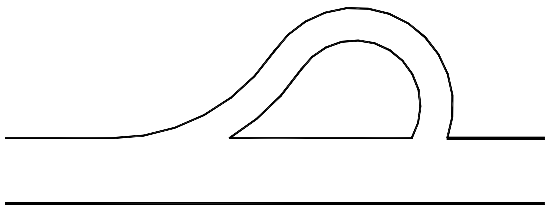


Figure 137: Turning site next to the roadway extension (non-symmetrical turning site)

The required dimensions of the project-technical elements of turning sites depend on the size of the motor vehicles for which the turning site is designed. The basic information is the relevant length of the motor vehicle needed for designing turning sites. This length (mark D) consists of the inter-axis distance of a vehicle and the length (distance) of the front overhang of the relevant motor vehicle. The information about the D length values for various types of motor vehicles is included in Table 19.

Table 19: Dimensions of individual types of relevant vehicles

Relevant vehicle	Width of the roadway $š_{voz}$ (m)	Inter-axis distance + the length of the front overhang of the vehicle D (m)
passenger vehicle	1.8	4
bus	2.5	8 - 9
small truck	2.5	5
medium-sized truck	2.5	6.5
large truck	2.5	9.1

5.5.2.1 Symmetrical turning bow

Symmetrical turning site for vehicles (symmetrical bow) is presented in Figure 5.3. The length of the bow has to be determined taking into account the width of the roadway.

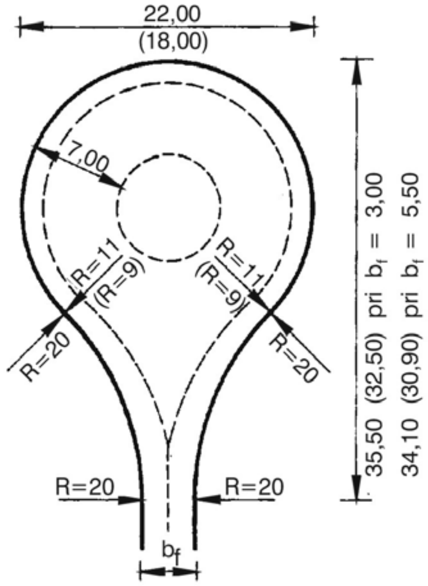


Figure 138: Symmetrical bow for turning vehicles for D = 9.1 m (dimensions in brackets apply for D = 6.5 m)

5.5.2.2 Non-symmetrical turning bow

Non-symmetrical turning site for vehicles (non-symmetrical bow) is presented in Figure 139. The length of the bow has to be determined taking into account the width of the roadway.

5.5.2.3 Symmetrical rectangular turning site

Symmetrical rectangular turning site is shown in Figure 140. In the case of such turning site a vehicle changes the direction of the drive by manoeuvring "forward-backwards". The dimensions of this turning site (Fig. 140) do not take into account the front and rear overhang of the vehicle, which is why a suitable area free of any obstacles, at least 2 m wide, has to be provided outside the roadway of such turning site.

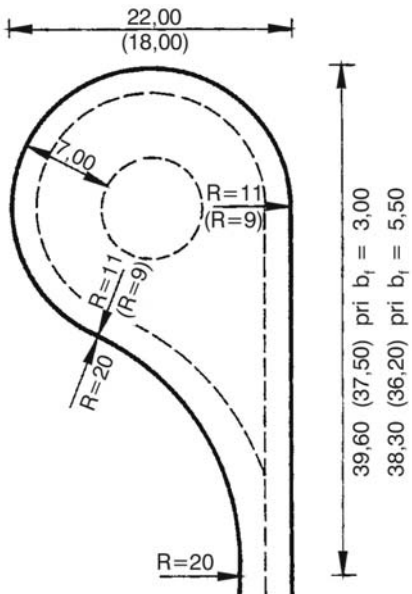


Figure 139: Non-symmetrical bow for turning vehicles for D = 9.1 m (dimensions in brackets apply for D = 6.5 m)

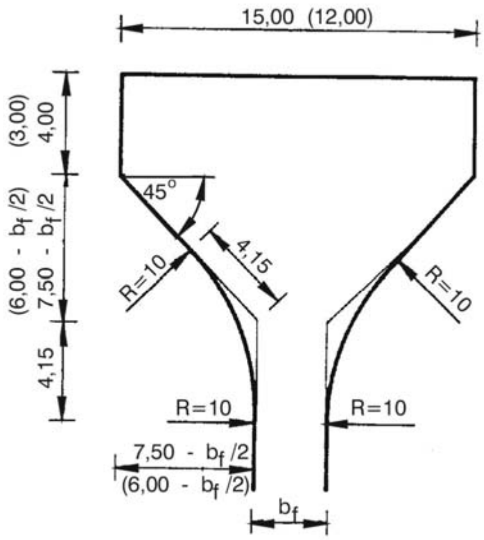


Figure 140: Symmetrical rectangular turning site for vehicles for D = 6.5 m (dimensions in brackets apply for D = 5.0 m)

5.5.2.4 Non-symmetrical rectangular turning site

Non-symmetrical rectangular turning site is shown in Figure 141. Also in the case of such turning site a vehicle changes the direction of the drive by manoeuvring "forward-backwards". The dimensions of this turning site (Fig. 141) also do not take into account the front and rear overhang of the vehicle, which is why a suitable area free of any obstacles, at least 2 m wide, has to be provided outside the roadway of such turning site.

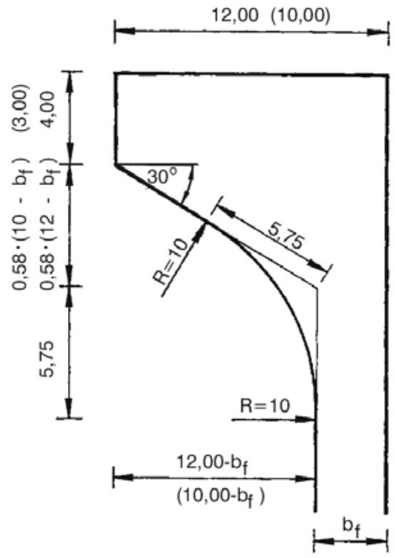


Figure 141: Non-symmetrical rectangular turning site for vehicles for D = 6.5 m dimensions in brackets apply for D = 5.0 m)

5.6 TRAFFIC SIGNS AND EQUIPMENT

Traffic signs at passing bays and turning sites are legally prescribed traffic signs, defined in the *Safety of Public Roads Act* (Official Journal of Serbia and Bosnia and Herzegovina, nos. 3/90, 11/90, Official Journal of the Republic of Bosnia and Herzegovina, nos. 2/92, 13/94) and stipulated in the *Rules on Traffic Signs* (Official Journal of the SFRY, nos. 48/81, 59/81, 17/85).

The information about the traffic signs and equipment of passing bays and turning points is an obligatory constituent part of a road project.

6 ROAD SURFACES FOR CYCLISTS, PEDESTRIANS AND HANDICAPPED PERSONS

6.1 AREA OF APPLICATION

Ova smjenica se upotrebljava za projektovanje i izgradnju površina na putu predviđenih za bicikliste, pješake i handikepirane osobe.

The cyclist is the driver, balancer and worker at the same time. This combination of tasks entails a series of more or less conflict characteristics on account of which cyclists have a special position in traffic. On the one hand, a bicycle is vulnerable and on the other, it is a very deft and flexible means of transport. Cyclists are classified to slow-moving traffic, but in cities they represent one of the fastest forms of transport (Figure 142)

A pedestrian is the most common, the slowest and most unprotected traffic participant. Every type of travel starts by walking, every traffic participant is also a pedestrian. The surfaces where pedestrians walk are rarely reserved for pedestrians alone, as a rule they share these areas with other traffic participants and means of transport, from inline skaters, skaters, cyclists, bicycles with a motor to motors and motor traffic.

Pedestrians are exposed to conflicts with the users of other means of transport practically at all times and this exposure heightens depending on the direction and type of movement - to crossing with various types of traffic participants.

One of the most common conflict situations is the crossing between pedestrians and road motor traffic. Crossing the road is a stressful situation for a pedestrian. Pedestrians differ one from another by psycho-physical characteristics and perceive differently the current traffic situation. The road is crossed by practically everybody - from children to the elderly, who react more slowly to sudden changes and perceive them differently.

In view of various circumstances the pedestrian crossings are differently (un)organised and (un)equipped. Most certainly there are many needs and wishes for new crossings or the arrangement of the existing ones, however, such interventions have to be made in a broader context of traffic arrangement and routing, taking into account the safety of all traffic participants.

Functionally handicapped persons represent one of the characteristic population groups that deserve special attention in environmental planning and design. The inclusion of these people in everyday life depends mainly on the constructed environment which may present an obstacle for them. On account of such obstacles the handicapped are deprived of their rights, since they encounter insurmountable problems practically everywhere.

6.2 BICYCLE AREAS

6.2.1 Technical elements

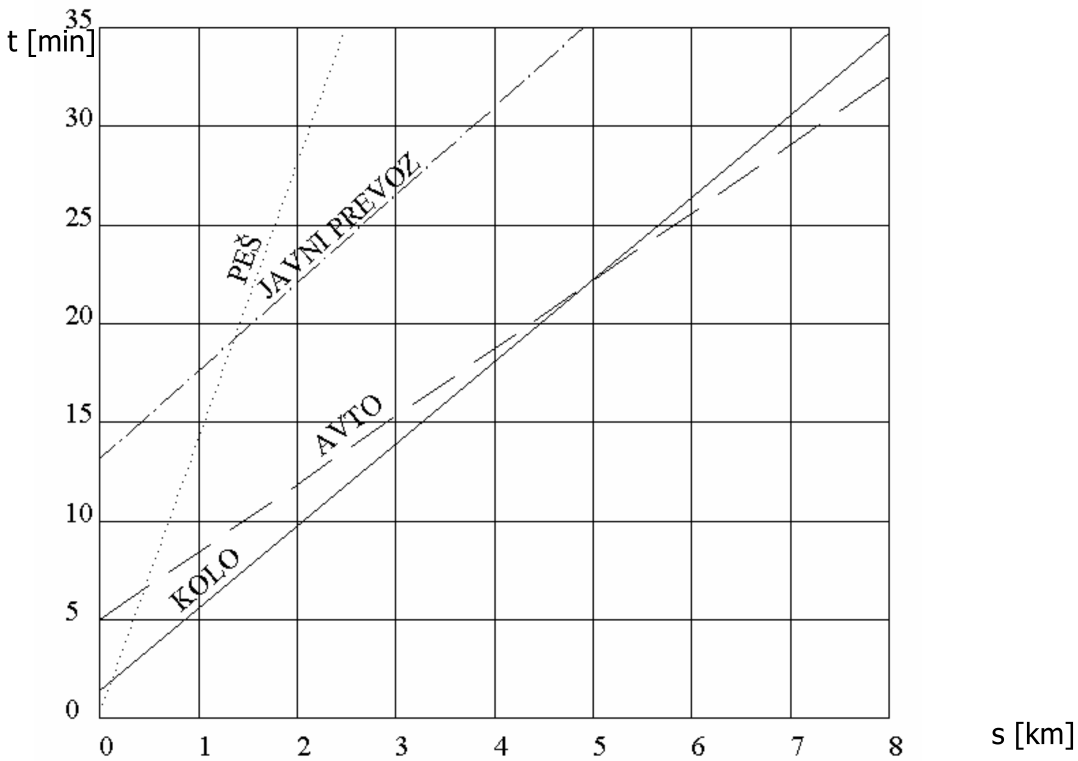
6.2.1.1 Definitions:

Mixed profile: cyclists are on the roadway together with motor traffic;

Bicycle lane: is located on the roadway and is divided from the rest of the traffic by a continuous white line; it is recommended that it is coloured in red and sensibly marked with pictograms;

Cycle path: it the usual solution in urban areas and cities; it is located next to the roadway used by motor vehicles, it is separated by grade and may be separated from the roadway by a green area; it can also be routed along the pedestrian walkway;

Bicycle path: is the surface of top service level that is independent of the rest of the road network.



Translation of figure text

PEŠ	ON FOOT
JAVNI PREVOZ	PUBLIC TRANSPORT
AVTO	CAR
KOLO	BICYCLE

Figure 142: Hudson diagram for the time needed to travel from door to door in urban area

Some basic characteristics of bicycle traffic:

1. In planning horizontal and vertical elements of cyclist surface the designer has to be take into account the physical capacities of cyclists;
2. The loss of energy has to be reduced to a minimum;
3. Flat and well maintained traffic area is a precondition for cyclist-friendly and comfortable ride;
4. Cyclists are very vulnerable, which is why the maximum number of points of conflict resulting in an impact between motor vehicles and cyclists has to be eliminated;
5. Cyclists are unstable - lateral wind, drafts caused by trucks, uneven sections on the wearing course of the cyclist surface - all this affects the stability and also the safety of cyclists;
6. Attention has to be devoted to aesthetic value of the environment where the cyclist surface is located;
7. Sufficient space has to be provided for cyclists to ride side by side, in addition to which rest and relaxation areas have to be created.

Five basic criteria for cyclist-friendly infrastructure:

1. Completion of the cyclist network - without interruptions, good possibilities for connections with the rest of the traffic network, possibility of returning to the starting point;

2. Direct connection - avoidance of bypasses (selected variant is no more than 20% longer than the shortest one);
3. Attractive solution - friendly environment, designing of road surroundings and rest areas.
4. Safety of the traffic area - suitably selected technical solution and good markings;
5. Comfortable traffic area - enabling fast and simple travel.

Before designing cyclist surfaces the designer has to study in great detail the function of the surface (short or long travel) and the purpose for which it will be used (daily or recreational-travel ride). This means that the design has to be in line with the basic requirements and function.

The designer chooses the technical form of the cyclist surface, which should be as much as possible adjusted to the planned function and expected use. The planned function has to satisfy all five basic requirements for the bicycle infrastructure to the highest degree possible.

6.2.1.2 Form of cyclist surfaces

The technical form of cyclist surface selected based on the planned function often cannot be implemented due to spatial requirements. In such case the solution is adjusted to other users of the surface, as it is better to implement a certain bicycle connection in reduced form than if there were no available safe cyclist surfaces. However, point congestions have to be avoided.

6.2.1.3 Use of cyclist surfaces

If on account of other spatial requirements cyclist surfaces cannot be designed according to the guidelines contained herein, it has to be decided if it is proper to influence the planned use of these surfaces. It can be decided that the planned surface will be used also for other purposes.

6.2.1.4 Function of cyclist surfaces

As a last resort the function of a cyclist surface can be changed - this means that e.g. the connecting cyclist surface is changed into an accessible one.

The task of the designer is to properly specify the ratio between the form, use and function of a cyclist surface, since every planned cyclist surface cannot at the same time fully provide all the desired functions.

6.2.1.5 Approach to solving bicycle problems

The entire process of planning priority cyclist surface implementation is compiled of the following stages:

1. Initial phase - inventory of the existing cyclist surfaces and planning of new ones;
2. Development of bicycle traffic - analysis of relations between existing and potential users of cyclist surfaces and specification of the most frequent connections;
3. Analysis of danger points and jams - analysis of the entire network and setting of priorities for improving conditions;
4. Implementation programme - which improvements are necessary and where;
5. Designing - technical plans for cyclist surfaces;
6. Actual implementation.

6.2.1.6 Classification and types of bicycle connections

Types of cyclist surfaces depending on the selected technical form of implementation, and their definitions:

Bicycle connections are bicycle directions, being random sequence and in various technical implementation forms connect individual places, tourist and cultural-historic areas or are linked to international bicycle routes.

6.2.1.7 Use of various types of cyclist surfaces

During the ride, cyclists perform three different moves or changes of directions:

- meeting between cyclists or between cyclists and motor vehicles;
- overtaking of other cyclists or overtaking of motor vehicles;
- sudden movements in unexpected situations.

6.2.1.7.1 Meetings

Cyclists meet vehicles from the contrary traffic on:

- two-way cycle paths and one-way cycle paths and on lanes where bicycles ride in the wrong direction; the following should be considered: the width of the surface, the volume of bicycle traffic, the percentage of traffic in pair or even in platoon, weather conditions, visibility, distance from side obstacles;
- partially one-way roads with bicycle traffic in the opposite direction; the turning of vehicles to the left represents a problem;
- usual two-way roads where a problem can arise as a motor vehicle is met when cyclists overtake each other.

6.2.1.7.2 Overtaking

The possibility of overtaking in cyclist surfaces is conditioned by the width of the cyclist surface, the traffic volume, traffic direction, percentage of cyclists and moped drivers (who are also entitled to use the cyclist surfaces), longitudinal gradient of the roadway and the weather conditions. Overtaking on a mixed profile road can be problematic if the share of motor traffic is very high, while in the case of low traffic the safety of the overtaking cyclist is at risk due to higher speed of motor vehicles.

6.2.1.7.3 Unexpected events

Unexpected events may result in sudden and uncontrolled moves aside, which can cause a dangerous situation. The reasons for such moves are the following:

- contrary traffic;
- irregularly parked motor vehicles;
- opening doors of motor vehicles next to the cyclist surface;
- sudden crossing of cyclist surface (by people, animals);
- mechanic problems;
- weather conditions;
- errors in cyclist surface construction.

6.2.1.8 Selection of the technical form of a cyclist surface

6.2.1.8.1 Physically separated cyclist surface (cycle path or path)

The function of physically separated surface is to provide unimpeded safe surface for cyclists and moped drivers. Such solution is necessary in the event of high speed and large motor traffic volume.

The advantages of such solution are:

- greater safety of cyclists;
- easier overtaking of other cyclists;
- greater cyclist amenity.

The weaknesses of such solution are:

- poorer mobility;
- higher speed of all participants, including moped drivers;
- smaller attention of traffic participants travelling at higher speed;
- possibility of accidents at meetings is higher, especially at crossroads and when driving in the wrong direction or on the wrong side;
- greater use of space and more expensive implementation.

6.2.1.8.2 Bicycle lane

The use of a bicycle lane is sensible when a raised area cannot be provided for cyclists on roads characterised by a high traffic volume of motor vehicles (see the diagram on Figure 2, zone 4). The speed of motor vehicles has to be restricted to 40 - 60 km/h and the share of heavy trucks limited. It is recommended that the bicycle lane is coloured in red.

The advantages of a bicycle lane compared to the mixed profile are the following:

- greater safety of cyclists;
- lower cyclist stress than in the case of a mixed profile;
- easier overtaking;
- greater comfort;
- easier and smoother travel past traffic jams;
- cyclists retain mobility.

The weaknesses of a bicycle lane are the following:

- the drivers of motor vehicles pay less attention than in the case of mixed profile;
- when cyclists overtake other cyclists or parked vehicles and avoid conflicts when vehicles are parked parallel, they can drive over that part of the roadway which is not designated for them, since they wish to drive at constant speed; this may be dangerous for them due to motor traffic density;
- problems at entries to the parking lot, in bus stop areas and with crossing a bicycle lane at points of access;
- participants, especially moped drivers, travel at higher speed;
- smaller attention of traffic participants travelling at higher speed;
- possibility of incorrect usage, especially if personal vehicles are parked incorrectly;
- large vehicles can use the bicycle lane as an additional area to drive over.

6.2.1.8.3 Mixed profile (cyclists are on the roadway together with motor traffic)

It is used on roads with a low share of motor traffic or in the areas characterised by calm traffic in urban centres, where the speed, quantity and structure of motor traffic are restricted.

The advantages of mixed area are the following:

- there is no need to construct additional areas, as the maximum number of existing roads can be used simply and at low costs;
- cyclists retain the freedom of movement;
- greater safety at crossroads.

The weaknesses of mixed area are the following:

- the sections of roads involving this profile are more dangerous for a cyclist;
- parking on the streets is disturbing for a cyclist and it can also be dangerous (open doors of vehicles);
- cyclists present an obstacle for the motor traffic, especially at narrow profiles;
- cyclists have less possibilities to overtake and meet each other.

The danger of conflicts between cyclists and motor vehicles in the case of a mixed profile decreases, if independent surfaces are constructed for cyclists in the zone of crossroads or crossings for cyclists are provided or if motor traffic is reduced.

The traffic safety of the mixed profile can be improved by implementing the following measures:

- restriction of motor vehicles' speed on open road;
- restriction or re-routing of heavy motor vehicles;
- prohibition of parking and stopping at certain sections.

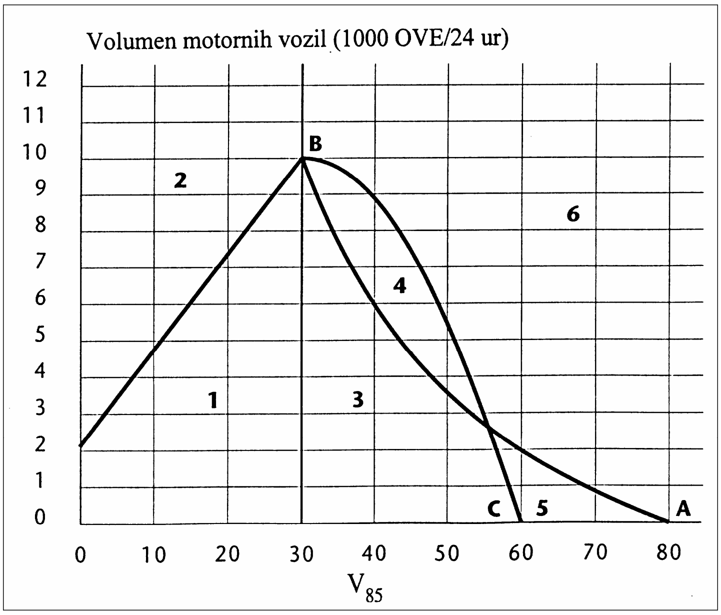
These measures are conditioned by the following characteristics:

- continuity or discontinuity of the bicycle network;
- traffic area function;
- spatial possibilities;
- attractiveness of cyclist surface;
- various restrictions - public traffic, access for intervention vehicles, etc.

The selection of a separate profile (lane, way or path) or mixed profile to a high degree depends also on the needs of other (either motorised or not) users of traffic areas.

6.2.1.9 Criteria for selecting the technical form of cyclist surface implementation

Research has shown that different profiles of cyclist surface influence the safety of cyclists in various situations. Based on research the selection of surfaces can be roughly categorised as shown in diagram in Figure 143.



Volumen motornih vozil (1000 OVE/24 h)	Motor vehicle volume (1000 PCE/24 h)

Figure 143: Criteria for selecting the technical form of cyclist surface implementation (Source: CROW 9)

The horizontal axis presents the actual speed of motor traffic (V_{85}) and not the permitted speed!

Area 1 If V_{85} of motor vehicles is less than 30 km/h, the mixed profile may be used, which means that cyclists share the area with motor traffic, as a result of which no separate cyclist surfaces are constructed in zones 30.

Area 2 Combinations of low speed and high traffic density are rare, which is why the use of cyclist surfaces is not specifically prescribed.

Area 3 The solutions without special bicycle lanes, ways or paths are still permissible, i.e. mixing with other traffic - depending on the traffic volume and road characteristics, except under special circumstances (e.g. high percentage of trucks).

Area 4 Outside urban areas a bicycle lane or path is necessary and in urban areas a bicycle lane or way has to be provided.

Area 5 A cycle path is preferred, however, since the density of motor traffic is lower, mixing with motor traffic is permissible, while bicycle lanes are not recommended (due to the attention that the drivers of motor vehicles pay to the cyclists).

Area 6 At high speed or in the case of great density of motor traffic a cycle path is necessary, while a bicycle path is the best alternative.

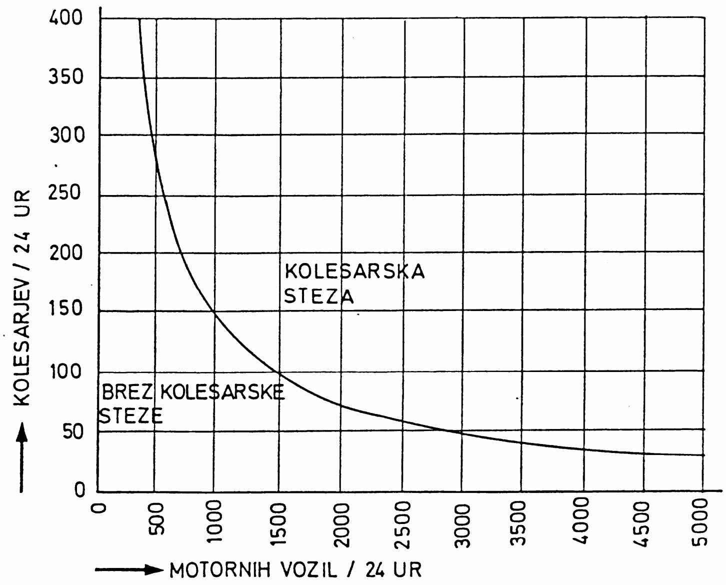
The diagram cannot provide solutions for all possible cases, which is why often some general solutions have to be applied, e.g.:

- introduction of bicycle lanes is not recommended on roads if the occupancy rate of the nearby parking lots during peak hours is more than 85% - there is a danger of vehicles being parked on the bicycle lanes - separated by grade or in some other way secured cycle path (e.g. columns) is a better solution;
- on roads where there are many important activities with AADT>1500 vehicles, a cycle path has somewhat less advantages - on account of many side entries; a bicycle lane is preferred;
- on roads driven by tramway it is recommended that bicycle traffic is separated by grade;
- on one-way roads it is recommended that bicycle traffic is separated by grade;
- also in the case of very low traffic volumes and when the speed of motor traffic is over 80 km/h it is recommended that bicycle traffic is separated by grade;
- combination of AADT of over 10,000 vehicles and speed around 30 km/h - separated by grade;
- if the speed exceeds 60 km/h, the bicycle lanes are not recommended (outside built-up areas).

At certain density of motor and bicycle traffic the implementation of one of the presented cyclist surfaces has to be provided, in most cases a cycle path.

The requirement to route the bicycle traffic to cyclist surfaces is justified based on the compliance with the following criteria:

1. The product of the number of motor vehicles and the number of cyclists is twenty-four hours has to equal or exceed 150,000 (diagram in Figure 144).
2. 100 or more cyclists recorded in rush hour.
3. The share of trucks and buses in total traffic exceeds 10%.



Translation of figure text:

KOLESARJEV / 24 UR	CYCLISTS / 24 HOURS
KOLESARSKA STEZA	CYCLE PATH
BREZ KOLESARSKE STEZE	NO CYCLE PATH
MOTORNIH VOZIL / 24 UR	MOTOR VEHICLES / 24 HOURS

Figure 144: Criteria for introducing a cyclist surface (Source: Technical Norms for Designing and Equipping Urban Traffic Areas, Part 1)

6.2.1.10 Travel speed and capacity of cyclist surfaces

The stability of a cyclist depends on his/her speed. At approximately 20 km/h, it is usually possible to maintain the stability by normal steering and body movements, while at lower speed it is difficult to maintain balance.

Technical elements in horizontal and vertical alignment of a cyclist surface are selected based on the planned speed. The travel speed depends on the physical abilities of a cyclist, the type and quality of the cyclist surface, the type of the bicycle and wind.

The average speed of cyclists on flat surface is from 10 to 45 km/h. Most cyclists drive at an average speed of 19 km/h (standard deviation is $\pm$ 3km/h).

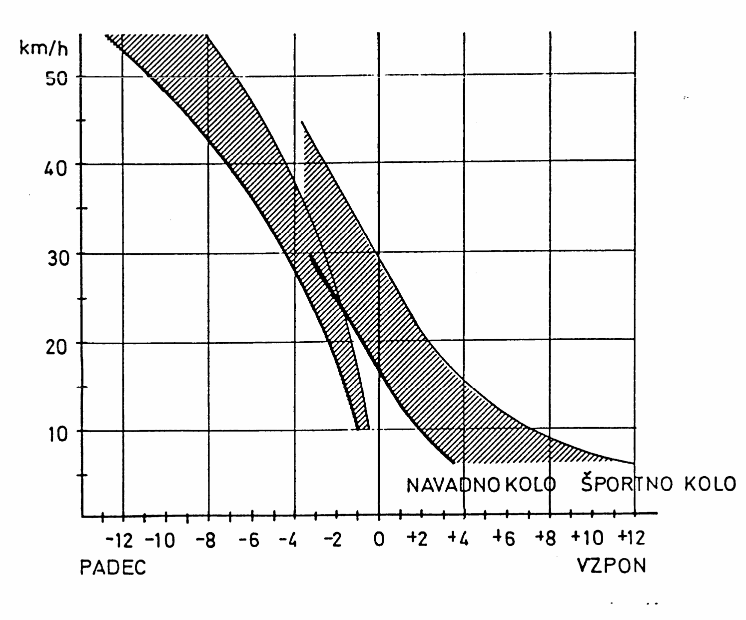
Speed V_{85} = 22 km/h. The most able cyclists can reach up to 70 km/h. On long and steep ascents the speed may be below 5 km/h and on descents over 65 km/h.

Based on experiential data the following calculation speeds were selected as the basis for specifying technical elements of the cyclist surfaces.

$Vrač_1$= 20 km/h - in urban areas

$Vrač_2$= 30 km/h - outside urban areas

The diagrams of cyclist speed at various longitudinal gradients for various types of bicycles (diagram in Figure 145)

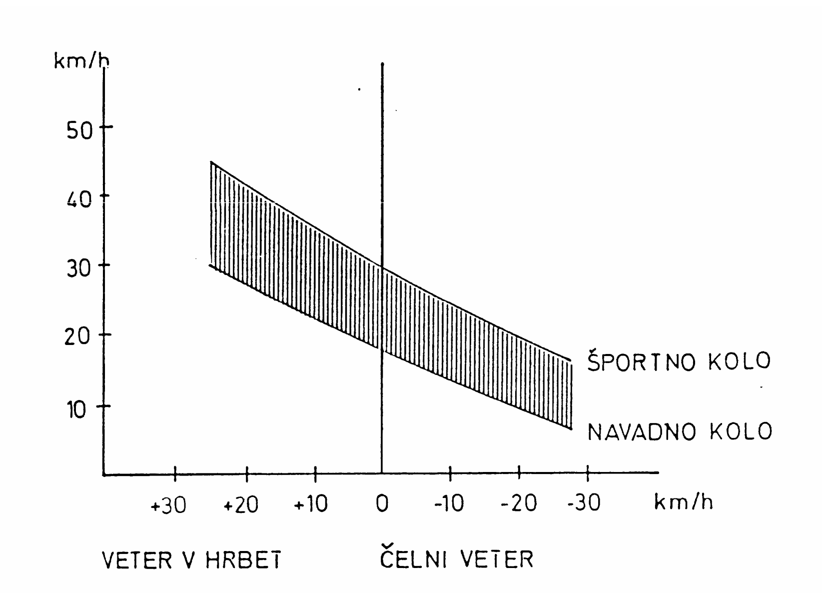


Translation of figure text:

NAVADNO KOLO	CONVENTIONAL BICYCLE
ŠPORTNO KOLO	SPORTING BICYCLE
PADEC	DESCENT
VZPON	ASCENT

Figure 145: The cyclist speed at various longitudinal gradients for various types of bicycles (Source: Technical Norms for Designing and Equipping Mixed Traffic Areas, Part 1)

The speed of cyclists with back or front wind.



Translation of figure text:

ŠPORTNO KOLO	SPORTING BICYCLE
NAVADNO KOLO	CONVENTIONAL BICYCLE
VETER V HRBET	BACK WIND
ČELNI VETER	FRONT WIND

Figure 146: The speed of cyclists with back or front wind (Source: Technical Norms for Designing and Equipping Mixed Traffic Areas, Part 1)

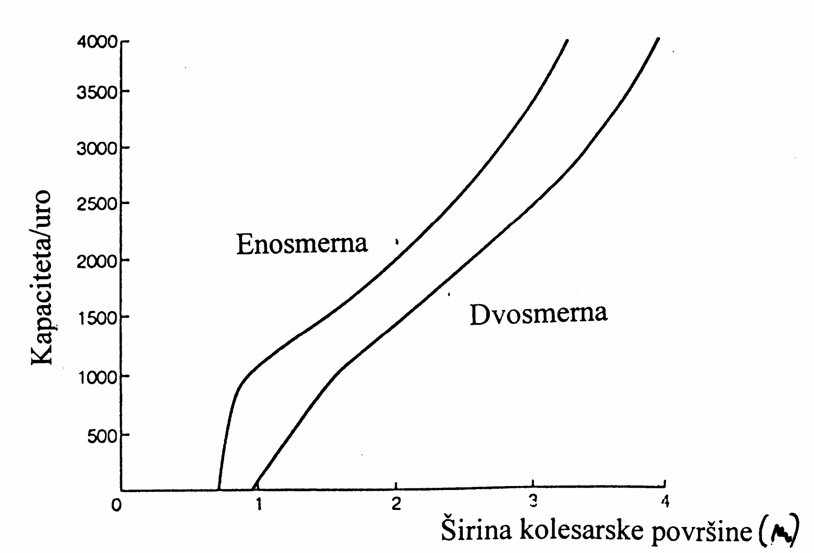
6.2.1.10.1 Capacity

The throughput of cyclist surfaces depends on the density of traffic, obstruction of traffic flow, distance of side obstacles, the width of the cyclist surface, the number of crossings, weather conditions, ascents and descents, etc.

Table 20: The capacity of the surface in relation to the number of lanes and traffic direction

traffic direction	number of lanes	capacity bicycles/hour
one-way	1	1300 to 2500
one-way	2	2000 to 5000
two-way	2	500 to 2000

The Hudson capacity diagram (Figure 147) points to the capacity of the cyclist surface in relation to the traffic direction and the width of the cyclist surface (m).



translation of figure text:

Kapaciteta/uro	Capacity/hour
Enosmerna	One-way
Dvosmerna	Two-way
Širina kolesarske površine	The width of the cyclist surface

Figure 147: Hudson capacity diagram (Source: BIKEWAYS - State of the art - 1974)

6.2.1.11 The width of the cyclist surface

6.2.1.11.1 Dimensioning and dependence of cyclist surface selection

The dimensions of a cyclist surface depend on:

- basic bicycle dimensions;
- cyclist manoeuvring area;
- safety area.

The dimensions of a bicycle are not specified and depend on modern designers, however the bicycle width restrictions have to be complied with. A bicycle must not be more than 0.75 m wide. Other dimensions are as follows:

- length: - conventional bicycle 2.00 m

- tandem 2.50 m

- bicycle with a trailer 4.00 m

95% of bicycles are up to 1.95 m long.

- width: - conventional bicycle 0.60 m

- tricycle 1.00 m

- bicycle with a trailer 1.00 m

10% of bicycles are within the 0.75 m limit.

- height: - bicycle with the cyclist 1.30 m (minimum)

2.00 m (maximum)

- driving mechanism 0.07 m (minimum)

0.15 m (maximum)

Children's bicycles, which account for approximately 5%, are no more than 1.0 m high, while the bicycles for adults (95%) are 1.85 m high.

- weight: - racing bicycle (< 5%) 12.80 kg

- 50% bicycles 17.80 kg

- 95% bicycles 25.60 kg

Modern bicycles with aluminium frames weigh less than 8.5 kg.

A cyclist needs manoeuvring space to maintain balance. What seems like a straight ride is in fact the winding of the cyclist's centre of gravity around the driveline. For this reason the additional manoeuvring space at either side of the bicycle is:

- normal 0.20 m
- at long congestions 0.15 m
- at short congestions 0.10 m

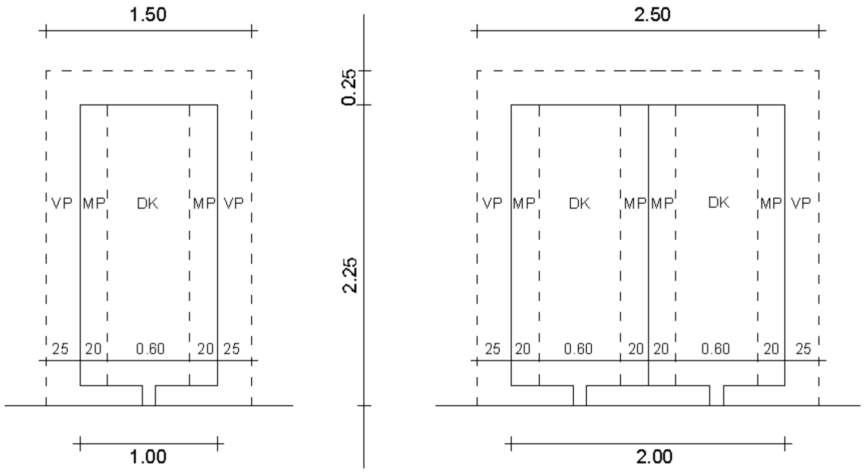
On both sides of the manoeuvring space a safety area has to be added in height. The dimension of the safety area is:

- normal 0.25 m
- at long congestions 0.15 m to 0.20 m
- at short congestions 0.10 m

The width can also be greater, depending on the adjacent area. Minimum distance from individual objects bordering the cycle path are the following:

- pavement 0.30 m
- trees 0.50 m
- wall 0.60 m
- motor vehicle 0.10 m

Figure 148 shows the minimum space needed by one or two cyclists (bicycle lane or way).



Key:
DK……..bicycle dimensions
MP……..manoeuvring space
VP……...safety area
N………..number of traffic profiles or lanes
Traffic profile = DK + 2 MP
Clearance = (DK + 2 MP) * N + 2 VP

Figure 148: Minimum space needed by one or two cyclists

The width of the cyclist surface depends also on:

- the type of the cyclist surface;
- comfortableness;
- spatial possibilities;
- maintenance requirements;
- bicycle traffic density.

Taking into account spatial possibilities, cyclists have to be enabled to ride side by side, since this makes cycling more attractive. Lack of space, mostly in city centres, results in the use of mixed areas or bicycle lanes, which, however, must not be less than 1.00 m wide. If a bicycle lane of such width cannot be provided, it is not separately marked, but rather the drivers of motor vehicles have to be cautioned about the cyclists by additional vertical and horizontal signalisation installed.

The density of bicycle traffic affects the frequency of overtaking manoeuvres, meetings and moves aside, due to which the surfaces have to be wider to provide cyclist safety. Moreover, it is prudent to consider that some cyclists drive in the wrong direction, which leads to more moves and conflicts.

The following three conditions are also important as regards the selection of the width of cyclist surfaces:

- safe overtaking;
- side by side riding by two cyclists;
- position of cyclist surface.

Safe overtaking:

Due to bicycles with motors space has to be provided on a one-way cycle path for at least one additional cyclist clearance to enable safe overtaking. Cycle paths with a single clearance can be exceptionally planned on short distances (if there is lack of space).

Side by side riding by two cyclists:

To provide for comfortable ride side by side riding has to be enabled - one additional cyclist clearance width has to be provided.

Location of the cyclist surface:

The type of cyclist surface and its width depend on the location of the cyclist surface. Outside urban areas bicycle paths and ways are constructed, while bicycle lanes are built only if the motor traffic volume is low enough (less than 1000 vehicles/day) and the speed is restricted to 60 km/h. In urban areas most often bicycle lanes and ways are constructed, while in urban centres also mixed areas are provided, if the relevant conditions are met. Bicycle paths are used only exceptionally, when the long distance bicycle connection is being provided and there is sufficient space.

The following has to be provided on account of bicycle traffic protection:

- protection lane between the cycle path and the motor traffic roadway, at least 0.75 m wide;
- green area between the bicycle path and the motor traffic roadway, at least 1.50 m wide;

For roads with mixed traffic (where a bicycle path or way cannot be implemented) the compatibility of the bicycle and motor traffic has to be checked on a case by case basis, with the major elements being the speed of motor vehicles and the width of the roadway.

Bicycle lanes next to parking lots have to be at least 0.60 m away from the parking niches so that there are no conflicts as the doors of the parked vehicles are opened.

6.2.1.12 Bicycle lanes

6.2.1.12.1 Bicycles lanes in urban area

It is recommended that the bicycle lanes in urban area are two-sided and one-way and in the case of new constructions physically (by a kerb) separated from the areas designated for pedestrians (Figure 149). If such surfaces are located only on one side of the roadway, the bicycle lane may be constructed on that part where the verge is located (Figure 150), since after a bicycle lane is constructed it no longer functions as a stabilised edge. However, suitable drainage has to be provided.

The width of a bicycle lane is influenced by:

- bicycle dimensions (DK = 0.60 m),
- manoeuvring space (2 x 0.20 m),
- safety area (2 x 0.25 m).

Bicycle lane is 1.50 m wide.

Exceptionally (spatial requirements) the lane may be narrowed to 1.00 m.

In this case vertical signalisation has to be set up (traffic signs I-5 and II-34), pointing out the narrowing and prohibiting parking.

It is recommended that the bicycle lane surface is of different colour, the best being red, so that it is additionally accented.

The necessary distance of a bicycle lane:

- from fixed short obstacles (lighting poles, traffic signs) - at least 0.50 m (Figure 151);
- from long obstacles (walls of buildings or underpasses and rails) - at least 0.75 m (Figure 152); from parking niches - at least 0.60 m (Figure 153).

Figure 149: Optimal width of one-way bicycle lane without obstacles and restrictions, with a pedestrian walkway

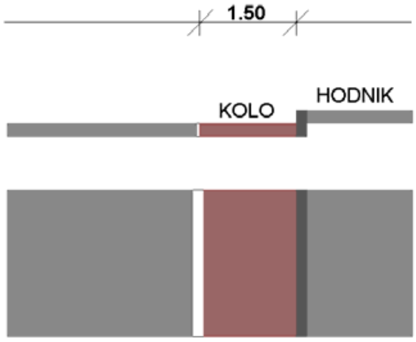
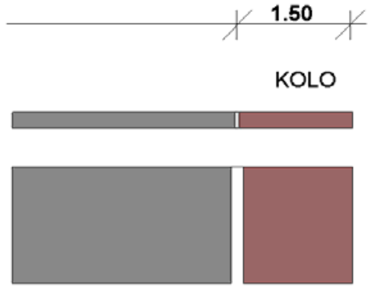


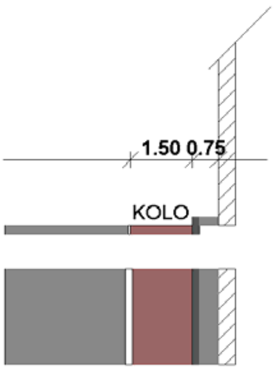
Figure 150: Optimal width of one-way bicycle lane without obstacles and restrictions, without a pedestrian walkway



Translation of figure text:

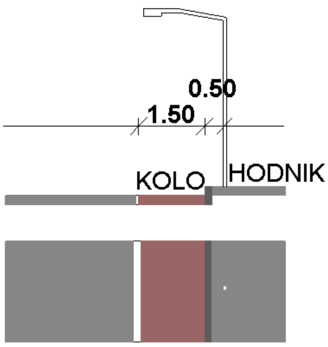
KOLO	BICYCLE
HODNIK	WALKWAY

Figure 151: Bicycle lane along a long obstacle



KOLO	BICYCLE

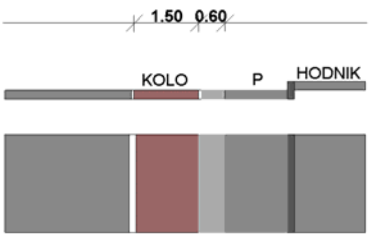
Figure 152: Bicycle lane along a short obstacle



KOLO	BICYCLE
HODNIK	WALKWAY

Figure 153: Bicycle lane along parking spaces

Translation of figure text:



KOLO	BICYCLE
HODNIK	WALKWAY

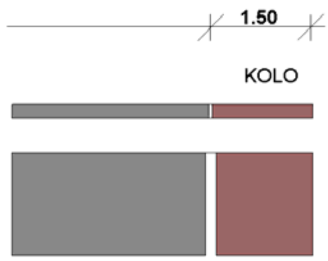
6.2.1.12.2 Bicycle lanes outside urban area

Bicycle lanes outside urban area are not recommended for safety reasons. A cycle pathis a better solution. Where this is not possible, a warning sign I-16 "Cyclists on the Road" should be erected and the bicycle lane marked. It is recommended that the bicycle lane is coloured in red.

The width of a bicycle lane outside urban area is influenced by:

- bicycle dimensions (DK = 0.60 m),
- manoeuvring space (2 x 0.20 m),
- safety distance from the motor vehicle (0.50 m).

The width of a bicycle lane outside urban area is 1.50 m. Exceptionally (spatial requirements and AADT < 1000) the lane may be narrowed to 1.00 m. If such width cannot be provided, the lane is not marked! According to practice the drivers of motor vehicles pay more attention to cyclists if the latter do not have a specifically marked bicycle lane.



KOLO	BICYCLE

Figure 154: Example of a bicycle lane outside urban area

6.2.1.13 Cycle paths

6.2.1.13.1 Cycle paths in urban area

It is recommended that cycle paths in urban area are one-way and two-sided, exceptionally two-way (lack of space). In the case of a two-way cycle path the intermediate protection lane has to be at least 0.75 m wide. The cycle path has to be physically separated from the roadway - if possible by a rail.

The required distance between the cycle path and:

- parking niche - at least 0.60 m (Figure 155),
- walls of buildings or underpasses and rails - at least 0.75 m (Figure 158),
- fixed obstacles (lighting poles, traffic signs) - at least 0.50 m (Figure 159).

One-way two-sided cycle path

The width of a one-way two-sided way is influenced by:

- bicycle dimensions (DK = 0.60 m),
- manoeuvring space (2 x 0.20 m),
- possibility of overtaking (double cyclist clearance).

The width of a one-way two-sided way is 2.00 m. In the area of a bus stop, shop windows and where there is insufficient space, a one-way two-sided way may be reduced to 1.75 m, which still enables overtaking, however, the narrowing has to be suitably marked with vertical and horizontal signalisation.

Two-way cycle path

The width of a two-way cycle path is influenced by:

- bicycle dimensions (2 x DK = 1.20m),
- manoeuvring space (4 x 0.20 m),
- safety area between clearances (VP = 0.50 m).

A two-way cycle path is 2.50 m wide. At bus stops it is suitable that the speed of cyclists is somewhat reduced, which is why at such locations the way may be narrower, exceptionally (lack of space) 2.00 m wide (Figure 23), however, the narrowing has to be suitably marked with vertical and horizontal signalisation. The cycle path has to be separated from the pedestrian surface by a kerb of maximum 5 cm in height.

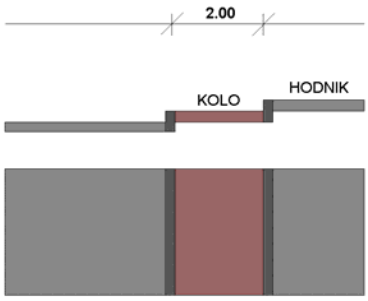
Two-way cycle path must be at least 0.75 m away from the roadway.

Cycle paths in urban areas, at crossroads and anywhere where they enter mixed traffic areas are recommended to be painted in different colour. This improves the visibility of the cycle path considerably and decreases the possibility of accidents.

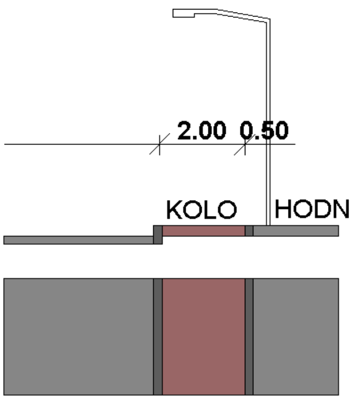
One-way two-sided cycle path along a walkway and a short obstacle:

Figure 155

Figure 156



KOLO	BICYCLE
HODNIK	WALKWAY

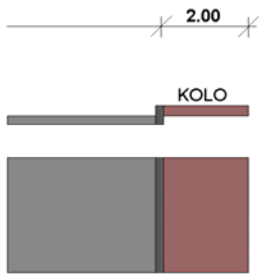


KOLO	BICYCLE
HODNIK	WALKWAY

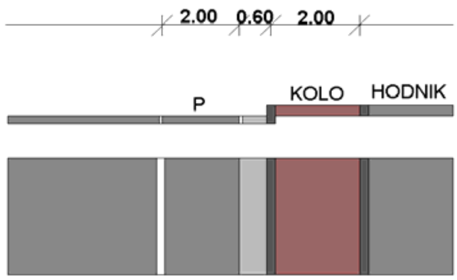
Optimal one-way two-sided cycle path along the edge of the road and along parallel parking spaces.

Figure 157

Figure 158



KOLO	BICYCLE

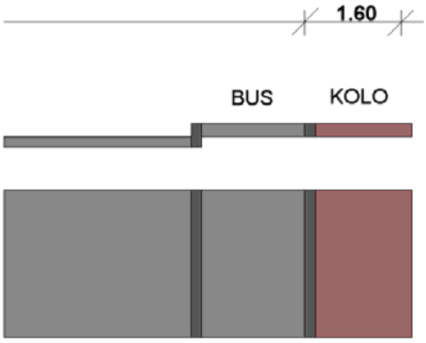


KOLO	BICYCLE
HODNIK	WALKWAY

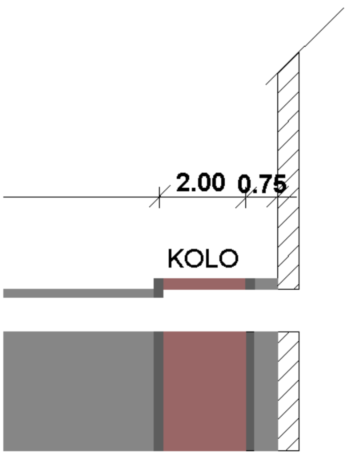
One-way two-sided cycle path next to a bus stop and a building or underpass.

Figure 159

Figure 160



BUS	BUS
KOLO	BICYCLE

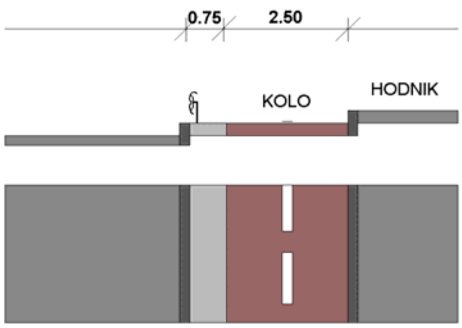


KOLO	BICYCLE

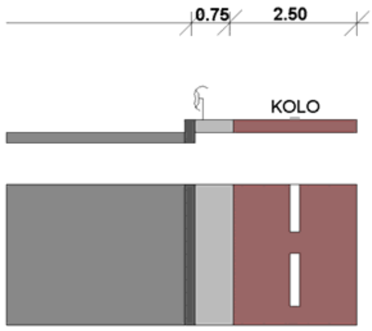
Two-way cycle path next to the pavement and an independent cycle path:

Figure 161

Figure 162



KOLO	BICYCLE
HODNIK	WALKWAY

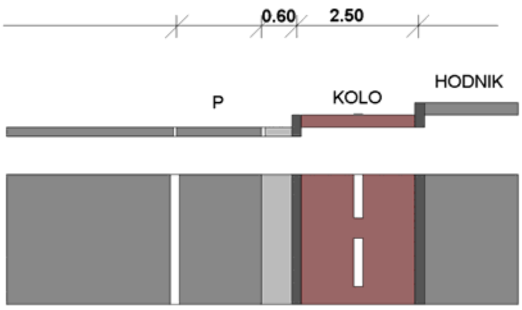


KOLO	BICYCLE

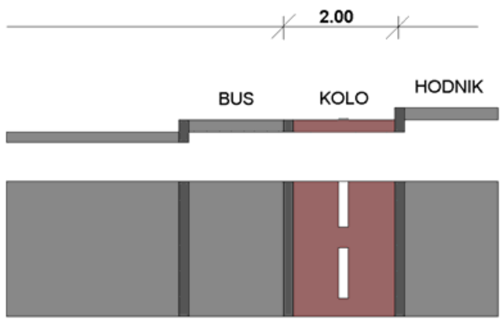
Two-way cycle path next to parking spaces and a bus station.

Figure 163

Figure 164



KOLO	BICYCLE
HODNIK	WALKWAY



BUS	BUS
KOLO	BICYCLE
HODNIK	WALKWAY

6.2.1.13.2 Cycle path outside urban area

The conditions that apply to cycle paths outside urban areas are the same as those for cycle paths in urban areas. Due to higher speed of motor vehicles (90 km/h) the one-way cycle path has to be at least 0.75 m away from the roadway and physically separated by a rail or bushes as well as grade separated by a kerb or 1.50 m away from the roadway and separated from it by a green area, possibly without a kerb (Figure 167).

The width of a cycle path outside urban area:

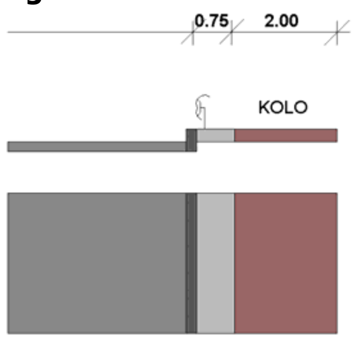
- one-way cycle path - 2.00 m (Figure 165),
- two-way cycle path - 2.50 m (Figure 166).

Cycle path outside the urban area may be narrowed only in the area of a bridge or underpass. In these areas a two-way and a one-way cycle path has to be at least 2.00 m and 1.75 m wide respectively. The narrowing has to be clearly marked by vertical (sign I-5) and horizontal signalisation.

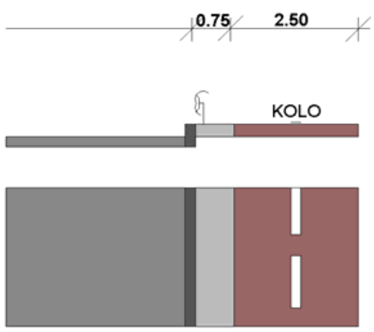
Example of a one-way two-sided and two-way cycle path outside urban area:

Figure 165

Figure 166



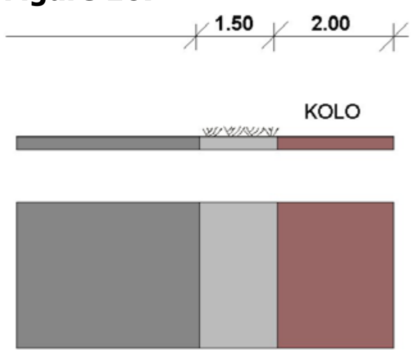
KOLO	BICYCLE



KOLO	BICYCLE

Example of a one-way two-sided cycle path with a separation green area of 1.50 m in width:

Figure 167



KOLO	BICYCLE

6.2.1.14 Bicycle paths

6.2.1.14.1 Bicycle paths outside urban area

Bicycle paths are suitable for connecting distant places and are thus designed for longer cycling trips. Absolute safety of cyclists has to be provided, since they meet also at high speed (up to 40 km/h), in addition to which comfort has to be ensured - including side by side riding by two cyclists. At a certain moment there may be as many as three cyclists on the cross section of a bicycle path. The above-mentioned two conditions determine the width of the bicycle path with 1.00 m of clearance for every cyclist and 0.50 m between the clearances of cyclists who meet each other.

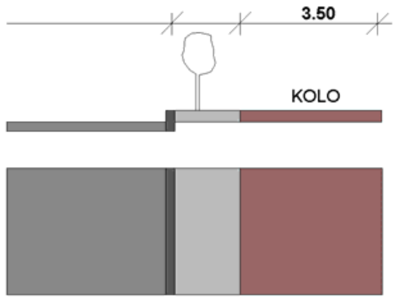
The width of a bicycle path is influenced by:

- dimensions of three clearances (3 x 1.00 m),
- safety area between two clearances (0.50 m).

The width of optimal bicycle path is thus 3.50 m. Exceptionally, a bicycle path may be reduced to 2.50 m in the area of a bridge or underpass, however, the narrowing has to be clearly marked with vertical (sign I-5) and horizontal signalisation. The distance of a bicycle path from the roadway has to be at least 1.50 m (Figure 169), so that no unpleasant interferences (suction force, etc.) arise at higher speed of motor vehicles and the cyclists travelling in the opposite direction over the bicycle path. It is recommended that the bicycle path is separate and independent of motor traffic. The lanes need not be separated by a central line, since the width is sufficient to ensure a safe ride of cyclists travelling in opposite directions.

Distance of the bicycle path from various obstacles (the same conditions apply as to cycle paths):

- from parking spaces - at least 06 m,
- from fixed obstacles (poles, trees, etc.) - at least 0.50 m,
- from the walls of underpasses or rails - at least 0.75 m.



KOLO	BICYCLE

Figure 168: Independent bicycle path

6.2.1.14.2 Bicycle paths in urban areas

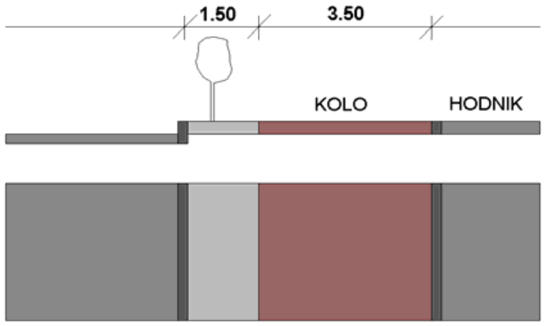
Bicycle paths are usually not used in urban areas, because cycle paths are more suitable. The conditions that apply to bicycle paths in urban areas are the same as those for bicycle paths outside urban areas.

Distance of a bicycle path from:

- the roadway - no less than 1.50 m,
- the walls of buildings and underpasses, the rails of overpasses and bridges - no less than 0.75 m,
- fixed obstacles (trees and public lighting poles) - no less than 0.50 m,
- kerbs of pavements bordering the bicycle path must not exceed 0.05 m in height.

Figure 169: Bicycle path in urban area

KOLO	BICYCLE
HODNIK	WALKWAY



The table below (Table 21) presents the optimal and minimum design width depending on individual forms of technical implementation of a cyclist surface:

Table 21: The width of a cyclist surface

	Width (m)	
Type of a cyclist surface	optimal	minimum
bicycle lane	1,60	1,00
one-way cycle path	2,00	1,75
two-way cycle path	2,50	2,00
bicycle path	3.50	2,50

6.2.1.15 Horizontal radii

A cyclist can ride over the curves with very small radii. The experiential equation for determining the ratio between the speed of a cyclist (km/h) and the radius of the inner curve (m) which still enables a cyclist to travel without braking and to still maintain balance is the following:

$R = 0.238\ V + 0.41$

V= speed (km/h)

R= radius (m)

The equation is suitable for the calculation of curve radii in urban areas at the calculation speed of 20 km/h.

As the speed rises, the radius of the curve which a cyclist can travel safely and comfortably increases also.

The smallest possible radius is 3.5 m, since in the event of lower radii the speed of a cyclist falls below 12 km/h, which results in instability. Exceptionally (spatial reasons) the radius may be smaller, however, a traffic sign (I-1) has to be placed in front of a radius of less than 3.0 m, cautioning about a dangerous turn, while in front of a radius of less than 2.0 m a traffic sign has to be erected warning the cyclist to step off the bicycle.

The values for minimum horizontal radii apply if the cross grade is

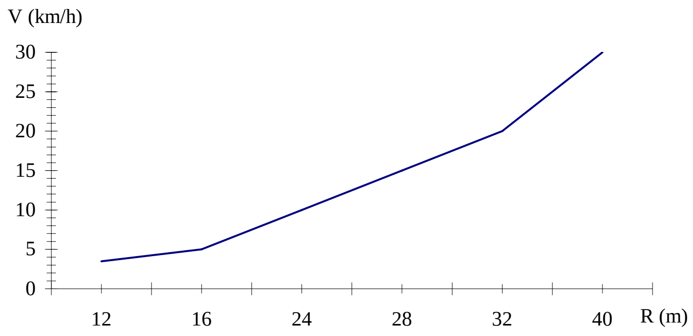
$q = 2.5\%$.

The horizontal radius on bicycle paths has to be at least R = 10 m.

Table 22: Ratios between the speed of a cyclist and the radius of the cyclist surface curve

Speed	12	16	24	28	32	40
R (m)	3.5	5	10	15	20	30

Figure 170: The graph showing the ratios between the speed of a cyclist and the radius of the cyclist surface curve



6.2.1.16 Widening of cyclist surface

Widening of cyclist surfaces are necessary:

- at the beginning and towards the end of the ride, when a cyclist continues on foot,
- at ascents,
- at curves.

In the first two cases a widening is needed because the speed of a cyclist decreases and his/her stability is poorer. The area needed by cyclists to stop and start should be 0.30 m wider than the rest of the surface.

The widening at curves is necessary on account of technical characteristics of bicycle riding and the inclination of a cyclist while riding through a curve.

At smaller speed the widening has to be provided due to smaller radius traced by the back wheel and at higher speed due to the cyclist inclination while travelling through a curve. The widening is as a rule provided on the inner side of the curve (Figure 172).

Table 23: Widening at small curves reasonable for small speed

(Source: Technical Norms for Designing and Equipping Urban Traffic Areas, Part 1)

R (m)	Widening (cm)
2	40
3	25
8	10

At high speed and radii below 30 m a widening is necessary because of a cyclist's inclination equalling up to 25° from the vertical line. Usually the provided widening is between 50 and 60 cm.

Figure 171: The space needed when riding through a curve

(Source: Technical Norms for Designing and Equipping Urban Traffic Areas, Part 1)

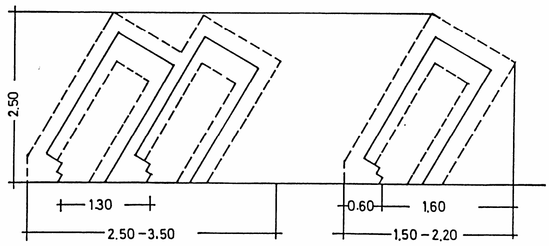
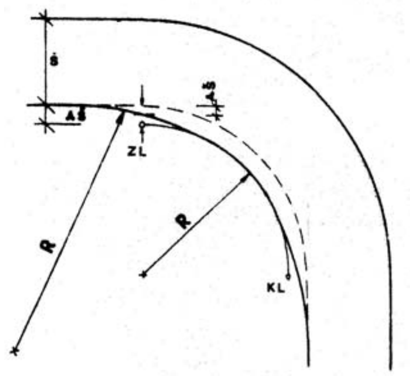
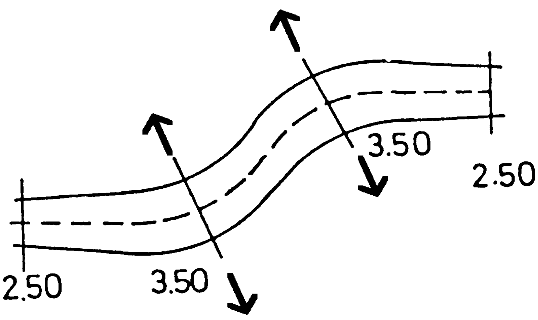


Figure 172: Implementation of curve widening (Source: Bicycle in Traffic - Consultation, 1987)



R - curve radius
Š - cyclist surface width
∆š - widening
ZL - start of the arch
KL - end of the arch

Figure 173: In the case of a two-way bicycle path a widening has to be provided also on the outer side (Source: Technical Norms for Designing and Equipping Urban Traffic Areas, Part 1)



6.2.1.17 Cross falls

Due to drainage the cross fall equals 2.5%. If the cyclist surfaces are on the same level as the pedestrian surfaces, the cross fall may be reduced to 1.5%. On bicycle paths or at locations were higher speed is involved (greater longitudinal falls), the planned cross fall has to be between 2.5% and 5% (depending on the radius of the horizontal curve).

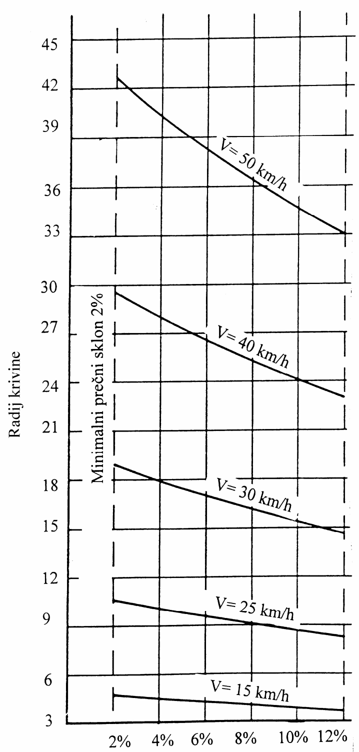


Figure 174

Radij krivine	Curve radius
Minimalni prečni sklon 2 %	Minimum cross fall 2%

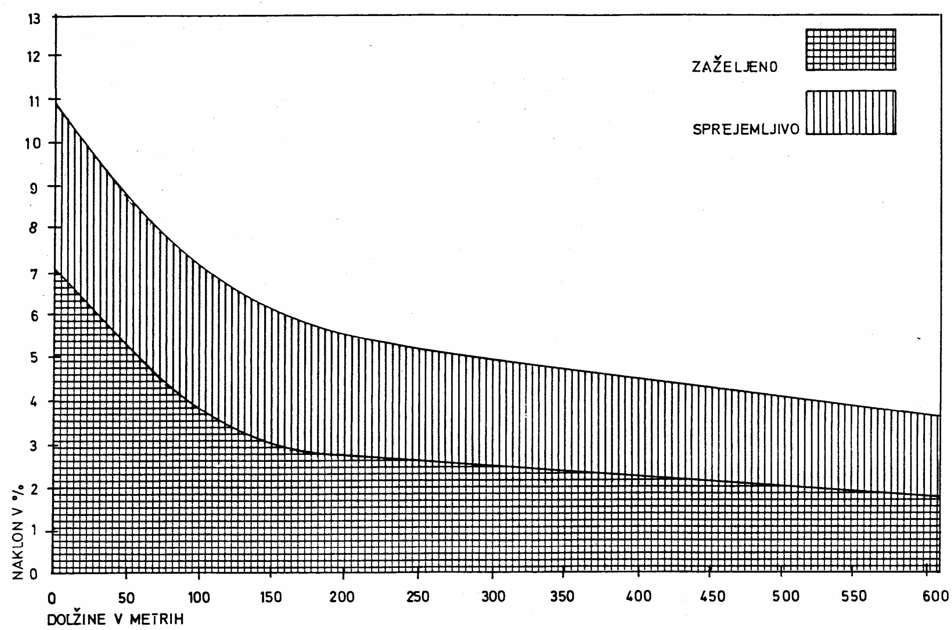
6.2.1.18 Longitudinal falls

Longitudinal gradients are conditioned by physical abilities of cyclists, technical and driving characteristics of bicycles, the speed of the wind, air resistance and the quality of driving surface. The same attention has to be paid to the specification of ascents and descents. Longitudinal gradients have to be acceptable for an average cyclist, while for active recreational cyclists they can also be greater.

Table 24: Recommended and maximum length of ascent in relation to longitudinal gradients

Ascent (%)	Recommended length (m)	Maximum length (m)
10.0	10	20
5.0	40	80
4.5	51	102
4.0	62	124
3.5	90	180
3.3	90	180
2.9	122	244
2.5	160	360
2.0	250	500

Figure 175: Diagram of recommended and maximum length of ascent in relation to longitudinal gradients



Translation of figure text

ZAŽELJENO	PREFERRED
SPREJEMLJIVO	ACCEPTABLE
NAKLON V %	GRADIENT IN %
DOLŽINE V METRIH	LENGTH IN METRES

The co-ordination of horizontal and vertical elements is also important. Namely, it enables a relaxed descent of a cyclist.

The limit values for descents on bicycle paths shorter than 200 m:

- free conclusion (horizontal, with an ascent) - 10%
- hindered conclusion (turn) - 8%
- restricted conclusion (requires a stop) - 6%

Table 25: The height difference overcome by a cyclist is also important

Height distance (m)	Ascent (%)	Length of ascent (m)
1	12	8
2	10	20
4	6	65
6	5	120
10	4	250
>10	3	

Greater ascents are permissible only at short distance and with an intermediate lessening of the longitudinal gradient below 4%. In general, on bicycle paths where the speed is planned to be 15 km/h the gradient should not exceed:

- 2% over a distance of 4 km,
- 4% over a distance of 2 km.

6.2.1.19 Vertical curvatures

If cyclist surfaces are routed vertically, the curvatures at the locations where the gradient changes are important as well. Vertical curvatures are not necessary at locations where the gradient changes by less than 5%, however, if they are planned, they should exceed 4 m.

Minimum vertical curvatures at locations where the longitudinal gradient changes by more than 5% have to equal at least R=30 m for summit (convex curve) and R=10 m for sag (concave curve).

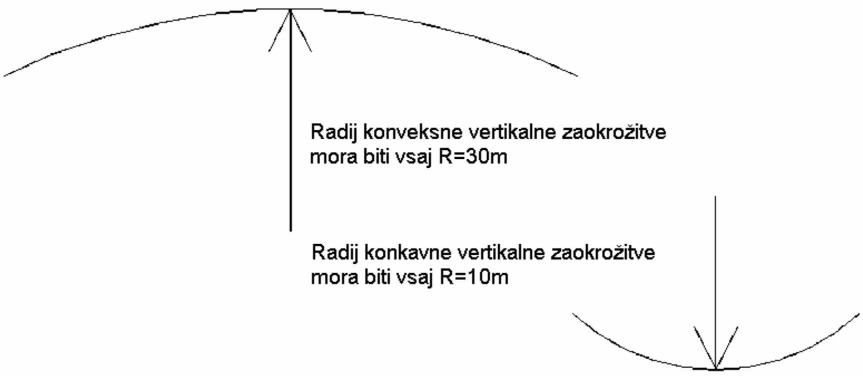


Figure 176

Radij konveksne vertikalne zaokrožitve mora biti vsaj R = 30 m	The radius of a summit has to be at least R = 30 m
Radij konkavne vertikalne zaokrožitve mora biti vsaj R = 10 m	The radius of a sag has to be at least R = 10 m

6.2.1.20 Sight distance

From the point of view of traffic safety the distance at which a cyclist notices or detects the crossing of major roads or other traffic is important. The following three distance values are important:

- sight distance during movement,

- braking sight distance;
- sight distance during the approach to a crossing.

6.2.1.20.1 Sight distance during movement

While riding, a cyclist has to supervise the area which he/she travels in 8 to 10 seconds. This distance is set based on project speed.

Table 26

Project speed	20 km/h	25 km/h	30 km/h
Sight distance during movement	45 - 55 m	55 - 70 m	70 - 85 m

6.2.1.20.2 Braking sight distance

Braking sight distance is the distance needed for reaction and safe stopping. It is composed of the distance travelled by a cyclist from the time he/she detects and obstacle to the time he/she reacts, and of the braking distance. It depends on the speed of the cyclist.

Table 27

Project speed	1 20 km/h	25 km/h	30 km/h
Sight distance during movement	> 20 m	> 30 m	> 40 m

6.2.1.20.3 Sight distance during the approach to a crossing

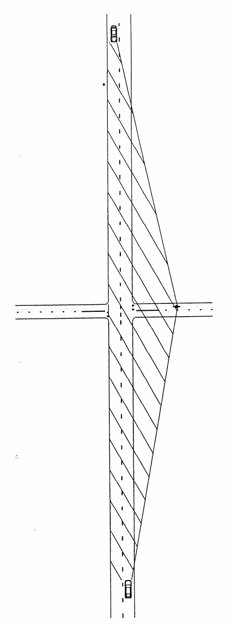
In order to safely cross a road the cyclist must have sufficient view of the rest of the traffic. He/she must realistically estimate the distance and speed of other traffic participants. The above-mentioned distance depends on the speed of traffic and the time needed for a cyclist to cross the road.

The table below gives the values of this distance based on the planned acceleration of 0.8 m/sec^2, the reaction time equalling 1 sec and the average cyclist speed of 10 km/h.

Table 28

crossing distance	time needed for crossing	speed of motorised traffic 30 km/h	speed of motorised traffic 50 km/h	speed of motorised traffic 70 km/h	speed of motorised traffic 90 km/h
5.00 m	4.5 sec	40 m	65 m	90 m	115 m
6.00 m	4.9 sec	40 m	70 m	95 m	125 m
7.00 m	5.3 sec	45 m	75 m	105 m	135 m
8.00 m	5.6 sec	50 m	80 m	110 m	140 m

Sight field as a cyclist approaches a crossroads:



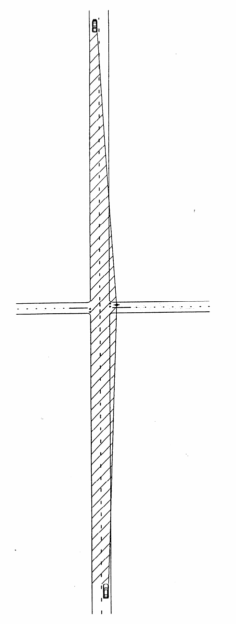


Figure 177: Stopping sight distance

Figure 178:Sight distance during the approach

In addition, sight distance has to be provided:

- at berm,
- at vertical curves,
- at horizontal curves.

The sight distance at berm equals the braking sight distance.

When designing points of access, the cyclist's sight field has to be taken into account. It is recommended that the points of access are provided at least at a 60° angle, ideally at the right angle.

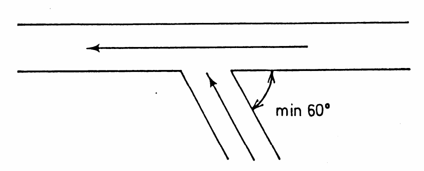
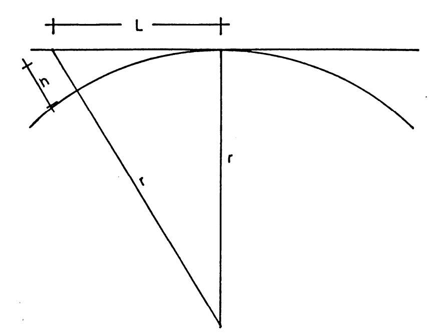


Figure 179: Cyclist's sight field

Vertical sight distance is ensured by suitable curvature of the grade.



L... sight distance

h... sight line above the roadway (1.25 m)

r... curvature radius

Figure 180: Ensuring vertical sight distance

The curvature radius can be set also based on an approximate equation:

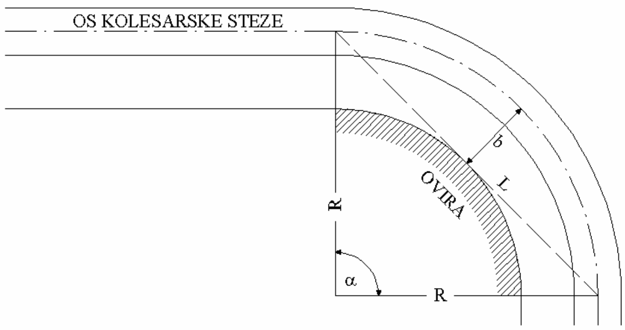
$r = 0{,}4\ L^2$

L... sight distance

h... sight line above the roadway (1.25 m)

r... curvature radius

Sight distance at horizontal curves is provided as obstacles are suitably moved aside on the inner side of the curve.



OS KOLESARSKE STEZE	CYCLE PATH AXIS
OVIRA	OBSTACLE

Figure 181: Sight distance at horizontal curves

b - distance between the obstacle and the bicycle lane axis
R - curve radius
L - sight distance
α – central angle
$b = R (1 - \cos α/2)$
$L = 2R \sin α/2)$

6.2.2 Crossing of cyclist surfaces with other traffic areas

6.2.2.1 Safety

Half of all traffic accidents in which cyclists are involved occur at crossroads. To ensure safe traffic the cyclist surfaces have to comply with the following conditions as they cross other traffic areas:

- safe separation of bicycle traffic from other traffic;
- very clear and unambiguous routing of bicycle traffic;
- understandable marking of the right-of-way;
- good visibility.

6.2.2.2 Methods of bicycle traffic routing

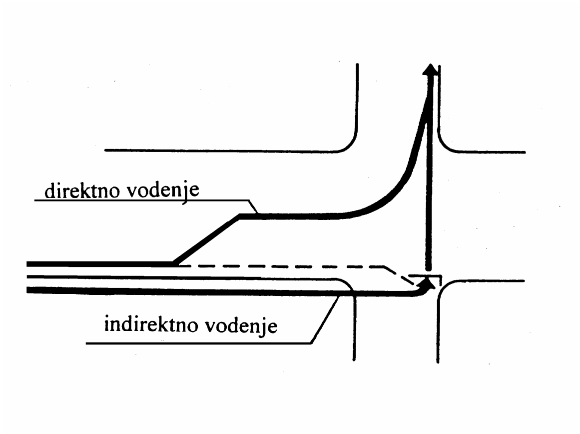
To provide for proper crossing of cyclist surfaces the following terms have to be explained:

- indirect and direct routing of traffic participants turning left;
- routing bicycle traffic across a branch of a side road;
- routing bicycle traffic across islands.

6.2.2.2.1 Indirect and direct routing of traffic participants turning left

Direct routing of traffic participants turning left can only be used when a cycle path is before the crossroads converted into a bicycle lane or a mixed traffic area and when due to scarce traffic (AADT< 1000 veh/day) the cyclists can without disturbance be placed next to the traffic participants turning left. In our situation this is not the most suitable solution.

When indirectly routed, a cyclist turns left by entering the crossroads on the right side, crossing the side road and in the next cycle crossing the main road.



direktno vodenje	direct routing
indirektno vodenje	indirect routing

Figure 182: Direct and indirect routing of bicycle traffic

6.2.2.2.2 Routing bicycle traffic across a branch of a side road

6.2.2.2.2.1 Direct routing

Direct routing is recommended at crossroads without light signalling devices. Riding next to the edge of the road implies that the cyclist is riding in priority direction. Unfavourable aspects of this solution are the following:

- vehicles waiting on non-priority road impede traffic;
- vehicles turning right hinder traffic on the main road, as they wait for the cyclists;
- there is no waiting area for pedestrians.

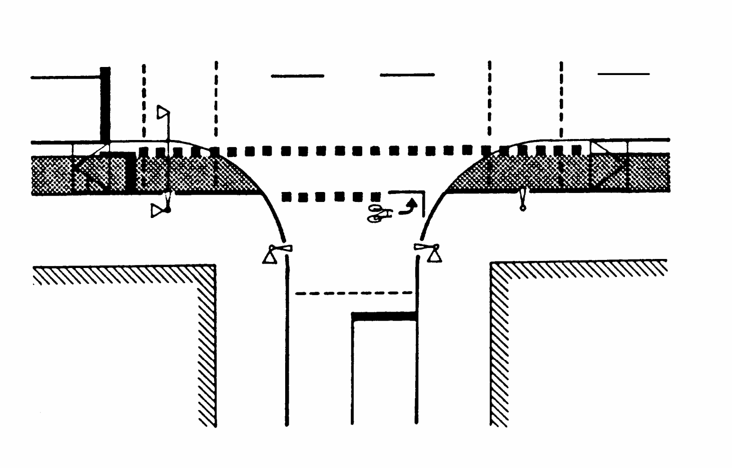


Figure 183: Direct routing of bicycle traffic

6.2.2.2.2.2 Partly indirect routing

In terms of traffic safety the solution whereby a cycle path in the crossing area is shifted by 2 to 3 metres is better - partly indirect routing.

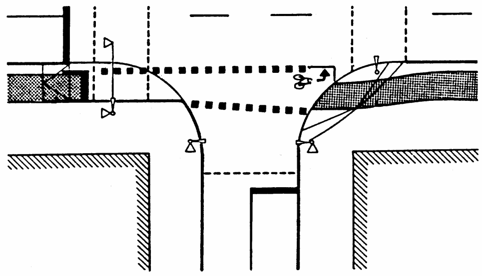


Figure 184: Partly indirect routing of bicycle traffic

6.2.2.2.2.3 Indirect routing

In the case of indirect routing the cycle path is shifted by 5 to 6 metres, so that the vehicles turning right can clear the priority direction. Thanks to this the pedestrians are provided a waiting area. Unfavourable aspects of this solution are the following:

- due to the shifted cycle path the vehicles turning right can overlook the fact that cyclists have the right of way;
- the drivers of motor vehicles from the side road stop incorrectly and hinder cyclists crossing the side road.

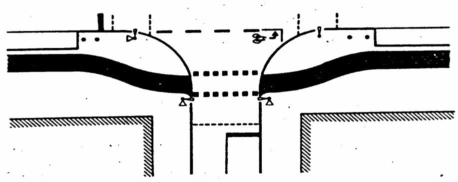


Figure 185: Indirect routing of bicycle traffic

6.2.2.2.2.4 Routing bicycle traffic across islands

6.2.2.2.2.4.1 Direct routing

As they ride next to the edge of the roadway, the cyclists are more visible to the traffic participants turning right, which is favourable for the cyclists, while on the other hand they cross the exit slip road at a small angle which is unfavourable. The unfavourable aspects of this solution are the following:

- vehicles turning right impede traffic on the main road, as they wait for the cyclists;
- there is no waiting area for pedestrians.

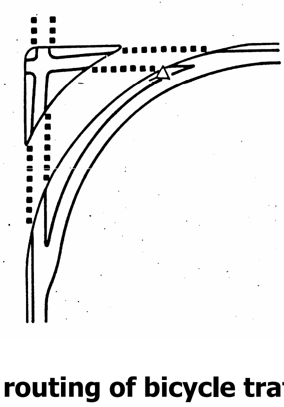


Figure 186: Direct routing of bicycle traffic across islands

6.2.2.2.2.5 Indirect routing with the cyclist having the right of way

In the case of indirect routing with the cyclist having the right of way the cycle path is shifted so that the cyclists cross the exit slip road at the right angle, in addition to which the vehicles turning right can clear the priority direction. Thanks to this the pedestrians are provided a waiting area. Unfavourable aspects of this solution are the following:

- due to the shifted cycle path the vehicles turning right can overlook the fact that cyclists have the right of way;
- the drivers of motor vehicles at the exit slip road stop incorrectly and hinder cyclists crossing the side road.

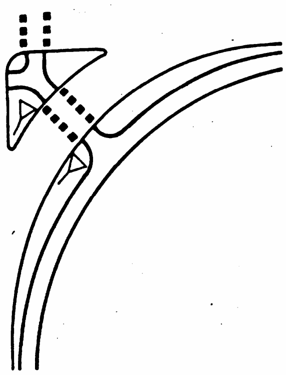
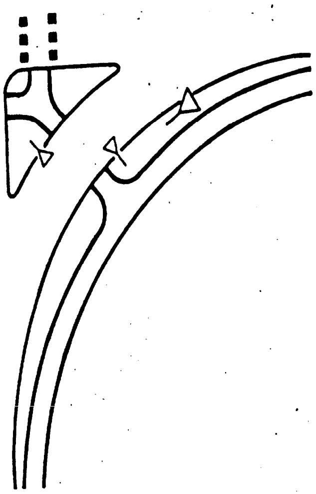


Figure 187: Indirect routing of bicycle traffic across islands

6.2.2.2.2.6 Indirect routing with a waiting area for cyclists

In the case of indirect routing with a waiting area for cyclists the cycle path is shifted so that the cyclists cross the exit slip road at the right angle. In this case the cyclists do not have priority, which is why they have to be cautioned thereof by vertical and horizontal signalisation. Thanks to this the pedestrians are provided a waiting area. Unfavourable aspect of this solution is:

- the drivers of motor vehicles pay less attention to the cyclists crossing the exit slip road.



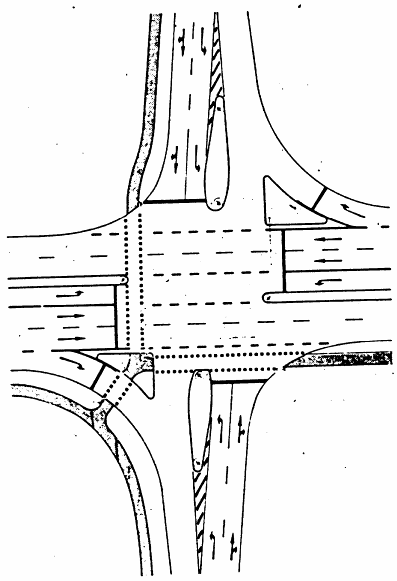


Figure 188: Indirect routing with a waiting area for cyclists **Figure 189**

6.2.2.2.3 Routing bicycle traffic at crossroads

An example of partly indirect routing of bicycle traffic with light signalling devices (LSD). The island at the crossroads is somewhat shortened due to bicycle traffic routing.

An example of indirect routing of bicycle traffic; the motor traffic has priority, the horizontal and vertical signalisation is used without light signalling devices.

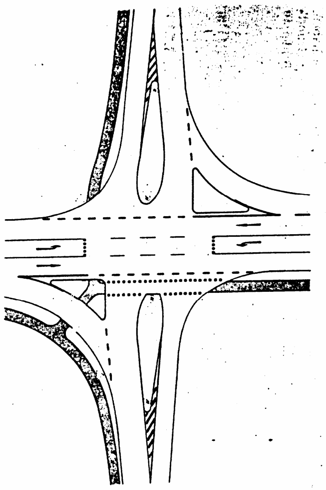


Figure 190

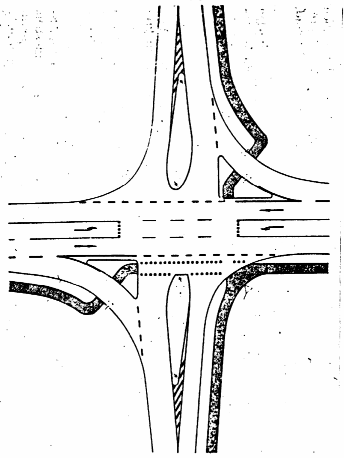


Figure 191

6.2.2.2.4 Crossings at grade outside crossroads

A crossing outside the crossroads is located at the beginning or at the end of a two-way cycle path where the cycle path continues to a mixed profile. Cyclists riding in one direction have to cross the roadway to continue the ride. The crossing method presented in Figure 192 does not function in practice, since very few cyclists decide to ride over the marked surface. Most cyclists cross the roadway as indicated by the broken line, which is dangerous for a cyclist, since the crossing distance is greater. Such crossing arrangement can be only temporary, if there are works carried out on the cycle path or the roadway.

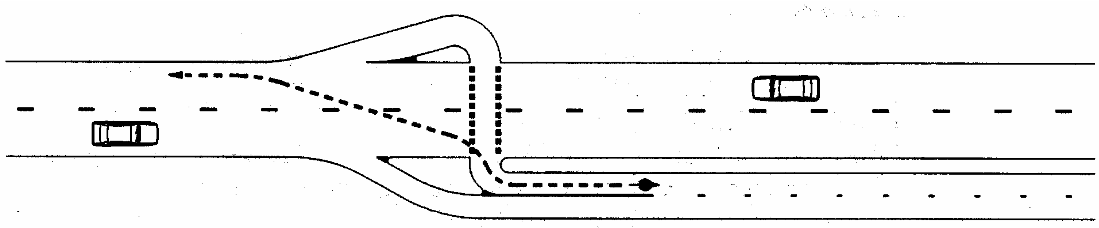
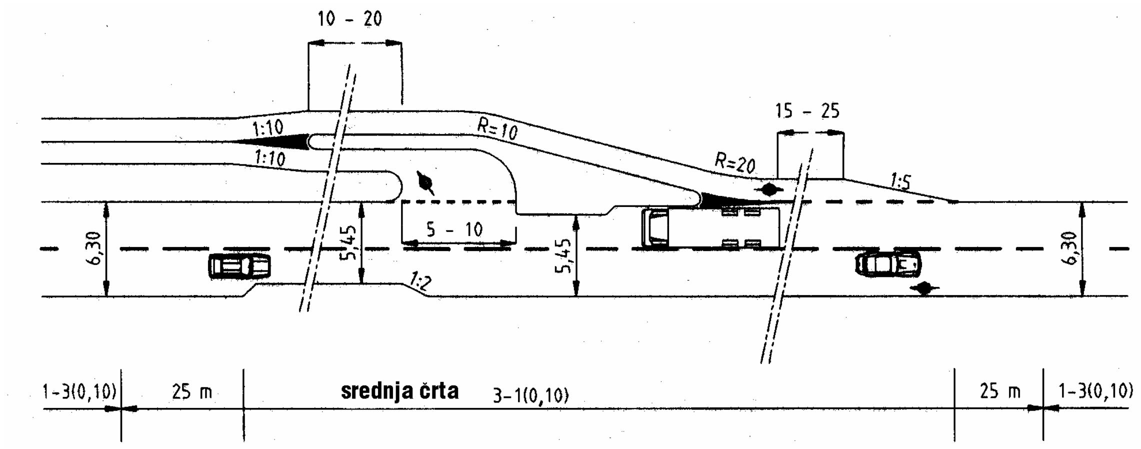


Figure 192

The solutions where motor vehicles have to reduce speed and cyclists are provided safe crossing of the roadway are safer. Slower cyclists find it more comfortable to cross the roadway at the right angle, which also improves the detectability. An example of such situation with very dense motor traffic and little space available is presented in Figure 193.



srednja črta	central line

Figure 193

If the spatial conditions are not critical, an obstacle can be introduced to reduce the speed of motor vehicles and facilitate the crossing by cyclists. The obstacle has to ensure safe entry of cyclists into the lane, which is why it has to be at least 2.00 m to 2.50 m long. This example is given in Figure 194:

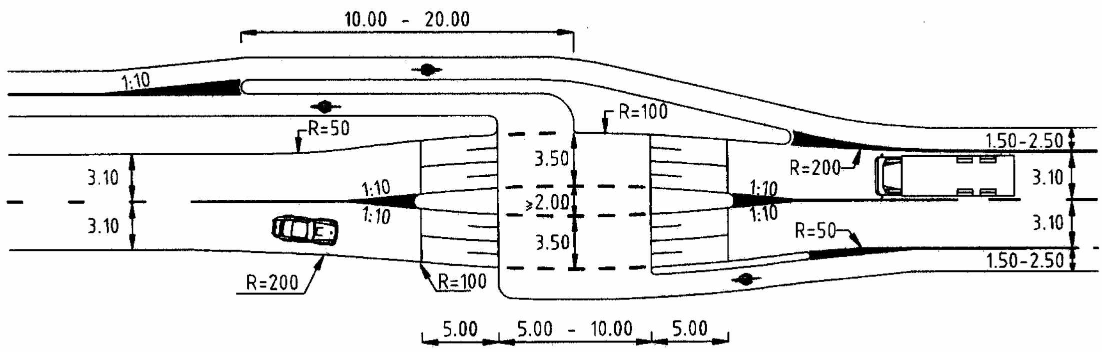


Figure 194

The cyclist surface can cross the roadway also due to a fork. Crossing is provided with special waiting area where cyclists wait for the possibility to cross and by vertical signalisation as shown in Figure 54 or by LSD and a detector as presented in Figure 55.

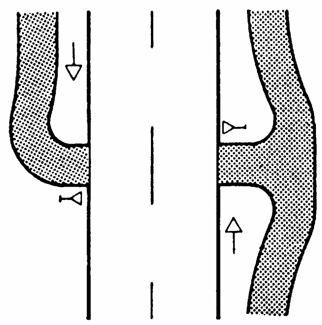
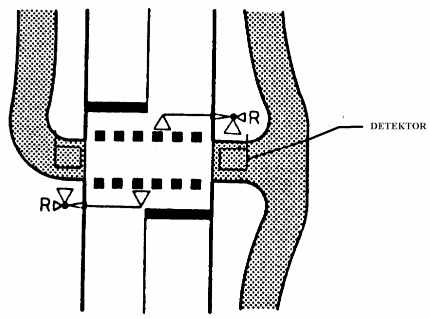


Figure 195: With waiting area



DETEKTOR	DETECTOR

Figure 196: Signalised and with a detector

6.2.2.2.5 Routing bicycle traffic at roundabouts

Bicycle lane is physically separated from other traffic - at roundabouts and approaches.

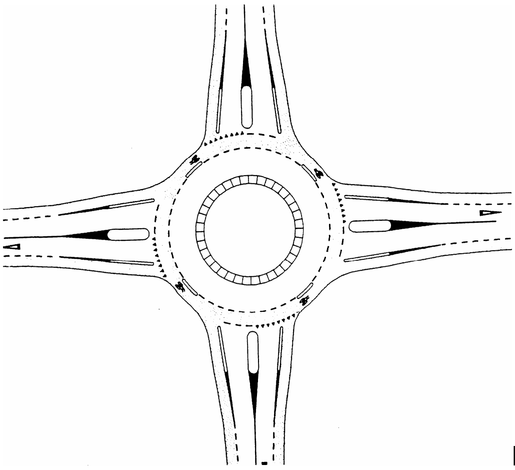


Figure 197

A bicycle lane is in part physically separated from the rest of the traffic. At roundabouts, cyclists, similarly as motor traffic, have priority over other traffic participants approaching the roundabout. Motor vehicles exiting a roundabout have to yield to the cyclists riding in the roundabout. This solution can be applied in areas with speed restriction of 30 km/h.

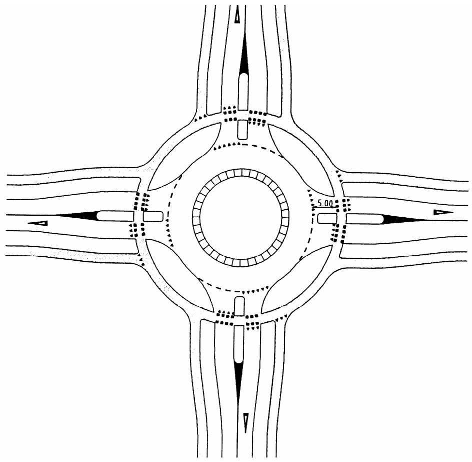


Figure 198: Cycle path separated from other traffic - cyclists have the right of way

The cycle path is approximately 5 metres away from the outer edge of the roundabout. Only one-way bicycle traffic is provided.

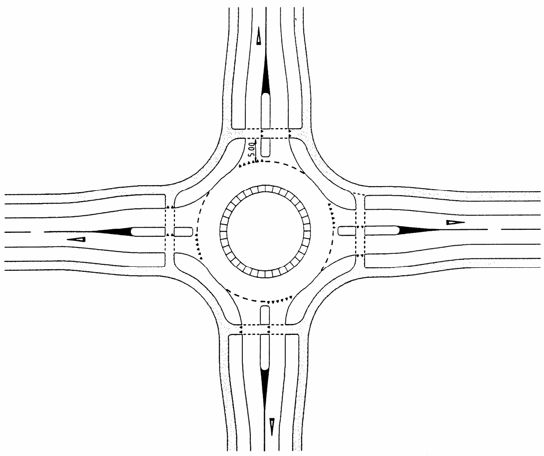


Figure 199: Cycle path separated from other traffic - cyclists do not have the right of way

Horizontal routing of cycle path is here different than in the previous example when the cyclists have priority. Crossings are implemented at the right angle - the cyclists do not have the right of way. A cycle path has to be approximately 5 metres away from the outer edge of the roundabout, so that the waiting passenger vehicles would not block the cyclists. Such solution enables two-way bicycle traffic.

Cycle path-railway crossing - application of automatic threshold block with a half-barrier. A traffic sign denoting a railway crossing (I – 33) has to be installed.

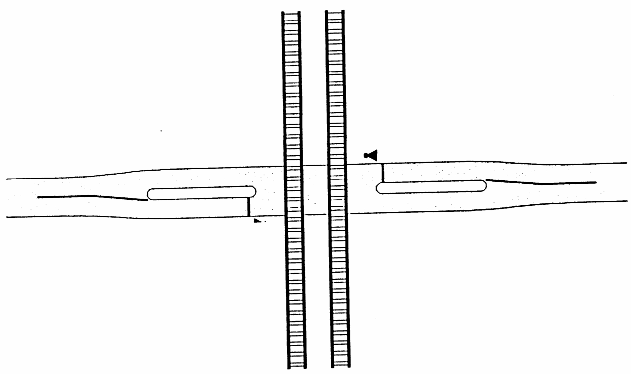


Figure 200

6.2.3 Bicycle storage areas

6.2.3.1 Basic requirements

At the end of every bicycle trip, the bicycle is parked and/or stored. Just like the drivers of motor vehicles the cyclists need parking areas at the start and the end of the ride. At first glance there do not seem to be any major problems, since bicycles are small and mobile and can therefore access most destinations, which would lead us to think that the possibilities for direct storage of bicycles are unlimited. However, since the number of cyclists is increasing, the problem of bicycle parking already arises in urban centres. Most of all, cyclists want safe parking areas in the approximate vicinity of their final destination.

Bicycle theft has become a major problem in the world. In Slovenia various systems for locking bicycles have been established. Many different bicycle racks have been designed, yet there are so far no completely safe, simple and above all cheap systems. The consequence of poorly arranged bicycle parking areas is unutilised bicycle potential and the use of older bicycles of poorer quality for everyday rides. The findings from abroad show that by introducing a secure bicycle shed at certain locations the number of arrivals by bicycle can be doubled.

The basic requirements for still bicycle traffic can be summarised in five main items:

1. easily found (parking area has to be visible from all directions from which it can be accessed, if not, suitable marking has to be provided);
2. suitable accessibility (it is best if a cyclist can ride directly to the parking area, adequate distances between the racks and the distance from fixed obstacles have to be provided);
3. attractiveness (the shape, functionality and practicability have to be balanced);
4. safety (personal safety of cyclists, safety of parked bicycle, other traffic participants must not be hindered);
5. comfort (shelter from unfavourable weather conditions, accompanying activities at locations where bicycles are parked for a longer period of time: service, store, dressing rooms, etc.).

6.2.3.2 Demand for bicycle parking lots

Bicycle parking lots would have to be provided at the end and the beginning of a trip, at locations characterised by major potential generators of bicycle traffic, e.g. schools, shopping centres, railway and bus stops, working places, sports facilities, cultural facilities, etc. Long-term parking lots with shelter for protection against unfavourable weather conditions have to be located at working centres and schools, while short-term parking lots are intended mainly for visitors, customers, buyers. The parking lot location has to be stated on bicycle maps and public access to them provided. If the parking lots are not available at proper locations, the cyclists will not use them and will leave bicycles against the building façade, chained to the street lighting poles or leaned against nearby trees. Especially important is to determine the locations of short-term parking lots, which have to be provided at suitable locations in order to be efficient.

There are several methods available for determining and selecting new locations of bicycle parking lots:

- in principle, the following rule applies: the locations where bicycles are parked call for bicycle parking lots;
- the locations can be established also based on source target matrices;
- the most accurate data about the locations where bicycle parking lots are needed are acquired based on research methods such as surveys (at home, on the street, among employees, etc.) and count (bicycle traffic census, counting of parked bicycles, etc.).

The specification of locations of short-term parking lots is more sensitive.

6.2.3.3 Parking methods

How the area for storing bicycles is arranged depends on the method of parking, which can be divided into short- and long-term parking. Long-term parking is parking lasting over two hours.

6.2.3.3.1 Short-term parking

Short-term parking lasts less than two hours. In order to arrange short-term parking an area is selected outside a facility on the functional land of that facility. There are several bicycle rack systems, which are as a rule an obligatory part of the bicycle storage areas. When selecting the racks, attention has to be paid to the fact that some types of racks can damage the bicycles or their (theft)protection mechanisms are so complex that the users find them difficult to understand. When suitable arrangement of bicycle storage areas is being selected, the requirements stated below have to be taken into consideration.

6.2.3.3.2 Theft protection

Arrangement within or outside a facility requires that such rack system is provided which enables bicycles to be safely chained to the fixed part of the racks by a universal chain, a U-lock or a similar safety mechanism installed in the rack. The location of the bicycle shed or racks for parking bicycles has to be at frequented points, well visible and properly lit at night.

6.2.3.3.3 Safety

Bicycle parking lots have to be suitably distanced and protected from motor traffic (e.g. by raised kerbs). A minimum distance from the existing bicycle paths has to be provided. It is also important that the bicycle parking lots do not hinder other traffic participants, especially pedestrians.

6.2.3.3.4 Location

To select a good microlocation of cyclist surfaces the following requirements have to be met:

- the location must not be crowded (not only the prescribed number of parking lots has to be provided, but also a high level of service provided to cyclists and other traffic participants);
- direct proximity of the destination of most cyclists (minimum walking distance to the entry of a building), easily accessible by bicycle or on foot (stabilised area, good drainage);
- the location has to be safe in social terms (well visible, lit, frequented).

6.2.3.3.5 User-friendliness

The bicycle rack has to be of such type that it enables simple usage, incorporating a storage and a locking system. It must not be restricted to a certain lock or bicycle type and the distance between two adjacent parking spaces must not be too small (at least 30 cm for movable racks), since insufficient space makes it difficult to access and lock the bicycle. Moreover, the possibility of damage to the parked bicycle has to be minimised. A bicycle can be damaged also by a cyclist, e.g. when he/she wants to lock the bicycle or remove it from the parking space (improperly shaped rack, which can damage the tyres, the rim or even the frame). A bicycle can be damaged also if it is leaned against the neighbouring bicycle or if it is unstable in spite of the rack (wind).

6.2.3.3.6 Quality and durability

This criterion is important for the cyclist and the parking area manager. It is important for the cyclist that the rack is vandalism-proof, that it is free from sharp parts which could damage the bicycle or the cyclist (also passers-by). It is important for the manager that the rack is made of quality materials which do not require maintenance and that it is designed in such a way that dirt is not deposited on it.

6.2.3.3.7 Design

In addition to functionality the layout and arrangement of bicycle storage areas have to be such to ensure the aesthetic value. The racks and the relevant areas have to be designed consistently with the existing equipment of the street, city or building in front of which they are located. It is important that the design does not reduce the functionality of bicycle storage areas. Unified design of racks within a town, city is also suitable, as this provides greater noticability and recognisability, lower price and uniform appearance.

6.2.3.3.8 Long-term parking

If bicycles are parked for more than two hours the long-term parking systems have to be provided and suitably arranged. Long-term parking enables employees, students, citizens and others present in the building or the city for a longer period of time to safely store bicycles, which have to be protected also from weather conditions.

Safe storage of bicycles is much more important in the case of long-term parking than in the event of short-term parking.

When the areas for long-term bicycle storage are suitably arranged, the conditions applying also to short-term parking as well as the requirements stated below have to be complied with: the location of a long-term parking lot can be no more than 250 m away from cyclist's target destination, at least 50% of long-term parking area has to be sheltered, while greater safety can be provided by locks, supervision by an authorised person or video surveillance. A combination of the above-mentioned measures is also recommended.

Long-term parking of bicycles can be provided by several parking systems, depending on the needs.

6.2.3.3.9 "Boxes" for storing bicycles

Such storage system provides a high service level to the users, but it is one of the most expensive solutions for long-term bicycle storage. The space needed is twice as big as in the case of classic storage system, which is why prior to the introduction of such system the demands and the potential location have to be thoroughly researched.

6.2.3.3.10 Bicycle sheds

6.2.3.3.10.1 Private bicycle sheds

Bicycle sheds are usually located in apartment buildings or facilities where there are permanent users that we know of in advance (schools, factories, etc.). Every user has a key to the entrance door or the entry is secured by electronic locks. The door has to be equipped with a self-closing mechanism. The bicycle sheds have to be accessible directly from outside through a separate entry. If this is not possible, they have to be accessible through ramps next to the stairs, driving ramps (i = max. 15%) or an elevator that has to be large enough to enable normal transport of the cyclist and the bicycle.

6.2.3.3.10.2 Public bicycle sheds

Bicycle sheds can be suitably located also for occasional (unknown) users in public areas (railway stations, recreational areas, cultural facilities, etc.) or only as independent units in individual sections of the cities where there are more generators of bicycle traffic. In such case it is not possible for every user to have a key to the entrance door, which is why video surveillance or an authorised person for security has to be provided. Such bicycle sheds have to be accessible 24 hours a day. Particularly suitable location of bicycle sheds is in parking garages. It is important that the cyclists are separate from motor traffic, however, as they enter the bicycle shed, the cyclists must not hinder the pedestrians or motor vehicles in the parking garage.

6.2.3.3.10.3 Automatic bicycle sheds

Automatic bicycle sheds have several advantages compared to other bicycle storage systems, especially high level of theft safety, the expenses they incur can be covered by their operation and they make very good use of the space.

Automatic bicycle sheds became more common only recently. After the most efficient systems are established, it can be expected that they will be even more used. Automatic bicycle sheds have a future mainly at "park and ride" system stops, since they can operate non-stop. They are used at all locations where there is insufficient space for setting up classic bicycle sheds or in the event the racks would not be consistent with the architecture of a certain quadrangle (e.g. in old city centres).

6.2.3.3.10.4 Sheltered cyclist surfaces

Suitable for long-term bicycle storage are also the systems for short-term storage supplemented by a shelter and, if possible, heated. Such systems are appropriate when the bicycle parking lot has already been constructed and we wish to improve the level of services or when it is not possible to construct a bicycle shed within the building. The above stated systems are suitable in office buildings to be used by employees working there.

6.2.3.3.11 Selection of the bicycle parking method

The method or type of bicycle parking at a certain location depends on various factors. The needs of cyclists differ from case to case. Theft and vandalism safety improve as the period during which the bicycles are parked increases, the need for protection against unfavourable weather conditions is greater also, while the opening hours of secured bicycle sheds have to be adjusted to the majority of cyclists' arrivals and departures. Of high importance is the manipulation time in bicycle sheds, particularly at railway stations. At short-term bicycle parking lots parking should be free of charge.

6.2.3.4 Dimensioning and standards

When the necessary location of the bicycle parking lot is established and the parking method defined (short-term, long-term), the number and the capacity of bicycle parking lots has to be determined and the rack type and layout method specified (parallel, in a row, etc.).

6.2.3.4.1 Bicycle parking lot capacities

The capacity depends on location, type and size of an individual generator of bicycle travel.

The necessary parameter for a certain location, i.e. the number of parking lots/unit (area, no. of visitors, no. of beds, etc.) is determined based on the average number of all visitors, employees or students. This figure is then multiplied by the planned percentage of bicycle rides established based on the traffic policy. Dimensioning, i.e. the determination of the necessary number of parking lots, is based also on tables which contain the number of parking lots for the most common cases.

Data included in Table 10 have to be corrected according to the actual number of parked bicycles (obligatory count) and the data acquired based on the survey covering the current and potential users of the bicycle parking lot. And finally, monitoring and corrections, if any, have to be provided.

A rough estimate of the necessary number of parking spaces can be made based on the number of parking spaces for passenger vehicles (10-15%).

A parking space for cyclists is as a rule equipped with a rack in which a bicycle can be fixed and safely locked.

Table 29: Dimensioning of bicycle parking lots (Note: if not otherwise stated, the gross area is given)

LOCATION	EMPLOYEES/ 2 RESIDENTS 3 (PERMANENT USERS) NO. OF PARKING SPACES	CATEGORY	VISITORS NUMBER OF PARKING SPACES	CATEGORY
Banks	1/100m2	2	3 + 1/50m2	3
Hospitals	1/15 beds	1	1/30 beds	3
Galleries	1/500m2	2	3 + 1/500m2	3
Hotels	1/10 employees	1 or 2	5 or 1/20 veh.	1
Industrial facilities	1/350m2	1 or 2	1/500m2	3
Libraries	1/500m2	1 or 2	5 + 2/200m2	3
Light industry	1/500m2	1 or 2	1/500m2	3
Outlets	1 / 4 employees	2	3 + 1/50m2	3
Motels	1/40 rooms	1	1/500m2	2
Museums	1/500m2	2	5 + 1/400m2	3
Shopping centre	1/300m2 g.sal.a.	1	5/150m2 g.sal.a.	3
Municipal administrative building	1/500m2	2	3 +1/150m2	3

Offices	1/100m2	1 or 2	5 + 1/450m2	3
Swimming pools	1/400m2	1 or 2	2/10m2 pool area	3
Recreational facilities (indoor)	1 / 4 employees	1 or 2	1/200m2	3
Restaurants	1/100m2	2	2 + 1/100m2	3
Sacral facilities	1/2 employees	1 or 2	1/25m2	3
Singles or student dormitories	1 / 4 rooms	1	1/16 sob	3
Schools	1/5 students +1/10 employees	1 or 2	1/500m2	3
Sports halls	1/500 seats	1	1/150 seats	3
Residential buildings	1/unit 1/5 units	1	1/10 units	3
Shops	1/150m2 sal.a.	1	3 + 1/100m2	3
Market places	1/500m2	2	1/5 stalls	3
Amusement centres	1/500m2	1 or 2	3 + 1/50m2	2
Health facilities	1/400m2	1 or 2	1/200m2	3

Table 30: Classification of bicycle parking lots by safety level

CLASSIFICATION OF BICYCLE PARKING LOTS			
Category	Level of safety	Description	Main users
1	High	Locked individual bicycle boxes, secure bicycle sheds	At railway and bus stops, where the P+R system has been established.
2	Medium	Various types of bicycle sheds with racks for locking bicycles as in cat. 3. The locked bicycle shed may be entered by a key or electronic card.	For full time employees, students, regular users of P+R, neighbourhood or building residents.
3	Low	Various racks against which bicycles are leaned and to which the frame and bicycle are locked.	Visitors, shoppers, recreational cyclists, employees, students, etc., where the parking lot can be directly supervised.

6.2.3.4.2 Basic types of racks for bicycle parking

The basic dimensions of a rack depend on the dimensions of a bicycle and on how the bicycle is leaned against the rack.

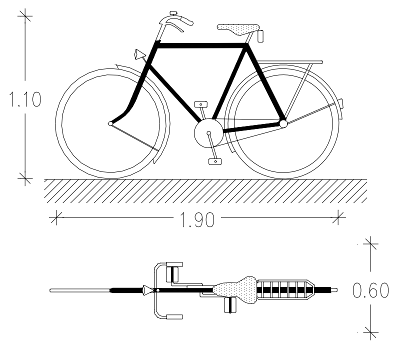


Figure 201: Basic dimensions of a bicycle

There are several types of bicycle racks. Such a rack has to be selected which meets the following requirements:

- theft protection (the rack has to be fixed, it has to enable that the frame and bicycle are locked to it),
- user-friendly (bicycle can be simply mounted on the rack, it is designed for different types of bicycles),
- minimum possibility of damage (it has to be suitable for bicycles with different rims, the bicycle frame has to be in a stable position, the rack must have any sharp edges),
- rack production quality and durability (the rack has to be weather-proof and salt-resistant as well as vandalism-proof).
- use of space (the rack design has to enable the racks to be positioned parallel, in a row, in a circle; the space available for the parking lot has to be put to best use).

The racks which support only the rim of the bicycle and the racks which do not enable the frame of the bicycle to be locked are not suitable!

6.2.3.4.2.1 Horizontal bicycle racks

6.2.3.4.2.1.1 Basic rack type or standard rack

This rack meets all the above-mentioned conditions.

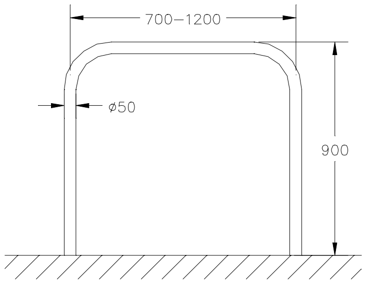


Figure 202: Standard rack for horizontal parking made of corrosion-protected bended material

Standard rack for parking bicycles enables the use of the most common locks as well as the so-called U-locks.

Since the standard rack supports the frame of the bicycle, the rims of the bicycle cannot be damaged. The rack enables the frame and rim to be locked at the same time. Every rack can take up to two bicycles. The approach direction and the bicycle orientation are irrelevant.

6.2.3.4.2.1.2 Alternative racks

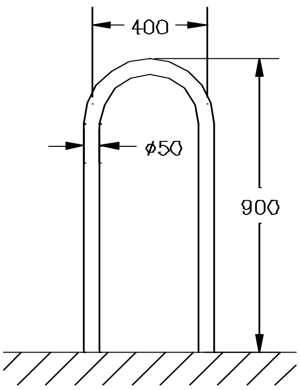


Figure 203

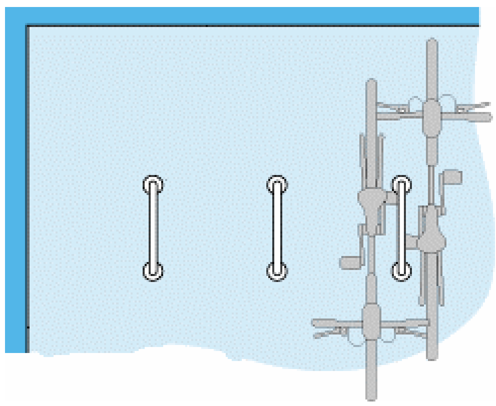
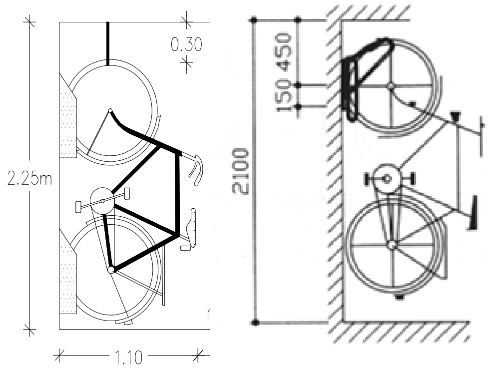


Figure 204

6.2.3.4.2.1.3 Vertical bicycle racks



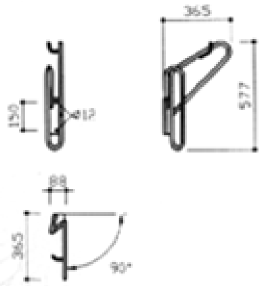


Figure 205: Classic "hook" vertical system for storing bicycles
Figure 206: Vertical rack for bicycles - "Gama" type

6.2.3.4.3 Basic set-up of bicycle racks

6.2.3.4.3.1 Horizontal rack set-up

Mainly the following set-ups are used:

6.2.3.4.3.1.1 Both-sided racks set-up in a row

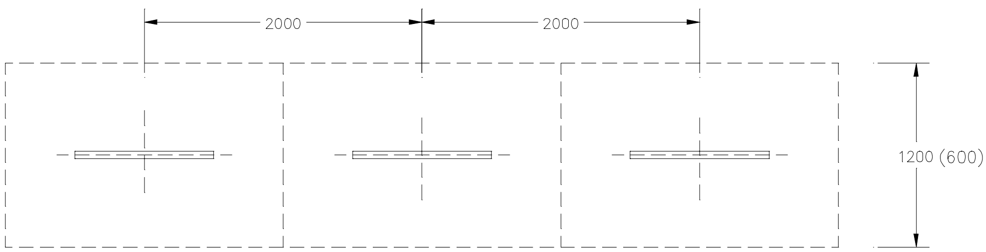
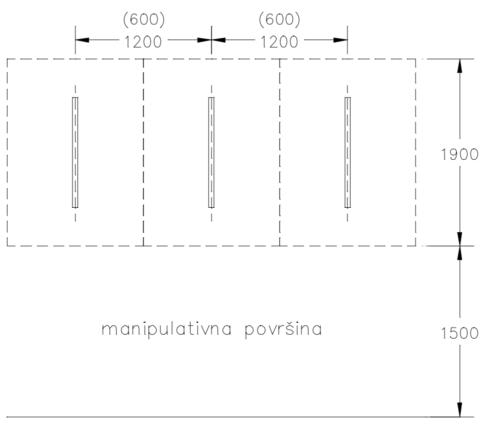


Figure 207: Both-sided racks set-up in a row. The figures in the brackets represent the width of one-sided racks

6.2.3.4.3.1.2 Parallel rack set-up



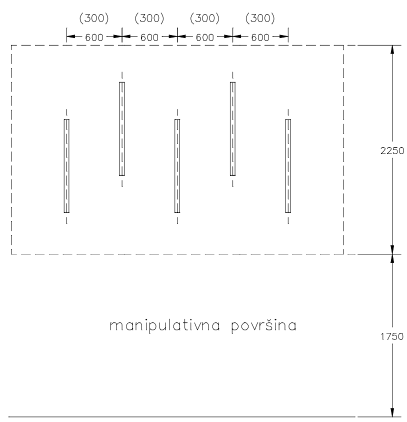
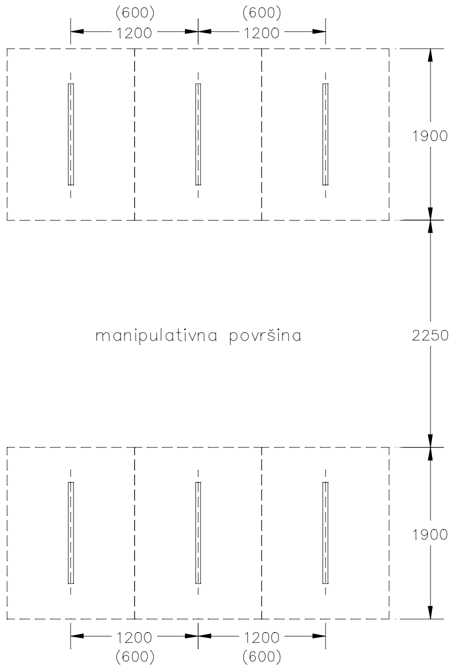


Figure 208: Both-sided parallel rack set-up (the figures in the brackets represent the width of one-sided racks)

manipulativna površina	handling area

manipulativna površina	handling area

Figure 209: Both-sided parallel rack set-up



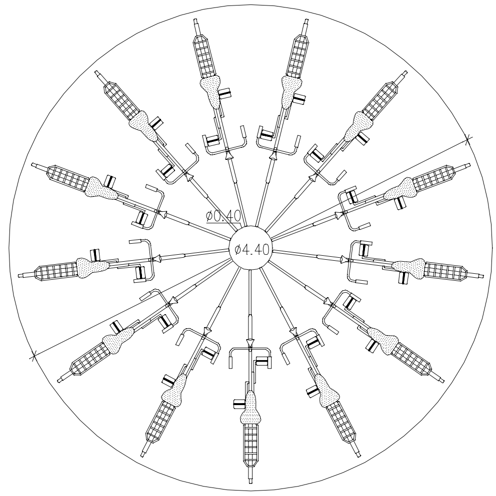
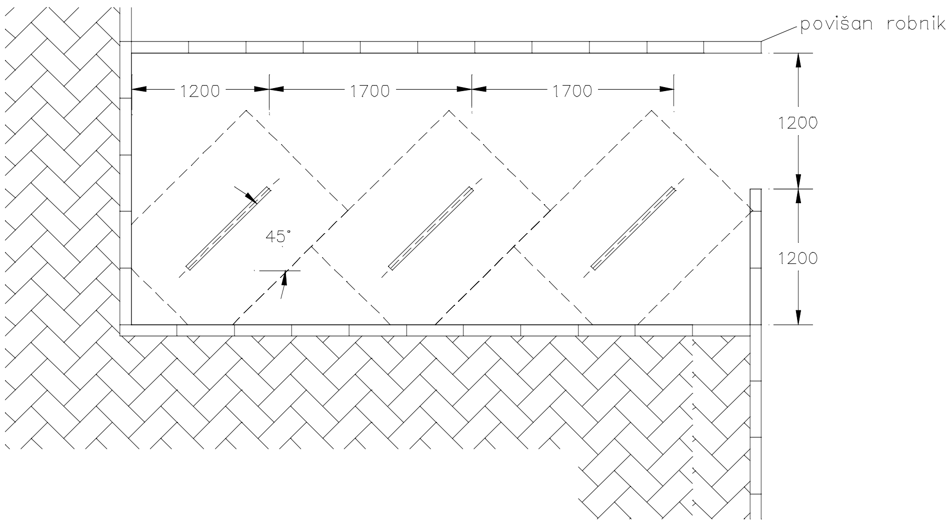


Figure 210: Radial rack set-up

The figures in the brackets represent the width of one-sided racks.

6.2.3.4.3.1.3 Sideways rack set-up:



povišan robnik	raised kerb

Figure 211: Six bicycle parking spaces can be arranged at one passenger vehicle parking space

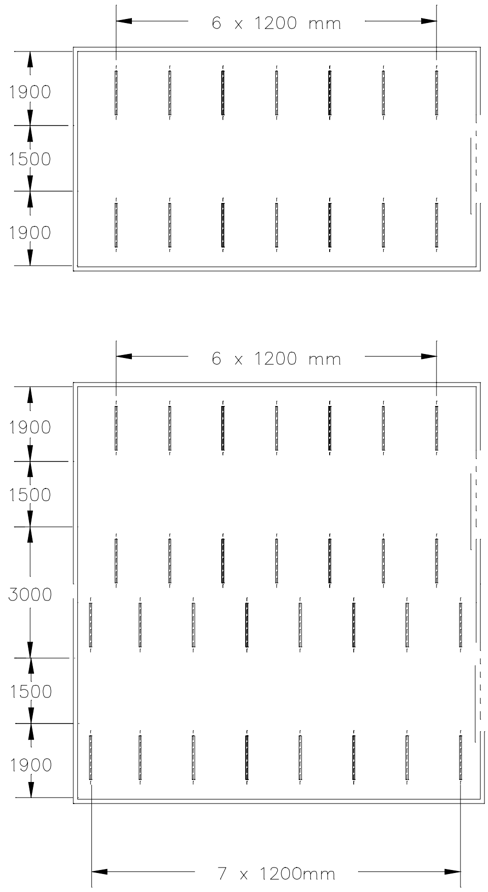


Figure 212: Rack set-up in enclosed (closed) bicycle sheds

6.2.3.4.3.2 Vertical rack set-up

6.2.3.4.3.2.1 Basic set-ups

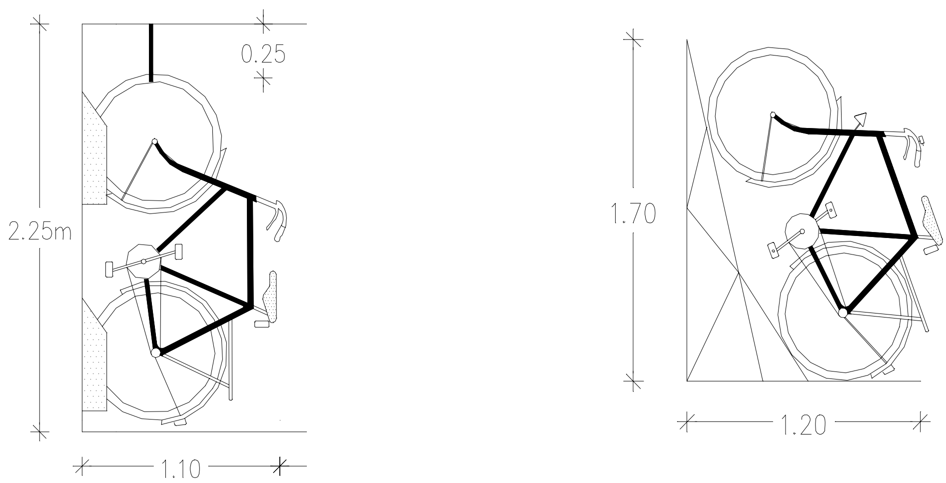
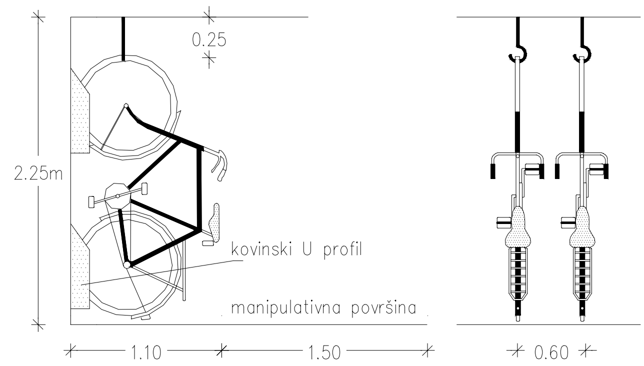
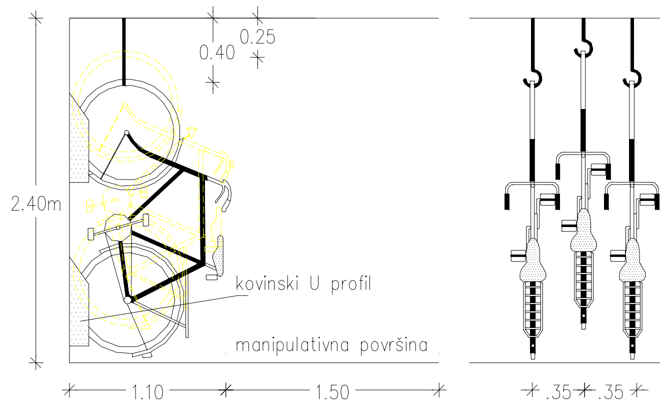


Figure 213: Basic vertical set-up and the type of set-up in the event of insufficient space



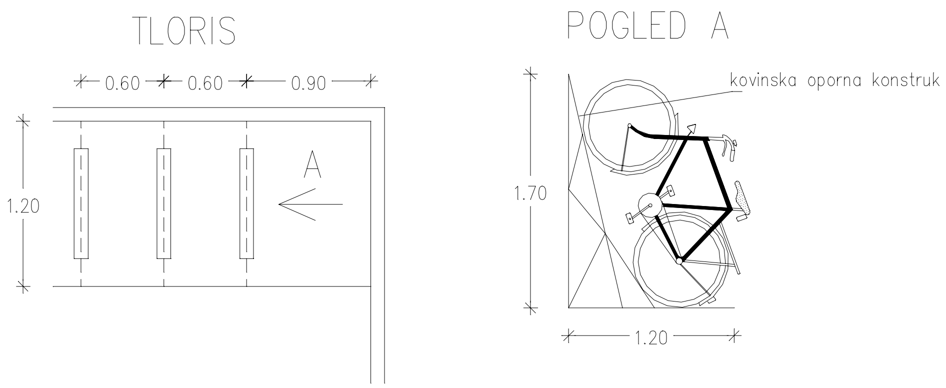
kovinski U profil	metal U profile
manipulativna površina	handling area

Figure 214: Vertical set-up if the room is at least 2.00 m high and the presentation of distance from fixed obstacles



kovinski U profil	metal U profile
manipulativna površina	handling area

Figure 215: Vertical set-up if the room is at least 2.40 m high and the presentation of distance from fixed obstacles



TLORIS	GROUND PLAN
POGLED A	VIEW A
kovinska oporna konstrukcija	metal supporting construction

Figure 216: Vertical set-up if the room is at least 2.00 m high and the presentation of distance from fixed obstacles

6.2.4 Pavement structure

6.2.4.1 General

Quality pavement structure has to provide safety as well as comfortable ride of the cyclist. A precondition for comfortable ride is uniform surface, while for safety suitable friction has to be ensured, which is important for the cyclist's balance and braking. Cyclist surface must be free from bumps and gaps. If the basic conditions are not met, the cyclists will use other areas even though such areas were not designed for them and can potentially be dangerous.

Some basic requirements for the pavement structure of the cyclist surface are given below:

6.2.4.2 Bearing capacity

The bearing capacity of the surface has to be provided also in the critical period in spring, during thaw, and has to hold the weight of urgent motor vehicles (rescue vans, fire department vehicles). The bearing capacity is measured as deflection, which can at newly constructed cyclist surfaces equal 1 - 1.5 mm below the wheel load of 50 KN.

6.2.4.3 Evenness

The basic element of usability of cyclist surface is evenness, especially because classic bicycles do not have suspension. The evenness depends on uneven sections, which can be periodic (of same shape and size), accidental (of different shape and size at different distance) and individual which are more distant one from the other. Uneven sections are divided into rough sections (wave length up to 0.03 m) and corrugated sections (wave length in excess of 0.03 m) and cause mechanical bicycle oscillation with the frequency depending on the speed of the cyclist. The comfort of the ride is influenced mainly by the frequencies between 6 Hz and 8 Hz, which is a particular perception area for humans (own backbone frequency); the wave lengths of uneven sections are between 2 m and 1 m. The more the frequencies differ from the above values (and consequently the wavelengths) the lesser the impact on the comfort of the ride. This is important when cyclist surfaces are constructed over entries where often such corrugations occur. The influence of corrugations which are 5 to 10 m long is moderate, while the corrugations exceeding 10 m have practically no impact. Uneven sections at entries have to be constructed undulatingly and not joltingly. It is particularly important that the kerbs at the beginning and the end of the cyclist surface are below 5 cm, so that cyclists are still comfortable and the bicycle is not damaged at higher speed.

6.2.4.4 Skidding resistance

Skidding resistance is defined as the connection of geometric characteristics and the appearance of the driving surface, which includes the deepening between stone particles on the driving surface and the structure of these particles. The friction force between the tyre and the driving surface and thus the possibility of transferring forces from the bicycle to the surface is provided only if the used materials are not only rough but also of suitable quality. In order for a vehicle to safely move over the driving surface the following has to be considered:

- movement characteristics, such as speed of driving, skid, slipping,
- tyre characteristics, such as type, inner pressure, cross-section, profile design and condition, rubber characteristics,
- the characteristics of the medium between the tyre and the driving surface, such as water, snow, ice, dust, oil,
- skidding resistance of the driving surface.

6.2.4.5 Drainage

Drainage on wet surface ensures friction and comfort as it prevents water splashing in the case of rain or after it.

6.2.4.6 Implementation costs

The implementation costs influence the comfort, safety and maintenance expenses. If insufficient funds are spent on the implementation, this usually results in more expensive maintenance.

6.2.4.7 Colour an structure

The colour and structure ensure visual separation of surfaces used by different users and at the same time attract greater attention of other traffic participants. At crossroads the surface designated for cyclists has to be especially highlighted.

6.2.4.8 Combination with public infrastructure

Combination with public infrastructure (underground waterworks, electric line above ground, etc.) is not welcome, since its servicing and maintenance disturb the bicycle traffic. Drainage shafts and covers have to be properly installed - transversely to the direction of the drive, the covers have to be levelled with the surrounding surface.

6.2.4.9 Materials

The materials stated below are usually used for cyclist surfaces:

6.2.4.9.1 Asphalt

It has relatively low friction and it is durable if not excessively loaded. During the summer heat, the characteristics (friction) of the bitumen can change, which results in poorer safety of cyclists.

The surface designated for cyclists and pedestrians can be 6 cm to 8 cm thick.

6.2.4.9.2 Concrete

Concrete cyclist surfaces are more expensive than the asphalt ones, however, the maintenance is cheaper. They are more resistant to cracks caused by roots, but they require suitably prepared basis so that no breaking and cracks occur. On account of safety the surface has to be slightly rough, but not so much as to cause inconvenient cycling.

6.2.4.9.3 Washed pavers

Paving by washed pavers is very expensive and the maintenance is expensive also. Kerbs have to be inbuilt, so that the pavers do not move transversely. Due to the compact nature of the surface these pavers have to be at least 4 cm thick. Drainage is very important, since water washes away fine particles from the gravel layer, which results in honeycombing, subsidence and cracks in pavers. Because of the joints the surface is relatively uneven and uncomfortable, suitable mainly for city centres.

6.2.4.9.4 Paving slabs

Paving slabs are relatively expensive and complicated for maintenance. Because of joints between individual elements the surfaces are not so comfortable as the concrete or asphalt surfaces. The paving slabs are placed on at least 3 cm of underlying mortar with additions of silicon or limestone, while the joints are filled by mortar. The surface designated for cyclists and pedestrians alone can be covered with 6 cm to 8 cm thick paving slabs.

6.2.4.9.5 Sand

The sandy barrier layer is very suitable for cyclist surfaces that are completely separate from motor traffic (e.g. bicycle paths through the forest). On account of drainage it is very important that the surface is slightly stressed.

The best basis is cement stabilisation or crushed gravel layer.

6.3 PEDESTRIAN SURFACES

6.3.1 Introduction

A pedestrian is the most common, the slowest and most unprotected traffic participant. Every type of travel starts by walking, every traffic participant is also a pedestrian. The surfaces where pedestrians walk are rarely reserved for pedestrians alone, as a rule they share these areas with other traffic participants and means of transport, from inline skaters, skaters, cyclists, bicycles with a motor to motors and motor traffic.

Pedestrians are exposed to conflicts with the users of other means of transport practically at all times and this exposure heightens depending on the direction and type of movement - to crossing with various types of traffic participants.

One of the most common conflict situations is the crossing between pedestrians and road motor traffic. Crossing the road is a stressful situation for a pedestrian. Pedestrians differ one from another by psycho-physical characteristics and perceive differently the current traffic situation. The road is crossed by practically everybody - from children to the elderly, who react more slowly to sudden changes and perceive them differently.

In view of various circumstances the pedestrian crossings are differently (un)organised and (un)equipped. Most certainly there are many needs and wishes for new crossings or the arrangement of the existing ones, however, such interventions have to be made in a broader context of traffic arrangement and routing, taking into account the safety of all traffic participants.

6.3.1.1 The bases of pedestrian traffic and the types of pedestrian crossings

The basic horizontal profile for pedestrians is defined based on shoulder breadth dimensions (0.60 m) and body depth (0.40 m). Every pedestrian needs manoeuvring space for safe, undisturbed and comfortable walk. This space differs depending on whether the pedestrian is standing still or moving. For this reason it is best defined based on the distance between pedestrians (Table 31).

Table 31: Distance between pedestrians

	parallel to shoulder breadth	perpendicular to shoulder breadth
standing pedestrian	0.80 m	0.60 m
walking pedestrian	0.80 m	1.00 m

The speed on unhindered pedestrians in general depends on the age, psycho-physical ability, disposition and place where the pedestrian is at.

Pedestrian density is the term referring to the number of pedestrians on a specific surface. It depends on the type of traffic flow (one-way, two-way).

The throughput of pedestrian crossings indicates the number of pedestrians who can cross a crossing within a time unit at a certain cross-section. The throughput, which is used as a parameter for setting width, is taken into account only in the case of a very high number of pedestrians. The throughput of one-way pedestrian flow is 39–82 pedestrians/m/min, for cities the figure 56 pedestrians/m/min can be applied.

The pedestrian walkway is defined by clearance and traffic clearance of the pedestrian way. Clearance is comprised of the traffic clearance and two safety lanes. The traffic clearance represents the pedestrian cross-section, needed for the pedestrian's movement, while safety lanes contribute to more comfortable and safer walk. No object must extend to the clearance, which represents an invisible dividing line between the built environment and the space designated for pedestrians.

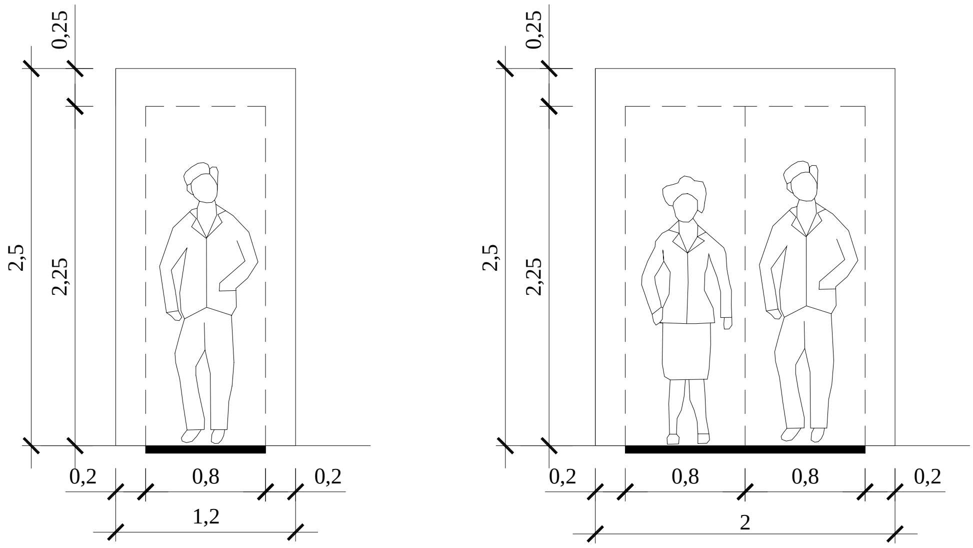


Figure 217: Clearance and traffic clearance of a pedestrian way (dimensions are given in metres)

Pedestrian crossings on national roads and also municipal roads are critical locations, where motor traffic and pedestrian traffic cross. As the way of pedestrians and motor vehicles' crosses on the same level the participants on both sides are endangered and traffic accidents may occur. Pedestrians have to be ensured the safest possible movement over their ways, while at the same time road throughput and minimum interruptions of traffic have to be provided.

Pedestrian crossings have to be located and equipped so that they meet the stated conditions to the highest degree possible.

As the procedure for deciding on the crossing design is underway, the following has to be checked:

- justification of the crossing,
- adequacy of the location,
- suitability of crossing equipment.

6.3.1.2 Waiting areas in front of pedestrian crossings

Before a pedestrian crossing sufficient area has to be provided on both sides for pedestrians who wish to cross the roadway. The dimensions of the waiting area are set based on the expected number of pedestrians.

Dimensions:

- minimum width is 2.0 m,
- length equals the width of the pedestrian crossing.

In the case of long pedestrian crossings where no light signalisation is provided, a waiting island has to be engineered between the carriageways, which are subject to the same conditions as other waiting areas. The service level of waiting areas for pedestrians depends on the average space available for each pedestrian, personal comfort and the degree of mobility.

Table 32: Recommended level of service in areas for waiting pedestrians

Level of service (LOS)	Area (m^2/pedestrian)	Inter-personal space (m)
A	⩾1.21	1.2
B	0.93-1.21	0.9-1.2
C	0.65-0.93	0.7-0.9
D	0.27-0.65	0.3-0.7
E	0.19-0.27	< 0.3
F	< 0.19	close contact

6.3.1.2.1 Procedure for calculating the necessary waiting area in front of the pedestrian crossing

Step 1

Acquisition of data for analysis by field measurements or forecasts:

- the number of waiting pedestrians on the waiting area in the critical 15 min VW15,
- total waiting area AT in m2,
- identification of obstacles in the waiting area.

Step 2

The effective waiting area A_E is set by deducting all unusable area from the total waiting area A_T.

Step 3

Setting the average area per pedestrian P_A:

$P_A = A_E / V_{W15}$

Step 4

Setting the level of service based on the comparison of the average area per pedestrian and the criteria stated in the table above.

6.3.1.3 Zebra pedestrian crossings

6.3.1.3.1 Elements of a pedestrian crossing

- pedestrian walkway,
- waiting areas,
- part of the road - crossing area,
- traffic signalisation,
- lighting,
- other elements (traffic calming elements and devices, etc.).

6.3.1.3.2 Criteria for installing and arranging pedestrian crossings

They are divided into:

- global site criteria,
- local site criteria,
- traffic criteria (no. of vehicles, no. of pedestrians, speed, load, type of traffic, type of road),
- safety criteria,

- technical criteria (arrangement of walkways and pedestrian waiting areas, suitable lighting, etc.).

6.3.1.3.2.1 Global site criteria

Traffic connections for slow traffic (pedestrians, cyclists) offer comfort and a certain level of safety until conflicts arise with other forms of traffic. They have to be provided particularly at locations characterised by great pedestrian traffic flow (shopping centres, bus stops, etc.). Such connections have to be as short as possible. Every deviation from the main traffic connection represents a relatively heavy time loss for pedestrians given their limited speed. Thus an attractive connection results in pedestrian accumulation and concentration.

The processing area is determined by circles around the destination in a situation of a particular area. The size of the area demonstrated in circles, within which a higher number of pedestrian travels can be expected, decreases as the population density increases in a certain area.

6.3.1.3.2.2 Local site criteria

In local terms, the number and method of crossings across road sections through processing area depend on the position of the road in view of the set goals and connections.

In general, we distinguish between two cases:

- Concentrated crossing - when the conflict road section runs across the main connection;
- Dispersion crossing - when the road section runs across many local connections.

Pedestrian crossings marked by horizontal signalisation can be planned where there is sufficient area next to the roadway for pedestrians to gather or at distances of no less than 200 m at least 100 m away from the nearest crossroads, except when the crossroads are less than 200 m apart.

6.3.1.3.2.3 Traffic criteria

The major factor is represented by stopping sight distance at the location of a potential pedestrian crossing. This distance depends on the speed and longitudinal gradient.

Minimum values for marking a pedestrian crossing:

Table 33: Ratio between vehicle and pedestrian density

Number of pedestrians per hour	0-200	200-300	300-450	450-600	600-750	over 750
0-50						
50-100		possible	possible	preferred	possible	
100-150		possible	preferred	preferred		
more than 150		possible				

6.3.1.3.2.4 Safety criteria

Pedestrian crossings are installed also in cases when the traffic volume criteria are not met. The exceptions are the following: proximity of hospitals, schools, kindergartens, health centres, old people's homes. Safety criteria condition also the selection of a certain crossing type.

In the case of pedestrian crossings controlled by traffic light the necessary pedestrian waiting area has to be provided for pedestrians who arrive at the crossing when the traffic lights are red. If a waiting island is designed between the carriageways, it has to be equipped with an intermediate light signal for pedestrians. If the latter is not provided, the protection time of pedestrians has to be long enough.

6.3.1.3.2.5 Technical criteria

Technical criteria include horizontal and vertical signalisation, variable light signalisation, lighting as well as traffic-calming facilities and devices. The arrangement of a pedestrian crossing depends on how critical is its location.

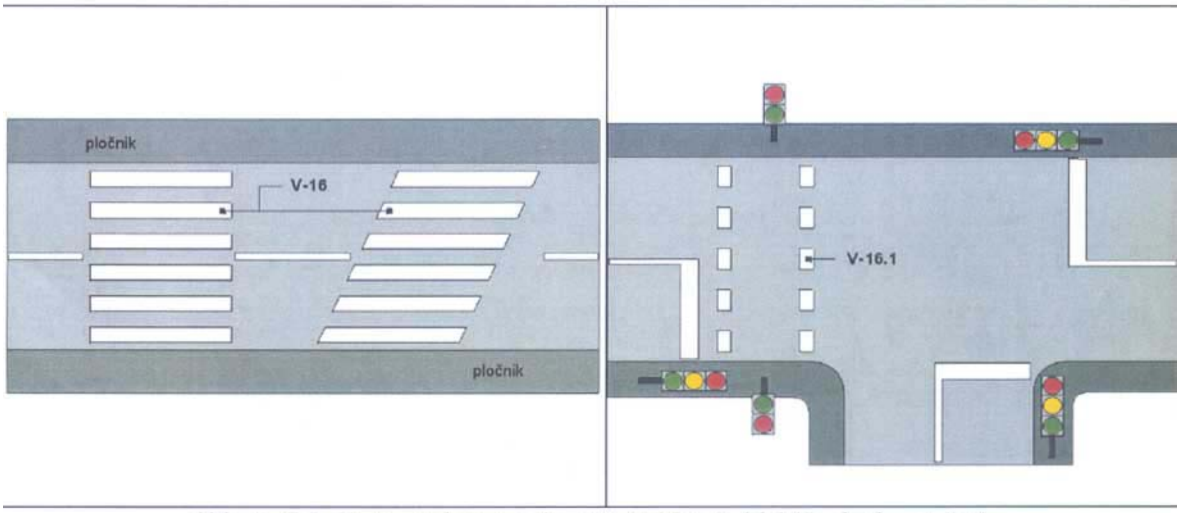
6.3.1.4 Equipment of pedestrian crossings marked with horizontal traffic signalisation (zebra)

6.3.1.4.1 Horizontal traffic signalisation

Horizontal traffic signalisation of the V-16 pedestrian crossing comprises rectangles parallel to the road axis. The distance between them equals the length of their shorter side. The coloured markings must not extend to the kerbs. They have to be 0.25 m to 0.5 m away from the kerbs. Moreover, they have to be faultless and durable under all conditions. They have to be of equal roughness as the rest of the roadway.

Horizontal signalisation is not provided at waiting islands.

At pedestrian crossings at crossroads where traffic is controlled by traffic light signalling devices - traffic lights, which function non-stop, a pedestrian crossing can be marked by horizontal traffic signalisation V-16.1. This comprises the rectangles with the shorter side parallel to the road axis. In such case the ratio between the sides is 1:2.



pločnik	pavement

Figure 218: Horizontal signalisation V-16 and V-16.1

Additional horizontal signalisation in the pedestrian crossing area comprises:

- Wide transversal line V-9, which is marked at pedestrian light-controlled crossings and pedestrian crossings installed based on safety criteria. The transversal stopping line is usually 1.0 m away from the horizontal signalisation for marking the pedestrian crossing. The same applies to pedestrian crossings controlled by traffic lights outside crossroads.
- The marking "X SCHOOL X", which is inscribed on the road surface in the vicinity of schools and educational institutions. The marking have to be applied on the traffic lane axis, if the lane is wider than 2.75 m or, if the latter is not the case, at least 0.1 m from the edge of the roadway. The markings are 5-10 m apart, depending on the location of the crossing.

6.3.1.4.2 Vertical traffic signalisation

6.3.1.4.2.1 Traffic signs

Traffic signs have to be installed on the right side of the road in the direction of the traffic next to the roadway over which the traffic to which the signs are intended streams. The surface of traffic signs has to be of made at least of light-reflective materials. No more than two signs may be installed on a single pole and the sign category has to be considered. In the event of two signs of different categories the main one is the sign representing danger or, if the latter does not exist, the regulatory traffic sign is considered the major one. Moreover, the traffic signs have to be equally reflective and lit (from the interior and exterior). The prescribed distance from the roadway that applies to traffic signs in urban areas is:

- vertical distance - at least 2.25 m between the ground and the lower edge of the traffic sign and 4.50 m for traffic signs installed above the roadway;
- horizontal distance - at least 0.30 m and no more than 2.0 m between the outer edge of the roadway (the edge of the extra width or the hard shoulder for emergency stop) and the closest edge of the traffic sign.

In exceptional cases (better visibility for road traffic participants) the traffic signs can be installed also on other poles or brackets.

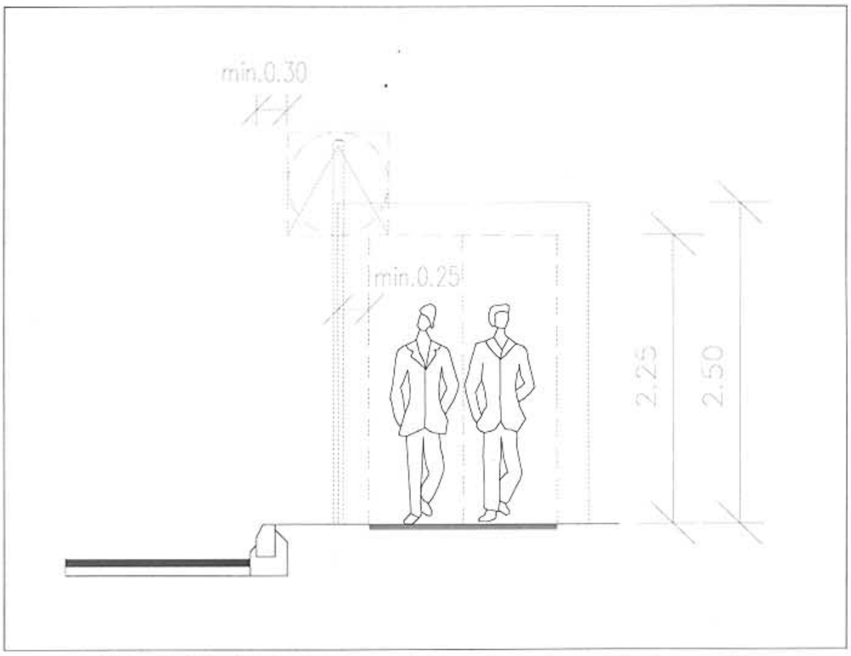


Figure 219: Installation of traffic signs next to pedestrian surfaces

6.3.1.4.2.2 Traffic lights for traffic controlling

Traffic is controlled by devices emitting light signals using red and green lights (pedestrian traffic lights). The green light can flash at a certain interval, before it turns off. The red and green light must not be lit at the same time. In special cases, when the adjacent bicycle and pedestrian crossings cross a crossroads, the bicycle and pedestrian traffic can be controlled by a single device emitting two-colour light traffic signals.

6.3.1.4.3 Lighting of pedestrian crossings

The basic intention of lighting pedestrian crossings is to provide good visibility conditions for traffic participants, ensuring them to timely notice the following:

- pedestrian crossing marking,

- pedestrians waiting on the pedestrian walkway, entering the crossing or on the crossing.

The adequacy of pedestrian crossing lighting is determined by the brightness of the roadway expressed in cd/m^2. The adequacy of lighting of the pedestrian crossing area is expressed in luxes.

6.3.1.4.3.1 Basic criteria for pedestrian crossing illumination

Every pedestrian crossing has to be lit at night and during the period of decreased visibility. Suitable lighting of a pedestrian crossing and its area means that street lighting is provided on the roadway, i.e.:

- 50 m before and after the crossing the average roadway lighting is 2 cd/m^2 minimum;
- waiting area for pedestrians is 1 m from the edge of the roadway lit vertically at the height of 1 m above the pedestrian walkway by no less than 10 luxes;
- from the direction of the driver a pedestrian is perceived as a dark silhouette standing out from the bright background (roadway) - this involves the so-called "negative contrast".

If the above-mentioned brightness conditions are not met, additional lighting of a pedestrian crossing is planned so that the following conditions are complied with:

- pedestrian is lit from the direction of the driver and is characterised by higher luminance than the roadway: the lighting is designed based on the so-called positive contrast - a pedestrian is detected from the direction of the drive as a bright object against a dark background (roadway);
- the recommended average vertical luminosity has to be provided at the pedestrian crossing axis 1 m above the roadway;
- uniform vertical luminosity has to be provided along the entire crossing and pedestrian waiting areas depending on the light situation on the roadway before and after the crossing.

6.3.1.4.3.2 Methods of illumination

Suitable illumination of pedestrian crossings can be provided by:

- suitable street lighting;
- "whip" - the whip defines the pole with a light, lit traffic sign III-6, below which a sodium lamp and flashing signals which are on the same level as the sodium lamp and above the sign III-3;
- a combination of street lighting and the "whip".

6.3.1.4.3.3 Equipment for additional illumination

Pedestrian crossings which are more critical in view of pedestrian traffic safety (school, educ. institution, hospital, etc.) or marked on major and regional national roads, where the number of vehicles per hour exceeds the criterion for introducing marked pedestrian crossings with a certain crossing length with or without the island, while the condition for installing traffic lights is not met, have to be equipped with:

6.3.1.4.3.3.1 Light flashing signals - yellow flashing light

- Maximum efficiency is achieved by double flashing signals, installed on the side of the traffic sign with interior lighting;
- The criterion for the installation and the size of traffic signals represents the traffic safety criterion and traffic volume criterion (AADT of at least 4000);
- The size of light flashing signals is Φ 210 mm on the roads with traffic volume below 4000 AADT meeting the safety condition for their installation and Φ 300 mm on the roads with traffic volume exceeding 4000 AADT;
- The number of flashes: 60 flashes in one minute (each flashing signal);

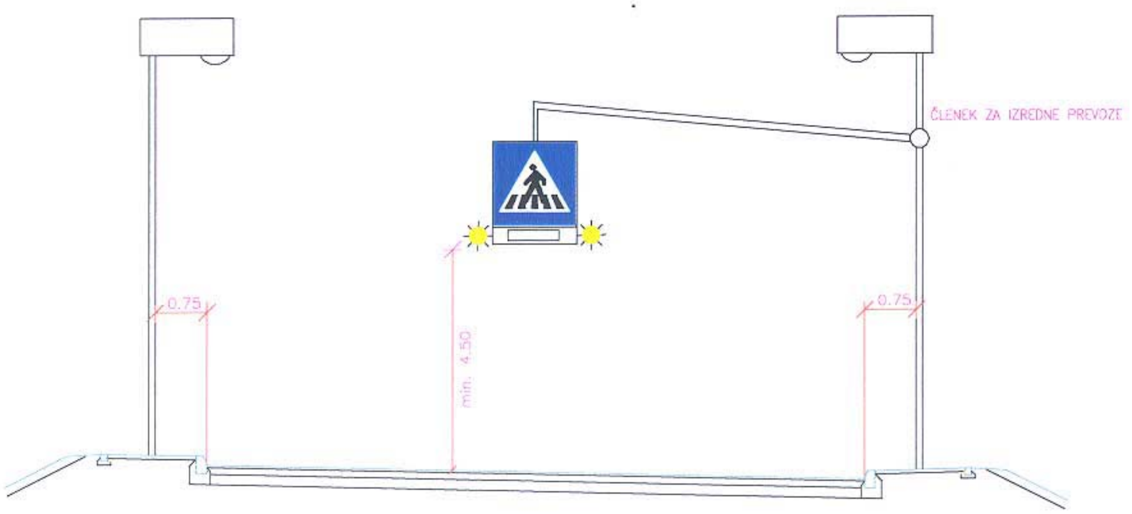
- Light flashing signals have to operate non-stop.

6.3.1.4.3.3.2 Sodium lamp

- It has to operate when public lighting is on;
- It has to be equipped with visors directing light only to the crossing and preventing drivers from directly perceiving the lamp, which could decrease the effect of the flashing signal.

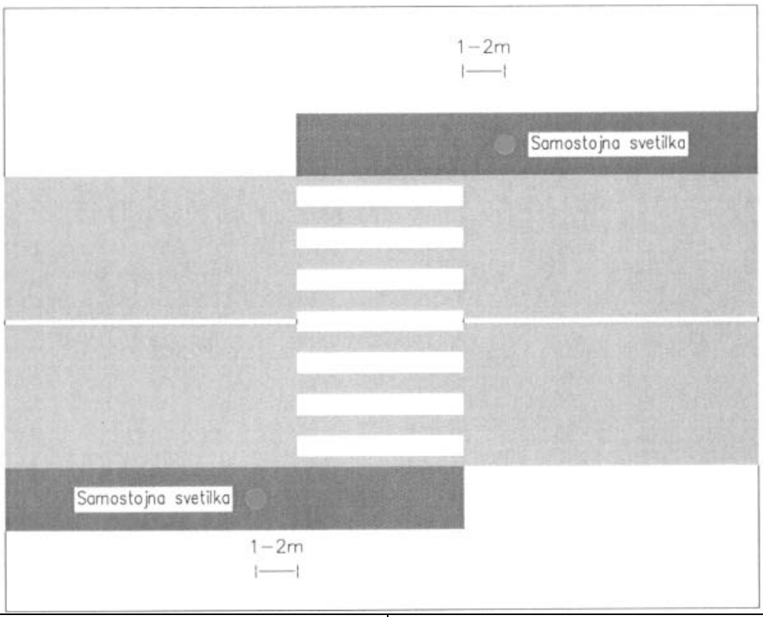
6.3.1.4.3.3.3 Supporting structure

- At locations where also public lighting is installed the pole has to be of the same height as public lighting. The criterion of optimal vertical lighting has to be considered, which depends on the distance between the vertical axis through the lamp and the axis of the pedestrian crossing symmetrical line as well as on the height of the installed lamp;
- It has to be hot-zinced.



ČLENEK ZA IZREDNE PREVOZE	SPECIAL TRANSPORT COUPLING

Figure 220: Elements of additional illumination in the pedestrian crossing area



Samostojna svetilka	Independent lamp

Figure 221: Lay out of lamps in the pedestrian crossing area

6.3.1.4.4 Implementation of pedestrian crossings

6.3.1.4.4.1 Pedestrian crossings outside crossroads

6.3.1.4.4.1.1 Pedestrian crossings not controlled by traffic lights

Pedestrian crossings outside crossroads are in addition to horizontal signalisation equipped with the traffic sign "pedestrian crossing", which is erected directly in front of the crossing on both sides or above it, if necessary (visibility or other reasons).

If the crossing is marked on a road with four or more lanes in a single direction, the crossing has to be equipped with light signalling devices.

If necessary for safety reasons, traffic calming measures are provided in the approximate vicinity.

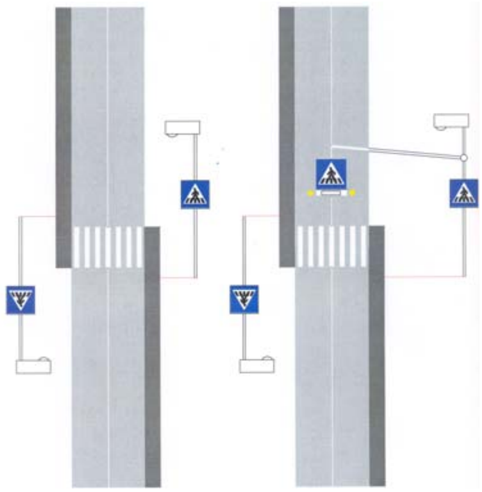


Figure 222: Types of pedestrian crossings

6.3.1.4.4.1.2 Light-controlled pedestrian crossings

Pedestrian crossings controlled by traffic lights are planned in the areas characterised by concentrated crossing of more pedestrians over roads with high traffic volume and more lanes in a single direction.

The recommended criteria adopted for *Pelican* (pedestrian light-controlled crossing) pedestrian crossings are:

- traffic volume of motor vehicles has to exceed 2,000 PCE/h in the peak hour and during regular pedestrian traffic;
- V_{85} has to be less than 70 km/h;
- the distance from the nearest crossroads has to be more than 40 m.

If necessary for safety reasons, traffic calming measures have to be provided in the approximate vicinity.

6.3.1.4.4.2 Pedestrian crossings in four-ways and T crossroads

6.3.1.4.4.2.1 Pedestrian crossings not controlled by traffic lights

Pedestrian crossings at crossroads are as a rule not marked by the traffic signal "pedestrian crossing", except in cases when the intersection with a side road is not sufficiently detectable and does not appear as a crossroads, which can cause a driver's dilemma about the presence of pedestrians at the crossroads.

At crossroads where the side road approaches the main one from the left or the right, only one pedestrian crossing is marked on the main road, as a rule on the right side from the direction of the side road.

If two side roads cross the main road, the pedestrian crossing is marked at the most suitable location in view of the side road.

The transversal stopping line is not marked before the crossing.

Besides the lighting which is planned for the illumination of crossroads, the pedestrian crossing has to be lit as well.

If necessary for safety reasons, traffic calming measures have to be provided in the approximate vicinity.

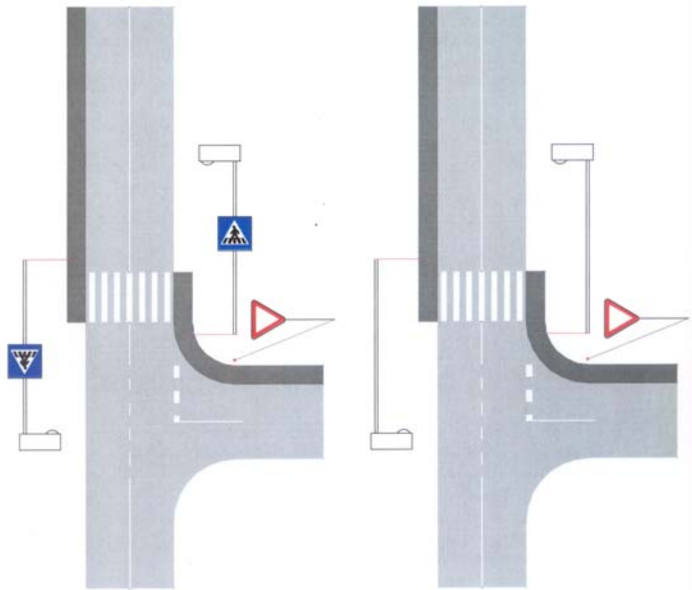


Figure 223: Pedestrian crossings at crossroads not controlled by traffic lights

6.3.1.4.4.2.2 Light-controlled pedestrian crossings

At crossroads where the motor vehicle traffic is controlled by light signalling devices the same have to be provided for pedestrian crossings also. Traffic lights are set up approximately at the pedestrian crossing axis.

Horizontal crossing signalisation is marked as V-16 or V-16.1. The stopping lines are marked on all legs of the crossroads irrespective of the main road route through the crossroads. The line has to be marked in such a way that the driver has a good view of the traffic lights, but no less than 1.0 m from the pedestrian crossing.

At crossroads where there are no lanes for vehicles turning right, the pedestrian crossings must not be installed too close to pavement corners along which vehicles turn, since by stopping before the crossing the vehicles hinder the traffic in the straight direction.

The distance between two crossings has to be at least 5 m. If a lane for vehicles turning right is provided, an additional intermediate signal is installed on the splitter island.

Figure 224: Pedestrian crossings at traffic light-controlled crossroads

6.3.1.4.4.3 Pedestrian crossings at roundabouts

Marking of pedestrian crossings at roundabouts is in principle subject to the same rules as marking of pedestrian crossings at crossroads that are not controlled by traffic lights. Under no circumstances is vertical traffic signalisation III-6 (pedestrian crossing) installed at roundabouts.

Horizontal traffic signalisation V-16 is always perpendicular to the road axis. It is not marked at the splitter island. Due to traffic safety under the conditions of decreased visibility, the roundabout has to be suitably lit. Additional illumination is provided at pedestrian crossings as in the case of other main roads.

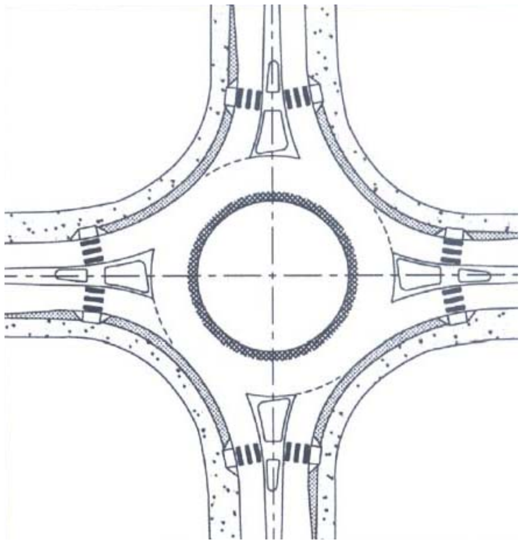


Figure 225: Pedestrian crossings at roundabout

6.3.2 Off-grade pedestrian crossings

6.3.2.1 Spatial layout

Independent off-grade pedestrian crossings are installed where the crossing of the main road has to be provided and where it is unsafe to apply any other solution (e.g. protected or light-controlled grade crossing). Due to safety and traffic flow at city bypasses and highways, crossings for pedestrians have to be constructed on a different level independently of the loading. If possible, they should be installed at rest areas, so that they can be used both by those crossing the street as well as the passengers of public transportation. Especially in city centres the underground pedestrian zones have to be connected with department stores and public institutions, if possible.

Independent off-grade pedestrian and bicycle crossings are reasonable as a solution replacing road crossings at grade under the following circumstances:

- when other method of road crossing at peak hours is not suitable due to dense traffic on the main road (example >1000 vehicles/hour/lane);
- when pedestrians and cyclists have to be provided unhindered crossing of the road at major routes;
- when it is not possible to install sufficiently noticeable signalling phases for pedestrians at traffic light-controlled crossroads;
- when the crossing locations can be combined with access to underground stations of public means of transport;
- when on account of topographic characteristics and the possibilities of expansion such off grade facilities are the best alternative;

- when it is not possible to provide safe crossing locations at grade at major roundabouts;
- when it is assumed that due to the position, construction and form all users will accept such a solution;
- when the interests of the mobility handicapped persons can be satisfactorily considered.

An additional factor for setting up a crossing can be great pressure and desire of the local people, school committee, functionally handicapped persons in that area and other groups.

In general off-grade crossings over a main road are (depending on the spatial requirements) installed:

- at every 800 to 1600 m or more in the areas characterised by low population density;
- at every 300 m or more in more densely populated areas;
- at every 90 m or more in exclusively business and trade centre of the town.

Off-grade crossings at crossroads in city centres are limited because a large area is needed for access, so the location in urban environment is more difficult, the construction costs are higher, steep ramps are unpopular or safety is insufficient.

The construction has to provide an available substitute crossing for those who do not dare use an independent off-grade crossing. In urban centres the light-controlled crossing or crossing not controlled by traffic lights should be located within 200 metres from the off-grade crossing.

6.3.2.2 Underpasses

Underpasses or underground crossings are facilities designed for routing pedestrians below the main road.

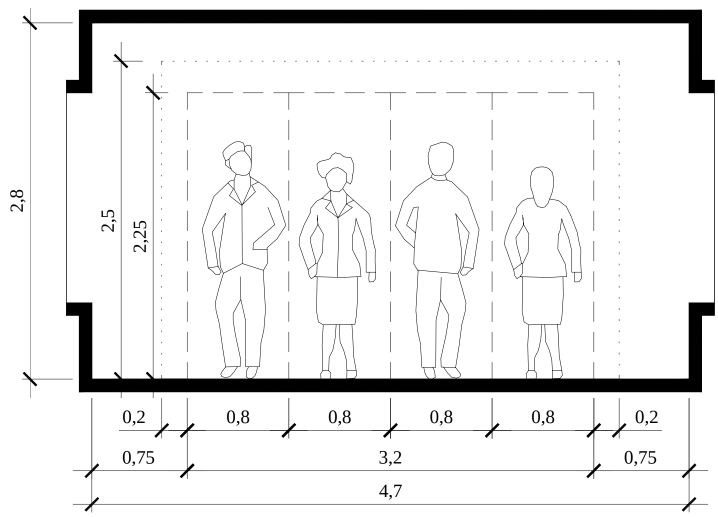
Pedestrians avoid long low and narrow underpasses, even though in terms of traffic their size is sufficient. Pedestrian way networks have to be organised in terms of position and height using such underpasses to ensure optimum dynamics, comfort and safety. Major gradients, numerous stairs and sections lacking visibility have to be avoided (e.g. sharp turns, niches).

To provide more comfort and greater safety the underpasses have to be carefully planned and designed. Access to underpasses has to be well visible. An underpass and its access points should be properly lit, visible, dry and clean. It is recommended that they are cladded with bright materials of tidy appearance which enable simple cleaning. The surface of floor covering should be wear-resistant. The design of underpasses has to provide for the air to exchange 4 to 6-time within one hour.

Minimum recommended width clearance of the underpass has to include two pedestrian lanes in either direction and the safety lane width along the underpass walls. Thus, minimum width clearance of the underpass equals:

- safety lane along the wall: 0.25 m
- pedestrian walkway (4 x 0.80 m): 3.20 m
- safety lane along the wall: 0.25 m
- underpass width clearance: 3.70 m

If the underpass includes shops, shop-windows, information signs or other facilities that are interesting for pedestrians, the safety lanes have to assume the function and the width of containment lanes that are 1.00 m wide. This width is taken into account also when jams are expected.



safety lane along the shop-window:0.75 m

pedestrian walkway (4 x 0.80 m): 3.20 m

safety lane along the shop-window: 0.75 m

underpass width clearance: 4.70 m

Figure 226: Recommended minimum width clearance of an underpass with shop-windows

When there are continuous elements (e.g. handles, wall lamps, etc.) extending from the wall of an underpass, the safety lane has to be expanded by 0.10 m.

Width clearance in underpasses increases as the length is greater, so that the users do not feel restricted. Width clearance is the function of visible length. Short underpasses have to be at least 3.50 m wide and there the bicycle ride should not be allowed. Pedestrian and bicycle underpasses up to 15 m long should have width clearance of at least 4.50 m or, if longer, 6.00 m. Irrespective of these figures the ratio between width and length clearance should not be less than 1:4. The ratio between width and length clearance can in the case of long underpasses lead to extremely wide underpasses, which are economically unjustified. For this reason the following ratio between width and length clearance should apply: ≥ 1:4 only up to 7.3 m in length. This is the limit width of an underpass, which still ensures that the underpass is not more expensive on account of width and construction expenses.

6.3.2.3 Overpasses

Overpasses or overhead crossings are facilities designed for routing pedestrians over the main road.

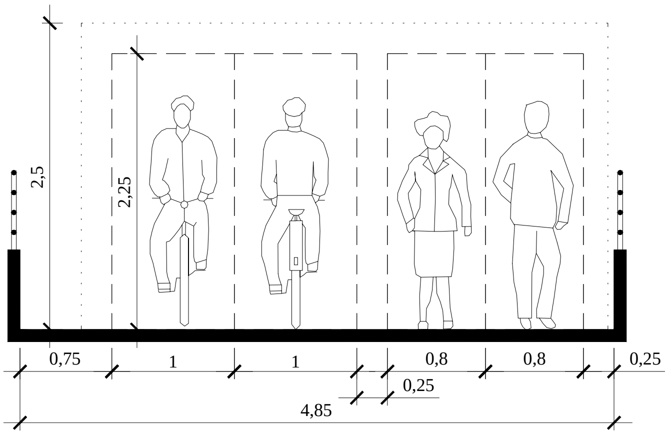
Compared to road and railroad viaducts and bridges overpasses can employ very different solutions in terms of design and traffic. Moreover, various different possibilities are considered for access to overpasses, which is very important as regards the use and convenience of the facilities. The constructions of overpasses should be simple, while the shape should be adjusted to the requirements of the users and suitably fitted in the environment.

Due to greater bridging height overpasses require lengthier access than underpasses. Pedestrian way and cycle path networks have to be organised in terms of position and height using such overpasses to ensure optimum dynamics, comfort and safety. Great gradients and long stairs have to be avoided.

The following has to be considered as an overpass is planned:

- the most suitable way for pedestrians and cyclists has to be created;
- the span, ramps and stairs should be visualised as a complete whole;
- maximum brightness and lightness of the facility have to be strived for;
- the best possible inclusion in the environment has to be provided.

Width clearance or the inner width of an overpass is the smallest horizontal distance between the rails, handles or vertical planes of the same cross-section. It is calculated by traffic calculation. As with underpasses, the necessary throughput is provided based on the estimated or specified number of users.



safety lane for cyclists along the rail: 0.75 m
cycle path (2 x 1.00 m): 2.00 m
safety lane between users: 0.25 m
pedestrian path (2 x 0.80 m): 1.60 m
safety lane for pedestrians along the rail: 0.25 m
overpass width: 4.85 m

Figure 227: Recommended width clearance of a pedestrian and bicycle overpass

The width clearance of overpasses reserved for pedestrians has to be 2.50 m, and of those accommodating pedestrians and cyclists 4 m. For narrow overpasses, where the cyclists ride along the rail, the rail is recommended to be 1.30 m high on account of cyclists (for pedestrians 1.10 m). Width clearance of the overpass should equal the width of the path before and after the overpass.

6.3.3 Staircases, escalators, ramps

6.3.3.1 Staircases

The usable width of a staircase has to be at least 2.40 m (3 x 0.80 m) between balustrades installed on both sides over the entire length. The usable width of a staircase can be decreased if the local characteristics are particularly unfavourable, if there are few users and when the staircase is combined with the escalator. Staircases with width in excess of 2.50 m should be equipped with the central railing.

The inclination angle of the staircase is most reflected in the ratio between the height and width of a stair. For vertical movement a person needs twice as much energy as for horizontal movement and the length of each vertical step is half the length of a horizontal step. The height and width are calculated based on the step equation:

$2v + s = k$

v... stair height [cm]
s... stair width [cm]
k... step length (Slovene regulations propose k = 63 cm)

Whether the stairs are comfortable depends more on width than on height. It is important that the entire foot can be placed on the stair or at least the front part of the foot and part of the heel also. In general, outdoor stairs are less steep and should be between 12–14 cm large. If the staircases are very busy, the stair height can be greater - between 14 and 16 cm. The ratio between the height and width (h/w) of a stair influences the comfort of ascent and the steepness of the staircase.

Table 34: Co-dependence between the volume of users, h/w ratio, comfort and steepness of staircases

volume of users	h/w [cm/cm]	comfort	steepness [%]
low	12/39	very comfortable	30.8
	13/37	comfortable	35.1
	14/35	acceptable	40.0
high	14.5/34	very comfortable	42.6
	15/33	comfortable	45.5
	15.5/32	acceptable	48.4

6.3.3.2 Escalator

Escalator or the moving staircase is designed for motorised (de)ascent of people. Their main advantage is that an escalator spares people the energy needed for moving from one level to another. Together with the staircase and ramps the escalator constitutes combined pedestrian transport on vertical and horizontal direction. The escalators have to be installed in parallel pairs, one leading upward and one downward. If there is not enough space, the installation of an upward escalator has priority. It is preferred that the escalator is sheltered (because of the staircase mechanism and the safety of users). The escalator can also be used when not operating.

The escalator supplements the staircase and does not provide a substitute for a necessary staircase. Suitable staircase has to be provided for servicing an uninterrupted pedestrian flow in the event the escalator breaks down and for those pedestrians who are afraid to it. The escalators and staircases can connect various levels even if physically separated. Since the escalator decreases the energy a pedestrian needs for ascent/descent, it can be used to accommodate a greater volume of pedestrians in a certain direction. At independent off-grade crossings it is suitable to install escalators where the traffic flows are high or the difference in height exceeds 3.60 m. The handrails run synchronously and parallel on both sides of the escalator 100 cm above the floor level. Height clearance of the escalator should be at least 2.30 m.

The step width of the escalator can differ (60, 80, 100 and 120 cm), but the steps of 80 and 100 cm prevail. Steps of 100 cm in width are most common and usually offer sufficient space for passing by a user of the escalator that stands still. The 80 cm width is used when the escalator is installed subsequently, so that the conventional stairs do not have to be excessively narrowed. The entry and exit area of the escalator has to be twice as wide (on the outer side), and the entrance depth of 250 cm from the start of the handrail has to be provided. This is required to utilise the maximum capacity of the stairs.

The most common angles of inclination are 27°18', 30° in 35°. The angle of 27°18' corresponds to the w:h ratio = 16:31 of normal stairs. The escalator speed is usually 0.5 m/s and must not exceed 0.65 m/s. If the escalator is not used regularly, it can be automatically switched on and off, so that it operates only when used.

6.3.3.3 Ramps

Ramps are used in the event of massive flow of people where a combination of pedestrians, cyclists and functionally handicapped is expected. If permitted by the available space, the height difference (to an underpass or overpass) should be bridged by ramps. In the case of overpasses outside the city centre such a solution is more easily implemented than in the city centre. The ramp should look as simple as possible, with a stress on low gradient. Ramps are designed as a substitute solution for outdoor stairs for people who have difficulties overcoming stairs. At the beginning and the end of the ramp a horizontal surface has to be provided 1.50 m long in the direction of movement. Such length has to be supplied with also as the ramp changes direction.

The width of the ramp depends on the type of users, the length and steepness of the ramp as well as the comfortableness and volume of users. Recommended width clearance at a low number of users differs depending on the type of users:

- Minimum width clearance for pedestrians in one direction is 1.20 m and for two-way traffic 2.00 m;
- Recommended width clearance for people on wheelchairs is from 1.50 m to 1.80 m; Width clearance of 1.30 is permissible, under the condition that 1.95 m wide passing bays are provided at every 10 m;
- Minimum width clearance for two-way bicycle flow is at least 2.50 m.

Longitudinal ramps should be suitable for an average cyclist, as in this way bypasses are avoided. As a rule, the ramp longitudinal gradient should not exceed 10%. For functionally handicapped persons the maximum longitudinal gradient is between 6 and 8%, as higher gradients are unsuitable and inadequate.

The ramps with the gradient between 10 and 20% are used mainly for pedestrians, but they are less comfortable. Such ramps have to be sheltered or heated to prevent slippery ice in the winter. If assisted, people on wheelchairs can overcome a ramp with a 13% gradient. In the case of ramps with gradients of 20 to 37%, stairs have to be provided parallel at least 0.60 m wide and with the entrance depth of 0.40 m.

6.4 ROAD SURFACES FOR HANDICAPPED PERSONS

6.4.1 Technical elements

6.4.1.1 Pedestrian way

Maximum longitudinal gradient of a pedestrian way is 5%. For handicapped people on wheelchairs the gradient up to 3% is acceptable, while for gradients from 4% to 5% a horizontal rest area of 1.5 in width has to be provided at every 30 m to 50 m.

The minimum width of a pedestrian way is 1.20 m, optimally 1.50 m.

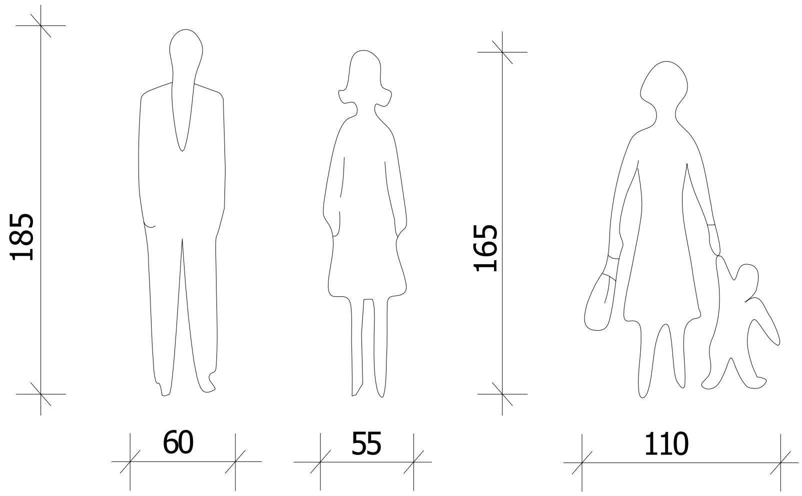


Figure 228

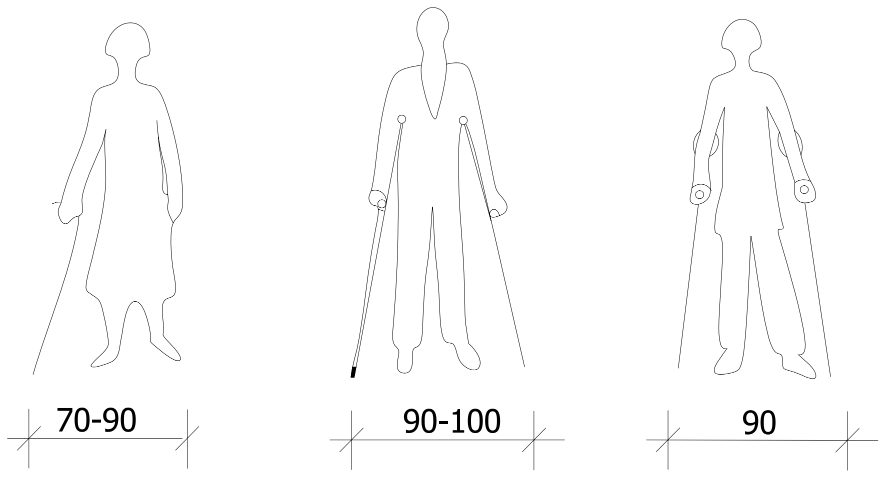


Figure 229

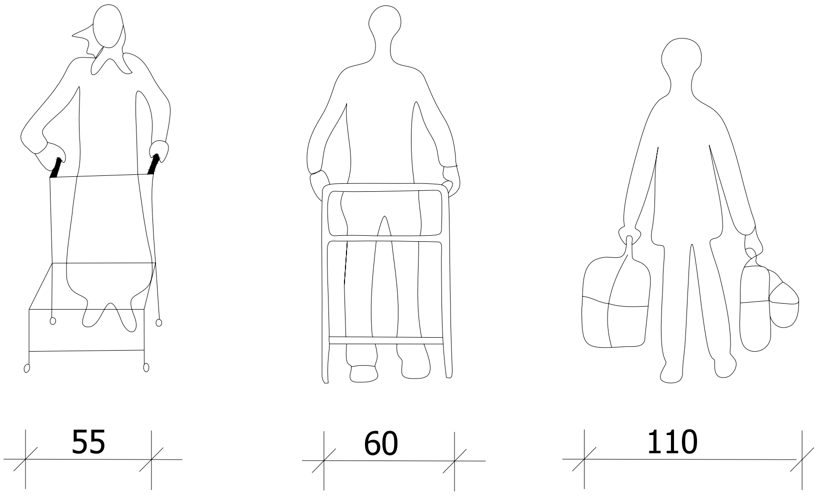


Figure 230

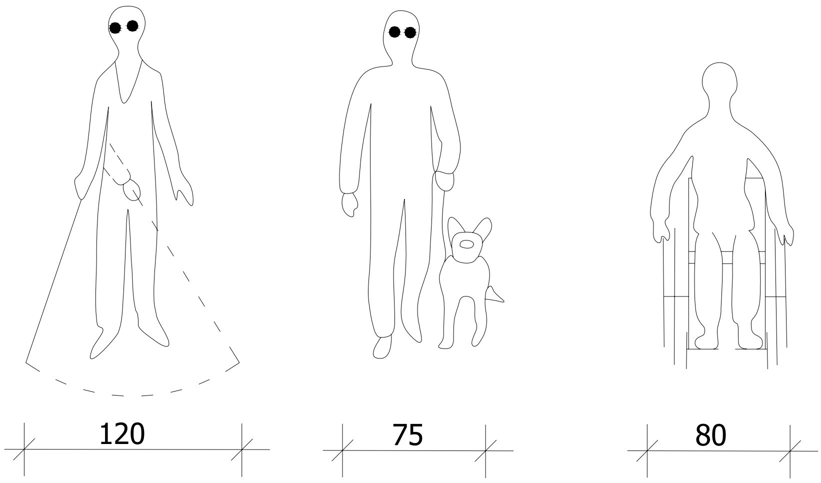


Figure 231

In the event of longer congestions, passing bays have to be provided at every 50 m maximum.

The cross gradient should not exceed 2%.

The pedestrian way surface has to be treated in such a way that it ensures safe movement, which means that it has to be hard, flat and well drained. Joints between individual elements have to be levelled. Moreover, a pedestrian way has to be suitably lit, with the lamps providing orientation guidance.

There must be no gratings of intake shafts on the pedestrian way. The covers of sewage shafts have to fit the surface without any deviations in level.

The pedestrian way should be separated from motor traffic by a green area and at least 3 cm raised.

6.4.1.2 Passages and halls

The required width is 1.5 minimum. If this is not provided, a passing bay of at least 1.95 m in width has to be provided at every 10 m.

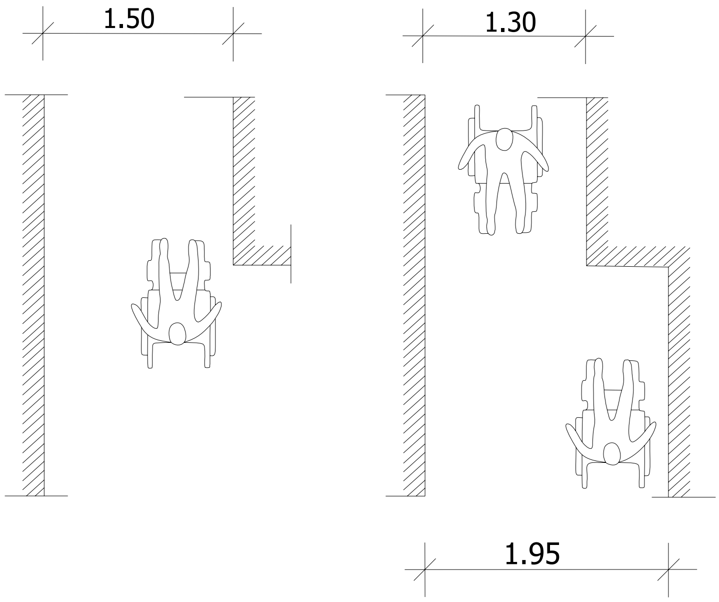


Figure 232

6.4.1.3 Pedestrian crossings

6.4.1.3.1 Not controlled traffic lights

The depth of the kerb separating a pedestrian way from the roadway has to be increased to 2 to 3 cm at the crossing.

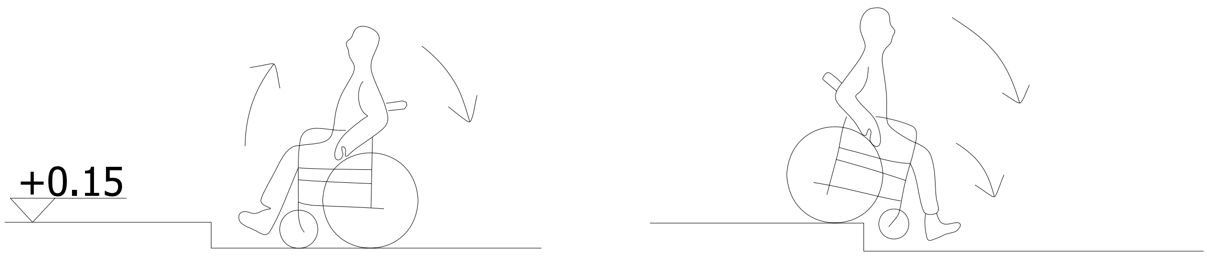


Figure 233

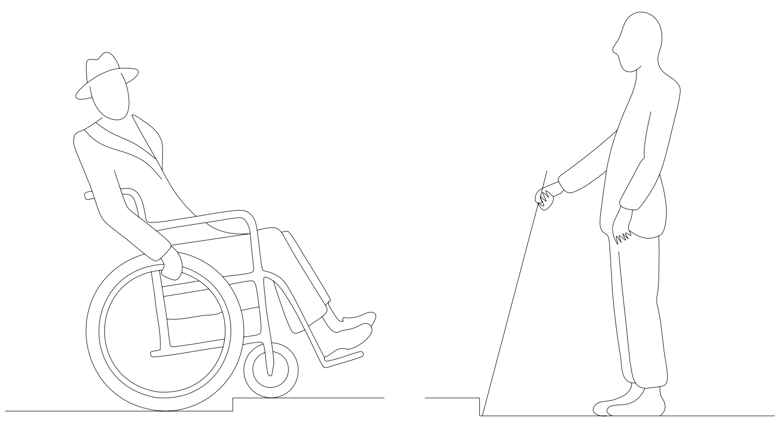


Figure 234

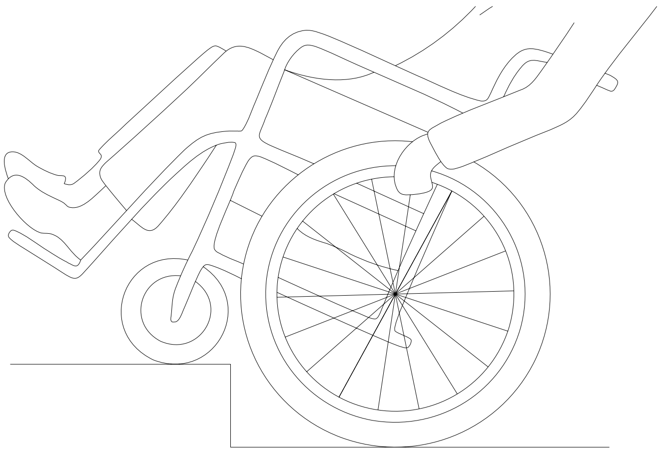


Figure 235

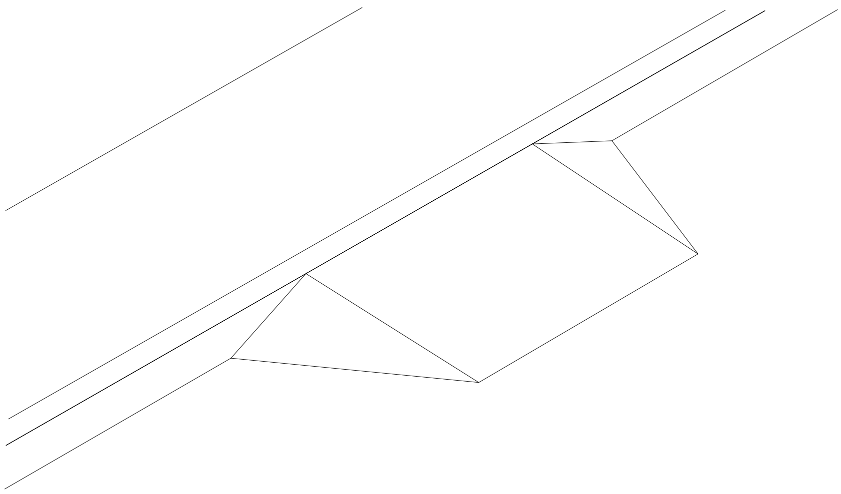


Figure 236

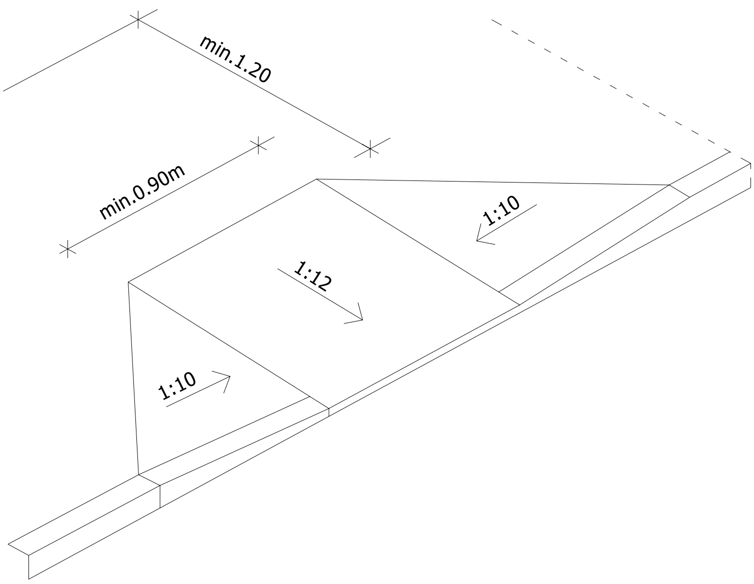


Figure 237

As the depth of the kerb of the pedestrian way or the pavement is increased, the gradient must be no more than 1:12 or 8%.

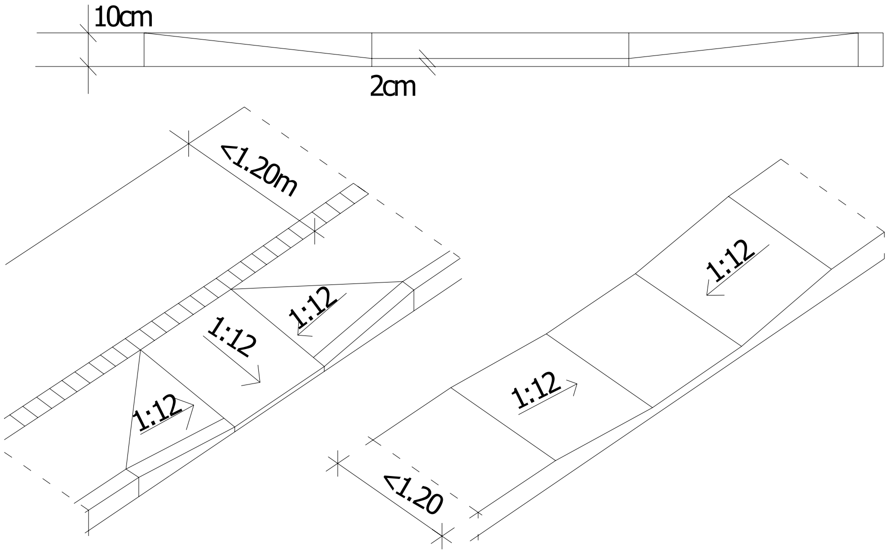


Figure 238

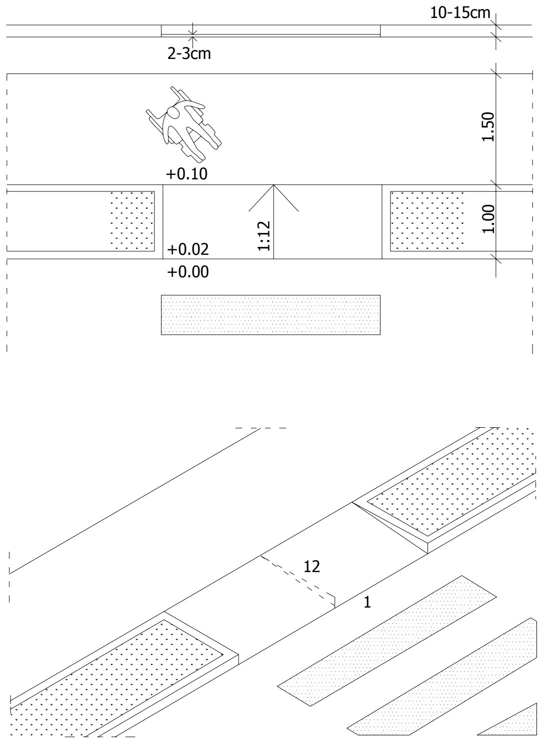


Figure 239

6.4.1.3.2 Controlled by traffic lights

In addition to light signals, crossings controlled by traffic lights have to be equipped with audible signals.

The sound-emitting device must not be installed higher than 1.0 m. The green phase - the duration of crossing - has to be longer where the mobility handicapped persons cross the road. The phase length is calculated based on the crossing speed of 0.5 m/sec.

6.4.1.3.3 Pedestrian crossing with an island

The island has to be at least 1.50 m wide and 2.0 m long. The island has to be levelled with the road along the entire width.

Figure 240

6.4.1.3.4 Pedestrian crossings at crossroads

At the crossroads the transition from the pavement to the roadway is in the form of:

- Preconstructed ramp
- Corner ramp

The gradient of both is 1:12.

6.4.1.3.4.1 Off-grade pedestrian crossings

A constituent part of off-grade pedestrian crossings is the stairs and ramps.

The stairs have to be at least 1.50 m wide, the preferable width is 2.50 m. They have to be equipped with balustrades on both sides. Proper ratio between the depth and height of a stair is 14-15 cm : 32-34 cm.

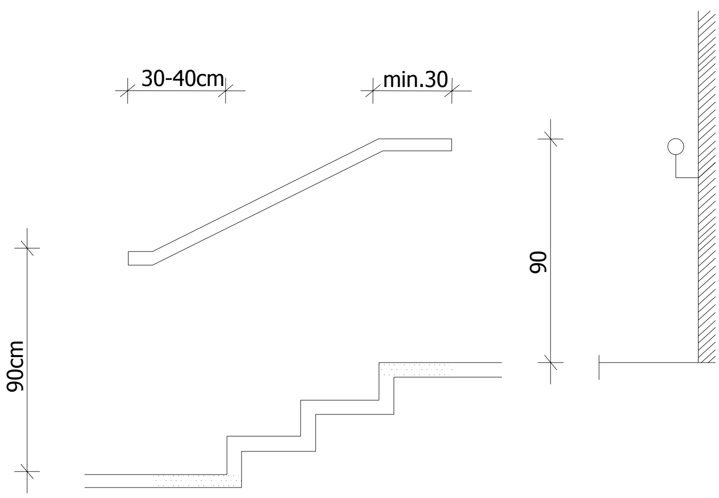


Figure 241

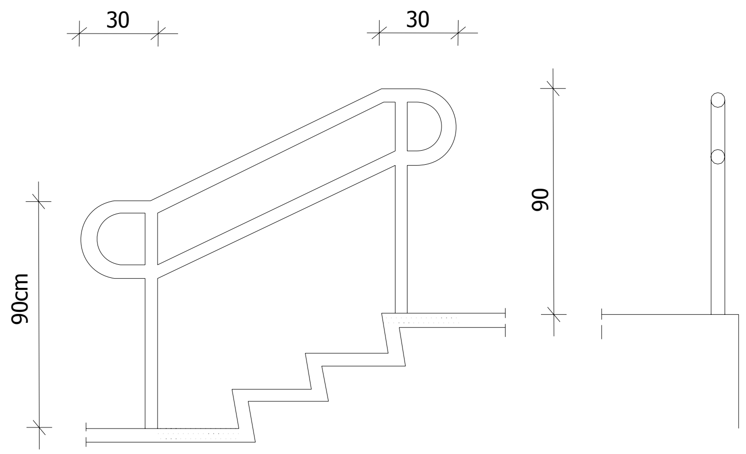


Figure 242

The cross-section of a stair has to be free from sharp edges and the overhang step plate. The surface has to be skid-resistant and equipped with a warning floor covering.

The ramps have to be made of skid-resistant material. Maximum gradient is 1:12 or 8%. Optimal gradient is up to 5%. At the beginning and the end of the ramp a horizontal surface with the width d=1.50 m has to be provided, also at turns and crossings.

If the ramp is longer than 10 m, an intermediate resting area has to be implemented.

The cross-section of a ramp has to be horizontal. The width should equal the width of the pedestrian way, i.e. 0.90 m minimum.

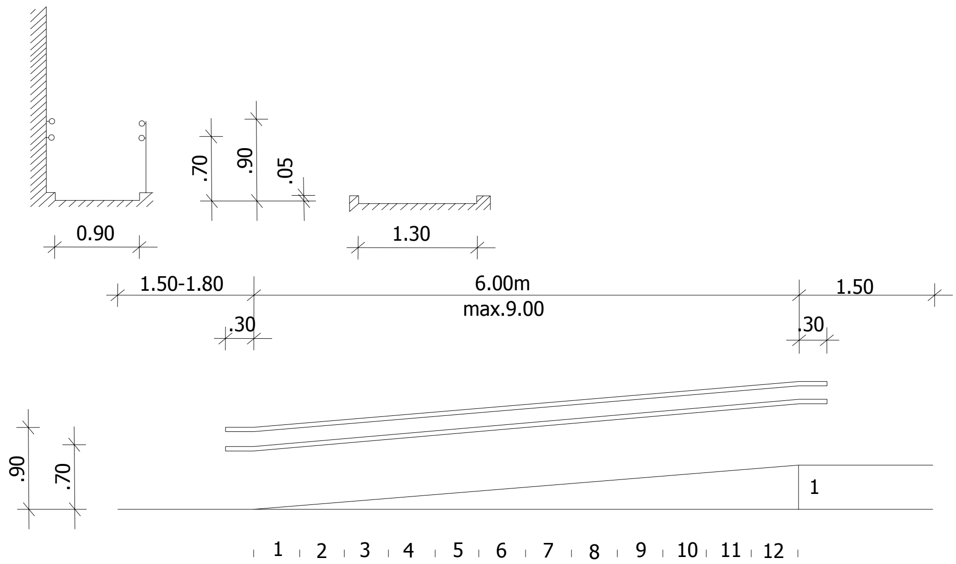


Figure 243

If there is not sufficient space available, a ramp leading in several directions is designed.

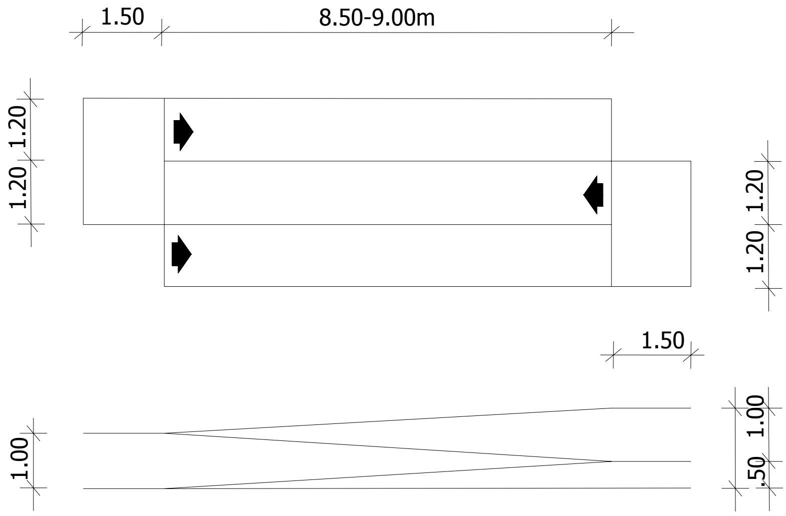


Figure 244

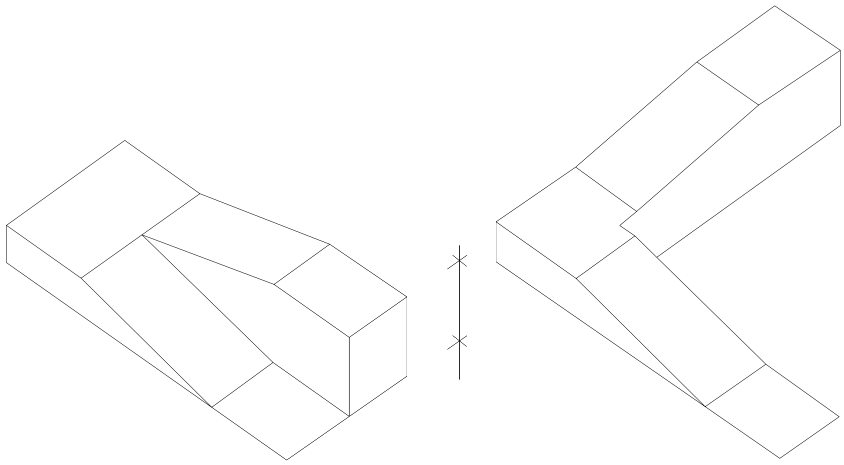


Figure 245

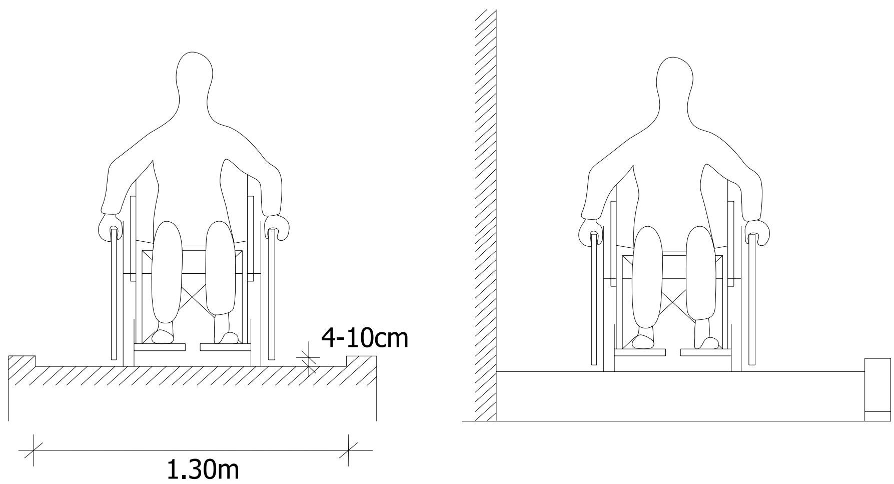


Figure 246

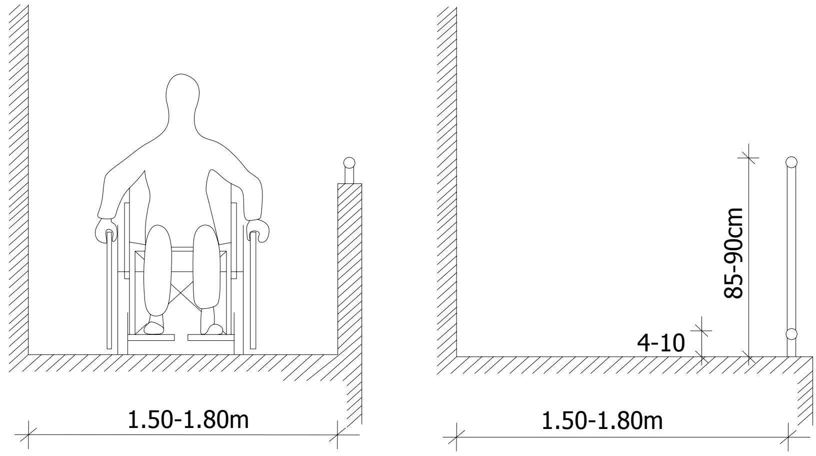


Figure 247

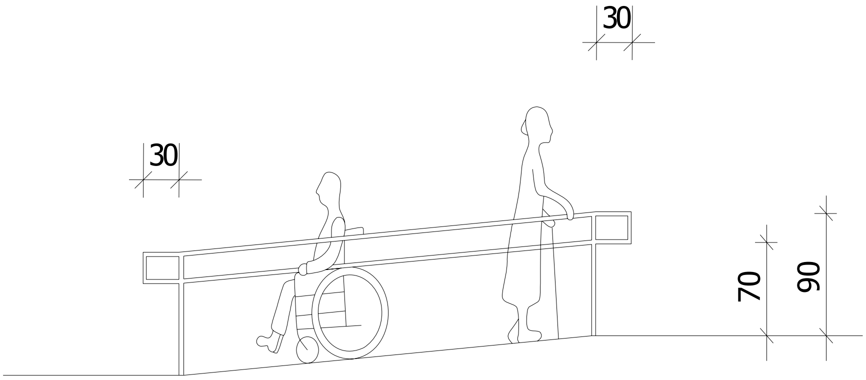


Figure 248

6.4.1.4 Parking areas

For head-in and parallel parking the parking area width is 3.50 m.

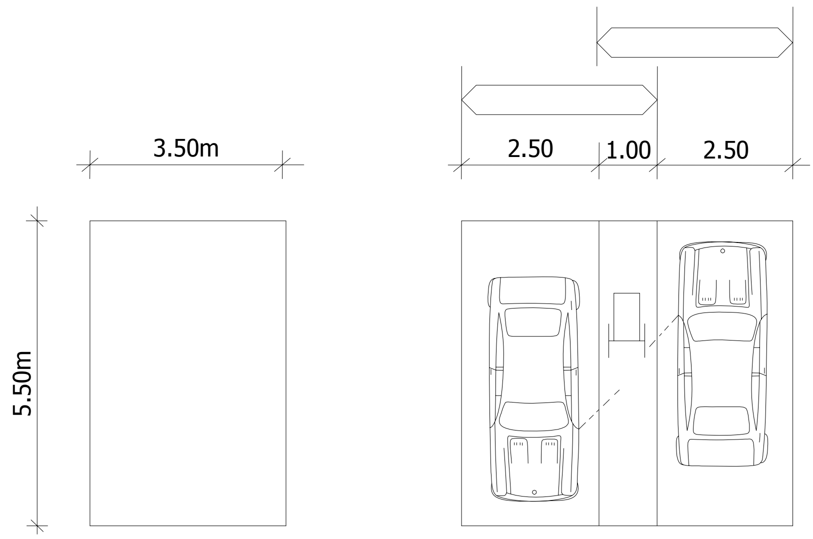


Figure 249

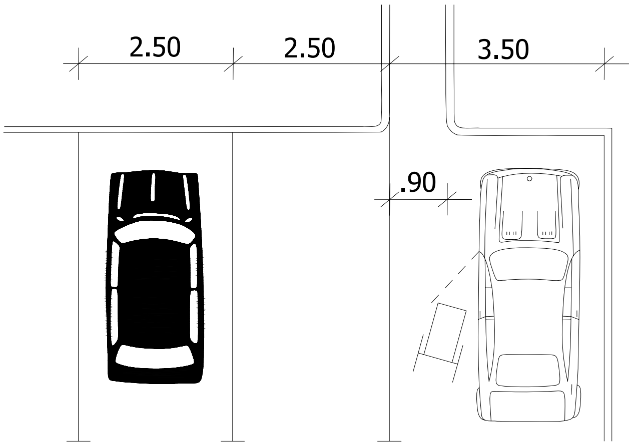


Figure 250

On all major parking areas or at parking garages one parking space has to be reserved for handicapped persons for every 50 parking spaces, while on small parking areas one parking space has to be reserved for handicapped persons. In the vicinity of public institutions a parking space has to be reserved for handicapped persons no more than 50 m away from the entrance.

6.4.1.5 Rest areas

Rest areas for the handicapped persons have to be properly distributed along the shopping centres, the stops of urban public transport, at entrances to public institutions, along pedestrian ways and walking paths, next to ramps in parks and in residential zones.

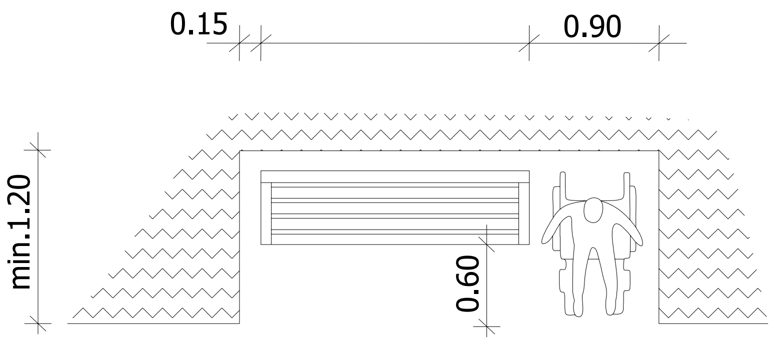


Figure 251

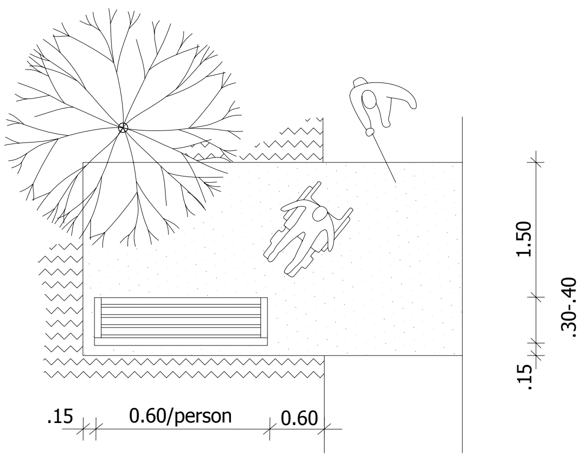


Figure 252

In the centre of a town rest areas should be located at every 100 m and outside the centre at every 200 m.

7 CONTROL STATIONS

7.1 AREA OF APPLICATION

This guideline defines the policies regarding project-technical design of control stations.

It contains instructions for designing project-technical elements of control stations and their equipment.

7.2 DEFINITION OF TERMS

Crossing is a point at which, on the same or different level, a road crosses another road or another infrastructural facility, such as a railway, water course, cable railway and similar.

Crossroads is every junction of three or more public roads.

Crossing at grade is a crossroads with road junction on a single plane - level.

Grade separated junction is a crossroads at which the roads cross on two or more levels.

Crossing at grade area is the area comprised of crossroads branches and the area of direct crossing of two or more roads, namely of the traffic area belonging to two or more roads at the same time. The crossroads area is therefore limited by the points at individual crossroads branches at which due to the crossing any changes (ground floor, longitudinally or transversally) are made to the shape of the road (roadway width, turning lanes, piping measures, turning radii, etc.). . The term is equivalent to the expression wider crossroads area.

Point of access is a junction (joint) between a public road and all areas from which vehicles directly enter and exit traffic on a public road. It is part of the road connecting that particular road with a public road of the same or lower category, non-categorised road or access to a facility or land. A point of access is a constituent part of a road covering the area to the edge of the road surroundings, which is 2.0 m from the outer edge of the ultimate point of the road body cross section with draining devices and the slope of the road body or from the protective fence set up along the body of a motorway.

Major public roads are the roads connecting the entire or the major part of the territory of Bosnia and Herzegovina, the Federation, integrating it into the European road network, while at the same time they comprise a mutually dependent traffic network.

Regional public roads connect settlements and localities within one or more districts, they integrate the entire district area and create a mutually dependent traffic network of one or more districts connected with the major road network.

Local public roads and streets in settlements and towns represent a mutually dependent traffic network of a municipality or a town, connected with the regional or major road network.

Non-categorised road is every traffic surface not categorised as a public road.

Traffic areas outside the roadway include rest areas, parking lots, bus stops or turning points, gas stations, traffic weighing and supervising premises and facilities, etc.

Traffic arrangement (method of traffic management) is the method in which traffic runs, determined for a road or part of it or for a settlement or part of it by the road manager. Traffic arrangement comprises the determination of priority directions as well as the traffic management system and method, the limitations of road use of the use of its parts by traffic type, the speed limits and specification of measures for calming traffic, arrangement of stand still traffic, setting the restricted traffic zones, limited speed zones and pedestrian zones, specification of other obligations of road traffic participants. Traffic arrangement has to be marked with prescribed traffic signs.

Central reservation is part of the roadway physically separating the opposite carriageways and the part of the roadway prohibited for traffic.

Directional lanes are the traffic lanes for directing traffic flows at a crossroads.

Sight field **is the area next to the roadway, determined by a sight triangle and berm, whose usage is limited.**

Sight triangle is the land next to the roadway whose usage is limited due to the provision of prescribed sight at crossings at grade or a road-railway crossing.

Traffic lane is marked or unmarked parallel part of a carriageway, wide enough to enable vehicles to drive in a single line unhindered.

Carriageway is a roadway or its longitudinal part, designed for vehicles driving in a single direction; it may consists of one, two or more traffic lanes.

Entry radius is the radius of the first arc of the right edge of a roadway at the entry to the crossing.

Exit radius is the radius of the last arc of the right edge of a roadway at the exit from the crossing.

Covered area is the area required by vehicle clearance at a traffic manoeuvre (turning left, turning right, driving straight ahead, backward turning left or right).

7.3 OPERATIONS AT CONTROL STATIONS

In the area of a control station various different operations of traffic control as well as passenger and cargo control are carried out. Their relationship, i.e. the sequence of individual control operations carried out in the control station area is shown in Figure 253.

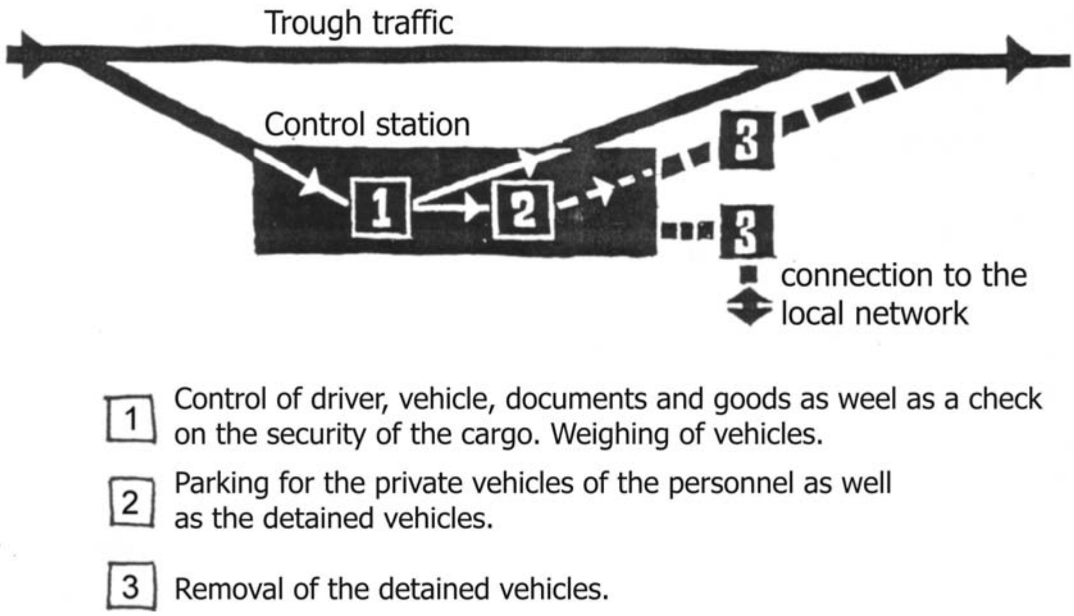


Figure 253: Operational and connection requirements at a control station

7.4 SELECTION OF CONTROL STATION LOCATION

The main condition for control station location is the visibility at the road section at which a control station is to be located. Traffic must not be hindered at the entry to and exit from the control station.

If control stations are located on both sides of a road for simultaneous control of traffic in both directions and are placed next to the public road roadway, the obstruction of contrary directional traffic has to be considered when control operations are carried out. Such control stations placed on both sides have to be located so that road users may access them from the direction of their travel. The distance between individual control stations depends on the characteristics of a public road, but shall not be less than 300 m.

As regards positioning of control stations, all attention has to be devoted to setting up traffic signs, which have to unambiguously inform the public road users about the approaching control station.

The required minimum distance for erecting traffic signs is shown in figures 254 and 255.

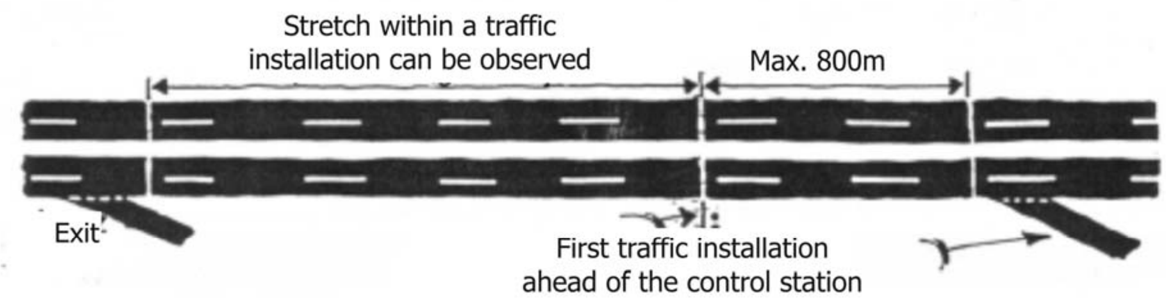


Figure 254: Setting of traffic installation along a dual carriageway road

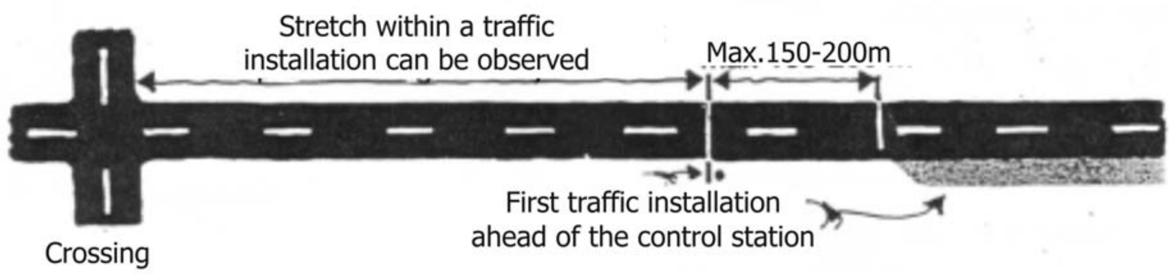


Figure 255: Setting of traffic installation along another road

Control station location has to be aligned with the planned locations of accompanying facilities next to public roads.

Control stations can often be established within the scope of accompanying facilities next to public roads, as a result of which the costs arising from setting up of new control stations are lower.

7.4.1 Crossings

In the case of crossings a control station has to be located next to the exit slip road.

A control station has to be located on the right sight of the exit slip road. At the end of the speed control section access to the station is provided. The final point of the control station, i.e. exit from the station, has to be located at least 50 m before the next crossroads.

As the microlocation for setting up a control station is being selected, the road/slip road axis route at this section has to be considered. A control station has to be located on a straight section of the road or on a horizontal curve with a large radius. Placing the control station at the slip road with bifurcations and points of access should be avoided.

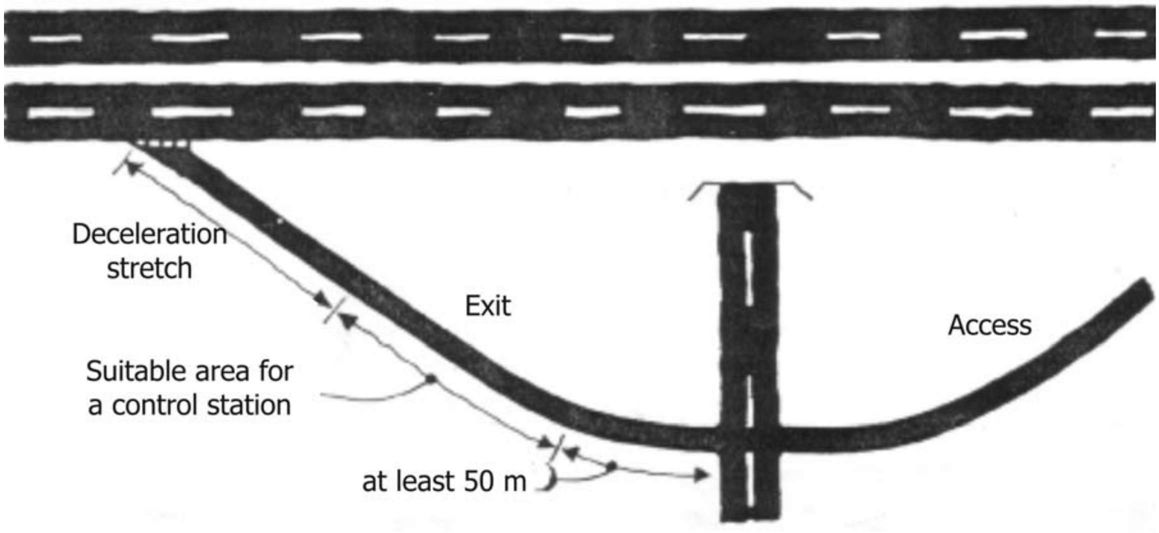


Figure 256: Example of the site on a diamond type exit ramp

7.5 PROJECT-TECHNICAL ELEMENTS OF A CONTROL STATION

A control station consists of individual specific zones designed for various operations. The size and layout of individual zones at a control station has to be adjusted to the available space.

If it is impossible to provide an area of sufficient size within the existing accompanying facility, the latter has to be expanded (increased) or another, more suitable solution has to be found for control station location.

If a control station is used exclusively for controlling vehicle, passenger and cargo traffic, it has to be arranged so that it cannot be accessed at the time when control is not carried out.

At the exit slip road a control station can be located also on the extension of an additional traffic lane (before a crossroads) intended for, for instance, vehicles turning right.

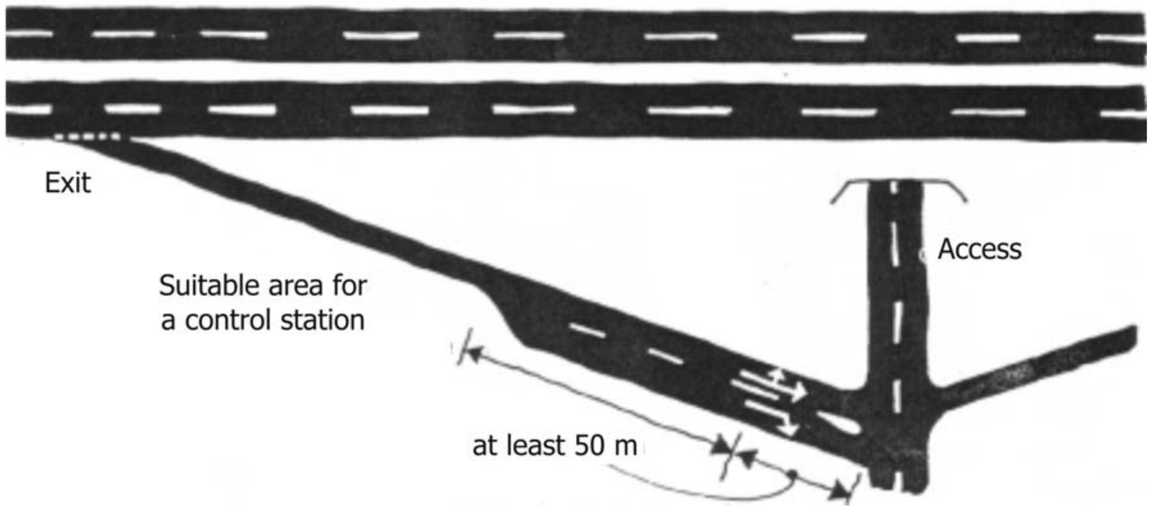


Figure 257: Control station at an exit ramp with two traffic lanes

7.5.1 Length and width of a control station

The length of a control station depends on the traffic control operations carried out at such station. The total length of the control station, including entry and exit, must not exceed 150 m.

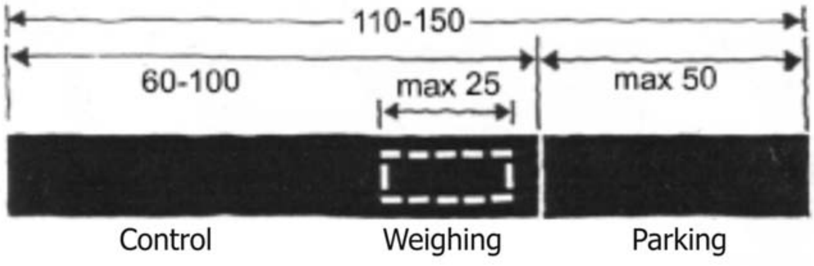


Figure 258: Length of the control station

7.5.2 Cross fall in the control station area

The roadway of a control station has to be paved (asphalt or concrete roadway construction). In the control station area the cross fall of the road and surfaces must not exceed 5%.

Table 35: Cross falls in the control station area

OPERATION CARRIED OUT	MAXIMUM PERMITTED CROSS FALL [%]
control	5
weighing	1.75 (recommended 0)
parking	7

7.5.3 Points of access in the control station area

A point of access has to be located at the entry slip road for those motor vehicles which after control has been carried out continue driving on the road which they exited. If the point of access is located between the entry and exit slip roads, it has to be equipped with a barrier, so that it cannot be accessed at the time when traffic control is not carried out.

This point of access or connecting road has to be dimensioned so that it enables passability by the selected relevant vehicle, i.e. allows the passage.

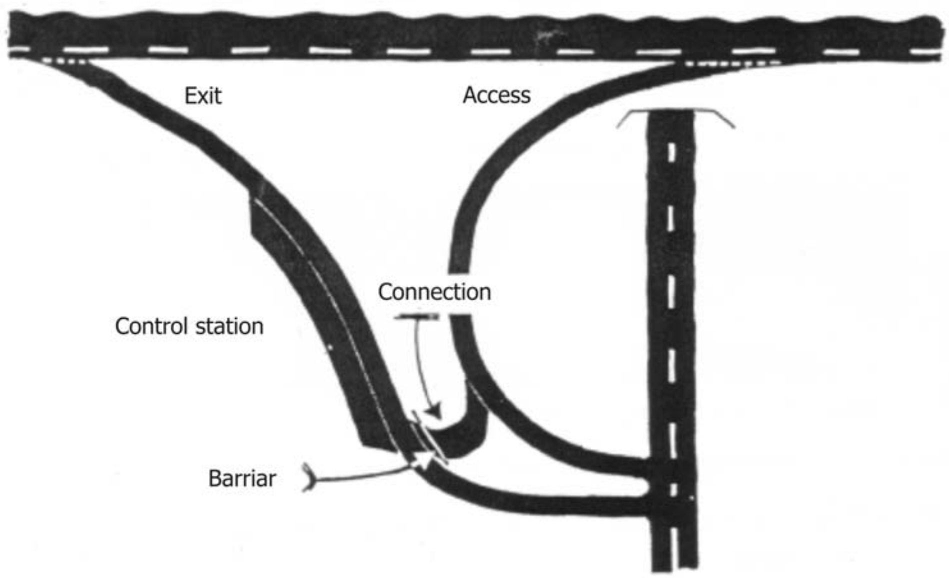


Figure 259: Control station with a special connection

As control station is designed, the point of access, i.e. exit from the control station, has to be planned allowing the removal of motor vehicles which for any reason must not continue driving from the control station. Due to this additional point of access additional parking spaces in the control station area, which should otherwise be designated for such vehicles, need not be designed and provided.

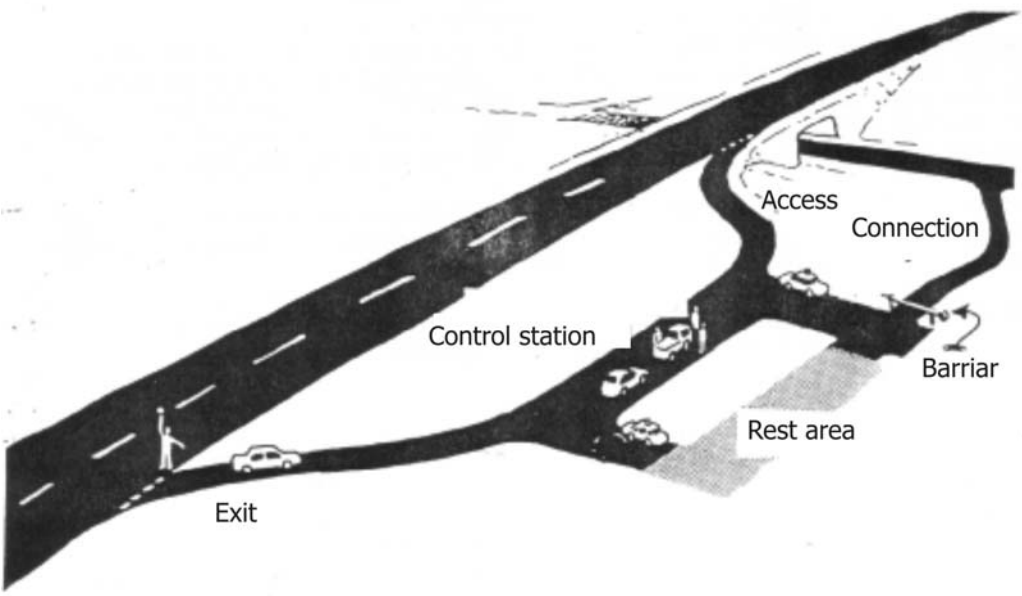


Figure 260: Example of a connecting road with a lockable barriar

If a control station is located next to a motorway (or multi-lane road without the central reservation), the barriers have to be installed at all entries and exits from a control station, and, naturally, have to prevent access at the time when traffic control is not carried out.

7.6 AREAS AT A CONTROL STATION

According to the purpose and type of individual control / operation, the areas at a control station are divided as follows:

- area for controlling drivers, vehicles, etc.,
- area for weighing vehicles,
- area for parking vehicles.

7.7 THE AREA FOR CONTROLLING DRIVERS AND VEHICLES

The area for controlling drivers and vehicles has to be approximately 60 to 100 m long. The required width of such area (Figure 261) is 8.0 m. The area is divided into:

- control area, which is 2.5 m wide and has a safety lane of 1.0 m at both sides. Total width thus equals 4.5 m;
- traffic lane at a control station, which is 3.5 m wide. It is restricted from one side by a temporary road barrier. Within this lane control operations are carried out.

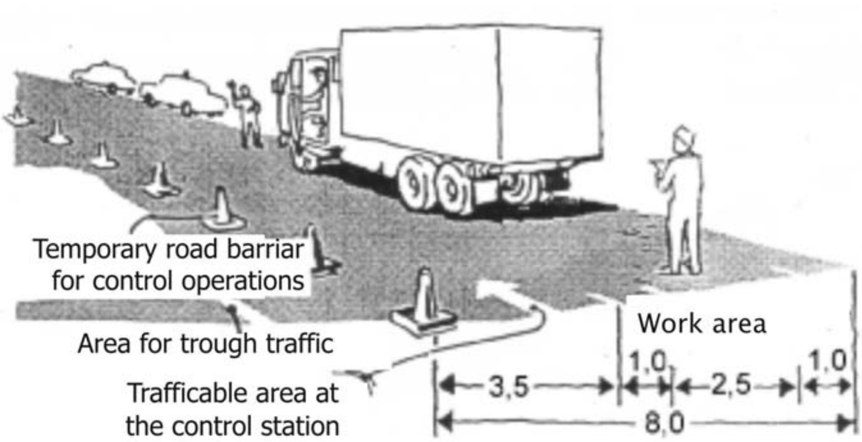


Figure 261: Width requirements for control operations within a temporarily closed off area

On a two-lane road or exit slip road the necessary width is provided by expansion of the roadway. The expansion size depends on the public road traffic (density, structure, etc.) and the existing cross section, i.e. roadway profile.Stabilised lane along the road should be - according to conformity with the control station - part of the station. The solution is shown in Figure 262.

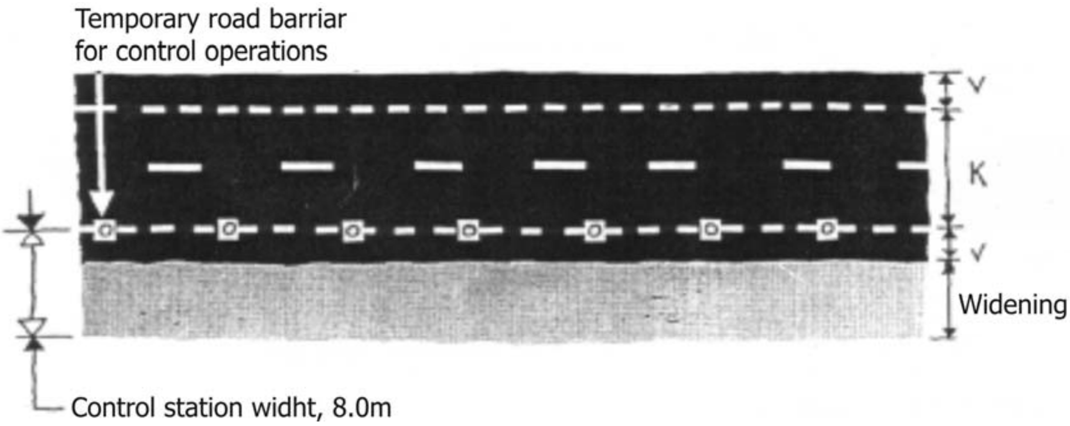


Figure 262: Widening outside the shoulder

On the road where the traffic volume is below 1,500 AADT or on the exit slip road with two lanes a part of the lane can be incorporated in the control station (Figure 7.3).

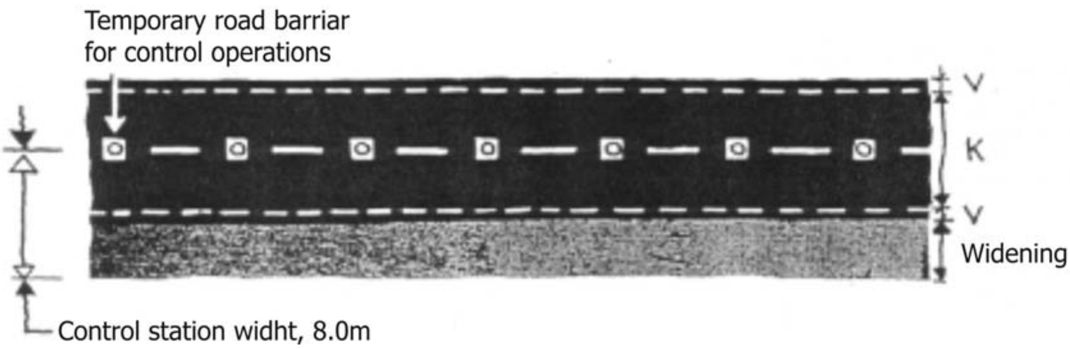


Figure 263: Widening where the traffic flow is less than 1500 AADT or on an exit ramp with two traffic lanes

The required width on the exit slip road and external stabilised lane next to the road has to be provided by setting a permanent barrier (Figure 264).

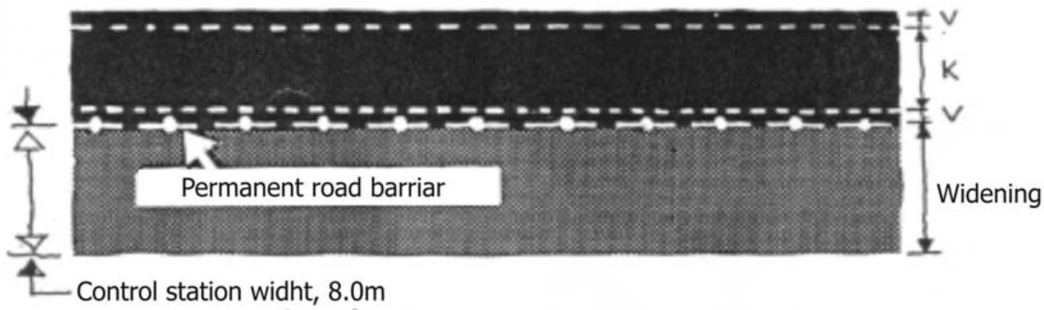


Figure 264: Widening at a permanently closed off control station

7.7.1 Area for weighing vehicles

The area for weighing vehicles has to be at least 25 m long and 4.5 m wide. It can form a special part of the control station.

7.7.2 Area for parking vehicles

The area for parking vehicles has to be large enough for two trucks with trailers at the same time. If the vehicles eliminated from traffic can be removed from the area of the control station (special point of access), the number of necessary parking spaces can be smaller.

In view of the above, parking area has to be provided in any case for at least one truck and one truck with a trailer.

7.8 TRAFFIC SIGNS AND EQUIPMENT OF A CONTROL STATION

A control station is used only for controlling vehicles, passenger and cargo traffic. It has to be equipped with the prescribed traffic signs and equipment, so that it provides the drivers a clear and unambiguous instruction on how to behave at and use the control station.

Traffic signs and equipment in the traffic station area can be:

– fixed and permanent in the event of a control station located in a special area and intended solely for traffic control;
– movable in the event such traffic station is set up for traffic control which intervenes in the existing public road and the area for traffic control has to be provided by movable traffic signs and equipment.

A suitable storage (small facility) has to be provided for storing movable traffic signs and equipment in the control station area. It is used for storing movable traffic signs and equipment as well as other accessories and devices necessary for traffic control.

A telephone line and a connection to the electricity network have to be provided at the control station.

Control stations have to be equipped with public lighting and lit at night.

8 BUS STATIONS

8.1 PODRUČJE PRIMJENE

This guideline defines the policies regarding project-technical design of bus stops.

The guidelines contain the instructions for selecting the project-technical elements of a bus stop and bus stop equipment.

8.2 DEFINITIONS OF TERMS

Bus stop - area separated from the roadway by means of ground markings or physically, intended exclusively for stopping of buses on regular bus lines.

Major bus stop (bus station) - area designed for bus stop, which must have a significant number of platforms for secure boarding and alighting of passengers, the ticket selling offices, outdoor or indoor premises for passengers, a board containing summarised schedules and working hours, public toilets and arranged traffic area.

Entry to the bus stop - the point where the bus leaves the roadway and enters the bus stop.

Exit from the bus stop - the point where the bus leaves the bus stop and re-enters traffic.

On-street bus stop - restricted area on the roadway with ground markings designed for bus stopping.

Off-street bus stop - area physically separated from the usual cross section of the road intended for bus stopping.

Bus bay - area between the entry to the bus stop and the exit from the bus stop, separate from the roadway and intended for bus stopping.

Bus stop entry radius - entry (first) radius (in the direction of the bus drive) or the radius of the first right curve.

Bus stop exit radius - exit (last) radius (in the direction of the bus drive) or the last radius of the right curve.

Waiting area - area intended for passengers, i.e. the area between the kerb, which represents the inner edge of the bus stop on the one hand, and the shelter on the other hand.

Bus stop width - the width of the bus expanded by safety distance towards the roadway and the waiting area.

8.3 CATEGORISATION OF BUS STOPS

Bus stops are usually located in urban environment. Outside towns bus stops are fewer. Usually, the bus stops outside towns are located in the crossroads area. In general bus stops are divided into two main groups:

- on-street bus stop and
- off-street bus stop

8.3.1 On-street bus stops

On-street bus stops (Fig. 265) are used only if due to limited space a bus stop can only be located on the roadway. The exception is bus stops in towns, where the public passenger transport vehicles have an exclusive bus lane reserved only for buses and light-traffic streets. In this case the bus stops are as a rule located on the roadway, but intended only for urban passenger transport.

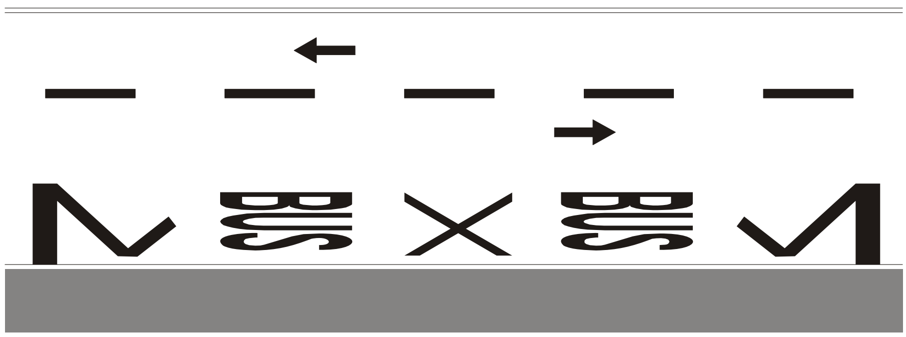


Figure 265: On-street bus stop

8.3.2 Off-street bus stops

On-street bus stops can be divided into two types:

- bus stops which are not physically separated from the roadway (Fig. 265) and
- bus stops which are physically separated from the roadway by a raised island (Fig. 266).

The main argument when deciding for one of these two types of off-street bus stops is the speed of the vehicles on the roadway and the AADT on that particular road section.

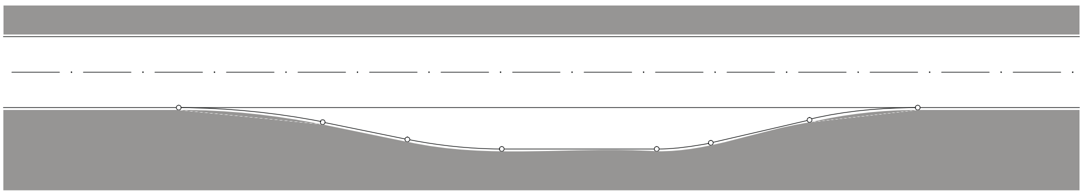


Figure 266: Off-street bus stop without a splitter island

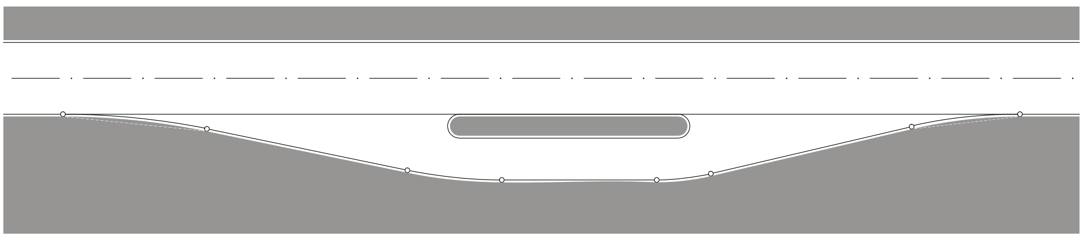


Figure 267: Off-street bus stop with a splitter island

8.4 PROJECT-TECHNICAL ELEMENTS OF A BUS STOP

8.4.1 Clearance and traffic profile of a bus stop

Minimum dimensions of project-technical elements of bus stops are determined based on the speed at which a bus enters a bus stop. Maximum permitted speed at which a bus leaves the public road and enters the bus stop area is 50 km/h, even though the technical elements of the road allow for higher speed of the bus.

Clearance for bus stop is shown in Figure 268 The following should be taken into account:

- the distance of the far most edge of the bus to the roof of the shelter (covered area); for passengers this distance has to be at least 0.5 m, while for other roofed constructions it has to be at least 0.75 m;
- the clearance is 4.5 m above the roadway;

- the edge of the raised waiting area has to be 0.10 m from the far most edge of the bus and raised above the bus stop level by 0.15 to 0.18 m;
- the roofed area for passengers (waiting area) has to be at least 2.5 m high and no less than 2 m wide;
- the width of the bus stop, measured from the outer edge of the roadway marking to the raised kerb of the bus stop has to be between 3.10 and 3.60 m.

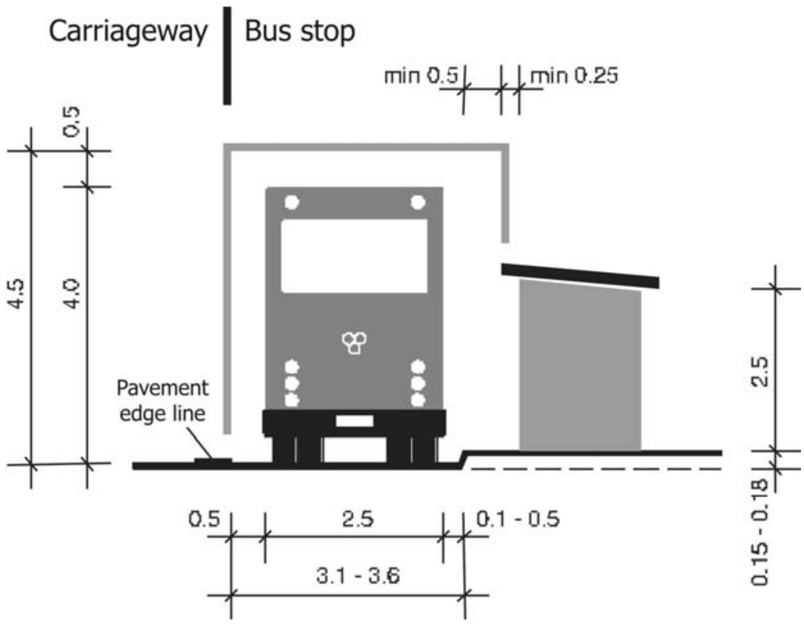


Figure 268: Dimensions of cross section elements of a bus stop

8.4.2 Width of a bus stop

The minimum width of a bus stop directly next to the roadway is 3.60 m. On the roads where the speed limit is 60 km/h or less, the permitted bus stop width is at least 3.10 m.

The minimum width of a bus stop which is physically separated from the roadway is 3.50 m. The minimum width of the intermediate lane between the roadway and the bus stop is 2 m. The inner radius of the bus stop curves must not be less than 6.50 m and the outer less than 12 m.

8.4.3 Width of the passenger waiting area

The minimum width of the passenger waiting area has to be at least 2 m, while the minimum length has to equal the length of the bus stop.

8.4.4 Conditions applying to bus stop location

The bus stop location has to be determined based on numerous criteria.

The volume of required space is often most important. The initial draft approach (functional requirements) is followed by fine design (design criteria), which is completed by the selection of project elements. After this, a bus stop can be designed further and, taking into account special requirements, attention is paid to the details. In this way the designer and their ideas can rely on the instructions in the form of a manual, which will help them decide on the most suitable type of a bus stop for a certain location (including inherent characteristics).

Bus stops are usually not located at or in front of curves with a radius of less than 300 m, since in such case the visibility of other traffic participants is limited due to the bus on the bus stop, in addition to which also the bus driver has limited visibility when leaving the bus stop, as they cannot see the vehicles approaching from behind, when they re-enter the traffic on the inner side of the curve. On the outer side of the curve, the bus driver has great problems when they wish to drive as close to the bus stop as possible, which results in difficult passenger boarding and alighting (from the waiting area to the roadway and then the bus step, instead of directly from the waiting area onto the bus step).

In order to accommodate the passengers as much as possible, it is desirable that the bus stops for buses driving in opposite directions are as close together as possible. On double-lane roads, the bus stops can be parallel, exactly one opposite the other. This can also be the case on roads in residential districts, if the traffic is not too dense. Rare occasions when buses stop paralelly, one opposite the other at the same time, represent satisfactory public transport service.

In all cases the bus stops are located apart along the road (Figure 269). In this case the visibility is optimal.

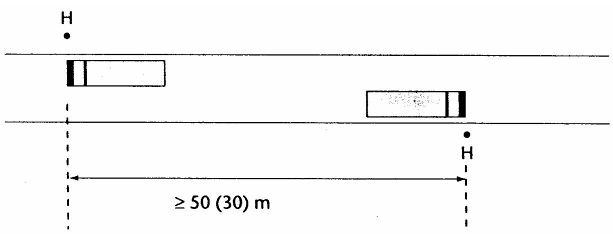


Figure 269: Correct layout of bus stops on a two-way road

8.4.5 Bus stop location at a crossroads

Crossroads with bus stops have to be lit.

Bus stops have to be clearly and correctly marked with traffic signs.

A waiting area has to be provided for the waiting passengers, possibly roofed, so as to protect the passengers from bad weather. At the crossroads which include bus stops, pedestrian paths have to be arranged, pedestrian crossings organised and the bicycle traffic adequately routed.

The basic rule for setting the position of a bus stop at a crossroads is that the bus stop has to be located after the crossroads and under no circumstances before it.

8.4.5.1 Bus stop location at a roundabout

Roundabouts are especially suitable as final stops and turning points of public passenger transport vehicles.

As a rule, a bus stop is not located within a roundabout. If this cannot be avoided, suitable space has to be provided and the pedestrian path adequately routed.

There are two possible locations of a bus stop in the roundabout area:

- in the case of transit lines it is more suitable to place a bus stop at the exit from the roundabout; thus it can form a constituent part of the outgoing leg of the roundabout (after the pedestrian crossing). The bus stop may be located at the approach area to the roundabout (before the pedestrian crossing) if this cannot be avoided due to justified reasons.
- in the case of final lines, when the roundabout is also the turning point of the bus (final stop), the bus stop can be located before or after the roundabout. Two bus stops can be set up: a bus stop for passenger alighting before a roundabout and a bus stop for passenger boarding at a roundabout exit.

8.4.5.2 Bus stop location at other crossings at grade

In general, the problems caused to other traffic participants at crossroads are smallest, if the bus stops are located outside the crossroads in both traffic flow directions (Figure 270).

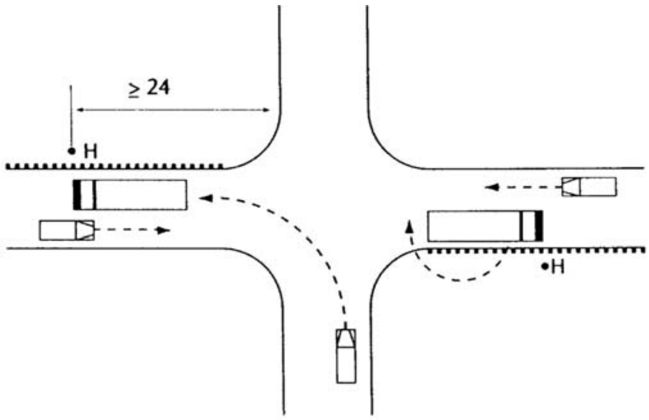


Figure 270: Recommended layout of bus stops near crossroads

For this reason bus stops are as a rule located after the direct road junction area. At a classic crossing at grade a bus stop has to be located at least 20 m from the extended edge of the cross road (Figure 271).

Only exceptionally can a bus stop be located before a crossroads, only if there is no special lane on the roadway for turning right, when buses change the direction at a crossroads and this does not represent a threat to traffic safety or an obstacle to traffic at a crossroads.

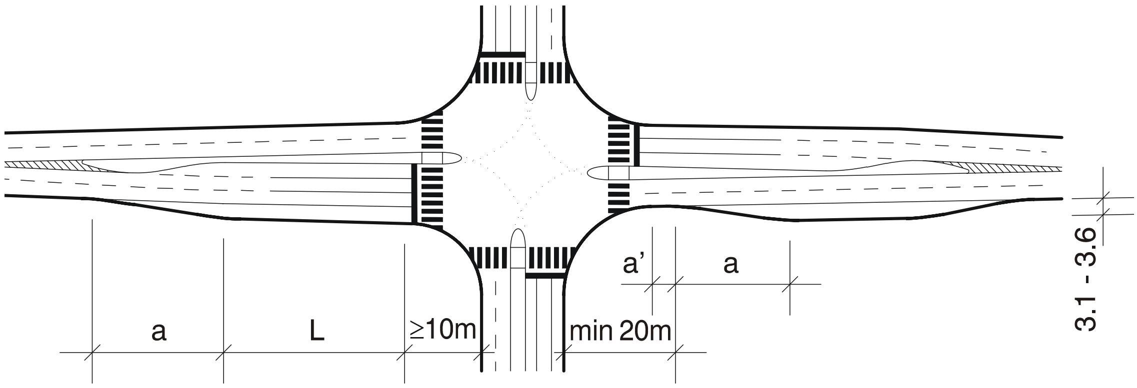


Figure 271: Distance of a bus stop from the crossroads branches

If, however, it is necessary to place bus stops before the crossroads because of traffic-technical reasons, there are some possible conditionally acceptable solutions. A distinction has to be made between crossroads without a traffic light and traffic light controlled crossroads.

At the former the bus stops have to be located so that the visibility of other traffic participants remains unrestricted (Figure 272).

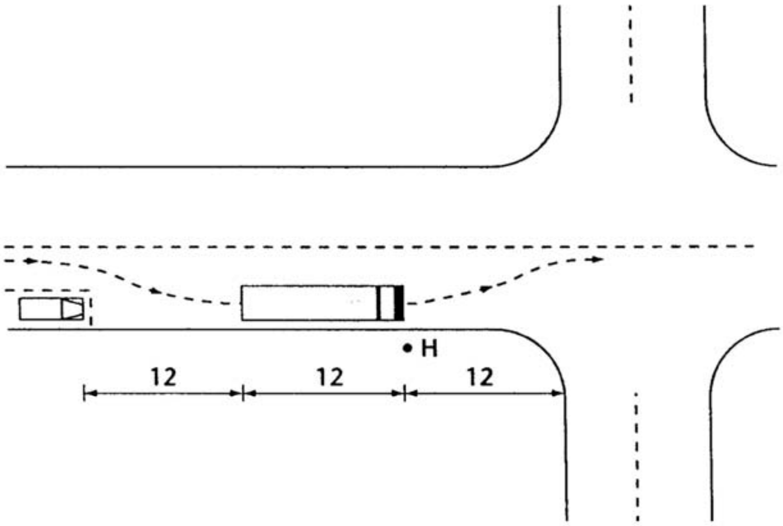


Figure 272: Positioning of bus stops before a crossroads without a traffic light

In the case of traffic light controlled crossroads the solutions involve an exclusive bus lane (Figure 273).

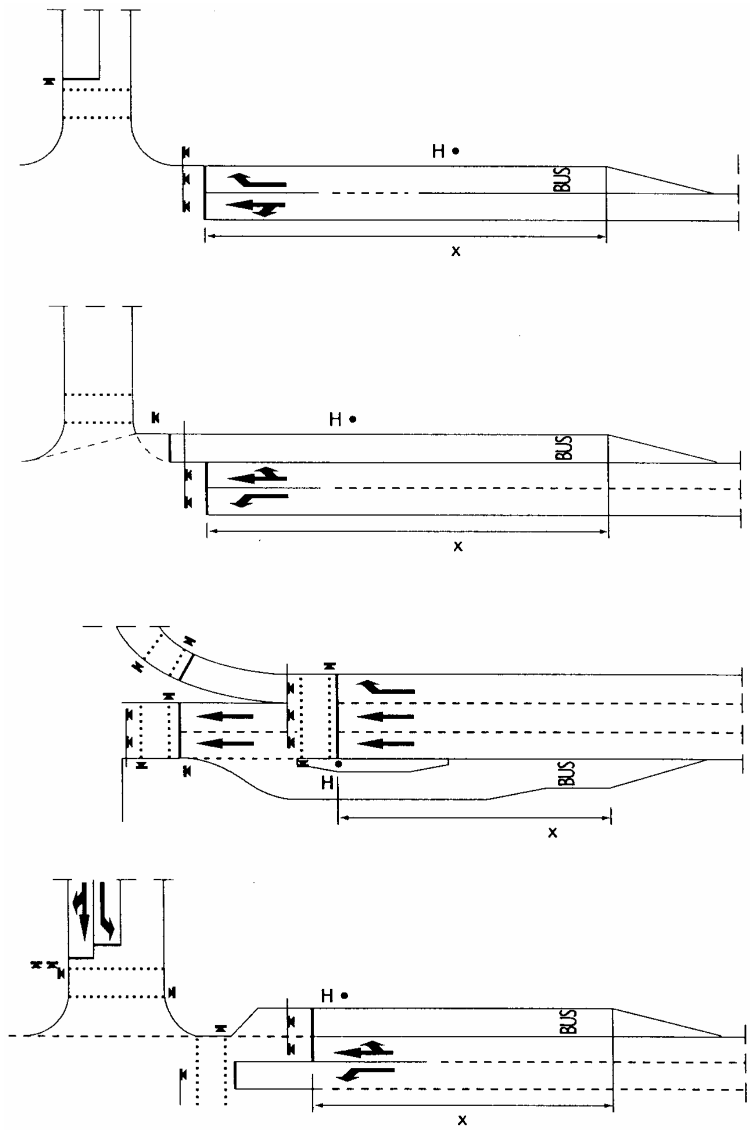


Figure 273: Positioning of a bus stop before traffic light controlled crossroads

8.4.6 Elements of the horizontal alignment of a bus stop

The ground plan elements of a bus stop depend on the speed of the buses while entering the bus stop and the number of buses standing at the bus stop at the same time (Figure 274 and Table 36).

The planned number of buses standing at a bus stop at the same time is established by an analysis of the regular bus line schedule.

Bus stops at which three or more buses are expected to stop at the same time confuse the passengers and lead to danger traffic situations between passengers and buses as well as cause problems as regards the provision of schedules.

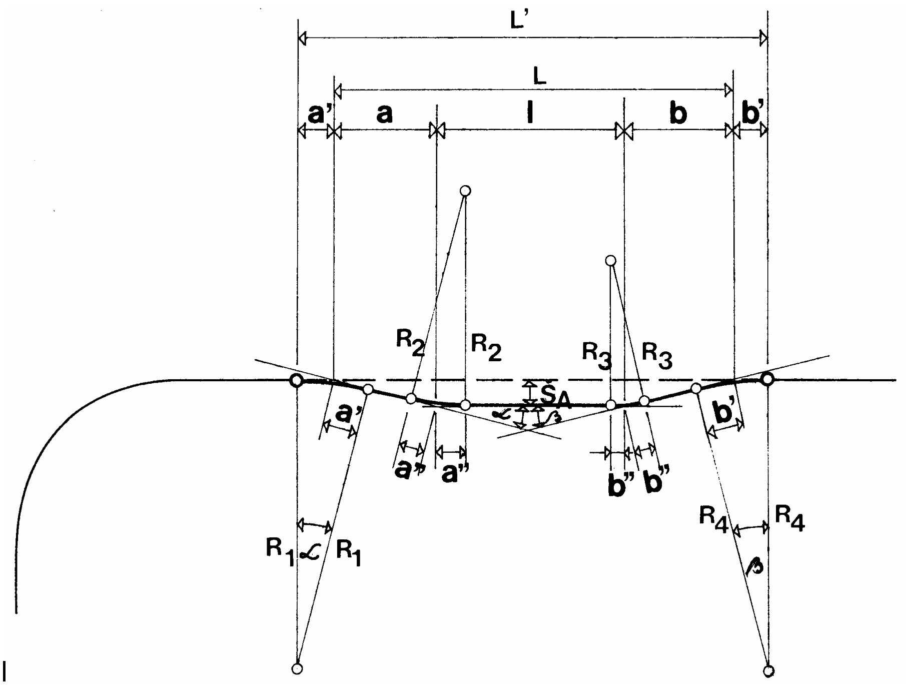


Figure 274: Ground floor elements of a bus stop

Table 36: Data needed for specifying ground floor elements of a bus stop

V (km/h)	a (m)	b (m)	R_1 (m)	R_2 (m)	R_3 (m)	R_4 (m)
30	16	15	40	30	20	40
40	17	15	60	40	20	40
50	25	15	80	60	20	40

$\alpha = \text{arc tg } Š_A/a$ $L = l + a + b$ $\beta = \text{arc tg } Š_A/b$ $L' = a' + L + b'$

$a' = R_1 \text{ tg } \alpha/2$ $a'' = R_2 \text{ tg } \alpha/2$ $b'' = R_3 \text{ tg } \beta/2$ $b' = R_4 \text{ tg } \beta/2$

No. of buses	1/(m)
1 bus	13
2 buses	26
articulated bus	18

8.4.7 Geometrical elements of a bus stop in longitudinal profile

A bus stop may be located only at a road section with longitudinal fall below 3.5% if the road has AADT of more than 5,000 vehicles daily and only on a road section with longitudinal fall below 5.0% if the road has AADT of less than 5,000 vehicles daily.

The entry and exit lanes of the bus stop carriageway are as a rule surrounded by raised kerb.

If a bus stop is located on that part of the road which has no pedestrian pavement, the raised kerbs of entry and exit lanes of the bus stop carriageway have to be at least 1.00 m away from the edge of the roadway.

Delineators or a reflective fence have to be installed on the shoulders of entry and exit lanes of the bus stop carriageway, if this is required for safety of passengers and traffic.

8.4.8 Pedestrian traffic in the area of a bus stop

Passenger crossing across the roadway may be marked only before the entry to the bus stop, if the bus stop is outside the roadway directly next to it, or before the bus stop, if the bus stop is located on the roadway.

The waiting area plane has to be raised 0.15 m minimum and 0.18 m maximum above the bus stop level. A bus stop without a waiting area must not be used.

A sign has to be placed on the waiting area plane, stating the name of the waiting area and containing a summarised schedule (arrivals and departures of buses) provided by bus carriers.

The waiting area of a bus stop has to be connected to the existing public areas for pedestrians by means of a pedestrian pavement or a pedestrian path, which has to be at least 0.80 m wide.

8.4.9 Bicycle traffic in the area of a bus stop

As regards bicycle traffic in the area of a bus stop attention has to be paid to two cases:

- in the bus stop area the bicycle traffic streams via the bicycle lane on the roadway;
- in the bus stop area the bicycle traffic streams via the bicycle path.

In the case of a bicycle lane on the roadway attention has to be paid that this bicycle lane is separated from the bus stop by ground markings. The line between the bicycle lane and the bus stop has to be a wide broken yellow line, while the line between the bicycle lane and the roadway has to be a broken edge (Figure 275).

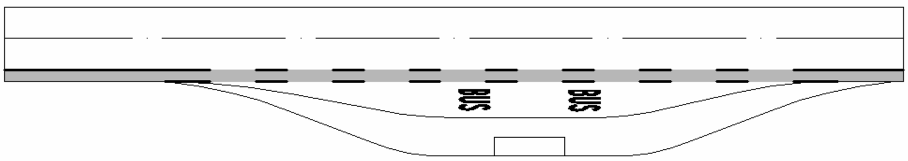


Figure 275: Bicycle lane on the roadway

If a bicycle lane runs across the area of the bus stop, attention has to be paid that the pedestrians at the waiting area and the cyclists do not obstruct each other. For this reason the bicycle path has to be routed behind the waiting area and shelter, if any. The pedestrian crossing across the bicycle path to the pedestrian pavement has to be marked as a pedestrian crossing (Figure 276).

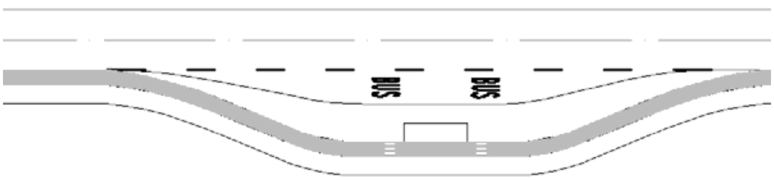


Figure 276: Bicycle path in the area of a bus stop

In towns where due to the lack of space a bicycle path cannot be routed around the waiting area, a bicycle path can be exceptionally routed next to the bus stop, however, special attention has to be devoted to markings of pedestrian crossings across the bicycle path. In front of the bus stop the bicycle path is by ground markings (hatching) visually narrowed and the cyclists are thus warned that they are approaching a bus stop (Figure 277).

Such solution is most often used at on-street bus stops.

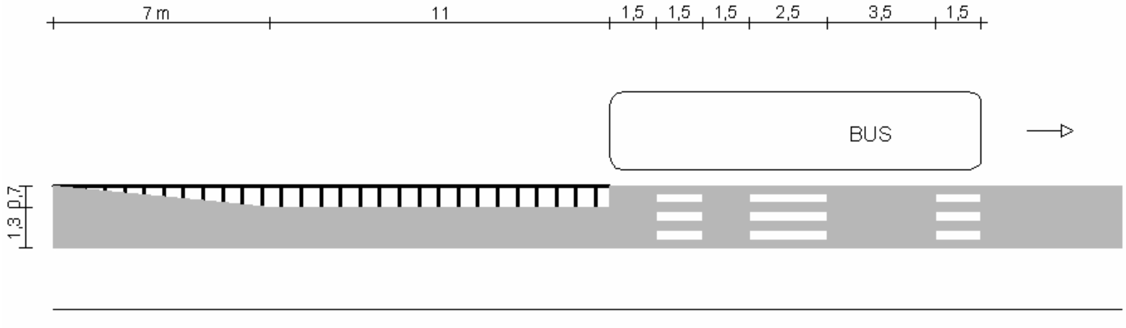


Figure 277: Bicycle path next to the bus stop

8.4.10 Pavement structure in the bus stop area

The base of the roadway in the area of a bus stop has to contain a cement stabilised layer, while the upper (wearing) course is the same as on the roadway next to the bus stop.

The pavement structure is in the area of a bus stop dimensioned for axle load of 100 kN with frost durability calculation.

The roadway in the area of a bus stop shall be constructed at a 2.5% inclination towards the road. Along the road edge and the bus stop a shallow depression has to be provided for suitable drainage of rain water.

8.5 TRAFFIC SIGNS AND EQUIPMENT

8.5.1 Traffic signs in the area of a bus stop

Every bus stop has to be equipped with standard traffic signs.

8.6 BUS STOP EQUIPMENT

User requirements have to be considered while designing and planning bus stops.

The following has to be taken into account, when bus stop equipment is selected:

- protection from inclement weather conditions;
- seats for the waiting passengers;
- clear and reliable information for passengers;
- lighting;
- greens and landscaped areas;
- suitable traffic signs and other signing;
- litter bin;
- suitable drainage of rain water.

9 PARKINGS AT CARRIAGEWAY

9.1 AREA OF APPLICATION

This guideline defines the policies regarding project-technical design of additional lane for still traffic i.e. longitudinal parking.

This guideline does not treat the design rules for parkings in resident areas.

Additional lanes shall be included in the carriageway section when the need for introduction of separate lanes for longitudinal parking areas.

9.2 TECHNICAL CONDITIONS

Longitudinal lanes for still traffic are intended for stopping and parking of vehicles. Their width depends on the type of parking of vehicles. Dimensions and system of parking (longitudinal, angle or right-angled) shall be determined in the Rules on Road Design. Cross fall of these lanes shall equal that of the carriageway. If the fall is made in the opposite direction, the lane for still traffic shall be widened in order to place facilities for longitudinal drainage (cut drains). Their width shall equal 0.5 m, while depth shall not exceed 10% of width.

It is generally not allowed to place longitudinal lanes for still traffic on roads in technical groups A and B. In exceptional cases such placement shall be substantiated by an assessment of their impact on traffic safety on the road.

Planning of placement of lanes for still traffic shall provide appropriate stopping visibility on the road. In case such visibility is not provided, driving speed on the road shall be reduced.

As regards low traffic roads and public roads in populated areas with elements $V_{zasn} \leq 40$ km/h, it is allowed to implement lanes for longitudinal parking of vehicles, which shall be 2.50 m wide, of which 0.50 m shall be the protective lane.

10 REST AND SERVICE AREAS

10.1 AREA OF APPLICATION

These guidelines provide orientation for project-technical design of public road service facilities in the Federation of Bosnia and Herzegovina.

Technical guidelines include the use of facilities, bases for their planning and give service facility types. These guidelines also include criteria for designing the service facilities network, criteria for determining and design of microlocations of service facilities and concept-programme design of service facility types.

The presented guidelines deal with various service facility types except petrol stations, which are discussed in a special guideline.

10.2 DEFINITION OF TERMS

Crossing shall be any spot, where a road crosses, at the same or different level, another road or any other infrastructure, such as railway, watercourse, cableway and similar.

Intersection shall be any juncture of three or more public roads.

Intersection at grade shall be an intersection where the juncture of roads is made at one level – grade.

Multi-level intersection shall be an intersection where the juncture of roads is made at two or more levels.

The intersection at grade area shall be the area including legs of the intersection and the area of direct intersection of two or more roads, i.e. the traffic area belonging to two or more roads at the same time. The intersection area is thus limited by those points on individual legs of the intersection in which the road's shape (roadway width, turning lanes, measures for channelling, turning radii…) begins to change in any way (as regards the ground plan, longitudinal direction or cross section) due to the intersection. . This term is equal to the term wider intersection area.

Point of access shall be the connection (junction) between a public road and all areas from which vehicles directly move in and out of traffic on a public road. It is a part of the public road whereby the public road of the same or lower category, a non-categorised road or access to a building or land connects to that road. A point of access is a part of the road in the length up to the edge of road area, which is 2.0 m from the outer edge of the final point of cross section of body of the road with road drainage facilities and slope of the body of the road or from the safety fence erected along the body of the motorway.

Major public roads shall be roads connecting the entire or larger part of the state Bosnia and Herzegovina and the Federation and integrating it in the European road network while at the same time being an interdependent transport network.

Regional public roads connect settlements and localities within one or more cantons, integrate the entire area of a canton and create an interdependent transport network of one or more cantons connected to the major roads network.

Local public roads and streets in settlements and towns shall be interdependent transport network of a municipality or town connected to the regional or major roads network.

Non-categorised road shall be any traffic area not categorised as a public road.

Traffic areas outside the roadway shall be rest areas, parking lots, bus stops and turning sites, petrol stations, facilities and buildings for weighing and control of traffic…

Traffic arrangement (method of traffic management) shall be the method of traffic flow determined by the road management entity for a road or its part or a settlement or its part. The traffic arrangement includes setting the directions with right of way and the system and method for traffic management, limitations of use of the road or its part with regard to traffic type, speed limits and determining of measures for slowing down traffic, stand still traffic arrangements, determining areas of slowed down traffic, areas of speed limits and pedestrian areas, determining other obligations of road users. The traffic arrangement shall be indicated by the prescribed traffic signs and signals.

Separation lane shall be the part of roadway, which physically separates directional roadways and the marked part of roadway on which traffic is prohibited.

Guiding lanes shall be traffic lanes for guiding traffic flows in an intersection.

Visibility field shall be the area along the road, determined by the visibility triangle and the visibility berm, the use of which is limited.

Visibility triangle shall be land along the road, the use of which is limited for the purpose of providing the prescribed visibility in intersections at grade between roads or between a road and railway.

Traffic lane shall be a marked or unmarked longitudinal part of the directional roadway, which is wide enough for unimpeded driving of vehicles in a single line.

Directional roadway shall be the roadway or its longitudinal part intended for driving of vehicles in one direction and may consist of one, two or more traffic lanes.

Approach radius shall be the radius of the first arc of the right edge of the roadway on the entry to the intersection.

Exit radius shall be the radius of the last arc of the right edge of the roadway on the exit from the intersection.

Covered area shall be the area occupied by the vehicle in a particular driving manoeuvre (turning left, turning right, driving straight, reverse turning left or right).

10.3 BASIC POSITIONS FOR DETERMINING TYPES OF SERVICE ACTIVITIES

The guidelines discuss service facilities intended for supplying vehicles, drivers and passengers on a motorway, which are usually located along the motorway in the "body of the motorway". Facilities and activities for motorway maintenance and traffic safety – namely road maintenance bases, police stations, rescue stations and toll stations – are not included in these guidelines although they are an important part of service activities on any motorway.

The guidelines also do not discuss service facilities in the area of influence of the motorway and its connecting roads.

The motorway service facilities discussed herein are functionally intended for:

- Supply of vehicles in motorway traffic; and
- Supply of drivers and passengers on the motorway.

The service facilities being the subject hereof are usually located along motorways or highways but may also be located along other higher categories of public roads.

10.3.1 Service Facilities for Supply of Vehicles

Supply of vehicles takes into account the following:

- Supply with fuel;
- Supply with spare parts and products for maintenance, equipment and care of vehicles;
- Servicing in case of vehicle breakdown.

Fuel, spare parts and products for maintenance, equipment and care of motor vehicles are supplied by petrol stations. A petrol station is a service-retail facility along the road with a parking lot, where in addition to fuel for motor vehicles, spare parts and products intended for motor vehicles, drivers and passengers can be obtained in the fastest, simplest and safest manner. Petrol stations in service facilities of a higher level along the motorway also offer car servicing.

10.3.2 The motorway Service Facilities for Supplying Drivers and Passengers

During travel, traffic participants on the motorway have certain needs, which they can satisfy in the motorway service facilities. These are as follows:

- Rest and break;
- Sanitary needs;
- Food and drink;
- Purchase of essential products;
- Purchase of food and other products to be used in further travel;
- Requirements for accommodation;
- Requirements for traffic information;
- Requirements for tourist information;
- Banking and postal services;
- Health care services.

Primary needs for rest, break and sanitary needs can be satisfied without any special services in rest areas with parking spaces, toilets, running water, container for waste, and appropriate equipment (benches, tables, walking path) and noise protection in the part intended for resting. The recommended distance between such sites is between 10 to 15 kilometres, if allowed by spatial and traffic-technical criteria for determining locations. It is recommended that such locations have good view and interesting surroundings.

The needs for refreshment – drink, simple food and essential products are in line with fatigue and must be provided in service facilities in the distance between 25 and 30 km and are usually located near parking lots for cars, buses and lorries (except for special transport arrangements), combined with a petrol station, snack bar and a small store offering packaged food, drink, tourist souvenirs and car spare parts.

A higher level of service is offered by the motorway service facilities, which in addition to parking and fuel supply also have a restaurant located indoors and on a terrace, which offers various cooked food, if possible also food typical for the region where the restaurant is located. Offer in such locations also includes recreational areas. They are placed in panoramically attractive sites with interesting surroundings, if possible near water areas. Such supply centres should be placed every 50 to 60 km.

The highest level of services is provided in service facilities with the possibility of accommodation in a motel. Service facilities and areas at the highest level also include a tourist information centre and higher level of retail store services, which should reflect the offer of local goods. Such supply centres should be placed every 80 to 100 km, if possible on those parts of the motorway passing through larger urban areas.

10.3.3 The motorway Service Facilities and Their Tourist and Information Function

Locations of supply centres for stopping – for transit and other travellers – should be placed on spatial or otherwise interesting areas also for the purpose of tourist promotion. Supply centres and stations should be located directly along the motorway and used as follows with regard to tourist information and animation purposes:

To provide information about the country as a tourist destination;

To provide information on tourist offer in the region;

To promote tourist destinations located in the vicinity.

A special criterion in selection of the location appropriate for supply centres and stations is the possibility for linking to programmes interesting in terms of tourism and landscaping.

10.4 TYPES OF THE MOTORWAY SERVICE FACILITIES

The motorway service facilities intended for supplying vehicles and traffic participants (drivers and passengers) are with regard to functions and scope of services offered and on the basis of projected motorway traffic classified in four basic types and given a number and name of the type:

- Type 1: REST AREA
- Type 2: PETROL STATION
- Type 3: SUPPLY STATION
- Type 4: SUPPLY CENTRE

A border tourist-supply centre is usually planned near a border crossing; such centre as a rule belongs to type 1 – rest area – with regard to scope of services offered.

A more detailed offer of various service facilities types is presented in Table 37.

The objective of planning service facilities is to provide quality equipment and offer in such facilities; consequently the minimal utility infrastructure of service facilities with regard to the lowest type (seasonally opened rest areas) consists of the following: drinking water, toilets, local waste water treatment, container for waste, public lighting and telephone. All other types of service facilities include other utility infrastructure in addition to the minimum specified above (see Table 38).

With regard to economics of operations and by taking into account concrete conditions on a particular location, types 1 and 2 (rest areas and petrol stations) are usually located on both sides of the road (parallel or one after another…). As regards service facilities of a higher level, the possibility of one-sided, two-sided or combined locations is allowed.

The distance between individual types of facilities depends on their function as well as economic factors. Service facilities of a higher level should be placed at the centre of needs, if possible near larger urban areas. As some needs provided for by service facilities occur more often than others, the increased scope of services and offer also increases the distance between service facilities with complete offer as oppose to those with less complete offer.

Table 37: A more detailed overview of offer in the motorway service facilities.

TYPE/CONTENTS	PSC	PSL	T	TI	SB	PS	RS	RE	MO	RR
Rest area 1.0	•		•							
Rest area 1.1	•		•							•
Rest area 1.2	•	•	•	•	•					•
Petrol station	•	•	•	•	•	•	•			•
Supply station	•	•	•	•	•	•	•	•		•
Supply centre	•	•	•	•	•	•	•	•	•	•
Border supply centre	•	•	•	•	•		•			•

<u>Note:</u> Description of abbreviations in the table:
PSC – Parking spaces for cars
PSL – Parking spaces for lorries
T – Toilet
TI – Tourist information
SB – Snack bar
PS – Petrol station
RS – Retail store (may be a part of the petrol station)
RE – Restaurant
MO – Accommodation capacity (motel,
RR – Rest and recreation area apartments)

Table 38: Utility infrastructure of the motorway service facilities.

Type	Name	Location	Utility infrastructure
1.0	Existing rest area	Two-sided	Toilet (local cleaning), container for waste, electricity
1.1	Rest area	Two-sided	Minimum infrastructure: drinking water, toilet, local waste water treatment, container for waste, electricity, public lighting, telephone, information table
1.2	Rest area	Two-sided	Minimal infrastructure identical to type 1 + heating of premises
2	Petrol station	Two-sided	Identical to type 1.1 + provision of fire safety and tourist information
3	Supply station	One- or two sided	Utility infrastructure identical to type 2, if possible also gas, local waste water treatment plant or connection to local sewage network, tourist information centre (regional information)
4	Supply centre	One- or two sided	Utility infrastructure identical to type 3, tourist information centre
	Border supply centre	Two-sided	Utility infrastructure in line with the type of the border service facility

Note: The decision on one-sided, two-sided or combined location of programmes of higher-level service facilities (supply stations and supply centres) along the motorway is made when the specific microlocation is determined.

The distance between specific types of service facilities foremost depends on goals to be achieved by locations of service facilities.

In case the underlying objective of locations and design of the motorway service facilities is to promote the country and its various regions, its identity and variety and other things on offer in the area through which the motorway passes, the decision should be to increase frequency of the motorway service facilities. Table 39 gives approximate distances between particular types of service facilities.

Table 39: Distance between various types of service facilities.

Type	Distance [km]
Rest area	10-15
Petrol station	25-30
Supply station	50-60
Supply centre	80-100

Below is a description of individual types of service facilities.

10.4.1 Rest Area

Rest area is the simplest type of the motorway service facilities intended for rest and break.

In addition to the moving traffic area, a rest area includes the following: parking spaces and rest area – recreational area (walking path, children's playground and picnic area in the shadow, tables with benches and arranged green area).

Minimal utility infrastructure includes provided and well-kept toilets with running water, local waste water treatment, drinking water, container for waste, electricity, public lighting and telephone.

Each rest area also has an information table specifying local tourist sights and points of interest and other information.

With regard to spatial arrangements of the rest area's microlocation it is recommended that the recreational area is provided outside the parking space level.

Rest areas are placed on both sides. An important criterion regarding the location of rest areas is tourist attractiveness of the location – view of the typical landscape or attractive tourist areas. Noise protection of the area intended for resting is recommended. We recommend placement of a catering facility (snack bar) on important "tourist attractive locations".

Landscaping of rest areas can include solutions for recreational areas (children's playgrounds), for which specific expert bases should be prepared.

If allowed by spatial conditions and criteria for selection of locations, rest areas should be located in the distance between 10 and 15 kilometres. Approximate land requirements for a rest area equal 2-3 ha, depending on the number of parking spaces and the location of the catering facility (if any).

Rest areas are divided into three subtypes:

10.4.1.1 Rest area type 1.0

It is an existing rest area with seasonal offer. This category includes the existing rest areas intended for personal traffic. They are the smallest in size. Parking spaces are located on both sides of the access road. The rest area has toilets, container for waste and some also have a snack bar opened during the season.

The rest area type 1.0 is presented in Figure 278.

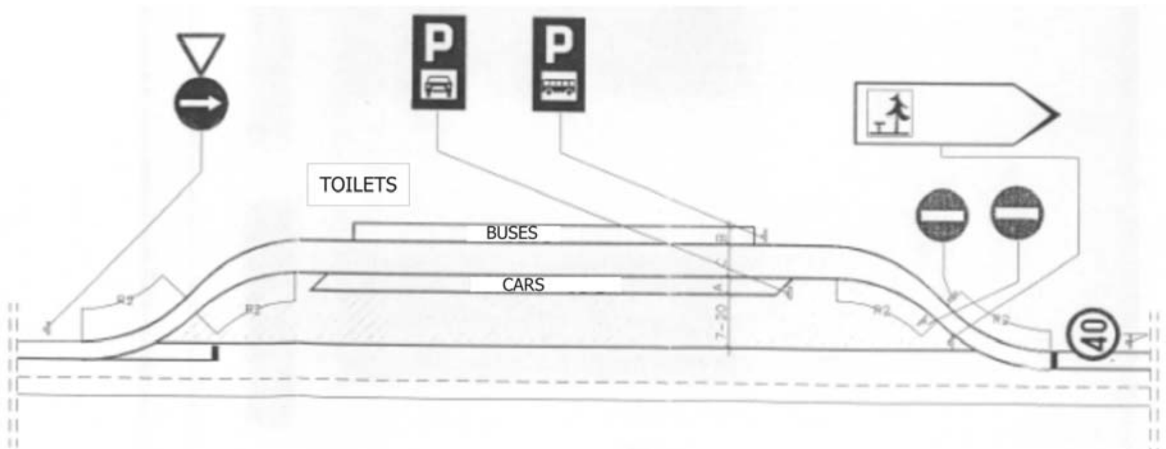


Figure 278: Service facilities of type 1.0 – Rest area

10.4.1.2 Rest area type 1.1

It is a rest area with seasonal offer without a catering facility. It is intended to personal traffic only. It is closed during the winter (the access road to the rest area is closed), as toilets are unavailable. Motorway maintenance service takes care of toilets and the surroundings.

The rest area type 1.1 is presented in Figure 279.

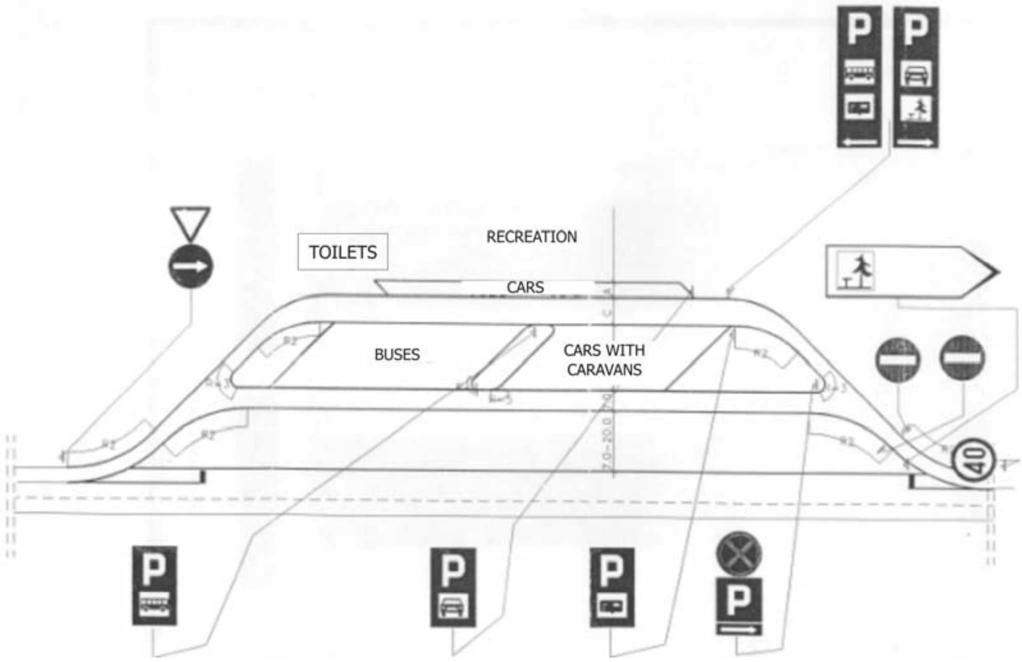


Figure 279: Service facilities of type 1.1 – Rest area

10.4.1.3 Rest area type 1.2

It is a rest area with year-round offer including a small catering facility – snack bar. The rest area is opened all year. The condition is that toilets are arranged and maintained in a way preventing freezing during the winter. A tender for catering concession for several years is recommended in order to ensure quality offer and maintenance of toilets and taking care of surroundings. The rest area and the catering facility are opened all year.

The rest area type 1.2 is presented in Figure 280.

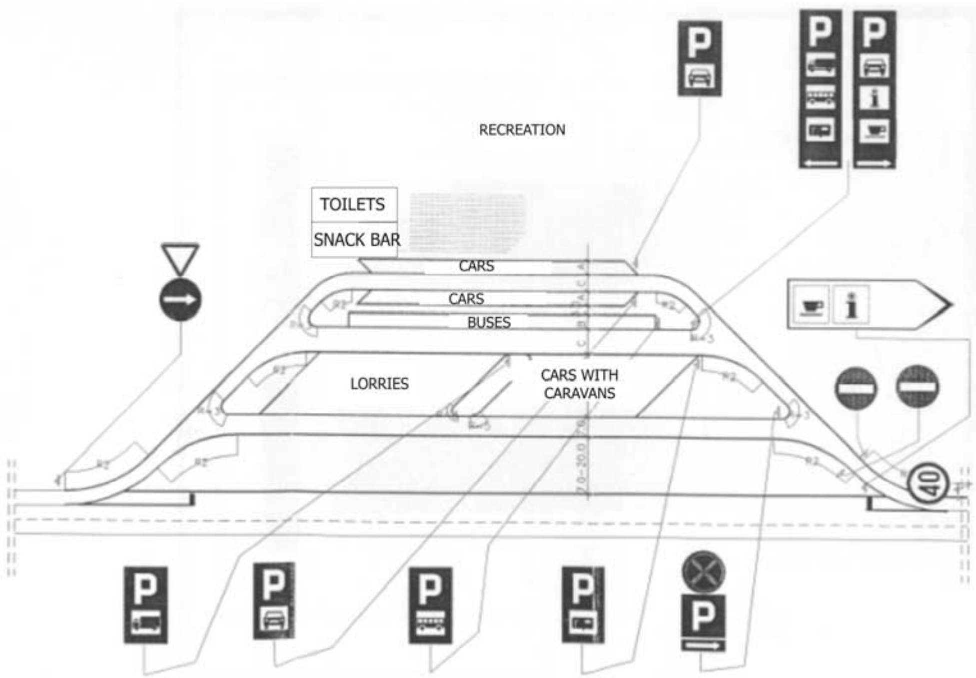


Figure 280: Service facilities of type 1.2 – Rest area

10.4.2 Petrol station

The service facilities of type 2 – petrol station – include in addition to the moving traffic area, parking area (for cars, cars with caravans, buses and lorries with or without trailers) and recreational area for rest and recreation also the area for the petrol station.

As regards supply facilities, it has a petrol station, usually including a small store and a snack bar, and appropriate sanitary premises and toilets (including those for disabled persons). The design of toilets and sanitary premises should take into account the needs of truck drivers (e.g. the possibility of taking a shower).

As regards recognisability, the order of activities is as follows: fuel supply and the ancillary supply and services, parking and rest – break.

The traffic regime is planned in accordance with the principles of one-way, non-conflict and transparent management.

Utility infrastructure includes the following: water supply, local treatment of waste water (or linking to the sewage system if possible), electricity supply, public lighting, telephone, collection and removal of waste, providing fire safety and protection of the environment.

This type of service facilities also offers tourist information on local and regional tourist sights and offer.

The distance between petrol stations is between 25 to 30 kilometres, if allowed by spatial and other criteria for placement of service facilities. The approximate required land equals up to 5 ha. Petrol stations are usually located on both sides of the motorway.

The petrol station service facilities work all year and fuel supply, access to sanitary premises and catering is provided 24 hours a day.

A petrol station is presented in Figure 5.4.

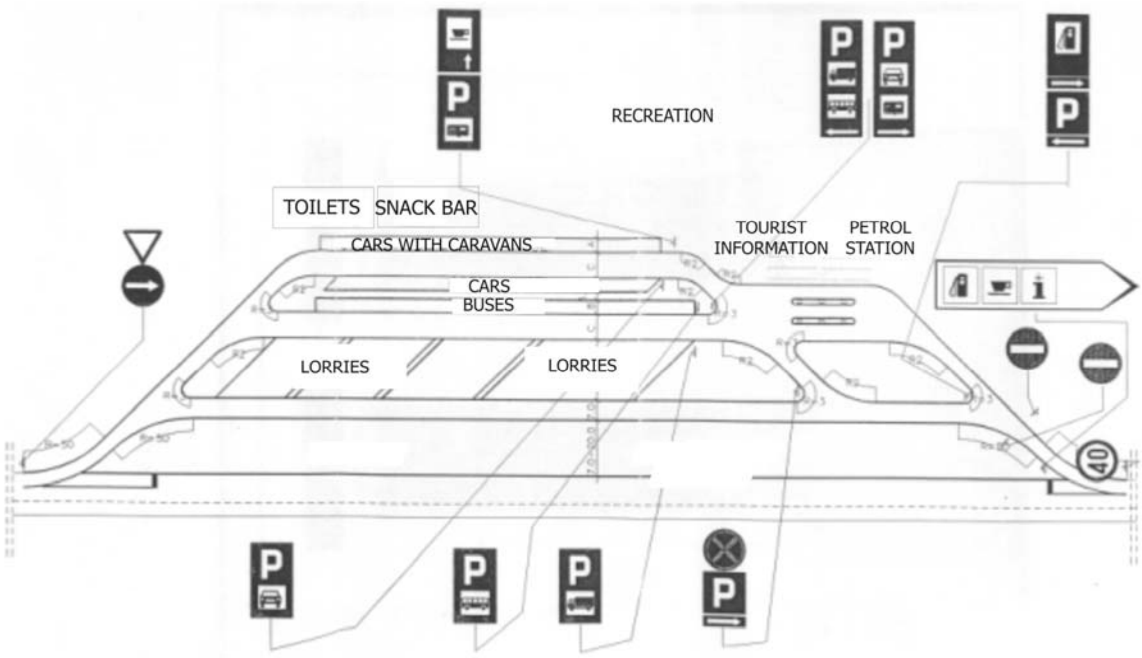


Figure 281: Service facilities of type 2 – Petrol station

10.4.3 Supply station

The service facilities of type 3 – supply station – include catering facilities with a restaurant, snack bar, retail store, petrol station, parking lot for cars and lorries and space for resting with recreational area. The order of services is fuel supply, parking, catering, rest and recreation.

The traffic arrangements provide for division of personal and freight traffic upon entry in the area of the supply station during movement and parking.

Parking areas are separated for cars, buses and lorries by taking into account the principle that parking spaces for lorries are the closest to the motorway.

Utility infrastructure is the same as in service facilities of type 2 and includes the following: water supply, local treatment of waste water (or linking to the sewage system if possible), electricity supply, public lighting, telephone, collection and removal of waste, providing fire safety and protection of the environment. Gas supply is also recommended.

The tourist information centre provides tourist information on local and regional area.

The average distance between service facilities of type 3 equals 50 to 60 kilometres. The required land equals up to 7 ha. The supply station is a type of the motorway service facilities with year-round, 24-hour a day services.

A supply station is presented in Figure 282.

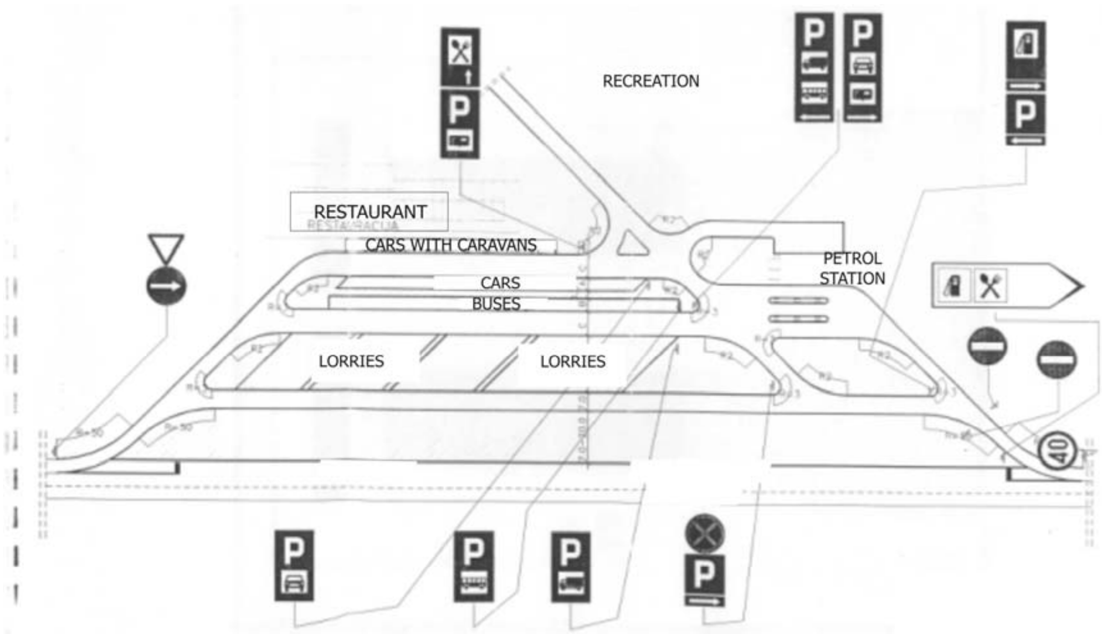


Figure 282: Service facilities of type 3 – Supply station

10.4.4 Supply centre

The motorway service facilities of type 4 – supply centre – include accommodation capacities (a motel, apartments), a restaurant, department store, petrol station, car repair,

parking areas for cars and lorries, space for resting and a recreational centre.

It makes sense to build the accommodation capacities, the restaurant and the department store only on one side of the road and connect it by an overpass with the other side of the motorway. The petrol station with parking lot and space for resting with recreational area are built on both sides of the motorway.

The decision on providing complete programme (i.e. a supply centre on both sides of the motorway) or incomplete programme (a supply centre on one side of the motorway and petrol station on the other side with the option of off-level access to services on the other side of the road) is left to assessment in determining of the actual microlocation of the motorway service facilities.

The order of services in a supply centre is as follows: fuel supply, parkin
(restaurant, store), rest – recreation, accommodation. A constituent part

and maintained toilets and sanitary premises (including showers for disabled persons, room for baby care and for requirements of drivers).

The parking lot for additional offer (e.g. department store) are designed separately.

Utility infrastructure includes supply with drinking and sanitary water, removal or cleaning of waste water, energy supply (electricity, public lighting, heating, gas), telephone and collection and removal of waste. Conditions regarding fire safety and protection of the environment must be met.

An important element is the tourist information centre providing tourist information on local, regional and national tourist offer.

Supply centres on motorways are usually located near large regional centres close to which the motorway passes. Their average distance is between 80 and 100 kilometres. Services are provided year-round and 24 hours a day.

A supply centre is presented in Figure 283.

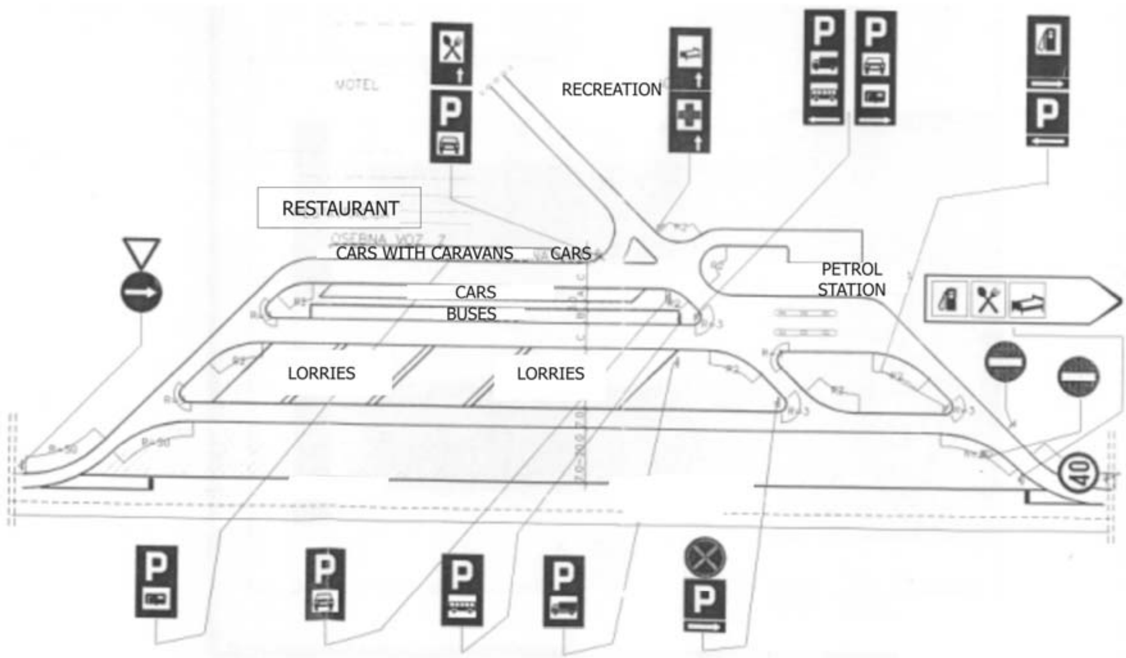


Figure 283: Service facilities of type 4 – Supply centre

10.4.5 Border supply centre

The border supply and tourist centre is classified as a distinct type. Such centres are usually located between 500 metres up to 1 km from an international border crossing. The infrastructure of a border supply and tourist centre depends on the proximity of the existing motorway service facilities on both sides of the border.

Where border service facilities have not yet been built, the service facilities of type 2 – rest area – are built within 500 metres to 1 km from the border crossing. These include – in addition to the moving traffic area – a parking lot, smaller catering facilities (snack bar) and a retail store offering tourist products characteristic for the national or regional tourist offer.

Important elements are providing tourist information and an exchange office. Service facilities of type 1 – rest area – being a border supply and tourist centre are equipped with sanitary premises and arranged space for resting.

The location must meet the condition of minimal utility infrastructure being present. The motorway service facilities of a higher level – type 3 or 4 – are built 10-15 km from the national border.

10.5 CRITERIA FOR DESIGNING THE SERVICE FACILITIES NETWORK

Several substantive sets of criteria for locating the service facilities must be taken into account in designing of the service facilities network. These criteria are:

- Traffic-technical criteria;
- Spatial criteria;
- Landscape, urban planning and design criteria;
- Tourist criteria;
- Utility infrastructure criteria.

10.5.1 Traffic-Technical Criteria

Compliance with traffic-technical criteria is very important in designing the public road service facilities network. The following should be provided:

- General traffic-technical safety in the area of service facilities and upon entry and exit thereto;
- Safe supply of vehicles in the area of service facilities;
- Safe supply and stay of drivers and passengers in the area of service facilities;
- Diversion (or relieving) of traffic in exceptional cases.

The following should be separated as regards the **traffic safety**:

- General traffic safety subject to psychophysical abilities of traffic participants (drivers and passengers), which is related primarily to tiredness;
- Traffic safety in functioning of the motorway service facilities.

The general traffic safety is affected primarily by a set of criteria depending foremost on psychophysical abilities reflected in tiredness and reduced concentration of drivers and passengers:

- The distance travelled: Research and experience have shown that the duration of driving without stopping in an average driver on average equals 2 hours. The average travelling speed on motorways for all vehicles equals between 80 and 100 km/h. Consequently, the distance travelled without stopping equals roughly between 160 and 200 km.
- Complexity and quality of the motorway sections affects the tiredness of drivers and passengers. Road sections on diverse terrain configuration (e.g. steep or long ascents) or sections with frequent tunnels in particular have an effect on placement of rest areas.
- Traffic jams: They include queues related to crossing of national borders and jams resulting from extraordinary weather conditions and traffic accidents. In order to reduce traffic jams (e.g. in unfavourable weather conditions) service facilities of petrol station or supply station types are planned and located for example before larger ascents.
- Habits and characteristics of traffic participants are extremely heterogeneous. Planning should particularly note the specific difference between drivers of lorries and cars. Truck drivers usually have planned stops, with larger distances between stops and on service facilities of a higher level (fuel, space for resting, store, restaurant). Higher level of pollution of lorries should be taken into account (emission of pollutants, noise, potential danger of fuel spillage, more space required, etc.). Bus drivers also plan their stops on service areas of higher level of services, while car drivers do not plan their stops and make them depending on how they feel, day/night, purpose of their travel (business, holiday, trip, shopping, etc.)

and social category of travellers. They stop in locations of various types of service facilities, often in rest areas.

Traffic safety in functioning of service facilities is foremost affected by the following:

- The distance of service facilities from motorway entries and exits: The distance of service facilities from motorway intersections equals 2 to 4 km on flat terrain (subject to positioning of warning signs and signals) with a view of the service facility, while the distance on diverse terrain equals up to 2 km. Minimal distance of service facilities from motorway entries and exits is at least 1 km (vertical signs should be placed – presignalling table at least at 1 km). It is appropriate that locations of service facilities on both sides of the road are made so that we first see the facility in the direction of driving and then the facility on the other side of the road.
- Distance from edge of the motorway: The average distance from the edge of the motorway should equal 20 m (green buffer, noise protection) and the minimum distance 7.5 m (traffic-technical criteria).
- Other criteria to be taken into account in determining of locations: The location of service facilities and buildings should be selected so that parked vehicles and buildings of service facilities do not reduce the visibility field on the motorway, the location should be selected so that the driver may visually see it, the driver should not be occupied with other tasks (e.g. in motorway entries and exits), entry to the service facilities should be made on the part of the motorway with appropriate visibility and suitable technical implementation of the road, the location of service facilities is usually not in the area of minimal horizontal and vertical radii nor on slopes requiring a lane for slower vehicles, motorway structures – forks, connections, toll stations – are usually places where the location of service facilities is excluded.

Supply of vehicles in traffic is performed at the petrol station (fuel, oil, basic spare parts, information). The distance between petrol stations is, given the quantity of reserve fuel in cars, between 25 and 35 km. Servicing of motor vehicles and the possibility for additional supply of vehicles (e.g. carwash) is provided in service facilities of type 4 – supply centres.

Relieving of traffic in extraordinary situations applies in the following cases:

- Jams due to unfavourable weather conditions for traffic, such as occur in the winter (ice, snowdrifts), in fog and critical air pollution, strong wind. The relieving is envisaged for service facilities of types 2 and 3 in locations in front of steeper ascents and tunnels and in areas with unfavourable climate conditions (e.g. strong winds, snowdrifts, etc.).
- Queues on border crossings.

10.5.2 Spatial Criteria

Definition of spatial criteria is the first step towards preparing the analytical models for determining the appropriateness of the area for designing of the motorway service facilities. Land use and activities of service facilities is determined in accordance with traffic-technical and spatial criteria.

10.5.2.1 Attractiveness of space

The attractiveness of space is determined by a set of criteria by which a particular area of road surroundings with potential characteristics for a certain use or activity is defined. It includes assessment of areas with already determined functions and programmes for use as well as areas for which such functions and programmes have not yet been defined:

- Spatial variety or interesting landscape is a quality of landscape, which is defined by a number of elements used to define spatial variety.

- Land use: These criteria are used for determining the existing qualities of space, their characteristics and suitability for organising the envisaged use or activity. Criteria used to define the quality of space (landscape) are substantively taken into account in determining the land use for particular types of service facilities. Thus a very attractive area for the simplest type of rest area is a forest or an area with passive farming (pasture), which represents a high level of attractiveness. For other service facilities of a higher level type, the attractiveness of space depends on a number of criteria.
- Activities in space: Just like the use, the existing activities may have characteristics rendering them more attractive for setting up road service facilities as they can enrich the envisaged programme of such facilities. Such activities are for example recreation, natural monuments, nature reserves, cultural monuments or otherwise defined natural or cultural areas.
- Meteorological phenomena: When planning locations of service facilities, rainfalls – snow (the winter service programme), wind, temperature inversion – fog, air pollution and air quality are taken into account.

10.5.2.2 Vulnerability of space

It regards studying the effects of potential road surroundings on service facilities from the point of view of vulnerability and protection of the landscape and protection of the environment in general as well preservation of certain natural resources. All elements of the environment, which are vulnerable as a result of the intervention, are examined:

- Land use: Areas protected by law (sources of drinking water and protected areas, protective forests and first category farmland). It should be pointed out that interventions on such land are not unfeasible in principle. The feasibility of an intervention should be demonstrated in the assessment procedure (conditions, guidelines, mitigation measures).
- Activities in space: These are used to define the areas protected by law and areas of limited use (protected areas or sites of natural monuments, protected areas or sites of cultural monuments, potential monuments, water management plants, energy and infrastructure facilities).
- Spatial variety: Similar elements of space as those regarding the attractiveness of space except in this case from the point of view of their protection. It should be noted that interventions in space tend to degrade the very elements of landscape that are interesting due to their attractiveness.

10.5.2.3 Functionality of space

This set of criteria studies the potential area from the economic and traffic-technical point of view and with regard to the possibilities of placing facilities along roads in general and as regards the selected type of facilities. The following criteria are taken into account:

- Topography: Spatial categories (flat grounds, slopes and expositions (northern or southern), hills).
- Size: A large land area is required for particular types of service facilities. The criteria for placement of service facilities is the land area size (between 2 and 3 ha, between 4 and 5 ha, between 5 and 7 ha and over 7 ha).
- Position with regard to the motorway's route: The motorway service facilities are placed parallelly, transversely, one-sided- two-sided, close to the road, distanced from the road.
- Accessibility from the hinterland: This regards the criteria on servicing service facilities and their multipurpose use (local population). Criteria include provided access, provided access road, no access and topography of the potential access road.

10.5.3 Spatial-Urban Planning Conditions and Guidelines

From the spatial-urban planning point of view, the use of the so-called urban planning tool is envisaged. The following criteria should be taken into account:

- Accessibility;
- Diversity;
- Readability;
- Adaptability; and
- Visual appropriateness.

Global guidelines for planning conditions are as follows:

- Analysis of the area with regard to scope of activities and the function of service facilities;
- Planning guidelines;
- Ground plan dimensions of the motorway service facilities;
- Height dimensions of the motorway service facilities;
- Minimum allowed distances from the facilities and buildings;
- Organisation of traffic;
- Special microlocation conditions.

10.5.4 Tourist Criteria

Motorways also pass through or near areas or centres interesting in terms of tourism. Consequently, the preparation of a special tourist offer within the motorway service facilities is one of the significant objectives. Certain tourist locations become interesting and attractive for tourism because of motorway construction as it makes them accessible and provides constant flow of guests (seasonal fluctuations).

In addition to traffic-technical and spatial criteria and planning guidelines, criteria regarding tourist orientation and function of service facilities are also considered in determining of their location. The following should be noted:

- Tourist attractiveness of the location, where attractiveness of the location with regard to the view of passengers from the road and attractiveness of the location on locations from which the view of areas of interest for tourism is dominant are taken into account.
- Connection of the location with adjacent tourist destinations and tourist locations – supply centres locations should be in the vicinity of exits for tourist destinations.

All types of the motorway service facilities (ranging from rest areas to the central supply centre along the motorway) should be used to promote tourism and provide information and animation. The service facilities of lower categories (rest areas) should foremost provide information on tourist locations and offer in the vicinity. The service facilities of higher categories (petrol stations, supply stations) should provide detailed information about locations in the vicinity and tourism in the wider region. Supply centres on motorways must – in addition to the above – provide detailed information and tourist services.

10.5.5 Utility Infrastructure Criteria

Utility infrastructure of the motorway service facilities is important criteria for quality of services provided along the motorway. The utility infrastructure criteria affecting the locations of the motorway service facilities are as follows:

- Vicinity of utility infrastructure networks (water, water supply, sewage systems, telecommunications networks, waste water treatment plant or cleaning of waste water, electricity, gas);

- The possibility of connection to utility and energy networks;
- Providing minimal utility infrastructure.

10.6 DESIGN OF THE NETWORK OF MOTORWAY SERVICE FACILITIES – DESIGN GUIDELINES

As regards the methodology, the design of the network of motorway service facilities should take into account the existing, already built motorway service facilities and their placement, while the following should be considered in designing of new service facilities:

Criteria for selection of locations for the motorway service facilities.

The defined average distance between particular types of service facilities.

Recording of currently known potential locations for the motorway service facilities.

The design of the network of motorway service facilities should take into account two sets of criteria, namely:

Screening criteria, which foremost include criteria regarding vulnerability of space and traffic-technical criteria relating to the course of the road's axis – horizontal and vertical – and structures on the motorway.

Decisive, priority criteria, which are taken into account in addition to other criteria in the search for locations of service facilities; these are criteria regarding the attractiveness of space, traffic-technical criteria related to traffic safety and data on traffic load expressed in AADT (which include data on the number of foreign vehicles and the number of freight vehicles), tourist criteria and utility infrastructure criteria.

10.7 CRITERIA FOR DETERMINING AND DESIGNING THE MICROLOCATION OF THE MOTORWAY SERVICE FACILITIES

In determining of microlocations of individual service facilities the design of the motorway service facilities at the national level should be taken into account, where traffic-technical, spatial, landscape-urban planning, design, tourist and utility infrastructure criteria as well as the recommended average distance between individual types of service facilities have already been taken into account.

The search for the most suitable microlocations for placement of service facilities in space is performed at the local level and at the location plan level.

Determining of actual microlocations of new motorway service facilities is performed in the stage of preparing expert bases for the location plan for a particular motorway section. The spatial microlocation criteria specified below are taken into account in determining of the actual microlocation for the given type of service facilities.

The spatial-location or spatial-design criteria with regard to the microlocation are conditions regarding the placement of service facilities in the selected location, adjustment to the situation on site and designing and planning of mitigating and other measures. Similarly to the macro level, criteria at the micro level are also divided into those regarding the attractiveness and those defining the vulnerability of space.

10.7.1 Criteria Regarding the Attractiveness of Space

These include assessment of space with already envisaged functions and the programme for use with regard to its spatial characteristics and potential qualities for particular use. Criteria are defined by set with regard to land use, activities in space, spatial and landscape characteristic of the area and other spatial phenomena:

- Land use: The issue is foremost the method and form of use and the possibility for adjustment or inclusion of the planned intervention with regard to criteria combined by individual land use, e.g. forest areas, farmland, water areas and areas surrounding water, assessment criteria and urban areas.
- Activities in space: The existing activities in space should be considered primarily with regard to the possibility for linking and inclusion of larger-scale programmes. Various land uses can enrich the envisaged programme of service facilities and at the same time save space and money as certain new buildings and facilities do not have to be built. The activities of interest are primarily recreation, activities related to transport (traffic) and activities related to protection of natural and cultural heritage.

10.7.2 Criteria Regarding the Vulnerability of Space

These criteria are used as the basis for studying and defining those elements, which are important for placement of the motorway service facilities with regard to protection of the landscape and other environment-related issues.

With regard to areas protected by law, the assessment and decision-making criteria are as follows:

- The protected area;
- Possible protective measures by using landscape, environmental and other measures;
- Possible preventive engineering (construction) protective measures;
- Other.

With regard to plant and animal species protected by law, the criteria are as follows:

- Plant (animal) species;
- Type, method of protection;
- Endangerment level;
- Possible protective measures;
- Other.

Criteria regarding other nature and landscape elements are based – similar to the determining of attractiveness – on establishing the presence of a landscape element, determining the frequency of occurrence and the quantity of elements (several different elements) and on determining the level of effect and endangerment.

10.8 CONCEPT-PROGRAMME DESIGN OF BASIC TYPES OF THE MOTORWAY SERVICE FACILITIES

10.8.1 Guidelines for Concept-Programme Design

As regards the concept design of individual types of the motorway service facilities, being the subject hereof, the following guidelines were taken into account:

Types of service motorway facilities are designed so that they complement each other, namely that each subsequent type complements the services offered in the preceding type of service facilities;

The order of services is considered in the design for the purpose of recognisability: Fuel supply, parking, tourist information, catering, accommodation, rest – recreation;

Appropriate visual separation from the motorway and noise protection shall be planned;

The traffic is one-way and directed as on the motorway;

Separation of personal and freight traffic is made upon entry to the service facilities area;

Traffic of lorries, buses and cars is separated during driving and parking without any crossing of individual types of traffic;

Minimal utility infrastructure of service facilities includes the following: Water supply, waste water treatment, toilets, container for waste, electricity supply, public lighting and telephone;

The design of facilities shall take into account the typology of architectural regions, through which the motorway passes;

The landscaping of service facilities area shall take into account the autochthonous vegetation and elements of landscape patterns;

All types of service facilities also have a tourist information function.

10.8.2 Spatial Arrangement Guidelines for Basic Types of The motorway service Facilities

10.8.2.1 General guidelines

Land use for the motorway service facilities shall be rational and environmentally friendly. In designing of the area one should seek a facility, which is easily accessible, adaptable to the location, diverse, spatially recognisable and visually suitable.

All spatial elements of motorways service facilities – traffic areas, built areas, green areas and infrastructure "mycelium" – must be in line with regard to quality in all aspects.

10.8.2.2 Placement in space

The basic parameters determining the size of a particular type of service facilities are primarily traffic-technical, the dimensioning is discussed in previous and in greater detail in the following chapters. Dimensioning of catering facilities, subject to the requirement for year-round and 24-hour service, shall be left to a more detailed economic and investment assessment regarding individual microlocations.

The total area required for particular motorway service facilities is shown in Table 40.

Table 40: Total area required for particular types of service facilities.

Type	Required area [ha]
Rest area	Between 2 and 3
Petrol station	Between 4 and 5
Supply station	Between 5 and 7
Supply centre	More than 7

These values are for orientation purposes only and may vary for individual locations with regard to the relief, existing quality vegetation and other natural attractions, e.g. water, the view.

The placement in space should take into account the criteria already presented herein, but foremost the reduction of noise – placement of activities from the motorway with regard to the noise and longitudinal placement of individual functions of facilities with regard to the technology for providing services to users.

For the majority of cases and functions provided by facilities, the access is directly from the motorway, however there is the possibility of local access and intervention roads with mobile blocking of such access, notably in service facilities of types 3 and 4.

The utility infrastructure of service facilities, which in case of type 1 includes minimal and in other types additional utility infrastructure (more details provided in Table 5.2) is, as regards the concept, adjusted to conditions and the situation at the particular microlocation of the service facilities.

10.8.2.3 Guidelines for buildings design

The bulk of dimensions of motorway service facilities is occupied by traffic areas, while their identification is provided by the so-called "tall" buildings, e.g. sanitary facilities, catering facilities, motels and petrol stations. Their design to a large extent gives the character to the entire route as it represents the so-called "support points" for travellers.

The main issue in designing of these facilities is usually the dilemma / conflict between the variety of landscape and the design of buildings, which are distinctly connected to the road (e.g. petrol stations) and usually have – depending on the company managing them – a recognisable image.

10.8.3 Guidelines for Designing of Green Areas Design

Non-built areas and areas not intended for traffic (roads, parking lots), which are a part of the functional area of the motorway service facilities are usually green areas.

10.8.3.1 Function of green areas in the service facilities area

There are several purposes for arrangement of green areas:

- *Design function.* The purpose of arranging green areas is to design the functional space of service facilities and to include them in the wider space. The function of green areas is also representative arrangement of space adjacent to facilities and creation of identity of the area (communicative role).
- *Connecting and separating function:* Making the available areas green enables the option to separate or connect functionally distinct areas within the functional area of service facilities and to separate them from or connect them to the contact area.
- *Sanitary function:* The sanitary role of green areas has to do with arranging noise protection and wind protection barriers, buffers for protection from dust particles and polluted air and with creating special microlocation conditions.
- *Recreational function:* A part of the area of the motorway service facilities is intended for areas for rest, recreation, relaxation and children's play.
- *Reserve function:* The size of the functional area of service facilities is defined with regard to the present and projected traffic load, the service facilities type and the possibilities offered by space. Beside their other functions, green areas also serve as a reserve, as they provide the option to expand traffic areas in the future and also offer additional parking space in extraordinary situations and may be used for placement of other elements.

10.8.3.2 Types of green areas in the area of the motorway service facilities

The functional land of service facilities is divided from the traffic and tourist services point of view to several separated (and at the same connected) elements. The areas between and around them and their immediate surroundings (the contact area) are usually arranged as green areas. These are the following:

The separation area between the motorway and the service plateau of 7.00 to 20,00 m in width, the purpose of which is to act as a sanitary buffer, separation area and the green area with communicative function.

The separation green area between lanes with mainly design and connecting (orientation, directing) function.

The buffer green areas between parking lines are important mostly for sanitary purposes and for providing favourable microclimatic conditions.

The green areas in front of buildings have mostly the design and representative functions, and those adjacent to facilities intended for rest also have sanitary function.

The green areas near space for resting, playing and recreation have all the functions mentioned above but foremost create pleasant microclimatic conditions, prevent negative impacts from the environment (noise, air…) and provide functional suitability of space.

The green areas of the contact area have the purpose of appropriate placement of the service plateau in the environment.

10.8.3.3 Conditions for arrangement of green areas

Design and arrangement of green areas as a part of the functional area of the motorway service facilities shall provide the following:

Appropriate functionality of space in the defined area: Providing of functionality of green areas depends foremost on the service facilities type and on internal arrangement of traffic areas, buildings and functional areas. Arrangement of green areas, notably planting trees, must take into account traffic safety, visibility, readability (orientation in space, directing), microlocation conditions (shadow over parking spaces and spaces for resting), appropriate separation of areas with different functions as well as their suitable connection.

Consideration of regional typology: The motorway service facilities are planned for the entire Bosnia and Herzegovina hence the design and notably the arrangement of green areas should take into account regional characteristics. The design and arrangement should take into account certain general principles: Appropriate management of and life in space for ensuring "healthy" landscape, use of local types of vegetation, created by interaction between natural, spontaneous processes and land use (space identity) and appropriate use of cultural landscape; all the above should be made on the basis of a preliminary analysis of local conditions with regard to objectives and the purpose of landscaping and design concepts.

Consideration of local distinctions: These conditions relate to principles outlined in the previous chapter, as local distinctions usually appear with regard to the landscape typology i.e. the local distinctions are exceptional landscape elements determined on the basis of rarity, distinctiveness, typical occurrence, visual appeal and the level of preservation.

Consideration of vegetation conditions: In order to achieve the objective, namely the appropriate project design of service areas on motorways, suitable conditions for plant growth should be provided from the point of view of construction and gardening.

10.9 GUIDELINES FOR TRAFFIC-TECHNICAL DESIGN OF THE MOTORWAY SERVICE FACILITIES

10.9.1 General

This chapter provides guidelines for traffic-technical design of the motorway service facilities. The basic objective of the proposed guidelines is to provide the following:

- General traffic-technical safety in the service facilities area;
- Safe and complete supply of vehicles during stay in the service facilities;
- Safe stay of vehicles and drivers in the service facilities;
- Safe and comfortable internal (driving and walking) paths;
- Safe entry and exit of vehicles from/to the motorway;
- Safe diversion (or relieving) of traffic in exceptional cases.

This will achieve the following:

- Quality and safe complete supply of drivers and passengers;
- Quality and safe supply with fuel, spare parts and servicing for motor vehicles.

Taking into account the presented guidelines will ensure uniformity in looking for project solutions by traffic experts regardless of the type and location of the service facilities in space and hence provide suitable visibility and understanding of project solutions by drivers and consequently increase traffic safety on the motorway network and the appertaining service facilities.

10.9.2 Traffic-Technical Design of the Service Facilities

The service facilities on the motorway network being the subject hereof are intended for supply of vehicles and drivers. Hence their design must take into account that these facilities will be used by travellers in domestic travel, transit travellers (in both personal and freight vehicles) and service departments (with access from the motorway or the hinterland).

The design shall thus consider the following design requirements:

- Local possibilities: The available space and terrain configuration.
- The classification, i.e. order of activities in the service facility: Fuel supply (petrol stations), parking (separate for different types of vehicles), food and drink (snack bars, restaurants), recreation (playgrounds), accommodation (motels).
- Traffic-technical requirements: External orientation (first the exit from the motorway, then provision of services and finally the entry to the motorway), internal orientation (easy to understand and simple road and vertical signs and signals, followed in intervals enabling timely comprehension by drivers).
- Capacity of individual activities of the service facility.

10.9.2.1 External orientation

Good external orientation means that drivers can timely and unambiguously decide on the manoeuvre of leaving the motorway and that the manoeuvre in question is performed safely and timely. Good external orientation is provided by vertical and road signs and signals before the service facilities as well as by suitable visibility. The correct placement of the service facilities also facilitates good external orientation. It is appropriate that locations of the service facilities on both sides of the motorway are made so that drivers first see the facility in the direction of driving and then the facility on the other side of the road (Figure 284). This is achieved by longitudinal shift of the service facilities. Because of the utility infrastructure and supply of the service facilities, the distance between "parallel facilities" should not be too great.

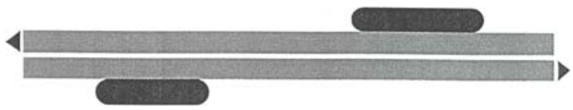


Figure 284: External orientation of the service facilities.

10.9.2.2 Internal understandability of traffic management in the service facilities

The internal understandability (shown in Figure 285) is required by the driver from the moment the vehicle is at the end of the entry route i.e. in the service facilities area. Internal orientation is particularly important for freight vehicles, which are more limited in movement due to their size.

Good internal orientation and understandability are achieved by the following:

Directing of traffic by the shortest route possible to the parking areas intended for particular vehicle types;

Unambiguous and simple signs and signals, placed in intervals enabling driver to comprehend them without any strain;

Freight vehicles should be directed through the shortest route possible to the parking lot and through the shortest route possible separately back to the motorway;

The internal traffic on the plateau should be – if at all feasible – implemented as one-way;

The internal traffic on the plateau should be in the same direction as the motorway traffic;

Returning to the motorway without passing through the entire plateau of the service facilities should be enabled for vehicles stopping only for refuelling;

The internal traffic on the plateau should not mix with transit traffic (in case of a joint bifurcation for exit from the motorway and access to the service facilities).

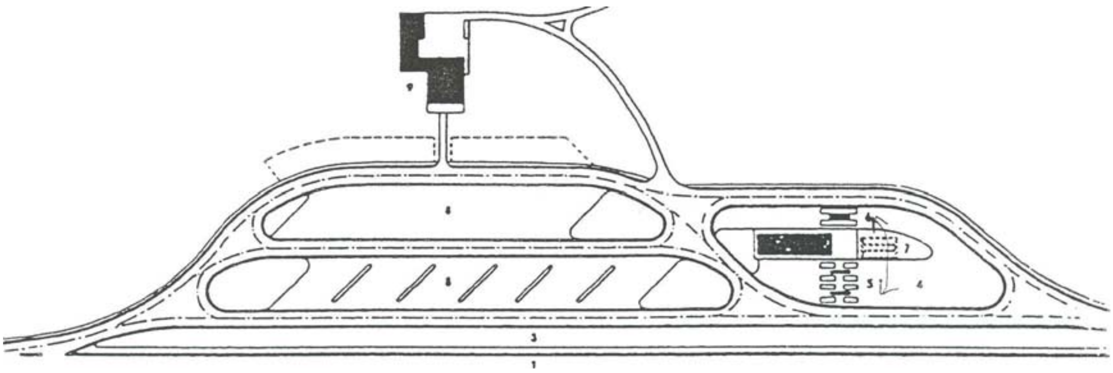


Figure 285: Sample service facilities configuration.

10.9.2.3 The order of activities with regard to distance from the motorway

The placement of individual activities within the service facilities plateau is extremely important for understandability of the underlying service facilities. Its importance lies foremost in the sequence of satisfying the needs of drivers and vehicles as well as (consequently) the height of buildings on the service plateau.

The following activities are placed transversely in the separation green area:

The distribution lane (an extension of the entry route intended for vehicles, which, for whatever reason, drive without stopping at the service facilities and for freight vehicles, which are returned from the parking lot to the motorway separately and by using the shortest possible route);

The parking area for lorries, tractors, buses, cars and cars with caravans;

Fuel supply (the petrol station), repair shop and parking area for cars;

Food supply, accommodation (the motel) and recreation.

The following activities are placed transversely in the separation green area:

Fuel supply (the petrol station), if possible with a parking lot for its staff;

The parking area for cars, cars with caravans and buses;

Food and drink supply (the restaurant, snack bar), accommodation (the motel) and recreation (playgrounds).

The parking area for freight vehicles, car repair shop, carwash;

Exit from the service facilities.

10.9.3 Placement of the Service Facilities in the Motorway Area from the Traffic-Technical Point of View

Placement of the service facilities in the motorway area should be given particular attention. It involves linking two entirely different types of traffic: the high-speed traffic on the motorway and still or low-speed traffic at the service facilities.

The proper placement of the service facilities in the motorway area provides the following:

The general traffic-technical safety in exiting and entering of traffic; and

Safe diversion (or relieving) of traffic in exceptional cases.

10.9.3.1 General principles

The general principles to be taken into account in determining of the service facilities locations are as follows:

- Location of the service facilities should be selected so that drivers can visually perceive it;
- Location of the service facilities should be selected so that the entry to the service facilities is made on the part of the motorway with appropriate visibility and suitable technical road implementation;
- Generally, the service facilities should not be placed in areas of minimal horizontal and vertical radii nor on slopes requiring a lane for slower vehicles;
- Location of the service areas and facilities should be selected so that parked vehicles and buildings do not hinder the visibility field on the motorway;
- Infrastructure structures of the motorway (forks, connections, toll stations) usually exclude placement of the service facilities;
- Motorway sections passing through urban areas have greater traffic loads and are more suitable for the service facilities of a higher level as they are interesting also for users from the hinterland.

10.9.3.2 Distance of the service facilities from motorway intersections

Distance of the service facilities from motorway intersections should (regardless of configuration of the terrain) equal at least 1 km (subject to placement of traffic signs and signals – the preceding sign at 1 km distance) (Figure 286). Only in exceptional cases (space limitations, configuration of the terrain, etc.) can the entry to the service facilities and exit from the motorway be made as a joint motorway exit for the service facilities and the bifurcation (Figure 287).

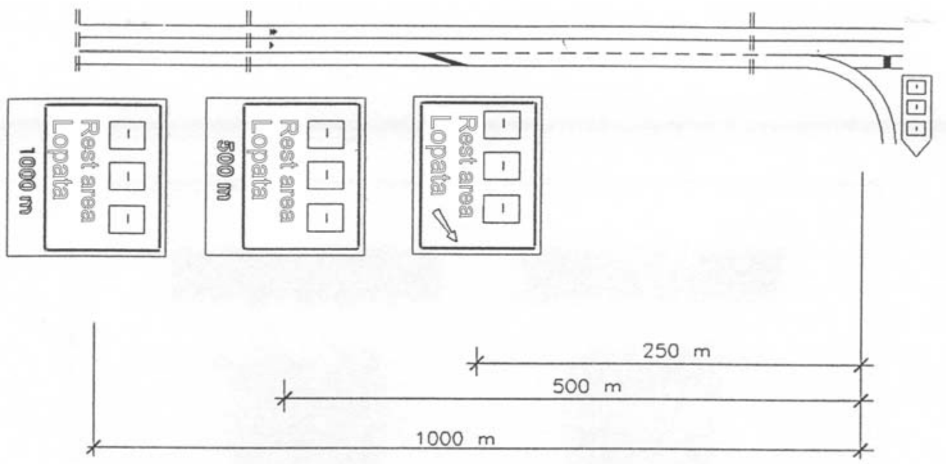


Figure 286: The minimum distance of the service facilities from a motorway intersection.

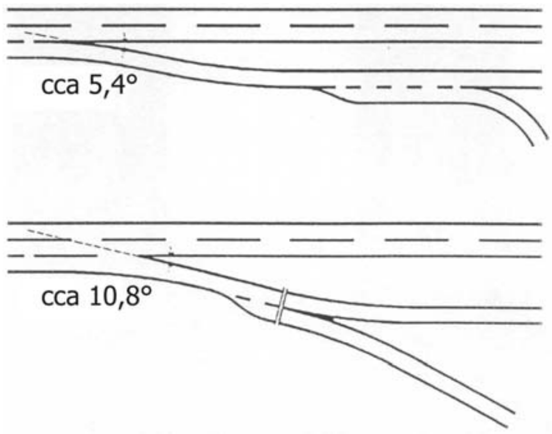


Figure 287: Joint bifurcation for the service facilities and exit from the motorway.

10.9.4 Traffic-Technical Design of the Service Facilities Elements

Conditions regarding the axis and level of the motorway for the purpose of the service facilities

Certain rules have to be taken into account in the design of exit and entry lanes.

As regards the bifurcation in a right bend (Figure 288) the view is directed towards the top of triangular distribution island of the ramp's exit – visibility must be provided.

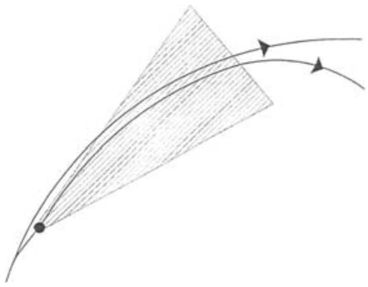


Figure 288: Bifurcation in a right bend.

As regards the bifurcation in a left bend (Figure 289), there are differences in the directions of cross falls of the transit roadway and the ramp. In such a case, the key is to ensure drainage of the roadway.

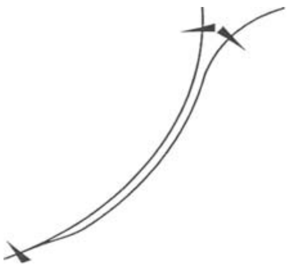


Figure 289: Bifurcation in a left bend.

As regards the point of access in a right bend (Figure 290), the problem of rear visibility may occur – i.e. the provision of rear visibility for safe entry of vehicles.

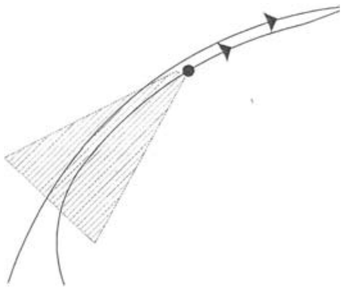


Figure 290: Point of access in a right bend.

As regards the point of access in a left bend (Figure 291), there are differences in the directions of cross falls of the transit roadway and the ramp – drainage of the roadway must be ensured.

Figure 291: Point of access in a left bend.

10.9.4.1 Designing of ramps

In areas of intersections and exits, traffic situations occur, which are not usual in open sections. This conditions the analysis of border ground plan and height elements of transit roadway. Each exit-entry ramp consists of three parts, different by their traffic function as well as the design method. The first part is the exit where separation of traffic flows is performed, the second is the ramp's route and the third entry, where traffic flows come together.

Provisions of the guideline *Off-Grade Intersection and Points of Access* are used for designing ramps for the service facilities, selection of minimal radii for horizontal route of the axis, exit/entry ramps and types of directional lanes (e.g. types of exit lanes).

10.9.4.2 Horizontal course of the directional lane

Maximum gradient of level of ramps on motorways should not exceed 5% and 6% for ramps in ascend and descend, respectively.

Equally applies to gradients of levels of the service facilities, which should always be in the same direction as the level of the motorway to which they are connected. In more demanding field conditions these values can be increased to 6.0% and 7.0%, respectively.

10.9.4.3 Cross section of directional lanes

The cross section of the roadway in the service facilities area also consists of driving and other traffic lanes. As regards the cross section, exit and entry lanes follow the basic profile of the motorway, meaning that they usually preserve the cross fall of the motorway's roadway. The size of cross section of the service facilities' ramp is determined with regard to the traffic load and the ramp's length in accordance with provisions of the guideline *Off-Grade Intersection and Points of Access*.

10.9.4.4 Project elements of traffic connections within the service facilities

All turning arcs in the service facilities the purpose of which is primarily passability and not permeability (petrol stations, parking lots, repair shops, etc.) are designed by three circular arcs (basket-like bend) in the ratio equalling R1 : R2 : R3 = 2 : 1 : 3, where

R2min depends on the vehicle type, with regard to which the size of turning arcs and the angle of turning are being determined.

Other design principles for such areas are described in greater detail in the guideline *Intersections and Points of Access at Grade*.

10.9.5 Parking Areas in the Service Facilities

The basic criteria for designing parking areas

The following should be considered in designing of parking areas on the motorway service facilities:

- If possible, parking areas are designed so that they enable one-way traffic flows;
- The parking lot for the petrol station's employees is if possible a part of the petrol station's complex itself and, in case the petrol station is not two-sided, on the rear part of the facility;
- Parking areas for buses should be (because of a large number of persons leaving the vehicles and entering catering facilities) located as close to the catering facilities as possible and, if feasible, so that the passengers cross no (or only one) traffic connection;
- Traffic areas for buses should have, if at all feasible, the possibility for direct exit – access traffic connection or the option for lateral parking;
- Parking areas for cars should be located as close to the catering facilities as possible so that travellers cross as few internal traffic connections as possible;
- Parking areas for lorries are usually located near the end of the service facilities so that they have direct exit to the transit road;
- Parking in the service facilities should be, if at all feasible, made under 45° angle;
- Dimensions of parking spaces in the service facilities are in principle the same as dimensions of parking spaces specified in other guidelines (the guideline *Parking*). These dimensions depend on the width of access roads and the angle of parking;
- As regards parking areas for lorries, it is advisable that an intermediary separating – physically delevelled – strip of 1 m in width is made for every four parking spaces;
- As regards parking areas for buses, it is required (in case a direct exit is provided) that an intermediary (physically delevelled) strip of 2.0 m in width is made for every parking space;
- As regards parking areas for buses, it is required (in case a direct exit is not provided) that an intermediary (physically delevelled) strip of 2.0 m in width and a plateau for entering of passengers is made on the front side of the parking area for buses;
- As regards parking areas for buses (in case lateral parking is provided and a direct exit is not provided), the physically delevelled plateau should be at least 2.0 m in width.

10.9.5.1 Methods of parking and dimensions of parking spaces

Dimensions of parking spaces and width of access roads is affected by the following:

Motor vehicle types (i.e. vehicle dimensions), which are parking (motorcycles, cars, cars with caravans, buses, lorries, lorries with trailers)

Type or method of parking (lateral on the roadway, askew or right-angled).

In general, we advise against right-angled parking in the motorway service facilities (except for cars) as it requires large widths of access roads and provision of direct exits.

The methods of parking of motor vehicles and dimensions of parking spaces and access roads are discussed in greater detail in the guideline *Parking*.

10.9.5.2 Dimensioning of the required number of parking spaces for individual vehicle types

The required number of parking spaces is determined separately for individual vehicle types (cars, buses, lorries, cars with caravans). Parking areas for individual vehicle types are physically separated.

The required number of parking spaces for cars and lorries is determined on the basis of experience with regard to the following:

The projected traffic load on the motorway section at the end of the planning period;

Distance from the next service facilities;

Type of the service facilities; and

Tourist attractiveness of the service facilities.

The second option for determining the required number of parking spaces is by the traffic load of the motorway section by using the following formula:

$PS_{PV,FV} = c_1 \times c_2 \times c_3 \times c_4 \times d_1 \times (AADT/2)$

where:

$PS_{PV,FV}$	The number of parking spaces for personal vehicles or freight vehicles
c_1	The proportion of personal ($_{PV}$) or freight ($_{FV}$) vehicles with regard to the total traffic load
c_2	The proportion of vehicles in the daily hourly peak traffic volumes
c_3	The proportion of vehicles coming to the service facilities during the daily peak traffic volumes
c_4	The proportion of vehicles of the total traffic load on the service facilities, which are parking
d_1	The average parking time of vehicles during the lunch hour
AADT	The average annual daily traffic

In case the dimensioning is made for a one-side service facility (accessible from both sides of the motorway), the last part of the formula shall not be divided by two.

The assumptions on which the preceding formula is based and approximate values of particular ratios given below are as follows:

- The traffic structure equals 77% of personal vehicles and 23% of freight vehicles;
- The peak hour for the total number of vehicles is 7% of daily traffic of personal vehicles and 5.5% of daily traffic of freight vehicles;
- The location of the service facilities may be as follows:
- I densely populated area (equal to the open system of the motorway network)
- II area with distinctive long-distance traffic (equal to the closed system of the motorway network)
- Service methods in the service facilities:
- Self-service from the bar (SB)
- Self-service with tables and additional serving (ST)
- Serving only (SO)

The proposed approximate ratios are presented in Table 41 and on the basis of the proposed approximate values, Table 42 was extracted for approximate values of individual factors.

Table 41: The proposed approximate ratios.

Service method:	SB	ST	SO
The proportion of vehicles coming to the service facilities: I Densely populated area	PV 15%, FV 15%	PV 15%, FV 15%	PV 15%, FV 10%

II Area with distinctive long-distance traffic	PV 20%, FV 25%	PV 20%, FV 15%	PV 20%, FV 10%
Proportion of parked vehicles	-	PV 80%, FV 90%	-
The average parking time of vehicles	PV 30%, FV 0%	PV 40%, FV 45%	PV 50%, FV 0%
The proportion of incoming vehicles with their passengers using the service facilities	PV 45%, FV 65%	PV 35%, FV 50%	PV 25%, FV 30%
Occupancy of the vehicle (persons)	- , -	PV 1.8, FV 1.5	- , -
The average time spent in the service facilities	PV 25, FV -	PV 35, FV 25	PV 45, FV -

Table 42: The approximate factor values.

Motor vehicles	PV						FV					
Location of the service facilities	I			II			I			II		
Service type	SB	ST	SO	SB	ST	SO	SB	ST	SO	SB	ST	SO
c_1	0.77			0.77			0.23			0.23		
c_2	0.07			0.07			0.055			0.055		
c_3	0.15			0.20	0.15		0.15	0.10		0.25	0.15	0.10
c_4	0.80			0.80			0.90			0.90		
d_1 [h]	0.667	0.883		0.50	0.667		0.883	0.583		0.583		

Certain German experience has shown that in 24 hours 6% of passing motor vehicles stop on any petrol station. Half of those vehicles immediately continues with their journey while others stop for a longer time period. Of those vehicles, 2/3 are cars and 1/3 lorries. In accordance with these data and by taking for example the load of 20,000 motor vehicles in 24 hours, the planned number of parking spaces equals 24 spaces for lorries, 6 spaces for buses and 60-80 parking spaces for cars.

The aforementioned formula for determining the required number of parking spaces cannot be used to determine the required parking spaces for buses. Usually the proposed number of parking spaces for buses is no more than 5. A larger number of planned parking spaces for buses is unjustified in terms of economics as (in extreme cases) buses can use parking spaces envisaged for freight vehicles with trailers.

The formula for determining the required number of parking spaces has no provisions for the number of parking spaces for cars with caravans. The approximate number of required parking spaces for cars with caravans is determined on the basis of experience and with regard to the motorway section where the service facilities are located.

10.9.5.3 Parking areas for other activities in the service facilities

The parking areas for other activities in the service facilities (repair shop, carwash, diversion of lorries in extraordinary situations, etc.) are determined on the basis of experience.

The extraordinary situations include jams due to unfavourable weather conditions for traffic, such as occur in the winter (ice, snowdrifts), in fog and critical air pollution, strong wind and jams during the tourist season. Parking areas for diversion of freight vehicles in extraordinary weather conditions are a constituent part of parking lots for lorries within the service facilities of a higher level (petrol stations, supply stations, supply centres) before steeper ascents and tunnels.

The dimensioning of parking areas for lorries does not take into account parking areas for lorries transporting dangerous substances. They are subject to a special transport regime. Lorries (and accompanying vehicles) transporting dangerous substances stop at predetermined points. Such stopping points may also be the service facilities of rest area types 1.0, 1.1 and 1.2, however in such cases they should be closed for all other traffic.

10.10 TRAFFIC SIGNS AND SIGNALS AND TRAFFIC EQUIPMENT OF THE SERVICE FACILITIES

Vertical signs, horizontal signs and traffic equipment in line with the applicable Rules on Traffic Signs on Public Roads (Official Gazette of the SFRY nos. 48/81, 59/81, 17/85) should be placed in the area of all types of the service facilities.

Other types of signs may be placed in the area of service facilities, the so-called non-traffic signs, which are intended exclusively for tourist and information purposes (e.g. marking of information tables, waste baskets, etc.).

11 PETROL AND GAS STATIONS

11.1 AREA OF APPLICATION

The present guideline provides directives for the petrol and gas station design.

The guideline includes and discusses the domain of incorporating petrol stations in the environment, as well as petrol station types in view of their size and access. It also contains provisions for planning petrol stations.

11.2 DEFINITIONS OF TERMS

Petrol station is an accompanying structure at roads, which basic function is to provide motor vehicles with fuel.

Accompanying activities are stations offered by a petrol station to its users in addition to its basic function. The most frequent accompanying activities are shops, car wash, buffet, etc.

Traffic flow splitting zone is a surface, on which a traffic flow branching off from the main road is split in several traffic lanes leading to the fuel supply zone (fuel filling devices).

Fuel supply zone is a traffic surface with islands, on which fuel filling devices are located.

Traffic flow joining zone is a traffic surface, on which the traffic arriving from the fuel supply zone joins the main traffic flow to be connected to the main road.

Outflow is a location on the road where vehicles leave the road at the petrol station entry.

Inflow is a location on the road where vehicles, arriving from the petrol station, are entering the road.

Filling devices are devices to supply vehicles with petrol, oil, gas, ...).

11.3 ENVIRONMENT INCORPORATION OF PETROL STATION

11.3.1 General conditions and criteria

The following general conditions and criteria shall be fulfilled in case of construction of a petrol and gas station: suitable ground where construction is permitted, access road, vicinity of public utility connections, vicinity of neighbouring structures and their intended use, ecological data of the environment, information on broader surroundings, etc.

11.3.2 Selection of petrol station location

Petrol stations shall be constructed on road sections of a good sight distance, as the traffic safety might be questionable in opposite cases.

When planning petrol stations, one shall also consider the safety to be ensured to the environment.

As a rule, in urban environment petrol stations shall be constructed extra for each individual traffic direction, which means that the particular station can be used by vehicles driving in one direction only. In opposite case, one shall be aware of the fact that at least one (generally two) three-directional crossroads is required.

On expressways and motorways the approach is somewhat different. Where a petrol station is located on one side only, an underpass or an overpass shall be built to link both traffic directions. However, such a solution shall be avoided by executing two petrol stations, one for each traffic direction.

11.4 GENERAL DIRECTIVES FOR PETROL STATION ARRANGEMENT

Instructions for dimensioning are particularly essential to petrol station designers, and a bit less to architects whose task is to foresee the petrol station arrangement.

By correct interventions, and considering all the current regulations, the selected solutions shall ensure safety, capacity, and economy; in addition, they shall satisfy all the customers' requirements.

The required surfaces for the individual activities of a petrol station shall generally be dimensioned in view of the following:

- expected average annual daily traffic (ADT) at the end of design life,
- remoteness of the next petrol station,
- type and tourist attractiveness of the accompanying structure, on which the petros station is located (if a petrol station is an independent structure, this criterion shall not be considered).

Petrol station design shall take account of the current legislation and general rules of traffic technics. Therefore, the traffic arrangement on a petrol station shall be verified from two standpoints:

- from the point of view of a public road it is essential that the petrol station location meets the requirements with regard to sight distance, visibility, and capacity, as well as to conditions of correct placing the traffic signs, and to conditions of dimensioning traffic surfaces for both connecting to and branching off.
- from the point of view of offering a good station on the petrol station is important to achieve the best possible traffic capacity, i.e. a minimum retarding in the supply area.

11.5 PETROL STATION TYPES IN VIEW OF THEIR SIZE AND VEHICLE ACCESS MODE

Basically it shall be distinguished between a petrol pump and a petrol station.

At petrol pump only one principal activity takes place, i.e. filling the fuel. A petrol pump is smaller than a petrol service, which offers customers (drivers) more services than filling the fuel only.

In the following text the term petrol pump will be replaced by "minor petrol station", whereas the term petrol station by "major petrol station".

11.5.1 Division by size

11.5.1.1 Minor petrol stations

Minor petrol stations are located in towns and settlements of less traffic, and are intended for local people and passengers. In addition to petrol and gas, such petrol stations also offer basic consumable materials such as oil, lubricants, car consumables, etc.

Such a station is equipped with a room for the personnel, parking place for the personnel, toilets for the personnel and customers, and a small magazine.

The width of a minor petrol station generally amounts to 5 m, whilst its height is 2.78 m.

11.5.1.2 Major petrol stations

Major petrol stations are located in expressways and motorways. These structures comprise a room for the personnel, parking place for the personnel (for 4 cars), a room for the customers, toilets for the personnel, toilets for the customers, a first aid room, and a magazine. In addition, a buffet, a shop, a car repair shop, and a car wash can also be foreseen.

The width of such a station amounts to 7.75 m, its length is 23.0 m, and its height amounts to 2.93 m.

The width of the roof located above the fuel filling area amounts to 13.75 m, whereas its height is 5.0 m.

Major petrol stations shall be accessible not only from the motorway or expressway, but also from other roads. In this way, a station is accessible to its personnel, different services, emergency vehicles, etc.

11.5.2 Division by vehicle access mode

The other division of petrol stations relates to placing the islands with fuel filling devices with regard to the petrol station structure. So the petrol stations are divided in petrol stations of parallel access, of diagonal access, of frontal access, and of both-sided access.

11.5.2.1 Parallel access

A petrol station of parallel access is such that the communication, at which fuel filling devices are located, is parallel to the petrol station structure (Fig. 292).

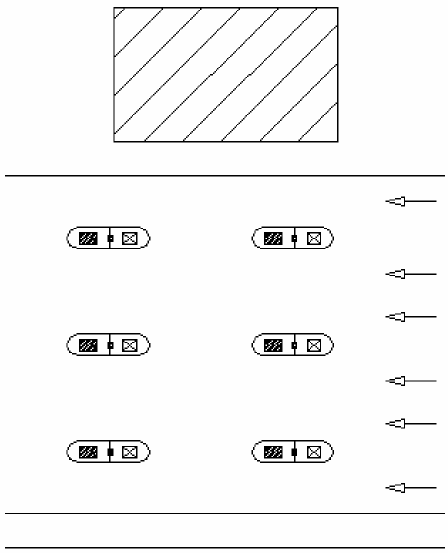


Figure 292: Parallel access

11.5.2.2 Diagonal access

A petrol station of diagonal access is such that the communication, at which fuel filling devices are located, is diagonal to the petrol station structure (Fig. 293).

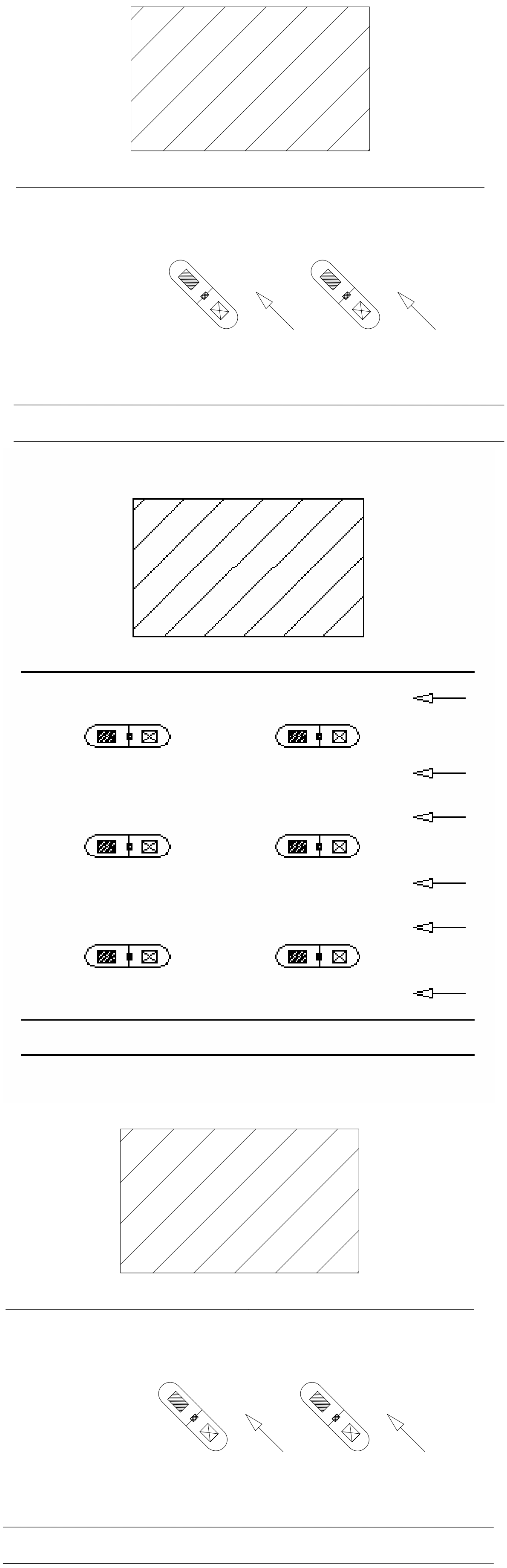


Figure 293: Diagonal access

11.5.2.3 Frontal access

A petrol station of frontal access is such that the petrol station structure is perpendicular to the access communication, at which the fuel filling devices are placed (Fig. 294).

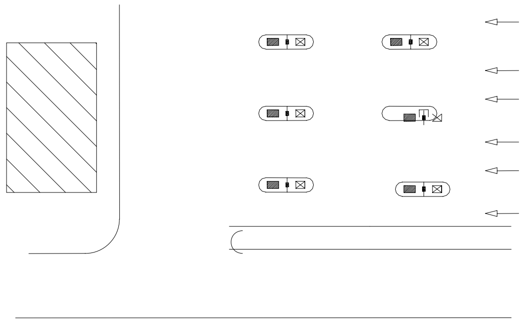


Figure 294: Frontal Access

11.5.2.4 Both-sided access

A petrol station of both-sided access is such that there are two parallel communications with fuel filling devices, and the petrol station structure is located between these communications (Fig. 295).

As a rule, in these cases the arrangement is such that on one side of the petrol station structure only lorries, and on the other side all other motor vehicles are supplied with the fuel.

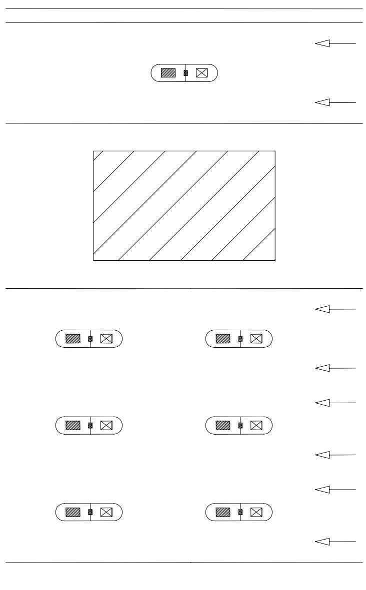


Figure 295: Both-sided access

11.6 PETROL STATION TRAFFIC SURFACES

11.6.1 Traffic surfaces leading towards and away from petrol station

When designing accesses to petrol stations, the access road capacity shall be ensured for the design traffic volume within a design period od 20 years.

The traffic increase in the design period is calculated on the basis of the average annual traffic growth rate in the area of the foreseen point of access.

In the area of approaching and leaving a petrol station, such traffic arrangement shall be provided that there will be no traffic obstruction and traffic safety jeopardy on the main communication due to entering or leaving the petrol station.

11.6.2 Traffic surfaces in the narrower area of petrol station

To the traffic surfaces in the narrower area of a petrol station the following traffic surfaces generally belong:

- traffic surfaces for arrivals and departures of vehicles;
- area for supply and maintenance;
- in special cases, parking place for personnel and customers of the petrol station.

The traffic among individual functional wholes of the petrol station (branching-off zone, supply zone, zone of additional services, connecting-to zone) is a one-way traffic of a reduced flexibility, and of a minimum possible freedom of movement within the traffic surfaces.

As a rule, the sequence of the aforementioned zones is as follows:

- zone of branching-off from the communication (or petrol station entry zone),
- supply zone,
- zone of connecting to the communication (or petrol station leaving zone).

For the supply zone and the zone of accompanying activities at the petrol station itself, parking places for cars, and areas for repair and other activities are foreseen.

The fundamental requirement to be met is a continuity of traffic flows without any interweaving. To achieve this goal, the traffic running among individual petrol station functional units shall run in one way only. In this way a maximum traffic capacity at optimum safety is achieved.

As a rule, only one-way traffic is allowed at petrol stations. Two-way traffic is only admitted at minor petrol stations, i.e. at roads of ADP < 5,000.

In the narrower area of a petrol station the traffic is arranged in a form of branching from the main traffic flow, and connecting to the main traffic flow in three zones:

- traffic flow splitting zone,
- fuel supply zone,
- traffic flow joining zone.

11.6.2.1 Traffic flow splitting zone

Trafic flow splitting zone (Fig. 296) is a surface, on which a traffic flow branching off from the main road is split in several traffic lanes leading to the fuel supply zone (fuel filling devices).

Both type and length of traffic lanes depends on the number and position of the islands with fuel filling devices (longitudinal or diagonal), on the position of islands with filling devices with regard to the petrol station structure (frontal, parallel, diagonal, or both-sided), as well as on the composition, intensity, and speed of the arriving traffic flow.

The abovementioned goals can be achieved by both horizontal and vertical traffic signs, as well as by dividing the traffic flows in such for lorries and buses, and such for motorcars.

The lorry and bus traffic lane width shall amount to at least 3.0 m.

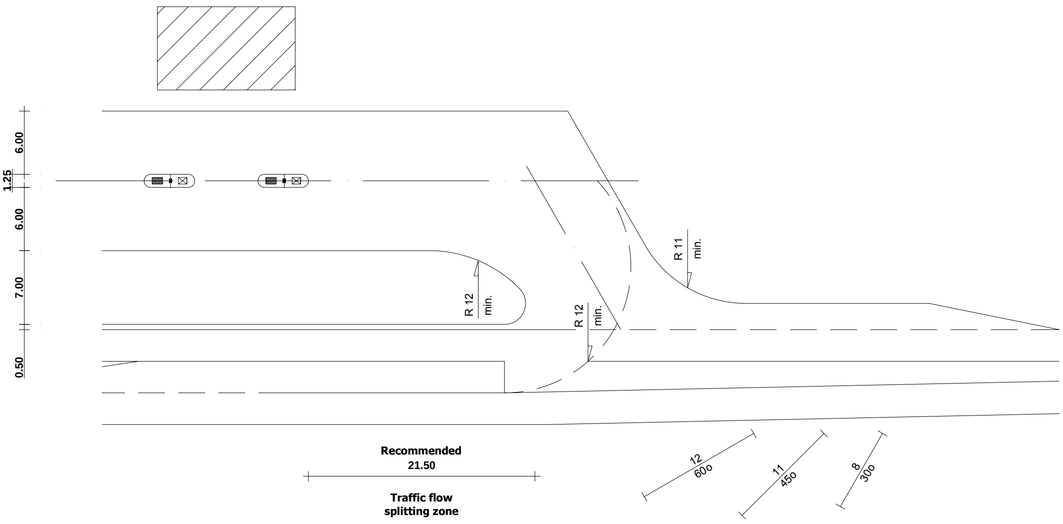


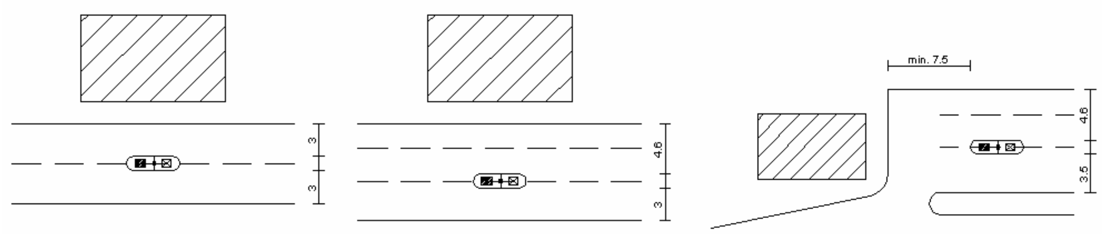
Figure 296: Traffic flow splitting zone

11.6.2.2 Fuel supply zone

Fuel supply zone is a traffic surface with islands, on which fuel filling devices are located.

The minimum dimensions of traffic surfaces depend on both number and position of the island with fuel filling devices (longitudinal or diagonal), on the position of the island with filling devices with regard to the petrol station structure

(frontal, parallel, diagonal, or both-sided), as well as on the composition, intensity, and speed of the arriving traffic flow (Figs. 297 – 299).



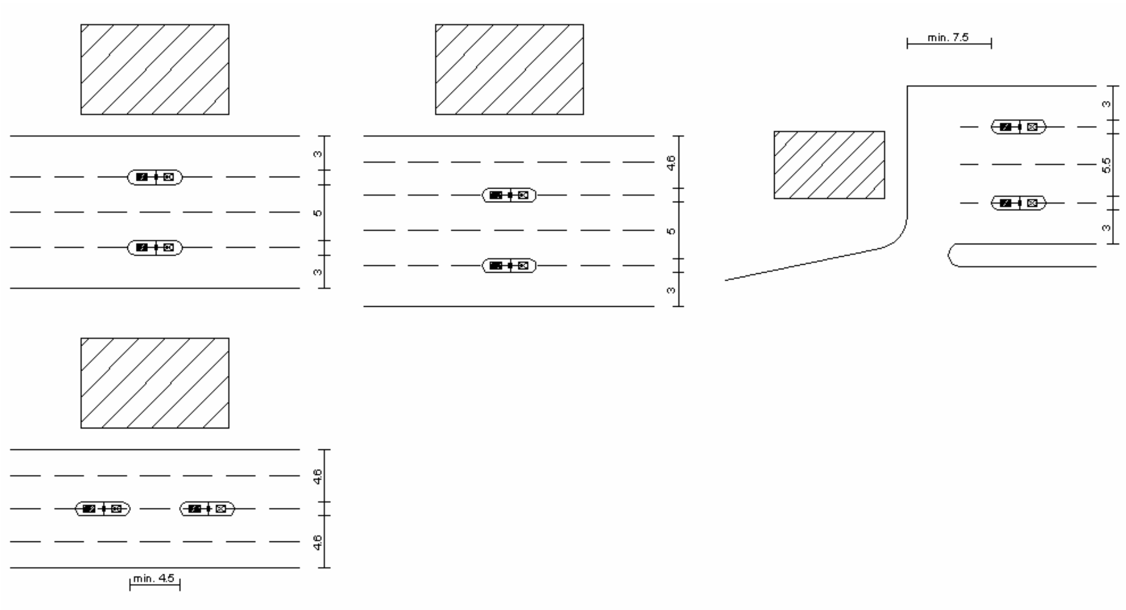


Figure 297: Minimum dimensions of traffic surfaces where islands with fuel filling devices are placed parallel or frontally - 1

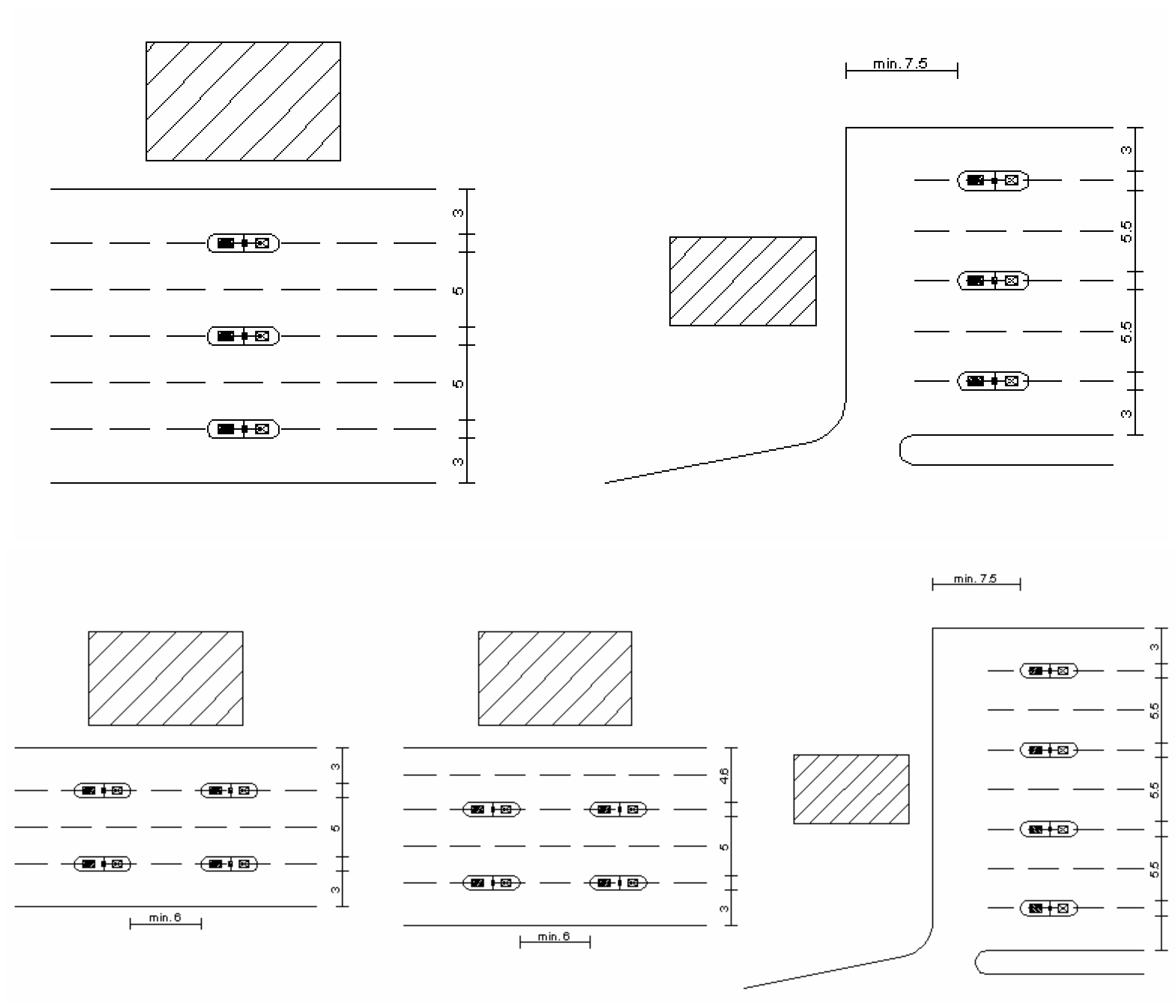


Figure 298: Minimum dimensions of traffic surfaces where islands with fuel filling devices are placed parallel or frontally - 2

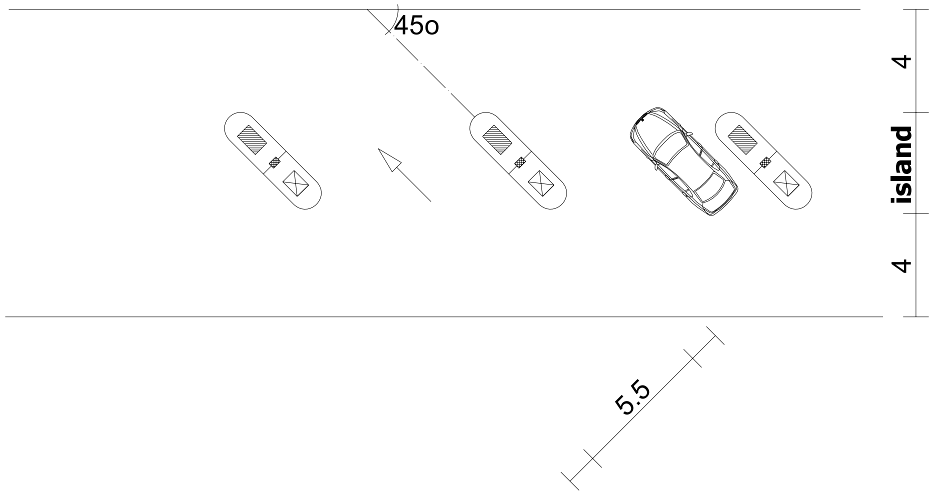


Figure 299: Minimum dimensions of traffic surfaces at petrol stations of diagonal access

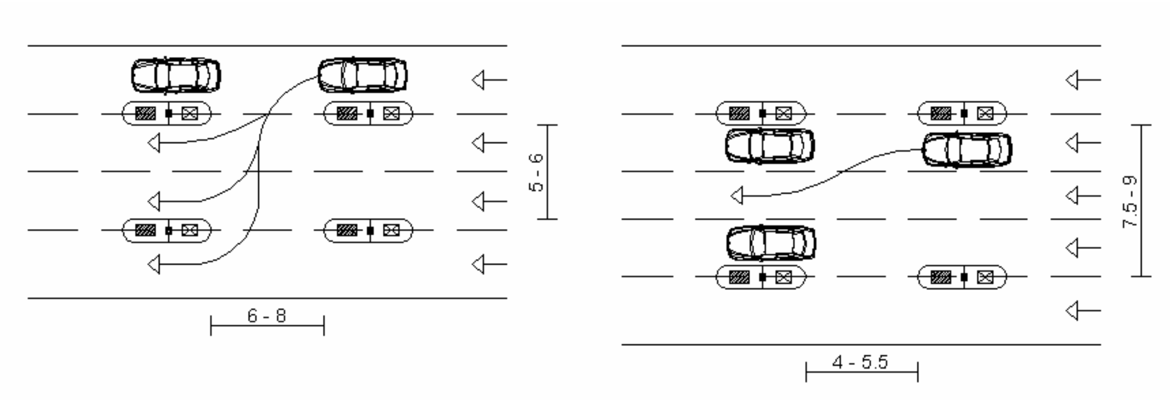


Figure 300: Traffic lane widths for intersection between islands with gas filling devices

11.6.2.3 Traffic flow joining zone

Traffic flow joining zone (Fig. 301) is a traffic surface, on which the traffic arriving from the fuel supply zone joins the main traffic flow to be connected to the main road. The length of the traffic flow joining zone depends on the number and position of the island with fuel filling devices, and on the additional petrol station activities.

As a rule, the traffic flow joining zone is shorter than the traffic flow splitting zone.

In the traffic flow joining zone vehicles should stay for the shortest time possible.

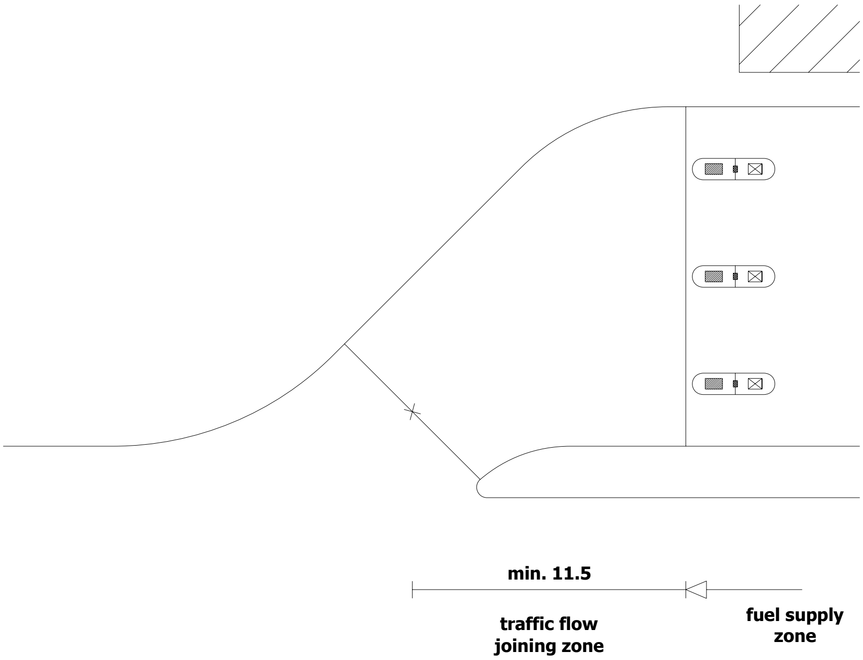


Figure 301: Traffic flow joining zone

11.7 ACCOMPANYING ACTIVITIES AT PETROL STATIONS

Each petrol station should generally comprise the following facilities:

- office with telephone for the personnel;
- minor magazine for consumable material (spare parts);
- toilet and a dressing room for the personnel;
- toilet with lavatory for customers (road users);
- shop of a wider assortment.

Nowadays almost every petrol station includes at least one of the following accompanying activities:

- shop of a wider assortment;
- car repair shop;
- car wash;
- pneumatic tyre repair shop;
- buffet,
- cash dispenser,
- telephone box.

11.8 SPECIAL PROVISIONS FOR PETROL STATION DESIGN

11.8.1 Distances from main communication

Between the main communication and petrol station traffic surfaces a dividing island shall be foreseen.

The minimum width of the dividing island amounts to 1.20 m, where no pedestrians can occur in the area considered, or 2.5 – 3.5 m, including a footway, to enable placing the traffic signs and public lighting posts.

The minimum length of the dividing island between the main communication and the petrol station traffic surfaces amounts to 16.0 m in condensed settlements, and 20.0 m out of settlements respectively.

At the edges of a dividing island planted with low growing vegetation 0.15 – 0.30 m high concrete or stone kerbs shall be foreseen at a distance of 0.25 or 0.50 m from the carriageway edge. In this way a physical separation of the petrol station traffic surfaces from the road, as well as the road drainage is ensured. Kerbs shall be placed 0.25 – 0.50 m from the right edge of the marginal strip or gutter.

The minimum distance of the fuel filling devices from the right outer edge of the main communication amounts to 5.0 m; the minimum distance from the outer carriageway edge shall be 3.0 m where the latter runs at the carriageway.

Underground tanks can be located at a minimum distance of 1.0 m from the road site edge, or 5.0 m from the right edge of the national road carriageway, on condition that stability of the carriageway and the road body respectively is ensured.

11.8.2 Connection to public road

The connection of a petrol station to the main communication shall be adjusted to the traffic arrangement and to the conditions of the existing road on the entire road section (Table 43).

When designing connections (points of access) it is reasonable to foresee the possibility of restoration or reconstruction of the main communication at the length concerned. The reconstruction or renewal of the main road can be carried out simultaneously with the construction of the connection (point of access), or subsequently, as agreed with the road authority.

During the petrol station connection design, a suitable traffic arrangement of the road shall be ensured as to prevent disturbance of the traffic, and jeopardizing the traffic safety on the main communication due to entering or leaving the petrol station.

A petrol station may be connected on a road, where the average vertical alignment fall of both road and connection amounts to $\leq$ 3.5 %, as well as on roads of ADT $<$ 1,500 vehicles/day, where the petrol station connection of $<$ 3.5 % of the vertical alignment fall is linked with the primary road of $\leq$ 5.0 (6.0) % of average fall of the vertical alignment.

A petrol station connection must not be foreseen in a horizontal curvature of bad sight distance, or in a convex vertical curvature of the road axis, where no additional left-turn traffic lane exists.

Table 43: Conditions of petrol station design

Road course	Entry to petrol station	Exit from petrol station	Distance between connection and adjacent crossroads
Out of settlement Vr $<$ 70 km/h ADT $<$ 5,000 veh./day	Adjacent crossroads or funnel of l = 20.0 – 30.0 m, w = 3.0 – 3.5 m	Connecting radius of Rr = 12.0 – 15.0 m, or combined curvature of 2:1:3	By the length of traffic arranging lane
Out of settlement Vr $>$ 70 km/h ADT $>$ 5,000 veh./h	Connecting radius of Rr = 12.0 – 15.0 m, or with additional lane l $>$ 30.0 m, w = 3.50 m	Connecting radius of Rr = 15.0 – 25 m, or with additional lane of l $>$ 45 m, w = 3.50 m	Total length of additional and arranging lane
In settlement Vr $\leq$ 50 km/h	Connecting radius of Rr = 12.0	Connecting radius of Rr =12.0 m	20.0 – 50.0 m
In settlement Vr $>$ 50 km/h	Connecting radius of Rr = 12.0 m with funnel of l = 15.0 – 20.0 m, w = 3.0 – 3.5 m	Connecting radius of Rr = 12.0 – 15.0 m, or combined curvature of 2:1:3	30.0 – 70.0 m

11.8.2.1 Vertical inflow and outflow

A vertical inflow and outflow can be foreseen on local roads and streets (in settlements) of secondary importance with a low ADT, in combination with two U-islands (Figs. 302 and 303).

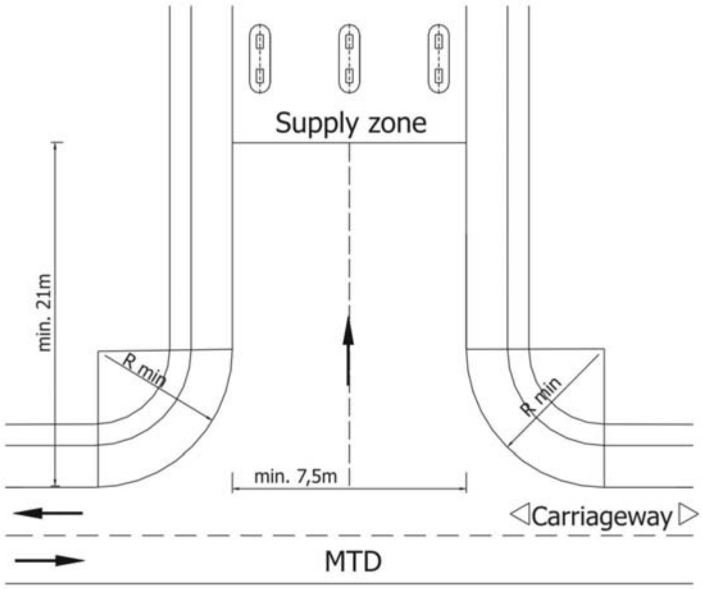


Figure 302: Vertical outflow

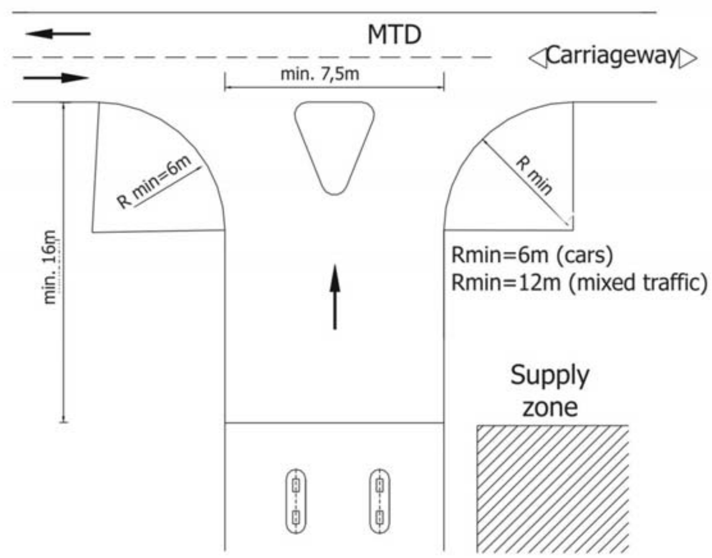


Figure 303: Vertical inflow

11.8.2.2 Diagonal inflow and outflow

A diagonal outflow can be foreseen on roads intended for mixed traffic where the ADT is considerably lower than 3,600 vehicles, and the admitted speed amounts to < 70 km/h, as well as at location where wedge-shaped outflow cannot be executed. The right edge of the footway where the outflow commences is shaped by a minimum radius of Rmin = 18.0 m (Fig. 304).

Figure 304: Diagonal inflow and outflow

11.8.2.3 Wedge-shaped inflow and outflow

A wedge-shaped inflow and outflow is used on roads intended for mixed traffic of ADT < 3,600, and admitted speed of < 70 km/h. The right kerb from the traffic flow direction runs to a curve shaped by Rmin = 12.0 m (Fig. 305).

Wedge-shaped inflow and outflow are preferential comparing to the diagonal ones.

Figure 305: Wedge-shaped inflow and outflow

11.8.2.4 Decelerating/accelerating lane

A decelerating lane (Fig. 306) is foreseen on main roads out of settlements, in settlements, on roads with both-sided kerbs, and on regional roads out of settlements, where the ADT amounts to > 3,600 vehicles/h. The outflow length shall be at least 60 m (Fig. 307).

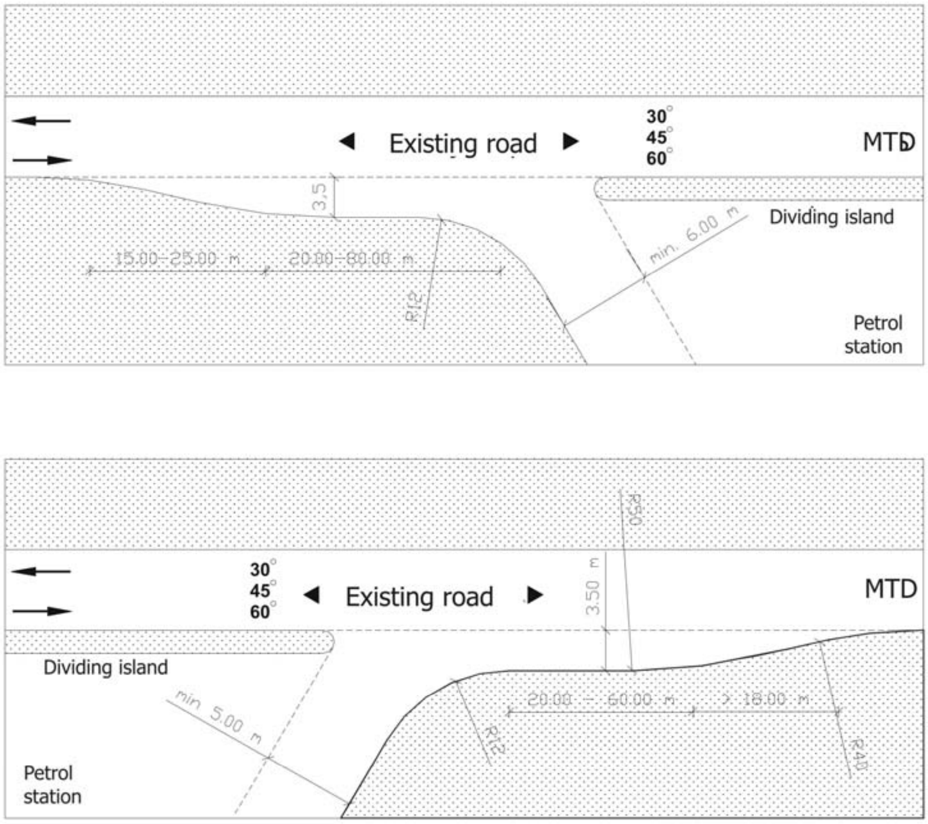


Figure 306: Decelerating/accelerating lane

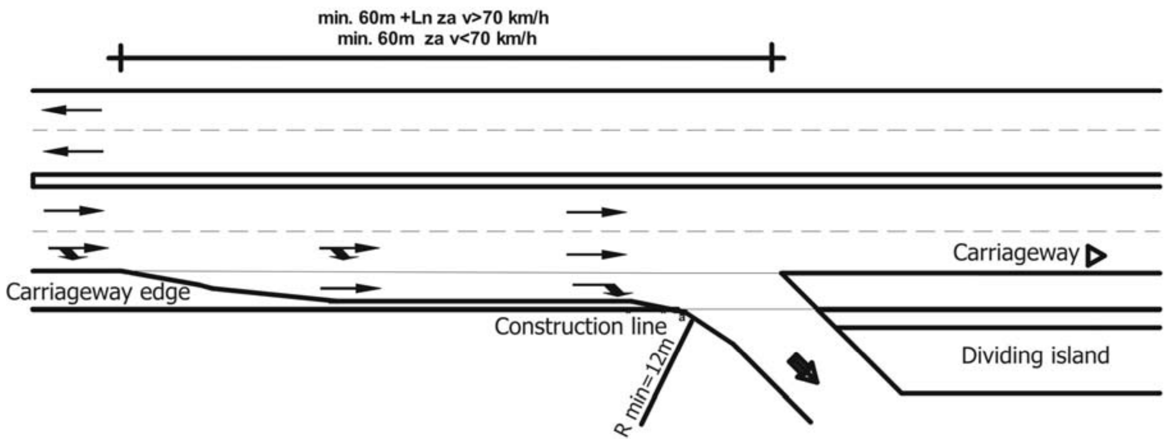


Figure 307: Inflow length

11.8.2.5 Left-turn lane

A left-turn lane is foreseen on main roads and regional roads intended for mixed traffic where the ADT amounts to > 3,600 vehicles at turning left from the main traffic flow to the petrol station traffic flow (Fig. 308).

The left-turn lane shall be 3.0 – 3.5 m wide. The minimum total length of the left-turn lane shall amount to 60 m at Vr < 70 km/h.

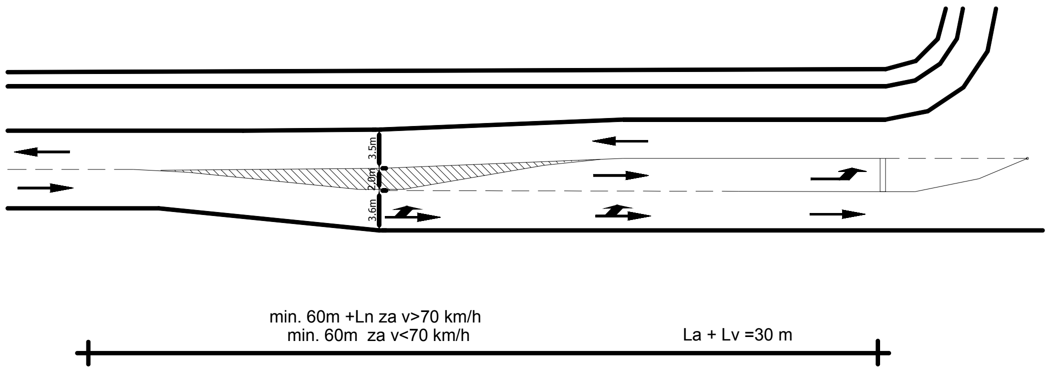


Figure 308: Left-turn lane

11.8.2.6 Minimum radii of turning curves

Minimum radii of turning curves determine traffic surfaces required for vehicle passing through the curvatures at petrol station entry and exit (Figs. 9.8 and 9.9). These are R1min, R2min, and R3min (at turning from the right-turn lane towards the petrol station at Vr = 10 – 30 km/h). For a wedge-shaped and parallel branch R2min = 12 m. The turning curve shall be designed with three circular bends at a ratio of R1 : R2 : R3 = 2 : 1 : 3, or R1 : R2 : R3 = 2.5 : 1 : 5.5.

11.8.2.7 Entry width

An entry is a place, where a driver makes a decision on which individual island with fuel filling devices to take, and where the incoming traffic flow splits in several flows. Therefore it is urgently necessary to ensure that at the time of making decision there are no obstacles to force the driver to change the movement direction. Petrol station entries shall enable a continuous traffic connection to the islands with fuel filling devices. The minimum entry width amounts to 6.0 m (Fig. 309).

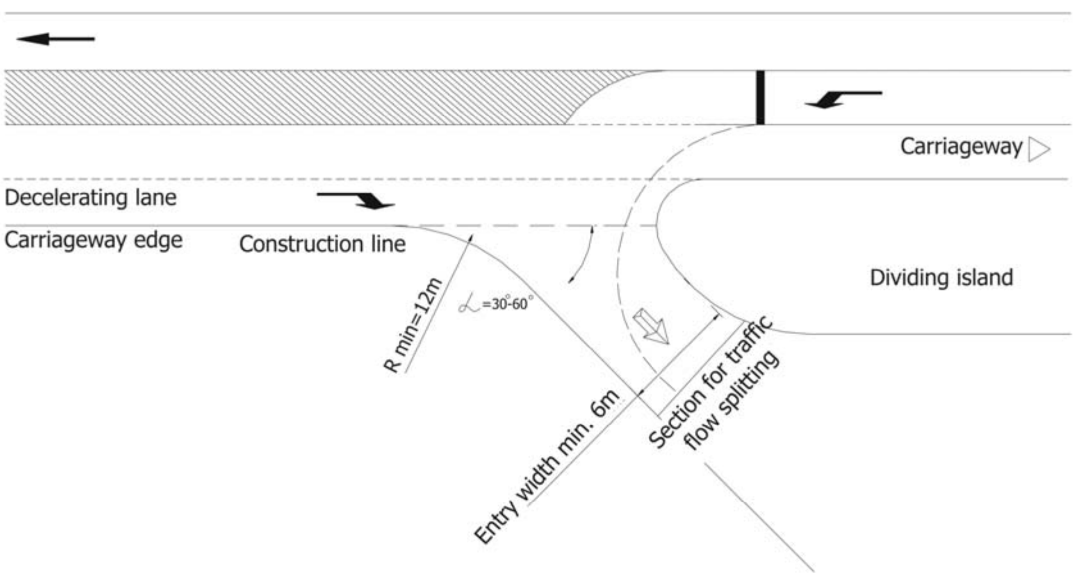


Figure 309: Minimum radii of turning curves – entry

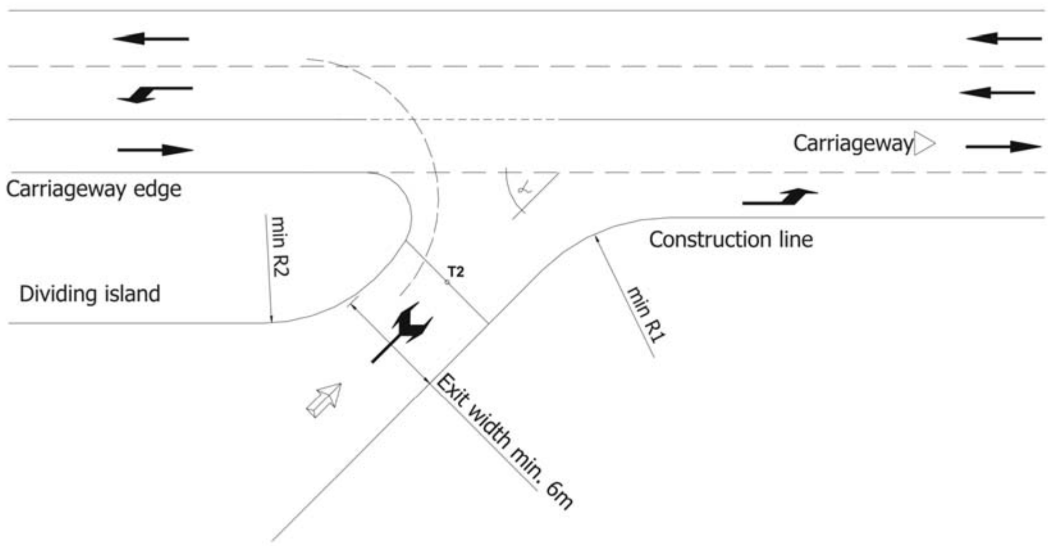


Figure 310: Minimum radii of tuding curves – exit

11.8.2.8 Exit width

The exit width shall enable a continuous traffic flow with regard to the main traffic flow into which the petrol station traffic flows in. The minimum exit width shall amount to 5.0 m.

11.8.3 Technical design of petrol station elements

11.8.3.1 Dividing islands

Between the main communication and the petrol station traffic surfaces a dividing island shall be foreseen. It shall meet the following requirements:

- its minimum width amounts to 1.20 m without a footway, or 2.5-3.5 m with a footway, which enables placing the traffic signs and public lighting posts;
- its minimum length shall be 16 m in condensed settlements, or 20 m out of settlements; the recommended length of a dividing island amounts to 30 m.

At the edges of a dividing island planted with low growing vegetation 0.15 – 0.30 m high concrete or stone kerbs shall be foreseen at a distance of 0.25 - 0.30 m from the carriageway edge. In this way a physical separation of the petrol station traffic surfaces from the road, as well as the road drainage is ensured.

Kerbs shall be placed at the right edge of the marginal strip or gutter, as well as at all the dividing islands, and islands with fuel filling devices.

No tanks, filling devices, and other similar equipment must be placed within the dividing island area.

11.8.3.2 Drainage of petrol station narrower area

All traffic surfaces shall be adequately drained as to prevent stagnation of different oils and precipitation water on the surface.

Drainage of petrol station traffic surfaces shall be so arranged as to prevent its impact on, and direct connection to the main communication drainage arrangement.

11.8.3.3 Pavement in entry and exit areas

The pavement at the petrol station entry and exit shall be, in a length of 15 m, of at least equal bearing capacity and quality, as the main communication pavement in the petrol station connecting area.

11.8.3.4 Fuel filling devices

The minimum distance of fuel filling devices from the right outer edge of the main communication amounts to 5.0 m.

Fuel filling devices shall be placed parallel one to another thus enabling optimum sight to the drivers.

The number of filling devices for individual fuel types is assessed empirically (or taking account of the information obtained from the existing petrol stations in the area considered), or from an approximate information on the poured out fuel quantity, amounting to 40 litres/vehicle per minute.

The following dimensions of islands with fuel filling devices are recommended (Fig. 311):

- 75 cm – minimum distance between a filling device and the jutting roof column axis,
- 75 cm – minimum distance between a filling device and other equipment elements on the island,
- 120 cm – distance between the column axis and the island edge,
- 75 cm – distance between the column axis and equipment elements on the island,
- 80 cm – maximum length of an equipment element on the island,
- 75 cm – distance of an equipment element from the island edge,
- 125 cm – standard width of an island with fuel filling device.

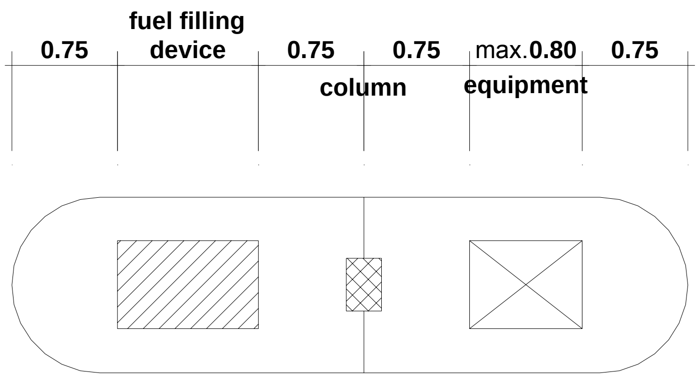


Figure 311: Island with fuel filling device

In addition to fuel filling devices each petrol station shall be equipped with a compressed air and water supplying device as well.

11.8.3.5 Tanks

Underground (buried) tanks shall be placed at least 1.0 m from the road site, or 5.0 m from the right edge of the main communication carriageway, on condition that the carriageway or road body stability is ensured. No tanks shall be placed in the dividing island area.

To meet the requirements related to both technological and ecological equipment, appropriate current regulations shall be considered. Double-wall underground tanks, a closed fuel filling system, systems for waste water separation, oil separators, and systems for a central fuel filling shall be used. Nowadays, all the aforementioned facilities represent standard equipment of a petrol station.

11.8.4 Parking places in petrol station areas

In the area of a petrol station (PS) parking places (PP) shall be foreseen. Their number depends on the accompanying activities at the particular petrol station. The following vaules are recommended:

- PS-personnel 2-5 PP
- catering personnel 1-2 PP / 3-4 employees
- PS-shop 2-4 PP/ 100 m2
- buffet 1-2 PP/ 5-8 places
- restaurant 1-2 PP/ 8-12 places
- car wash 3-5 PP
- car repair shop 4-6 PP

If necessary, additional parking places for buses and lorries can be foreseen in the petrol station catering area.

11.8.5 Traffic signs in petrol station areas

Road marking and vertical traffic signs represent a functional integrity enabling the most comfortable and the safest traffic.

The basis for a unified arrangement of traffic signs is provided by the regulation dealing with traffic signs, which shall be strictly considered.

As the traffic signs are an integral part of the road body and the petrol station, it shall be designed as thoroughly as other petrol station elements. Same as it applies to the petrol station, the traffic signs shall also be properly incorporated in the environment. It shall be suitably maintained not only for the traffic safety, but also for an adequate relation to the environment.

Both vertical and horizontal traffic signs shall be designed at petrol stations. It shall be so executed as to provide the traffic participants with a reliable conducting and a safe drive. Therefore it shall be so designed as to enable the road traffic participants to comprehend in a simple way the traffic sign importance, and to follow the traffic signs and the requirements imposed by the traffic signs respectively.

12 TOLL STATIONS

12.1 AREA OF APPLICATION

Toll stations (TS) are the facilities designed for the collection of toll, i.e. the fee levied for the use of roads. As a rule, they are installed on roads reserved for motor traffic.

TS are located on the roadway and cause a certain degree of traffic flow disturbance (hindered traffic flow) and significant negative environmental impacts (noise, exhaust gases, fuel consumption). For this purpose their location has to be selected carefully on a case by case basis, an environmental impact assessment has to be prepared (separately or in conjunction with the road) and the level of traffic (un-)safety resulting from toll stations being placed on the roadway has to be analysed. Toll stations should not be placed:

- in the areas of drinking water sources,
- (too)close to the densely built-up areas for peaceful residence (flats, hospitals, schools),
- in poorly ventilated areas,
- in the areas of sags or at major longitudinal falls of the grade (recommended: less than 2%),
- in the area of horizontal curves with such radius that the visibility berm on the right is above the roadway surface (sight distance at entry).

When these conditions cannot be complied with, the construction and/or other protective measures have to be provided separately for every case to enable normal operation of the toll station.

On account of (usually) large areas and relatively higher contamination of roadway waters, the system of drainage at toll stations has to be planned and designed separately from the rest of the road and obligatory cleaning of run-off waters provided.

12.2 TOLL SYSTEMS

European countries do not have a uniform toll system. Open and closed systems are used as well as the combination of both as different toll collection technologies are applied.

Subsequent transition from one toll system to another is possible, but it would entail high investment costs and additional construction interventions (demolition of the existing toll stations, changes of points of access and/or the construction of additional bridging facilities, etc.).

Toll systems are divided into:

- open toll system (OTS),
- closed toll system (CTS),
- supplemented open toll system (SOTS),
- supplemented closed toll system (SCTS).

12.2.1 Open toll system (OTS)

When the open toll system is used, the toll is collected as a vehicle passes the head entry - exit toll station (TSH). Toll is charged for a certain distance (travelled distance) irrespective of the location at which a vehicle entered or exited. Sections between individual points of access or crossroads located outside the TSH are not subject to toll.

The characteristics of the system are many points of access, free entry to and exit from them as well as shunpiking in order to avoid toll payment. For this reason the head toll stations are as a rule installed at such locations where shunpiking is impossible or at least difficult.

OTS enables that a certain section of the road is designed for a traffic function that is not typical of the tolled road and the vehicles within this section are not tolled. For this reason such system is as a rule introduced in the area where the road passes major towns and a section of the road is designed as a city bypass.

The advantages of the OTS are the following:

- less space used (less TSs),
- lower investment costs;
- lower toll collection expenses.

The weaknesses of the OTS are the following:

- vehicles stop within the travelled distance more often,
- the length is tolled irrespective of the travelled distance,
- traffic flows that do not pass the TSH are not tolled,
- lower inflows due to shunpiking,
- higher concentration of burdening of the environment.

12.2.2 Closed toll system (CTS)

Within the closed toll system the toll stations are located at points of access (TSP). The system functions based on the records at the entry station and charges the toll at the exit toll station. At the beginning and the end of the tolled section of the road a head toll station (TSH) is installed.

The system is characterised by points of access at approximately every 10 km (in rural) and 6 km (in suburban) areas as well as at all those locations with great traffic potential. If points of access are closer together, the expenses of TS construction and toll collection are as a rule much higher. It is often cheaper to construct an additional (service) road between two neighbouring points of access. Therefore the system is economically questionable in the area of large cities.

The advantages of the CTS are the following:

- passability of the entire road section without stopping or reducing speed,
- only the actually travelled way is tolled,
- all traffic flows on the entire length of the road are tolled,
- driving in the wrong direction is prevented.

The weaknesses of the CTS are the following:

- higher investment costs,
- higher toll collection expenses,
- poor usability in the areas with densely located points of access.

12.2.3 Supplemented open toll system (SOTS)

The supplemented open toll system is an open toll system upgraded by toll stations (TSP) installed on that two branches of the point of access that lead away from the nearby head toll station (TSH). A TSP should not be set up on a point of access which is directly in the middle of two consecutive TSHs. A TSP may be omitted as economically unjustified on those branches of a point of access where the traffic volume is very low.

This system involves a combination of the closed and open toll collection system, where all vehicles on the section are tolled, unless a TSP has been deliberately omitted on a particular branch of the point of access.

The aim of installing toll stations on branches of points of access is to prevent TSH shunpiking and to collect toll from traffic flows in the area between two TSHs which would otherwise not be tolled. The system enables subsequent installation of individual TSPs in the period of road operation where and when the traffic volume increases so much that toll collection becomes economically justified.

The advantages of the SOTS in comparison to the OTS:

- the toll loss resulting from TSH shunpiking decreases,

- the toll gain increases on account of toll charged on traffic flows that are not tolled within OTS,
- the costs borne by users are more equal,
- most users pay only for the actually travelled distance,
- reorganisation into a complete CTS would require demolition of the TSH (expenses),
- the possibility of gradual introduction of individual TSPs (economical aspect).

The weaknesses of the SOTS in comparison to the OTS:

- higher investment costs and additional collection costs.

12.2.4 Supplemented closed toll system (SCTS)

The supplemented closed toll system is an upgraded closed toll system in the event a TSH is not located at the beginning/end of the entire road section which is tolled within the scope of the CTS. TSP is installed on the branches of points of access located outside the closed toll system. They are located on those branches that lead away from the TSH.

Most often such system is introduced in the area of large cities, where the TSH is due to environmental (adverse impacts) and traffic (jams) reasons placed further away from densely built-up urban areas.

The advantages of the SOTS in comparison to the CTS:

- toll is charged on the traffic flows which would otherwise not be tolled,
- all vehicles in the area of a particular tolled road are tolled.

The weaknesses of the SOTS in comparison to the CTS:

- additional investment costs,
- additional toll collection expenses.

12.3 TYPES OF TOLL STATIONS

For a toll system the following is defined: toll station type, toll station location and the distance subject to toll at a particular TS. The location of a toll station is (usually) described by the name of the place where it is located.

The following types of toll stations are used:

- TSB toll station on the branch of the point of access for tolling individual traffic flows,
- TSP toll station on the point of access for tolling all flows on the branches of the point of access,
- TSH head toll station built across the roadway where all traffic flows on the road are tolled,
- ATS automatic toll stations combining the functions of all the above which are unmanned.

12.4 TRAFFIC DIMENSIONING OF A TS

Traffic events at toll stations are relatively complex, which is why in the majority of cases the most suitable analysis method is the computer simulation, which provides a wide range of entry traffic flow modelling and service characteristics modelling.

Analytical formulas from service theory may be used for dimensioning TS. This should not involve overly saturated condition when these formulas and/or method fails. Simulation methods are mandatory for the analysis of the existing (simple and more complex - in terms of dimensioning) TSs involving combined toll collection (electronic + manual).

In accordance with all insecurities related to the future traffic flows (e.g. the share of users of electronic toll collection on a single lane, the share of users of non-cash toll payments, changes in daily migrations, outflow rate caused by various economic and other factors), the connections between the entry traffic flow and the above-mentioned parameters are established for the estimate of average queuing time and length and the estimate of the vehicle queue after a 20-minute peak traffic flow simulation by means of the QTS software (Queuing Theory Software). The obtained results are approximate (planning values). It is assumed that the gaps between vehicles are distributed according to the exponential rule and the service time log normally.

The following criteria are used for dimensioning TSs and the introduction of additional toll stations in the event of an OTS:

- traffic volume criterion - capacity check,
- traffic stream criterion - queuing time criterion,
- queue length criterion.

In addition to the above stated criteria those specified below also have to be considered as potential locations are being selected:

- unification of the toll system,
- justness based on the principle "pay as much as you travel",
- feasibility in view of spatial conditions, the phase of motorway network construction and/or the phase of prepared spatial planning documentation.

12.4.1 Traffic volume criterion (capacity)

12.4.1.1 Types of lanes and capacity

Depending on theoretical capacity 4 types of toll lanes are defined:

- **A:** fast lane - intended for vehicles fitted with On Board Units - tag (for all categories): communication antenna + lifting barrier,
- **AB:** lane designed for all vehicles entering the road system: communication antenna + automatic ticket issuing machine - lifting barrier,
- **AD:** lane designed for all vehicles leaving the road system: communication antenna + automatic toll payment machine + lifting barrier Road Side Equipment – RSE
- **E:** computerised classic lane (electronic toll payment machine).

For each of the above the capacity expressed in PCE/h stated in Table 44 is applied:

Table 44: Basic capacity of automatic lanes

Lane type	Theoretic capacity [PCE/h]
A	800
AB	350
AD	90
E	200

12.4.1.2 Dimensioning of the number of lanes

The location of the toll station as well as the number and dimensions of lanes are estimated based on at least two-hour 10-minute count during established daily peak hours.

For an accurate estimate of the peak hours a traffic study has to be prepared and an analysis made about the influence of toll stations on the traffic flows in the planned period.

A rough estimate for analytical calculation or simulation-based calculation is made on the basis of a 20-minute peak hour traffic volume within the planned hour at the end of the planning period. The latter can be based on the AADT or on the assumption that 45% of the AADT is over in 5 hours in the case of a new construction on a new road. In the event of a new toll station on an existing road or for the analysis of the existing TS throughput the basis used is the hourly throughput according to the peak afternoon count. If a toll station can be located on an existing road, the traffic will decrease due to the outflow.

Thus, for every point of access or direction the estimate of the outflow share has to be provided. Taking into account the traffic outflow in a particular direction of the point of access, the hourly throughput in the base year is established and thus the planned hourly volume in the planned year is specified on the basis of the average annual increase in traffic volume or a traffic study. Taking into consideration the estimated share of the users of the automatic non-cash toll payment system, the planned hourly volumes are obtained for the calculation of classical E type lanes. For new constructions the peak hour factor of 0.8 is applied or, in the case of an existing road, the factor is estimated based on 10-minute two-hour count.

The number of toll lanes has a great impact on the possibility of establishing a toll station at a particular location. Problems arise mainly with respect to the existing points of access which are not constructed for toll collection, especially points of access built in difficult terrain conditions or in areas surrounded by buildings where upgrading is particularly demanding.

Thus obtained peak values (V) have to be checked against the capacity of the toll station (C) under the assumption that traffic flows on toll lanes are not interwoven. The criterion of traffic volume is expressed in terms of saturations X=V/C of lanes other than A type (fast toll lane). If the criterion is not met, the number of lanes has to be increased, the use of the automatic contact-free toll collection system stimulated in some other way or a toll station incorporating only classic E lanes introduced. At the end of the planning period the acceptable saturation level is from 0.9 to 1.0, when the traffic volume criterion has been met.

12.4.1.3 Capacities of classic toll stations without automatic toll collection lanes

Classic toll stations are dimensioned for the planning period until the transition to the electronic toll collection in free traffic flow or for 20 years.

The capacity analysis is made for traffic volumes in the planning year, which are based on the following assumptions:

- only classic E type lanes are taken into account indirectly,
- traffic on fast lanes is deducted from the total and also the number of fast lanes is deducted from the total number of lanes,
- directional distribution is defined (e.g. 60:40) to the benefit of the exit in the case of a CTS,
- 45% of traffic (AADT in the planning year) accounts for 5 hours,
- the capacity of classic lane at exit is 200 PCE/h,
- in the event of some maximum volumes a more unfavourable directional distribution is taken into account (70:30) and the percentage of fast lane users is halved (tourist peaks).

12.4.2 Queuing time criterion

Streaming of traffic flows through a toll station is checked by means of a 20-minute computer simulation under the following assumptions:

- every "server": toll booth, automatic toll payment machine, antenna for non-cash toll payment, etc. has its own lane for vehicle sorting,
- the sorting lanes are not interwoven.

The element for evaluating this criterion is defined, i.e. the queuing time of the last vehicle in a 20-minute simulation at the end of the planning period. The limit values of the queuing time and their respective acceptability are as follows:

- queuing time less than 2 minutes → acceptable,
- queuing time more than 2 min and less than 10 minutes →conditionally acceptable,
- queuing time more than 10 minutes → unacceptable.

In the last case the number of lanes has to be increased or the use of the automatic contact-free toll collection system additionally stimulated.

12.4.3 Queue length criterion

If in the planning period the criterion of traffic volume and the queuing time criterion are satisfied, the queue length criterion has to be checked as well. The criterion applies if in the relevant (peak) hour or after a 20-minute peak hour simulation a long queue forms on sorting lanes leading to the toll lanes. This applies especially if the queue extends to the exit lane of the motorway entry slip road or to the crossroads area in the case of the entry to the motorway. In this case every point of access has to be checked separately. If the criterion is not met, more toll lanes have to be designed or other measures taken to increase the throughput (e.g. the automatic non-cash toll collection system should be stimulated).

12.5 DIMENSIONS OF THE TOLL STATION CONSTRUCTION ELEMENTS

Dimensions of the cross section elements of a toll station are presented in Figure312, while the dimensions and the configuration of the toll plaza are given in Figure 313. The length of weaving in Figure 2 is not specifically determined, as it differs on a case by case basis (traffic volume, location). The length of weaving lanes is calculated using the HCM methodology in relation to the number of lanes and the maximum speed limit on the road leading to the toll station (in Figure 313 the length of weaving lanes is indicated by the term VARIES).

Depending on the selected type of station and the number of lanes the outer lane at every toll station has to be sufficiently wide to allow special transport.

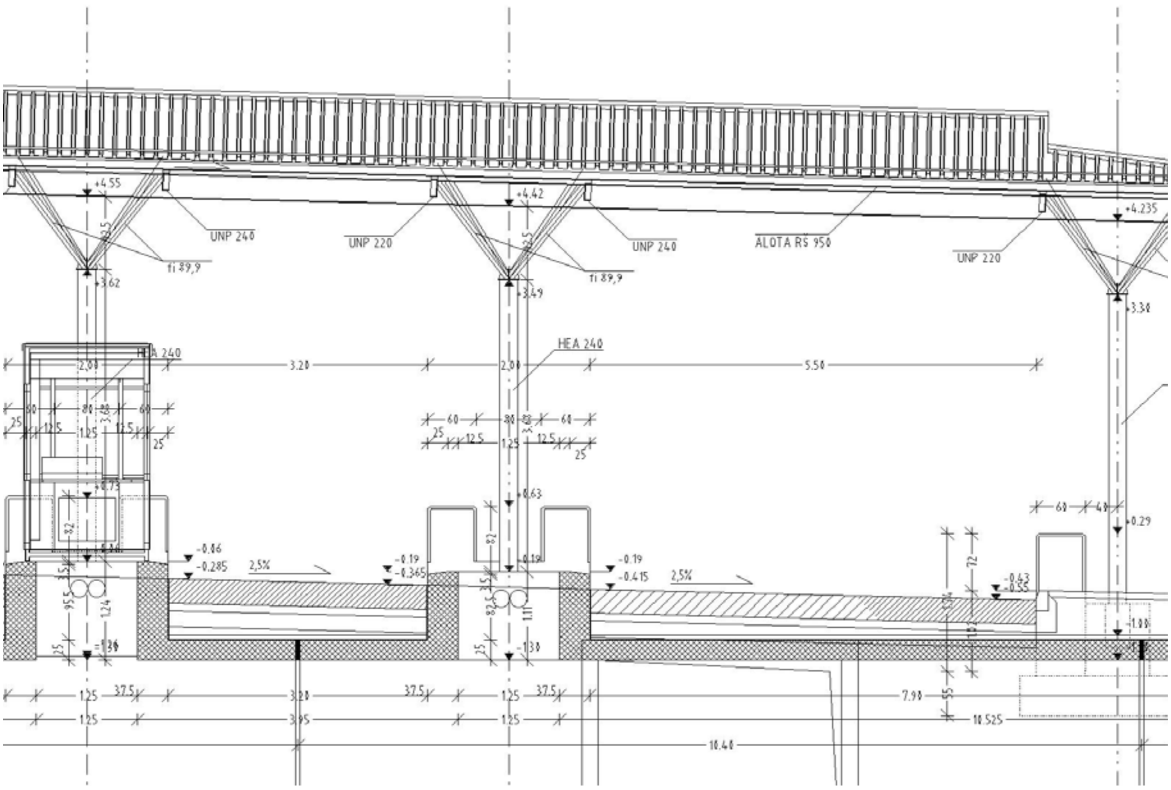


Figure 312: Cross section of a classic E type lane (left) and fast lane (right) designed also for special transport

At every toll station, with the exception of those on points of access to a road, an independent accessible road has to be designed and provided for intervention vehicles and staff as well as for toll station servicing. The elements of such road are not specifically prescribed, however, such road has to be constructed so as to be passable by the trucks of the public utility service.

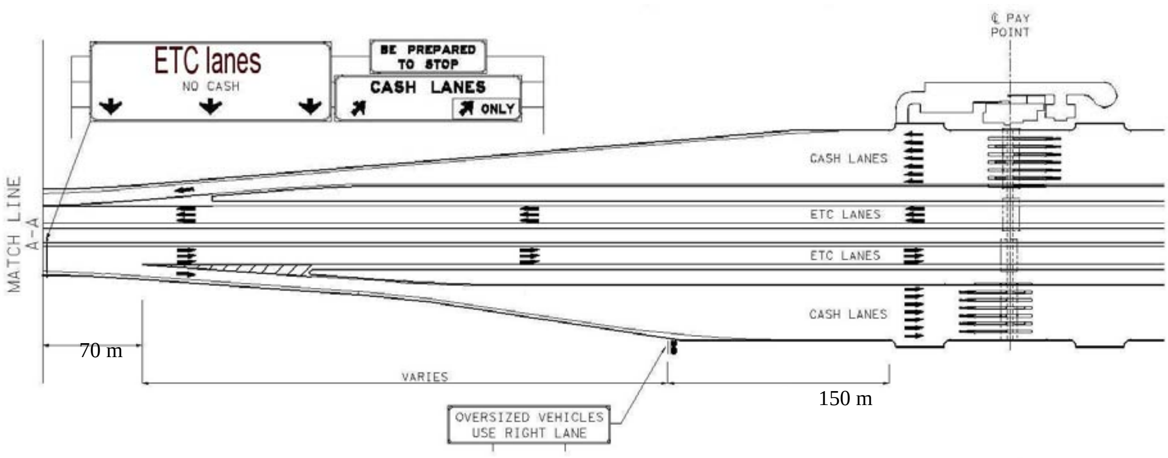


Figure 313: Toll plaza layout

The access road connects the toll station location with the rest of the public road network. The spatial design of such road (usually) conditions the design of the administrative part of the TS (administrative building, energy facility, gas tank, parking for employees).

13 ROAD MAINTENANCE FACILITIES

13.1 PODRUČJE PRIMJENE

Road maintenance plant carry out maintenance work to ensure that roads are continuously serviceable and safe for traffic under any weather conditions. When planning a road construction programme, a system of road maintenance plant must also be established to ensure successful road maintenance, serviceability and safety. The preparation of the road maintenance plant programme must take into account premises ensuring economical road maintenance and successful road safety.

13.2 ROAD MAINTENANCE PLANT SYSTEMS

Considering the varying technical characteristics of roads, motorways and other state roads, with the corresponding equipment necessary for road maintenance, and considering also the fact that motorways are organised as a separate road system, it is reasonable to provide two separate state road maintenance systems.

13.2.1 Motorway and expressway supervision and maintenance system

The motorway and expressway supervision and maintenance system is a unified system for the entire network of motorways and expressways. Supervision, information, and maintenance are organized in a unified way and managed centrally.

13.2.2 Trunk and regional road supervision and maintenance system

The trunk and regional road supervision and maintenance system is divided into several units, e.g. one for each region or part of a region. This system is not centrally governed and organised; however, the organization of supervision and inter-region notification systems must be coordinated. The state is responsible for oversight of the functioning of all these systems in all the units.

13.3 BASIC SYSETM MANAGEMENT ORGANIZATION

A system of road maintenance plant must be set up on the road network, forming the maintenance and supervision system for the entire road network. A road maintenance plant may, depending on the length or technical complexity of a road section, be augmented by an additional minor plant, subsidiary to the main plant for the road section in question. Plants for maintenance and supervision of traffic in longer tunnels are usually located next to such tunnels and their organization is adapted to the needs of interventions in tunnels; they may be referred to as tunnel plants.

From an organizational point of view, the entire system is managed from a central plant, which is one of the maintenance plants of the road network and is usually located near the centre of the road network. The central plant receives information about traffic conditions, weather conditions and any extraordinary circumstances on the roads from all supervision centres of the individual road maintenance plants from all parts of the road network.

Depending on the organization of work, road maintenance plants may be classified into:

- A central maintenance plant near the centre of the road network
- Road maintenance plants on individual road sections
- Subsidiary maintenance plants

Given that the motorway and highway supervision and maintenance system is unified for the entire road network, it has a single central maintenance plant near the centre of the motorway network, while other maintenance plants are located on individual road sections, with additional subsidiary plants where necessary due to the complexity of a section.

The trunk and regional road supervision and maintenance system is divided into units based on territories or regions. Each unit, covering a part of the entire trunk and regional road network, has a central plant and several maintenance and subsidiary plants, the latter being also known as "winter service points". However, exchange of information between different units or territories must be unified.

13.4 MAINTENANCE WORK

To ensure the continuous road serviceability and safety, the road maintenance plants carry out the following work:

- routine maintenance of the carriageway and the attendant surfaces (including minor carriageway repairs) and structures, as well as maintenance of signs and road furniture,
- winter service, consisting mainly of ploughing the snow and spreading of salt to ensure the roads are passable,
- daily routine inspection of the carriageway and structures,
- interventions in extraordinary circumstances, such as rush hours and traffic accidents,
- traffic guidance and supervision, carried out from control centres in road maintenance plants.

In addition to these works, the road plant also performs other maintenance works not directly related to road maintenance and supervision:

- Complete vehicle maintenance
- Equipment maintenance
- Road maintenance plants also have technically administrative tasks, such as:
- Issuing approvals and permits for works in the area of state roads, etc.

13.5 PLANING A ROAD MAINTENANCE PLANT SYSTEM

While planning a road construction programme, a system of road maintenance plants must also be established. Planning must take the existing maintenance plant network into account. The road maintenance plant programme must follow the guidelines for selecting the macro locations of road maintenance plants. Based on such guidelines, a study determines the entire system of road maintenance plants for the planned road network. This study is the technical foundation for determining the spatial components of the long-term national plan and the spatial aspects of the municipal planning acts. The study is also a basis for selecting the macrolocation of individual road maintenance plants on individual road sections.

13.5.1 Selecting the macrolocations of road plants

The following criteria are taken into account when planning a system of road maintenance plants and determining their macro locations:

- Length of road sections being maintained

Work technology limits the length of a section that can be maintained by a plant. The maximum acceptable length for the purpose of selecting plant macro locations will also depend on the type of roads.

- To ensure normal serviceability of a motorway in at most two hours during winter, the section should be no longer than 50 – 70 km, assuming a ploughing speed of 20-30 km/h and an optimal plant size. The routine maintenance regulations, requiring the road to be inspected three times each day, also limit the length to 50 km.

- For trunk and regional roads, a single plant may ensure normal serviceability for 150-250 km of roads.

The length of the roads controlled by a single plant also depends on the local climate conditions and the complexity of the route.

13.5.1.1 Climate conditions and meteorological phenomena:

Climate conditions are certainly the most important factor when designing a road maintenance plant network. The road plants must ensure continuous serviceability and safety of roads in any weather conditions.

A road section prone to adverse climate conditions should have a plant located at its centre.

Adverse climate conditions on a road include frequent and copious snowfall, a large number of days with low-temperature or frost, as well as strong and frequent winds.

13.5.1.2 The location of a plant or its subsidiary within the section being maintained

The road maintenance plant is usually located in the middle of the section which will be maintained by it.

The location of a road plant also depends on the technical complexity of the route; it should be located near the technically difficult part of the route, such as near tunnels, viaducts, bridges, or the part of the section with particularly adverse microclimate conditions.

To ensure the maintenance of a section in such technically difficult cases, an additional minor subsidiary plant may be established.

13.5.1.3 Traffic conditions

Areas with heavier traffic, such as urban areas, tourist areas or areas with heavy transit traffic, must also be taken into account when choosing plant locations.

In and near urban areas, tourist areas and areas with heavy traffic, more traffic supervision is needed. Heavier traffic also means more pollution, meaning that the road and the area next to it must be cleaned more frequently.

13.5.1.4 Proximity of settlements

To make the plant more easily accessible for its employees, it should be located reasonably close to settlements where the employees may live.

The location should also be influenced by the ability of the plant employees to reach their place of work, and by the possibility of cheaper or existing infrastructure.

13.6 SPATIAL PLACEMENT OF ROAD PLANT

While preparing the preliminary design of a road, the microlocation of the road maintenance plant must also be planned (its macrolocation having already been determined based on the plans for the entire maintenance plant system). The criteria listed below must be taken into account when determining the plant microlocation. The preliminary road design is the basis for the state or municipal location plans.

An extended preliminary design of the plant, including the utility installations connected to the proposed plant location, is sufficient as far as planning the road maintenance plant as part of a preliminary road design is concerned. To plan the preliminary plant design as a part of the preliminary road design and as a basis for location plans, it is advisable to understand, even at this early stage, all the factors influencing the size of a plant as well as its plans and its influence on the environment.

13.6.1 Determining the microlocation of road plants

When selecting the microlocation, the following criteria must be taken into account:

13.6.1.1 Proximity of access roads

The microlocation of a road plant is influenced by the proximity of access roads leading to the road section to be maintained. The plant must be located near the road section to be maintained, with the fastest possible access to the road, i.e. located near the access to the road being maintained.

13.6.1.2 Public utility installations

The availability of public utilities certainly also influences the selection of a plant location. The plant must be connected to all necessary utility installations.

The proximity of utility installations, as well as their capacity (as compared to the needs of the plant), must be taken into account. The plant will need to be connected to the power, gas, telecommunication, water, and sewage networks.

The provision of fuel may be carried out through a near-by petrol service station or directly at the plant.

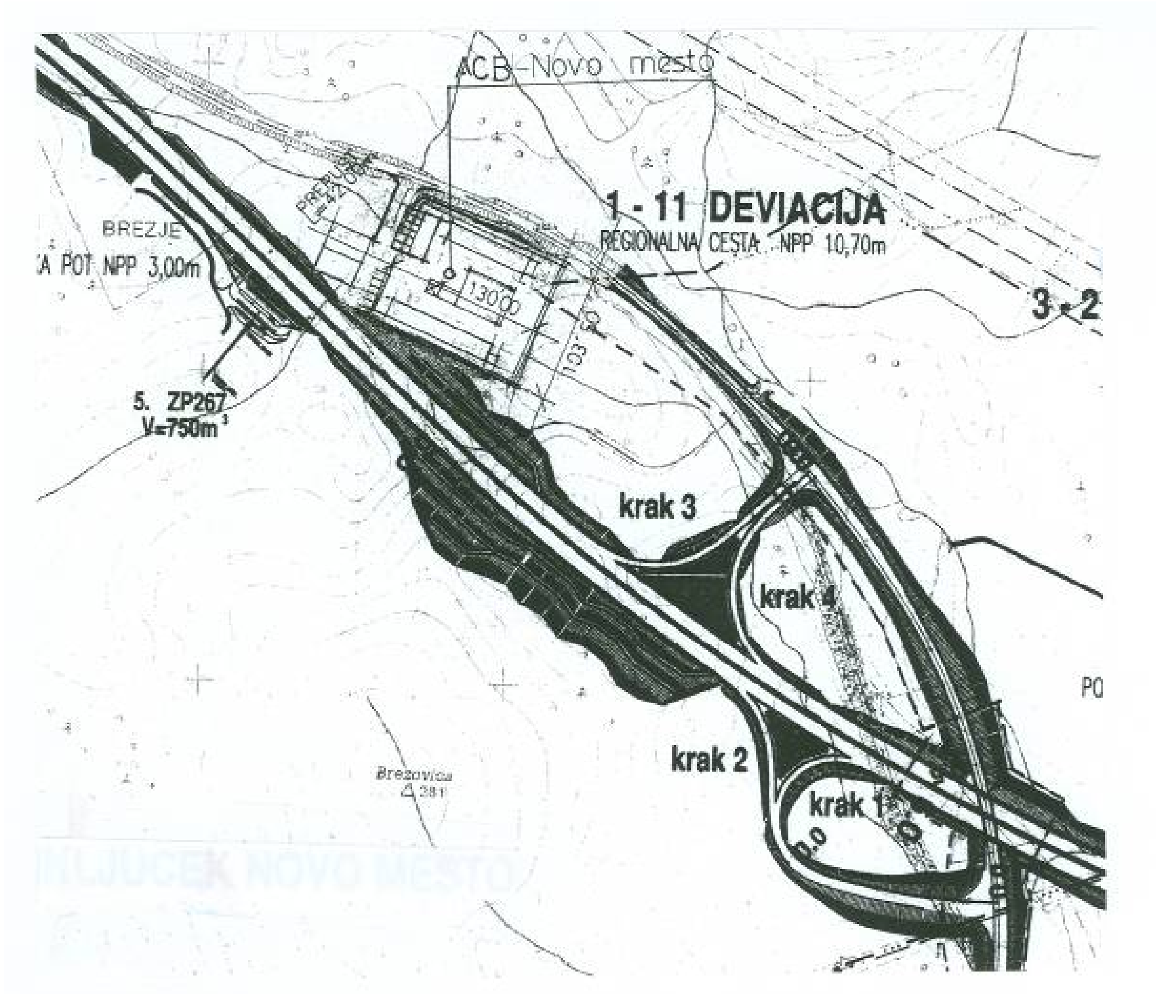


Figure 314

A motorway plant located near the access to the motorway. Its rectangular ground plan is the most efficient from the technological point of view and allows for easier placement of structures.

- Vulnerability of the area

The determination of a plant microlocation may also be influenced by the vulnerability of an area and related landscape and nature protection concerns, such as protected water areas, nature reserves, or protected cultural heritage.

13.6.1.3 The area of influence of a plant

Selecting the plant location must take into account the adjacent area where the environment is affected by the plant. The plant affects the environment in several ways, including noise and pollution of air and water.

13.6.1.4 Choice of terrain

A motorway plant with the attendant structures covers an area of 10-15 ha. Thus the area where the plant is to be constructed should be on mostly flat terrain.

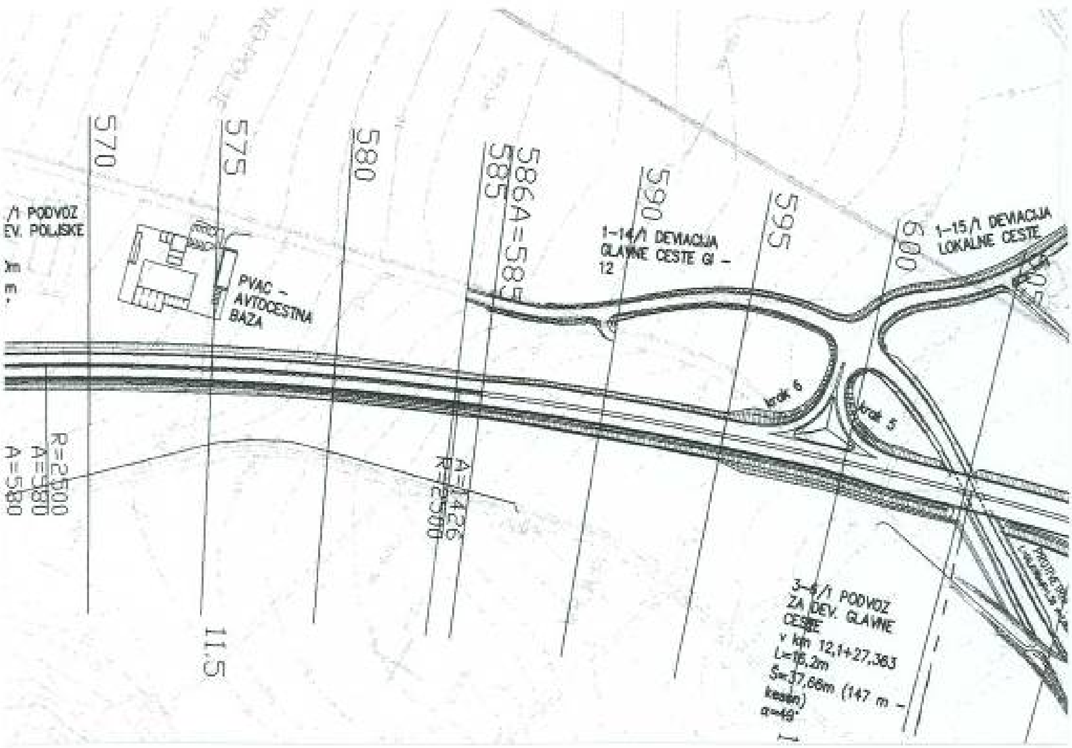


Figure 315

The subsidiary of a motorway plant has smaller structures and is organizationally subordinate to the main motorway plant. It is located near a technically challenging part of the expressway section.

13.6.1.5 Plant accessibility for the employees

For ease of access, the choice of location should also take into account the existing infrastructure or the possibility of introducing cheaper infrastructure.

Traffic connections or the possibility of using public transport to access the plant are important considerations when planning the plant location.

13.7 PLANNING THE MAINTENANCE PLANTS

Planning an individual road maintenance plant depends on several elements. Its size is based on the length and complexity of the road section as well as the microclimate conditions.

The main consideration when planning the size of a plant is to ensure successful winter service in normal winter circumstances, taking into account the location of the road section that will be maintained by the plant.

Given that the maintenance of trunk and regional roads has different requirements compared to the maintenance of motorways, and given that different roads have different technical characteristics and therefore required different maintenance equipment, plants must be distinguished based on which system they maintain:

- Road maintenance roads for trunk and regional roads
- Motorway maintenance roads

The size and complexity of the road systems also influence the size of the plants.

13.7.1 Road maintenance plants for trunk and regional roads

Considering that the maintenance of trunk and regional roads is divided by region or territory, each regional or territorial unit has its own centrally organized system for the supervision, notification, and maintenance of roads.

13.7.1.1 Determining the size of a road maintenance plant

The size of a road maintenance plant system for trunk and regional roads depends on the equipment requirements, which in turn depend on the length and complexity of the sections services by the plant, as well as on microclimate conditions. The typical length of trunk and regional road sections maintained by a single plant is 150-250 km, maintained by a centralized system for each territory or region.

Based on these considerations, the technical foundations for the planning of road maintenance structures and areas must be defined. The maintenance system for each territorial unit consists of:

- A central maintenance plant located near the centre of the road network for the territory or region under consideration
- Road maintenance plants for individual road sections
- Subsidiary plants

Technical considerations for the design of structures and areas:

- The spreading material required per km of maintained roads
- A list of motor equipment, machines and other equipment
- Staff

13.7.1.2 The required spreading material

- 100 tons of salt for each plant or subsidiary plant
- a plant with crushed stone for spreading (150 t of all fractions)

13.7.1.3 List of motor equipment, machines and other equipment

The necessary equipment for the territory under maintenance:

- The trunk and regional road supervision and maintenance system must have its own frequency and USW equipment, as well as GSM phones;
- The information system must be compatible with the customer's (as defined by the state),
- The number of self-propelled snow cutters and snow cutter attachments is defined based on the total number of roads in the maintained territory
- 1 compressor per territory
- 1 truck with an insulated tank for transporting hot asphalt mass per territory
- 1 road marking machine per territory

Equipment needed to maintain 400 km of roads:

- 1 asphalt cutter (as excavator attachment)

- 1 electric power generator
- 1 power tool
- 1 hydraulic pick hammer
- 1 set of portable traffic lights

Equipment needed to maintain 300 km of roads:

- 1 brine tank, with mixing facility
- 1 trailer with traffic signs for interventions; with standalone energy source

Equipment needed for the maintenance plant:

- 1 pickup truck with a 5-person cabin (with all equipment for the more difficult works), excluding inspection vehicles
- 1 vehicle carrying 9-12 tons
- 1 excavator
- 1 roller up to 1500 kg
- 1 automated spreader for wet salting, capacity of 1m3 per 20 km of road, with indicators of the amount of salt being spread
- 1 emulsion spreader
- 1 asphalt cutter
- 1 vibrating pounder
- 1 set of portable traffic lights
- 1 machine for washing the equipment
- 1 laser thermometer

Equipment needed to maintain 50 km of roads:

- 1 knapsack mower
- 1 motor saw
- 1 towed bulk spreader
- 1 inspection vehicle for the most urgent tasks, for up to 50 km of inspections per day

Equipment needed to maintain 25 km of roads:

- 1 snow plough

13.7.1.4 Staff

Staff needed for the territory under maintenance:

- The responsible maintenance chief

An emergency service must be organized for the whole territory:

- 1 person for the whole territory
- 1 intervention group, consisting of 2 workers, per 250-300 km of roads

Staff needed to maintain 400 km of roads:

2 technical administrators

- 1 accounting official

Staff needed for each maintenance plant:

- 1 maintenance unit chief
- 1 foreman
- 1 driver
- 1 engineer
- 1 mason

- 1 carpenter
- 1 equipment maintainer

Staff needed to maintain 50 km of roads:

- 1 road inspector per 50 km of daily road inspections

Staff needed to maintain 20 km of roads:

- 1 road maintainer

13.7.1.5 Structures and rooms

The following structures for work organization, supervision, management, and maintenance are planned in accordance with the technical bases for the design of structures and areas:

- Management and emergency duty areas
- Garages and other rooms for the required equipment
- Warehouses for road furniture and signs
- Warehouses for materials used for emergency road repairs
- A small mechanical workshop with a warehouse
- Covered warehouses or silos for salt

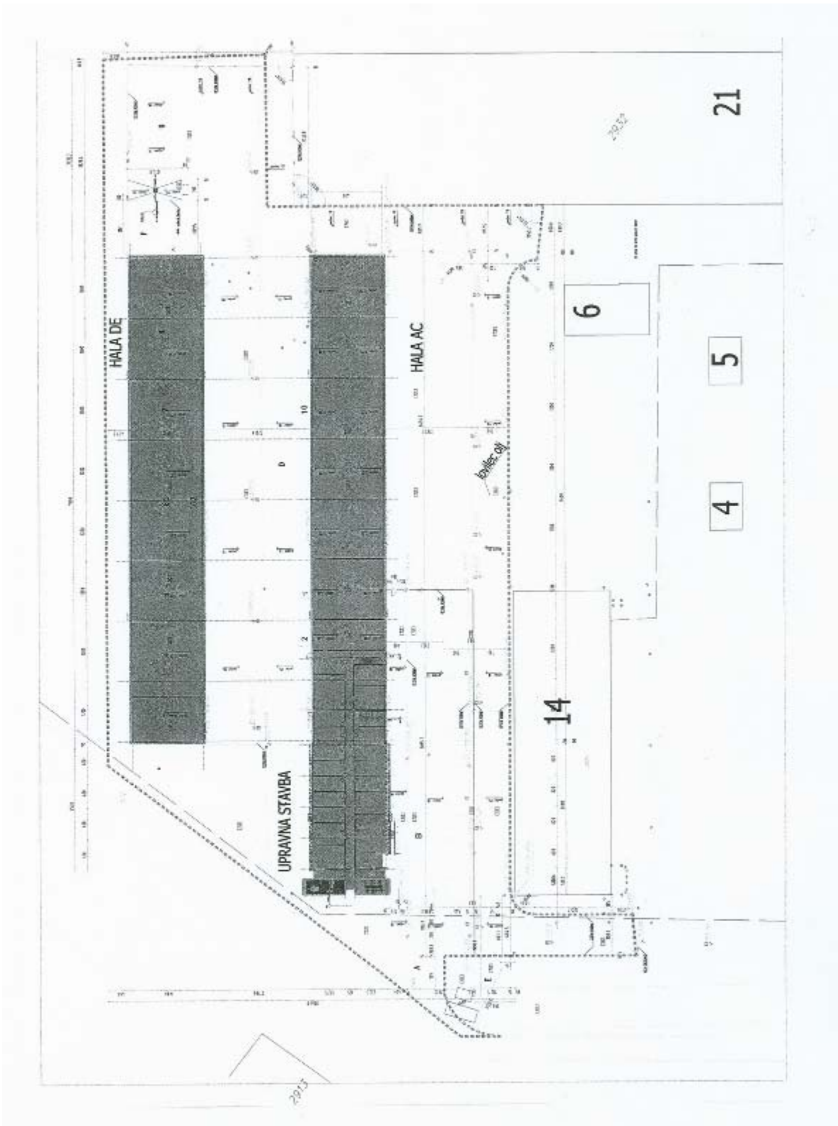


Figure 316: Maintenance Centre for 200 km of main and regional roads

Landscaping: A: Entry, B: Platform in front of the entrance, C: Green area, D: Handling areas between the eaves, E: Water pumping station, F: Wet salting;

Covered deposit sites: 1: Storage site for emulsion and cold asphalt, 2: Storage site for the paint and diluent, 3 and 4: Storage site for signs, barriers, marker posts, 5: Storage site for salt for local roads, 6.1: Storage site for spreading material, 6.2: Mixing, 7: Storage site for salt for state roads, 8: Covered areas, 9: Outdoor areas, 10: Eave for machinery;

A more detailed description of planning will be provided for the motorway maintenance plants below:

13.7.2 Motorway maintenance plants

13.7.2.1 Determining the size of a motorway maintenance plant

The size of a motorway maintenance plant depends on its equipment needs, which in turn depend on the length and complexity of the section under maintenance by the plant, as well as on the microclimate conditions. The typical length of the motorway section maintained by a single plant is 50-70 km. The most convenient plant shape is rectangular.

Based on this, the following can be prepared:

Technical considerations for the design of structures and areas:

- Consumption of spreading materials per km of maintained roads
- List of motor equipment, machines and other equipment
- Staff

13.7.2.2 Consumption of spreading materials per km of maintained roads

- The amount of salt reserves needed by the winter service must also be determined, usually as 60–70 % of the amount needed for one season.
- At the same time, the wet salting solution is also used.

13.7.2.3 List of motor equipment, machines, and other equipment

The list of motor equipment, machines, and other equipment for each maintenance plant is determined based on the length and complexity of the road section and on the microclimate conditions on the road section. Based on comparable criteria used in Austria, Germany, and Italy, the equipment of a typical road plant, maintaining approximately 50-70 km of motorways, should consist of the following:

VEHICLES:

- 6 heavy trucks for ploughing and spreading, allowing the attachment of front and side ploughs; also to be used for summer service,
- Unimogs with corresponding equipment and attachments for winter and summer service,
- light trucks
- vans
- cars
- lifting platform
- a tank truck
- a road sweeper

WINTER MECHANIZED EQUIPMENT:

- snow ploughs – front, reversible, five ploughs approx. 5 m long, two ploughs approx. 3.80 m long
- snow ploughs – 3 side ploughs
- side snow blowers – as attachments for a maintenance vehicle

- 1 frontal cutter
- salt spreading attachments for maintenance vehicles – four with a volume of 6 m^3, three with a volume of 4 m^3;

TRAILERS:

- trailer for transporting mechanized equipment
- trailer for mechanized equipment, with a light panel for closing a traffic lane
- trailer upgraded with a light panel for closing a traffic lane
- trailer upgraded with full graphic signs, attached to the road inspection vehicle
- full set of signs for setting up a road closure (A, B, and C)

SUMMER MECHANIZED EQUIPMENT

- mowers for slopes and shoulders, both powered and manual
- road sweeping and safety fence washing brushes
- earth augers
- clippers and wood chippers
- motor saw
- post pounder / post driver
- self-propelled shoulder cutter

OTHER MECHANIZED EQUIPMENT

- loader – excavator
- marking machine
- asphalt saw
- power generator – mobile and portable
- portable compressor
- fork lift

RADIO STATIONS

- base station of the mobile USW station
- 20 mobile stations
- handheld stations

OTHER EQUIPMENT

- 1 salt container (3000 l) with mixing equipment
- salt silo
- road surface salinometers
- installation testing instruments
- hygrometer
- infrared surface thermometer
- cable protection tester
- optical cable tester
- CaCl2 meter

13.7.2.4 Staff

The required work positions and number of employees are defined in coordination with the definition of mechanization and maintenance equipment requirements. An average motorway plant is expected to employ the following staff:

- 1 plant head
- 1 toll service head, if the toll collection service is organized as part of the motorway plant
- 1 head of maintenance
- 1 head of electric and mechanical equipment
- foremen
- 1 mechanical workshop head
- 1 mechanization head
- 1 workshop head
- group leaders
- 1 secretary
- 1 account official
- 1 salary official
- administrator
- 1 warehouse-keeper
- 1 cook
- 1 janitor
- 1 phone operator
- operators
- 1 cleaning-maid
- mechanics
- 1 locksmith
- 1 car electrician
- painters
- 6 road inspectors
- drivers – machinists
- 9 road maintainers
- electricians for power currents and low-tension currents

If the motorway plant is in charge of maintaining a tunnel and is therefore as it were a tunnel plant, the mechanization, equipment and staff requirements are supplemented to meet the needs of tunnel maintenance and supervision.

13.7.3 Planning of structures and external arrangements

The structures and external arrangements needed by the motorway plant must be planned:

- The motorway plant structure design is based on the technological requirements; the structures should have a simple and functional rectangular ground plan, in the sense of simple industrial objects, using the planned space rationally and meeting all appropriate regulations. The construction and finish of the structures should take the maintenance and renovation costs into account.
- The external arrangements are planned based on the technological needs of the plant.

13.7.3.1 Structures in a motorway plant:

- Administrative building with the traffic control and direction centre
- A building with large garages
- Building with smaller garages
- Spreading material plant
  - with a mixer and tank for wet salting
  - and a fuel pump
- Penthouse
- Flammable material plant
- Gas or light fuel oil tanks
- Biological sewage treatment plant or a connection to the sewage system

13.7.3.2 External arrangements:

- The plant design with the most suitable arrangement of the planned structures and areas in the plant area. Ideally, the ground plan of the plant should be rectangular.
- Motorway plant plateau arrangements:

- Plateau altitude regulation
- Areas within the fenced area:
  - Manipulative areas in front of buildings
  - Internal parking lots
  - Trash container area
  - Traffic arrangement
  - Fence
- Areas outside the fenced area:
  - External parking lots
  - Plant for damaged vehicles
- All utility lines within the fenced area of the plant
- Connection to utility lines
- Connection to the road network, access roads and access points
- Landscape and planting plan

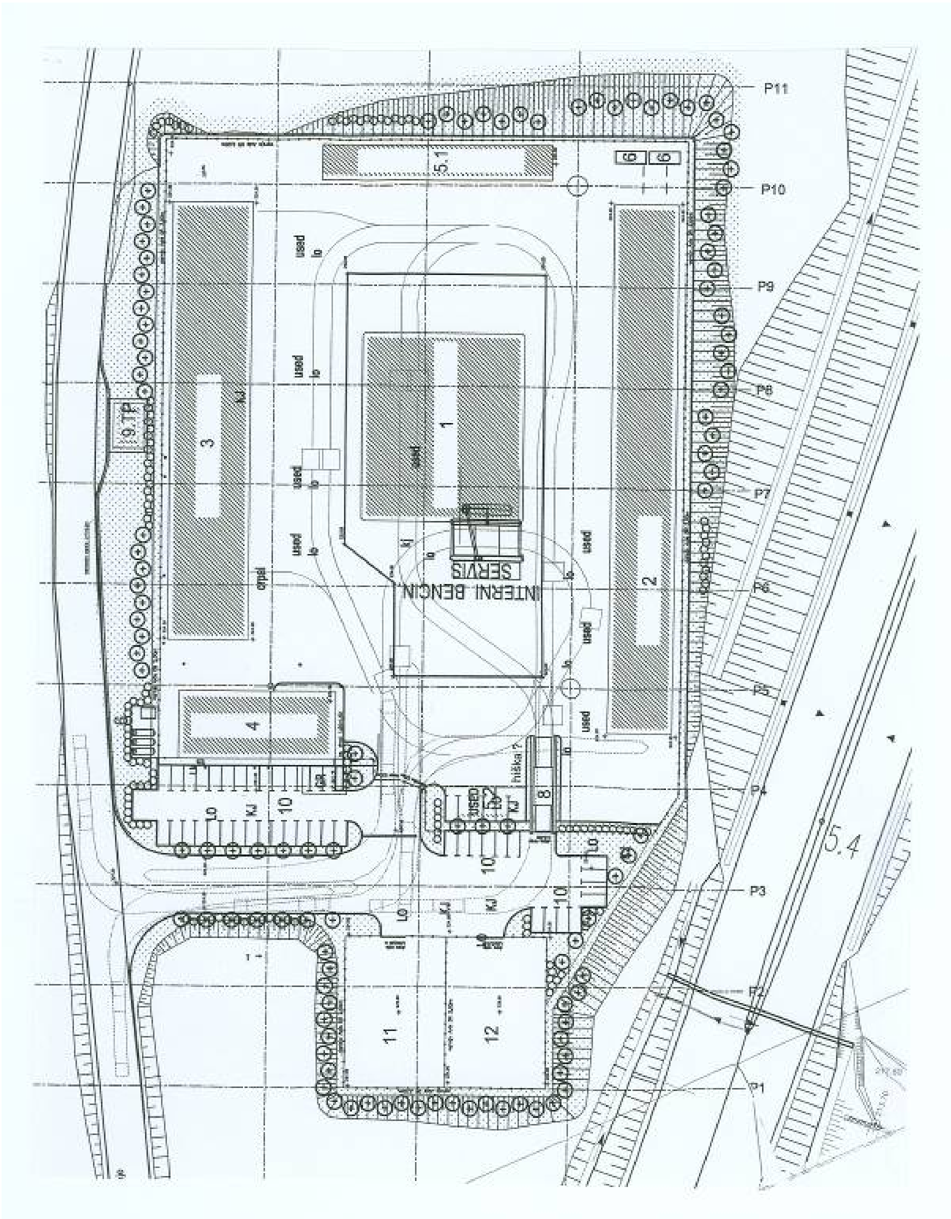


Figure 317: Motorway maintenance plant:

where:

1: spreading material plant, 2: small garages, 3: large garages, 4: administrative building, 5.1: covered ecological area, 5.2: covered parking lot, 6: flammable material plant, 8 – scales, 10 – external parking lot, 11 in 12: plants.

13.7.3.3 Required works, studies and elaborations

The following items must be prepared to produce the motorway plant design documentation:

- Geodetic image
- Geologic-geotechnical report

The design documents must include the requisite studies and elaborations:

- Fire safety study,
- Elaboration of the ecologic arrangements of the construction site,
- Safety plan,
- Cadastral elaboration:
- Setting-out layout

13.7.3.4 Design requirements

- The requirements of the current road location plans must be observed,
- Design documents must be coordinated with the motorway section design,
- Design documents must follow the current laws, regulations and standards.

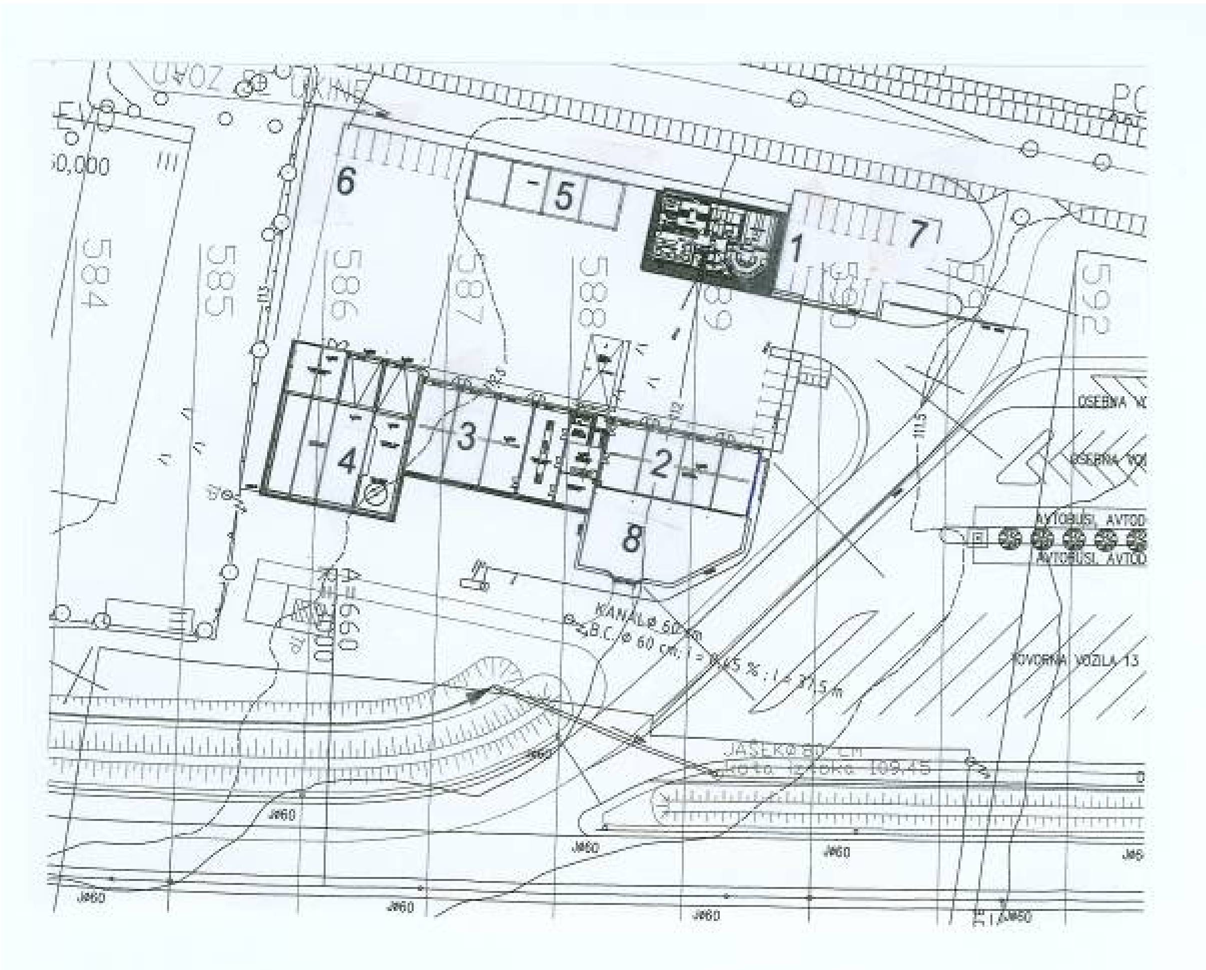


Figure 318: **A subsidiary motorway plant:**

where:

1: administrative building, 2: small garages, 3: large garages, 4: spreading material plant, 5: covered ecological area, internal parking lot, 7: external parking lot, 8: plant.

The plant is located in an area of frequent strong winds. Therefore the structures within the plant are facing away from the wind, to protect the entrances into the structures.

13.7.4 Buildings

13.7.4.1 Administrative building

The administrative building should contain rooms suitable given the number of employees and their work shifts. The arrangement of the rooms into floors takes the work process into account, allowing the drivers and team leaders to spend most of their time on the ground floor while the other administrative workers mostly work on the first floor.

The following rooms are planned:

GROUND FLOOR:

- Control centre with phone centre
- Electronics and UPS room
- Group leaders' office,
- Foremen's office,
- Tea kitchen (for the night shift),
- Canteen (common area for the workers),
- Kitchen (for food distribution)
- Change rooms
- Clothes-drying room
- Washing rooms
- Toilets M, F
- Cleaning supplies

FIRST FLOOR:

- Plant chief's office
- Secretaries' offices
- Accounting office
- Office of the maintenance head
- Office of the head of electric and mechanical equipment and the mechanization head
- Conference room
- Administrative room
- Salary office
- Archive
- Copying room and storage of office supplies
- Toilets M, F
- Cleaning supplies

ATTIC

- Air conditioner engine room

The CONTROL CENTRE must be planned to control and guide the motorway traffic as well as to control the motorway plant itself. The plant control centre collects data from the entire motorway section and from the motorway plant.

The motorway systems to which the control centre is connected may include the following:

- energy devices,
- emergency calls,
- interceptor pit control,
- motorway traffic control and direction,
- resting area supervision,
- changeable informational signs,
- weather stations,
- information transfer;

The motorway plant systems to which the control centre is connected may include the following:

- video surveillance of the motorway plant,
- motorway plant alarms,
- maintainers' wireless connections,
- telephony, telecommunications;

The plant control centre collects information from the entire route.

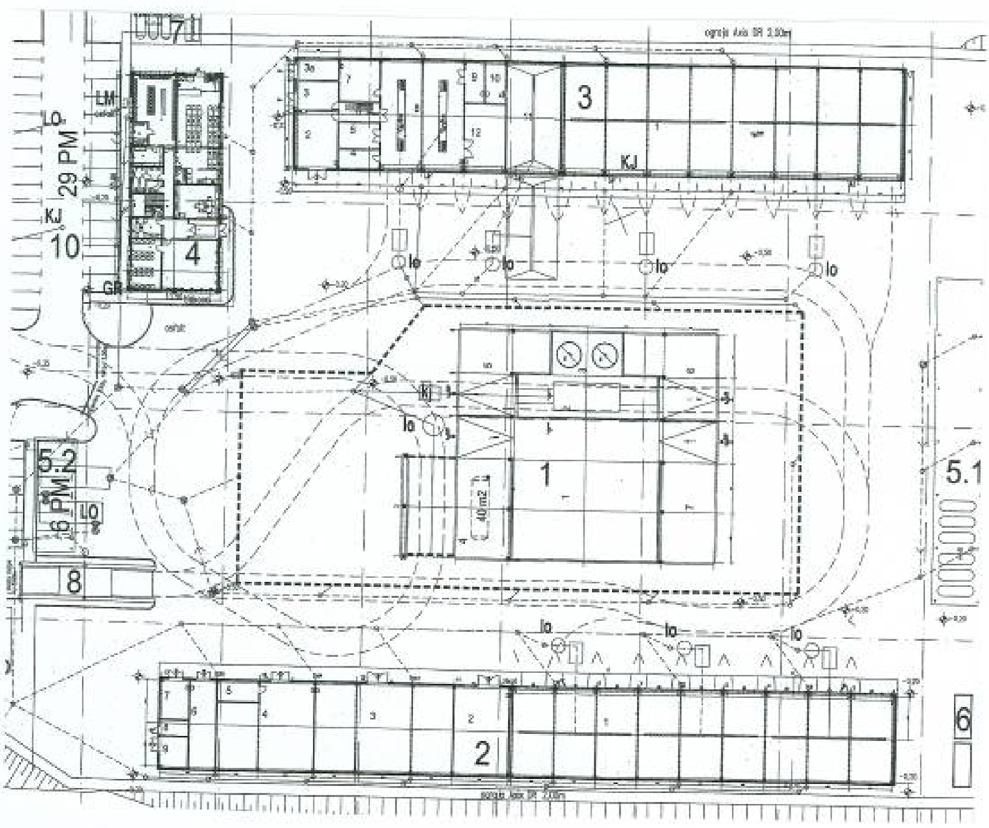


Figure 319: the structures of a motorway plant, with the room arrangement as numbered in the text.

13.7.4.2 The large garages building

The large garages building should be designed as a largely ground-level building, similar to simple industrial objects, each unit covering an area of 6 m x 15 m. This size allows ploughs to be parked along the back wall, and also enables a vehicle to enter and park while a motorway plough is attached to it. The clearance height to the girders should be approx. 5.30 m. The number of units and thus the size of the building depend on the mechanization, equipment and activities planned for the building. The construction and finish should take the renovation and maintenance costs into account. The roof (a suitable primary truss) should extend above the entrances into the garages. The installations, heating and ventilation should be based on the technological requirements of the individual rooms.

The following rooms are part of the large garages building:

- Garages for heavy trucks and their attachments - 1
- Car wash, including -11
- An external washing area
- Car wash machinery room -10
- Locksmith's workshop with adjoining warehouse -12
- Compressor station - 9
- Mechanical workshop - 8
- Car electrician's workshop - 7
- Warehouse for the mechanical workshop - 5
- Workshop chief's office - 4
- Electrical workshop for power current work - 2
- Diesel power generator room - 3, 3a
- Electrical workshop for telecommunications, with adjoining warehouse - on the first floor
- Toilets - on the first floor
- Boiler room - on the first floor

13.7.4.3 Small garages building

The small garages building should be planned as a ground-floor building, with units of 6 m x 11 m or 4 m x 11 m. This size allows ploughs to be placed along the back wall and enables a Unimog with a snow plough to enter and park. The clearance height to the girders should be approx. 4.60 m. The number of units and the size of the building depend on the mechanization, equipment and activities planned for the building. The construction and finish of the building should take the maintenance and renovation costs into account. The roof (a suitable primary truss) should extend for approx. 4 m above the entrances into the structure, the clearance height below the jutting part of the roof should be around 4,60 m. The doors of the building rooms should be selected based on the function and needs of the individual rooms.

The installations, heating and ventilation should be based on the technological requirements of the individual rooms.

The small garages building should contain the following rooms:

- Garages for light trucks, working attachments and sign trailers -1
- Warehouse of signs in use - 3
- Warehouse of new signs - 2
- Central warehouse for the entire motorway plant - 4
- Warehouse-keeper's office - 5
- Tool store - 6
- Battery station -7,8
- Energy rooms - 9

13.7.4.4 Spreading material warehouse

The design of the spreading material warehouse should take into account the required amounts of spreading materials, the size of the wet salting tank with its mixing device, as well as the required loading and access ramps. The spreading material warehouse should be designed as a ground-floor building with two access ramps. The construction and finish of the building should take the maintenance and renovation costs into account. The roof of the building should be made of wood and extend above the fuel pump and the external covered warehouses. The supply of installations to the individual rooms of the building should be based on the technological requirements of the rooms and devices in question.

The object is intended to house the following rooms and devices:

- A salt warehouse (1) large enough for the required amount of salt, which averages 60-70 % of the amount needed for the winter service, usually around 750–800 t.
- A room for the wet salting solution mixer (3)
- The room must be designed for the solution mixer and the wet salting solution tank.
- Loading ramp -2
- The ramp for loading salt onto trucks and for pumping the wet salting solution must allow access by a truck with an attachment (a plough), as well as access for wet salting. The ramp inclination should be appropriate for ploughs.
- Fuel pump -4
- The fuel pump is located next to the spreading material warehouse.
- External covered warehouses - 5, 6, 7

13.7.4.5 Salt silo

The salt silo should be located either within the maintenance plant or elsewhere in the area of the road section being maintained, thus enabling the plant to resupply with salt from within the road section itself.

13.7.4.6 Penthouse

A metal projecting roof should be planned, below which the service vehicles, personal cars and vans (according to the list) will be parked.

13.7.4.7 Flammable material plant

The size of the flammable material plant should be appropriate given the amount of the materials to be stored and the rates of supply and consumption.

13.7.4.8 Gas or oil tanks or gas pipeline connection

The heating of the motorway plant requires a sufficient amount of LPG or oil, or alternatively a connection to a gas pipeline.

13.7.4.9 Connection to the sewage system or a biological sewage treatment plant

The plant sewage system should be connected to an external sewage system. If this is not feasible, a sewage treatment facility should be planned, allowing the plant sewage to be treated and subsequently released into a nearby river.

13.7.4.10 Equipment design

INTERNAL BUILDING EQUIPMENT

All internal equipment must be planned, including all necessary movable items: furniture (desks, chairs, cabinets), kitchen equipment, special equipment (computers, phones, faxes), office supplies, workshop equipment (machines, tools, with detailed descriptions), external equipment.

MECHANIZATION; EQUIPMENT; SIGNS AND WORKSHOP EQUIPMENT

Detailed descriptions must be prepared for all mechanization, equipment and signs.

EXTERNAL ARRANGEMENT

The design of the external arrangement must be based on the technological requirements and the spatial acts.

While designing the external arrangement, all design solutions must be coordinated with the existing building designs and the current state of the site.

13.7.4.11 Plant design

Based on the technological requirements, the basic plant design should be an optimal solution of the spatial arrangement of the proposed buildings and areas.

The arrangement of buildings and the distances between them should take into account the turning radii of vehicles with attachments (ploughs, spreaders ...) and the manipulation of vehicles between the various buildings or manipulation areas.

13.7.4.12 Plateau

ALTITUDE REGULATION OF THE PLATEAU:
Plateau design must include the altitude regulation of the plateau, taking into account the hydraulic considerations, water management conditions, as well as geologic and hydrologic studies and other areas of expertise.

AREAS: within the fenced area of the plant:

- Manipulative areas

Manipulative areas between buildings must be designed based on the technical requirements of heavy and light trucks with attachments (ploughs, spreaders – turning radii), requirements of trailer trucks used to supply salt, and the existing experience concerning the design of such areas:

- in front of the large garages building, a clear manipulative area 22 m wide must be provided,
- in front of the small garages building, a clear manipulative area 17.5 m wide must be provided,
- in front of the spreading material warehouse, a manipulative area must be provided for the supplying of salt by trailer trucks; the projected width is 30 m but must be verified by drawing the trailer's path on a ground plan. the manipulative requirements of heavy trucks with attachments must also be considered.
- curbs should separate paved surfaces from lawns.
- Internal parking lots

A covered area within the fenced area of the plant should be provided for parking of service vehicles (cars and vans).

- Trash container area
- Damaged vehicles plant

Within the fenced area of the maintenance plant, an area for damaged vehicles should be planned. Such vehicles will be brought from the road section and temporarily stored on the plant.

- Ecological area

If possible given the spatial conditions, an area for selection of special types of waste, such as car tires, iron and other metals, etc.

- Traffic arrangements

The plant design should also include the traffic arrangements and road furniture within the plant. If possible, one-way driving should be enabled.

- Fence:

The motorway plant is surrounded by a wire fence approx. 2 m tall, with barrier gates on the exits.

The following areas are to be planned outside the fenced area of the plant:

- External parking lot:

External parking areas for employees and visitors should be planned in front of the entrance to the fenced area of the plant. The size of the parking lot should take the largest employee shift into account.

- Landscaping and planting design

the area around the base should be planted to reduce its visual impact. within the fenced area, there will be only minimal planting, since the required manipulative areas leave almost no unused space.

- distribution of utility lines around the plateau

the utility connections between the plant buildings must be planned: power lines, telecommunication lines and cable pipes, water supply, hydrant network, sewage.

13.7.4.13 Utility lines

Connections to all necessary utilities should be planned.

- Power
- Gas supply – pipeline (either connected to the gas network or to a local gas or oil tank).
- Telecommunications
- Cable pipes
- Water supply
- Sewage system or sewage treatment plant

13.7.4.14 Connection to the road network

Access to the plant, an access road and a connection to the existing road must be planned. A suitable traffic arrangement for access to the plant from the existing road should also be planned.

13.7.5 Planning the machine installations

13.7.5.1 Infrastructure – external connections and devices

13.7.5.1.1 Water supply

A water supply is arranged via a combined water meter and connected to the public water supply. The water is the distributed as drinking and sanitary water for the buildings, technological water in the buildings and on the plateau, and to the wet hydrant network.

13.7.5.1.2 Sewage

Several separate systems are implemented. Fecal sewage is directed into an on-site biological sewage treatment facility. Precipitation water from the plateau and ground water from the buildings is to be directed to an external collecting tank via sand settling basins and grease traps. Attention should be paid to the floodwater level and its effect on the sewage system.

13.7.5.1.3 Distribution of gas LPG (liquefied petroleum gas) or NG (natural gas)]

Gas is distributed from a common gas station or a gas pipeline network connection to the individual buildings and terminates in a gas shutoff valve in a wall-mounted box. Below carriageways, gas pipes must be adequately protected to withstand the pressure of vehicles. Gas installations in the buildings are based on steel gas pipes and follow the gas installation regulations.

13.7.5.1.4 Gas station - LPG

Our discussion will focus on the use of LPG, as this is the most common energy source in the plants designed so far. LPG tanks should be below ground level, thereby avoiding the need for gas evaporators. The amount of propane-butane gas should suffice for a total 30 day consumption. The gas station should be built in accordance with the LPG gas station regulations, equipped with necessary armatures and two-line, two-level gas pressure regulation 17 bar - 1 bar - 50 mbar.

13.7.5.1.5 Compressed air distribution

The distribution of compressed air proceeds from a common compressor station to the individual buildings. It is based on pre-insulated steel pipes with plastic coating. The pipes should be buried underground and be able to support the pressures on the plateau. The distribution of compressed air within the buildings should be coordinated with the technology in the individual buildings.

13.7.5.1.6 External distribution of heating water and sanitary hot water

The distribution of heating water and sanitary hot water should be based on steel pipes leading from a common boiler room in the garages to the administrative building. The implementation may be based either on pre-insulated pipes with plastic coating, to be buried directly into the ground, or in a reinforced-concrete canal, which however must meet all installation requirements and plateau pressures.

13.7.5.2 The administrative building

13.7.5.2.1 Gas boiler room for the administrative building and the large garages

The area and equipment of the gas boiler room must meet the LPG regulations and the requirements from the Fire Safety Study and the Work Safety Elaboration. The boiler should include an atmospheric gas burner and meet the heating requirements of the administrative buildings and radiator heating for the large garages. The boiler room contains all security and regulation devices, as well as pumps with distributors and mixers for the individual branches (consumers). Sanitary hot water should be prepared by an atmospheric gas-fired boiler with an attached hot-water accumulator of a suitable size. Chimneys of suitable width and height should be agreed upon with the architect. The boiler room should be aired naturally. To prevent the danger of freezing of individual elements of the devices and installations in case of a heating malfunction, suitable protection should be implemented, or the problem should be addressed by the operating instructions.

13.7.5.2.2 Cooling aggregate

For the purposes of air cooling and fan convectors, two cooling aggregates providing water at the temperature of $7/12^0$ C should be installed in the attic of a building. There should be separate aggregates for the convectors and for the purposes of ventilation. The cooling aggregates should be of the compressor type.

13.7.5.2.3 Heating of the building

The rooms in the administrative building are heated by radiators and by fan convectors. The heating system is a closed two-pipe pump system at 80/60 °C. The pipes should be installed in a double ceiling, made of copper and adequately insulated. The pipe system should be designed so as to allow the ground floor and the first floor to operate independently.

Fan convectors fit a four-pipe circulating air system, and are wall-mounted below windows. Radiator or convector heating completely covers the transmission losses, while the ventilation losses are covered by warm-air ventilation (during winter) or cooling (in the summer) – see the chapter on VENTILATING SYSTEMS.

Temperature regulation is both local and centralized from the boiler room, depending on the external temperature.

13.7.5.2.4 Cooling the building

During the summer, the administrative building rooms equipped with fan convectors are being cooled. The cooling system is a two-pipe 7/12°C system. The pipes are located in a double ceiling, made of copper and adequately insulated. The electronics and UPS rooms are cooled by standalone SPLIT cooling systems.

13.7.5.2.5 Ventilation systems in the building

- Control centre, conference room, dining area, canteen, kitchen, change room and washing room

Each room has its own ventilation unit with an inlet-outlet device, ensuring appropriate air during winter, summer, as well as intermediate seasons. The air must be appropriately cleaned (filtered) and temperate. Only as much air should be processed as necessary given the presence of people, the technology of work, and the requirement that the rooms must have higher pressure than the surrounding area. The primary air supplied by the inlet device is warmed during the winter and partly cooled during the summer (33-26^{0}C). The device regulator should provide a constant inflow temperature. In addition to air preparation (filtering, heating, cooling), the inlet-outlet device should enable frequency regulator based quantity regulation. A part of the air should also be blown into the halls.

- Clothes-drying room

A standalone room for drying wet working clothes is provided. A warm-air device for inflow and outflow of air should be provided, with an adjoining recuperator and heater. The system should support the regulation of the temperature and amount of air inflow.

- Toilets

The facilities are aired through either common or standalone outlet systems, composed of outlet channels, outlet valves and a ventilator. The contaminated air should be emitted above the roof. The ventilator should support air quantity regulation. The air inflow is intended to proceed through door grates. For this purpose a part of the air is also blown into the halls.

- Electronic room, UPS

The room is aired by a local ventilator, controlled by an in-room thermostat. The inflow of air may be through a door grating (if possible), or through a standalone inflow system. The room temperature must be at a constant and regulated working temperature level. Heating may be based on radiators or convectors. During summer, the room is cooled by a convector or a split device.

- Auxiliary rooms

Local ventilators should be planned for these rooms.

13.7.5.2.6 Water supply and sewage in the building

A zinced-pipe water supply is to be planned, leading from an external connection with the plant water supply distribution to the individual outflow points. The distribution also supplies the internal hydrants, located according to the Fire Safety Study requirements. Preparation of warm water (55°C) is based on a central gas boiler, to be placed in the boiler room.

A separate technology design for the kitchen should define the equipment of the distribution kitchen and the appropriate connections. The building sewage is based on plastic pipes (with vent pipes) leading vertically from individual sanitary elements to collecting pipes in the ground and then into external sewage.

13.7.5.3 The large and small garage buildings

In addition to garages for vehicles with diesel and petrol engines, the large garages building and the small garages building also contain other rooms, as described in the architectural-construction section. The machines and other devices for individual workshops must be defined.

13.7.5.3.1 Gas boiler room

This is common to the large garages building and the administrative building.

13.7.5.3.2 Heating of the large and small garages buildings

The buildings are heated by a combination of wall-mounted gas air heaters and radiators (for the garages in the large and small garage buildings, as well as the mechanical workshop and the car wash in the large garage building), or by radiators alone (in other rooms of the large garage building). The warehouse and sign rooms in the small garage buildings are unheated. The garages heated by gas heaters are completely automated by thermostats to maintain a temperature of 8°C. The gas needed by the heaters is taken from the gas station to the large and small garages according to the LPG gas installation regulations.

The rooms heated by radiators (the warehouse office and the battery station in the small garage building) are connected to the building gas supply. The devices work automatically, but also allow manual regulation to conserve power.

13.7.5.3.3 Ventilating system in the large and small garage buildings

- Garages

They are ventilated in three ways. Natural ventilating occurs through the diagonal inflow and outflow ventilation gratings. In the case of excessive smoke the outflow roof ventilators are activated; several levels of activation are supported. The ventilators are turned on either by CO detectors or manually. The outflow of car exhaust gases is based on local suction via suitably long flexible hoses to be attached to the exhaust pipe. The flexible hose and drum system is directed through a channel below the garage ceiling to an outlet ventilator. The exhaust gasses are emitted above the roof of the garage. In wintertime, the local and general ventilation must be coordinated with the heating system.

- Car wash

The car wash is force-aired by a roof ventilator. The inflow of air is provided by a wall-mounted gas heater with a chamber for fresh and circulated air. During summertime, fresh air is provided through door gratings. The ventilator should support multiple speeds. Ventilation must be switched on manually.

- Mechanical workshop

The mechanical workshop is force-ventilated by a roof ventilator. The inflow of air is provided by a wall-mounted gas heater with a chamber for fresh and circulated air.

The ventilating of exhaust gases is done similarly to the procedure in the garages. Ventilating the working channel is based on sucking the contaminated air near the bottom of the working channel and led to a roof outlet by a suitably strong ventilator. The ventilator is turned on and off by a time-controllable switch, the same one which controls the lights in the working channel. The system must contain an air flow indicator which prevents the lights from being turned on (and thus the channel from being accessed) in case of a ventilator malfunction.

In summertime, the inflow of air into the workshop proceeds though gratings; otherwise, when heating is required, air is provided by warm-air gas heaters with a chamber for fresh and circulated air. Turning on the inflow and outflow devices must be connected, particularly in the winter mode of functioning (warm-air heaters and outflow ventilators must be turned on and off together).

- Workshops, warehouses, car wash devices, toilets in the large garages; workshops, warehouses, battery charging room in the small garages

These rooms are force-aired via standalone outflow systems. The inflow of air is provided by pressure equalization gratings. Ventilators are switched on manually.

- The diesel power generator room

This room is aired locally by a suitable ventilator controlled by an in-room thermostat. The inflow of air is through wall and regulatory gratings. A regulation grating contains an engine to open and close the air flow opening, depending on whether the power generator is running. The outflow of the power generator exhaust gases must be provided by a separate system. Noise protection must also be organized to prevent the power generator noise from being emitted into the surroundings.

- Compressor station

The capacity of the screw compressor is defined based on the technological requirements of the entire motorway plant. A working pressure should be of 10 bar but armature nominal pressure 16. The compressor is placed on a floating foundation (noise, vibrations) and connected to a flexible pipe for the distribution of compressed air. The compressor stop is heated by radiators to a temperature of at least 8°C. Ventilation is provided by a ventilator below the ceiling, controlled by an in-room thermostat. Inflow of fresh air is provided by a channel and self-closing wall shutter, which also provides the air needed by the compressor. The compressed air is distributed through steel pipes going below the ceiling of the buildings where required by technological needs.

13.7.5.3.4 Water supply and sewage in the large and small garage buildings

The water supply consists of zinced pipes from the external connection to the outflow points. Washing technology for the car wash servicing the plant vehicles must be defined and appropriate devices must be designed. Heating the technological water needed by the car wash should be based on LPG. The water distribution also serves drinkable and sanitary water and other technological water. The appropriate internal and external connections are implemented according to the technological design, and hydrants are placed as required by the Fire Safety Study. Each sector is designed to contain rubber hose drains and a sink with an electrical through-flow boiler. The drains are channeled to the external sewage system through plastic pipes. In the garage pavement, sloping cast-iron gratings are provided for the removal of ground water. The drain in the mechanical workshop channel is equipped by a suitable collecting basin. Sand settling basins and appropriate oil traps are installed in the external collecting collector. To prevent water from being blocked in the pipes, the hydrants should be connected on a through-flow basis.

13.7.5.4 Flammable material plant

13.7.5.4.1 Heating and ventilation the building

The building should be heated to 5^0C by a warm-water radiator connected to an appropriate electric or gas boiler. The object should be force-aired.

13.7.5.5 Spreading material plant with a D2 pump

13.7.5.5.1 Water supply and sewage in the building

The water supply is connected to the external water supply by an attachment for the spreading material plant and for the water/air device on the fuel pump. The installation is based on suitably wide zinced pipes and must be protected from frost. The connections must meet the requirements of the Technological Plan and the Wet Salting Solution Mixer Device.

13.7.5.5.2 D2 fuel pump

An underground tank is planned. Two fuel pumps with an electronic petrol consumption control system should be provided. The attachments should be in accordance with the Technological Plan of the D2 Diesel Fuel Pump.

13.7.6 Power installation planning

The planning of power installations includes:

- Electrical power supply
- Electroenergetical installations
- Telecommunications and signal safety systems

13.7.6.1 Electrical power supply

13.7.6.1.1 Network supply:

The motorway plant will receive the power from an existing transformer station.

13.7.6.1.2 Generator supply:

As a backup solution, an automated diesel power generator should be installed. The following devices should be connected to the power generator:

- all UPS-powered devices
- emergency lights
- all (vital) consumers in the control centre
- approx. 1/3 of general lighting in the buildings
- a part of the sockets in individual buildings
- boiler room, excluding electrical heaters
- battery station
- the more important technological connections
- electric door engines

13.7.6.1.3 Uninterruptible power supply:

"Emergency" consumers must be supplied by an uninterruptible power supply (three-phase UPS). In the design phase, the autonomy must be coordinated with the requirements of the control centre's technological equipment. The following must be attached to the UPS:

- PC-network
- emergency call system
- traffic direction and control system
- the fire and burglary device system of the motorway plant
- the plant control and information system
- the rest area supervision system
- VHF system
- weather station system

All these devices must be connected via a diesel power generator.

13.7.6.2 Electrical installations - power currents

13.7.6.2.1 Implementation of electrical installations

The cable routes (cable canals, cable shelves, installation pipes, parapet canals) must be implemented so as to allow subsequent connections between the command centre, switching blocks and all (vital) devices within the motorway plant to be added without additional construction work.

The planning of the electrical installations must allow for a later switch to a central control system without requiring the rebuilding of switching blocks or other construction work or (major) wiring.

In all structures, the machine device design, the technological equipment and the fire safety elaboration must be taken into account. All electrical consumers will be powered from corresponding switching blocks, which are in one, two or three parts (depending on their power source: network, generator, or UPS) and are marked as required.

The influence of stray current must be studied, and protection planned if necessary.

13.7.6.2.2 Lighting electrical installations

Depending on the function of individual rooms, the following must be planned inside buildings:

- main – general lighting
- emergency – auxiliary lighting, connected to a diesel generator
- emergency lighting according to the fire safety elaboration, lighting the exit paths and connected to a local battery power supply as well as the diesel generator

The light level of individual rooms should be between 120 and 450 lx and must meet the appropriate regulations and the more recent light-technical recommendations.

13.7.6.2.3 Power and technology electrical installations

The design should indicate the distribution of one- and three-phase sockets. Offices should contain two-compartment installation parapet canals, the upper compartment for telecommunications and the lower for power lines. Sockets for computer equipment and the control centre must be connected to an uninterruptible power supply via a diesel power generator and separate switching blocks.

In the boiler room, electro installations must be planned depending on the chosen fuel source. Depending on the machine installation design, fixed connections for devices must be planned. In the garages, workshops, spreading material plant, salt silo, battery rooms, fuel pump area, etc., all connections must be planned in accordance with the planned equipment.

13.7.6.2.4 Electrical installations in the boiler room

The above-ground and underground tanks must be appropriately grounded and the electrical installations must be planned according to the current technical regulations for the selected energy source.

13.7.6.2.5 Heating and ventilating electrical installations

After the machine installation design, the heating and ventilation of electrical installations must also be designed. The electrical installation design must contain technological schemas with an appropriate coding of all the elements. The fire safety elaboration, defining the individual fire zones and rooms under danger of fire, must also be taken into account. Special attention must be paid to the electrical installation of the controlled ventilation of the battery rooms, the working channels in the mechanical workshop, etc.

13.7.6.2.6 External lighting

A design of external lighting must be prepared. The light poles must be grounded. Lighting must follow the appropriate regulations and the more recent light-technical recommendations.

13.7.6.2.7 External arrangements

The following must be taken into account when planning the electrical installations of the external arrangement of a motorway plant:

- all utility line arrangements for this motorway section
- cable pipes must be connected to the emergency call system cable pipes
- cable pipes must be connected to the cable pipes of the motorway section
- the internal cable pipes must observe or show all distances and crossings with other installations (water supply, hot water supply, gas pipes, etc.)
- electrical installations of the motorway plant sewage treatment facility
- grounding of all buildings must be connected together, including the fence

13.7.6.2.8 Lightning-rod and grounding

All buildings of the motorway plant must be protected from atmospheric discharges and high voltages. The administrative building, i.e. the control centre and the telecommunication hubs, must be planned particularly carefully. The command centre area must be equipped by a class I lightning protection system. Due to the high investment value and required reliability of the equipment, the most recent EU regulations and standards must be met in addition to the technical lightning-rod regulations.

Fuel tanks must be suitably grounded. For protection from high voltages, several levels of surge arresters should be provided. Main and supplementary potential equalization should also be implemented. On ventilating ducts and pipelines, all isolated connections must be made galvanic bridges.

13.7.6.3 Telecommunications and signal safety devices

This includes the following systems:

13.7.6.3.1 Emergency call

The emergency call central should be located in the motorway plant control centre. The cable pipes of the motorway section should be connected to the internal cable pipes of the motorway plant.

13.7.6.3.2 Telecommunications

Both internal and external telecommunications should use a digital phone switching box (EPBAC) linked to a common system of connections along the motorway. The fact that many types of data and signals will be transferred via SDH (synchronous digital hierarchy) equipment and optical fiber must be taken into account:

- transfer of signals from the burglary protection and video surveillance central to the intervention service
- transfer of signals from the fire notification central to the intervention service
- transfer of computer data
- transfer signals from the motorway sections
- transfer of data from the weather stations
- transfer of data from energy systems

Installations of telecommunications should be planned in the form of structured universal wiring for the purposes of telephony and computer network. This means that a common data node and the same carrier type should be used for both communication systems.

Considering the planned technological equipment and machine installations, universal wiring should also be provided for the following devices:

- till of the fuel pump
- modem connections and perhaps a central control system
- electronic date/hour/temperature display
- employee departures and parking

13.7.6.3.3 Automated fire reporting

The fire safety elaboration determines which rooms need to be protected by automated fire reporting. An addressable analog central should be planned to enable a more precise and faster discovery of the fire location. Depending on the work organization, a separate management console should be added to the command table of the control centre, showing the exact location of the fire. The transfer of a signal to the intervention service must also be supported.

13.7.6.3.4 Alarm and anti-burglary system

Anti-burglary protection should be provided to prevent unauthorized access to rooms containing important equipment, as defined subsequently by the investor.

The rooms are protected by spatial IR sensors. The central or utility console should be located in the control centre.

The alarm and anti-burglary system must be connected to a video surveillance system. A combined central for both fire and burglary reporting may be used.

13.7.6.3.5 Plant supervision and access control

Considering the traffic arrangement and work organization in the motorway plant, a suitable number of barrier gates should be set up on the service roads, to be opened by remote control either from a vehicle or from the control centre. The complex should also have video surveillance, with alarm and fire occurrences being recorded automatically on digital media. The entrance into the administrative building or the control centre should be controlled and enabled by a suitable sensor.

13.7.6.3.6 Sound system

The offices, workshops and some of the more important auxiliary rooms should be connected to a sound system. A loudness attenuator (with a force override option) should be located in every room. The sound system also allows announcements to be made. The amplifier should be located in the command centre. The sound system should consist of multiple channels, as required by the work organization.

13.7.6.3.7 Control and management system for viaducts and rest areas

Control and management of viaducts and rest areas on the motorway sections belonging to this motorway plant should be planned.

13.7.6.3.8 Plant control and information system

A system of control and information within the plant must be planned.

13.7.6.3.9 Traffic direction and control system

A system must be planned for directing and controlling traffic on all motorway sections that are difficult from a technical, meteorological or traffic point of view. This includes control over rest areas, bridges and viaducts, weather stations, and emergency calls. Special attention should be paid to traffic control in tunnels. These systems are particularly carefully designed and are led and controlled from the control centre.

13.7.6.3.10 VHF system

For the purposes of wireless communication, the coverage of the motorway by a VHF signal from a suitably located base station should be planned. VHF equipment should be planned in accordance with an elaboration of the future development of VHF connections on the motorway backbone.

14 CONDUCTION OF ROAD TRAFFIC ALONG INFRASTRUCTURE

14.1 AREA OF APPLICATION

This guideline regulate the conducting of road traffic along the water streams, public utility infrastructure, transport devices (cableways, belt tranport devices...) airports and stone pits.

14.2 WATER STREAMS

Preserving water regime is a fundamental condition when exploiting the environment for the road construction and operation. Rearrangements of riverbeds, stream devices, and water economy structures shall be adjusted to existing and foreseen arrangements of individual streams without any influence on the existing regime of surface and ground water, and in compliance with water economy directives.

Abandoned parts of beds of regulated or transferred stream shall be re-cultivated in accordance with the use of adjoining land, or reorganized as biotopes.

14.3 PUBLIC UTILITY INFRASTRUCTURE

Conducting primary public utilities in the road direction is typical space exploitation to which the planned road is adapted as a rule. Conditions and requirements by the managers of individual public utilities shall be considered, particularly in view of the required distances between the public utilities and pavement elements, which shall ensure a perfect stream operation and traffic safety, as well as suitable space for water maintenance.

To public utilities (installations and devices) sewage system, water supply, hot water supply, gas main, electric conduits, and telecommunication cables belong, which cross the road, or run along the road.

14.3.1 General conditions

Public utility conduits and cables may be placed into the road body below or along the carriageway under special conditions only. Horizontal and vertical, as well as safety spacing determined by technical norms for each individual public utility type shall be taken into account.

Underground conduits, ducts, and cables shall be placed under the pavement in such a way that the tops of those utilities or their protection are located at least 0.5 m below the carriageway surface (i.e. pavement substructure formation).

The top of any public utility element and of other installations placed into the road body must not reach above the substructure formation.

No public utilities are admitted in the pavement, with the exception of automatic traffic counting devices or pavement condition detectors.

When placing of public utilities into the road body is designed, such a width shall be foreseen for each individual conduit, duct, or cable, as to prevent affecting other utilities, and not obstruct or even make impossible the excavation during maintenance works.

To ensure accessibility, as well as to prevent mutual obstructing and interaction, it is not admitted to place one or more public utility installations in the same vertical in a road body.

Air ducts must not be placed within the road clearance gauge, whilst primary infrastructure installations shall not be laid in the air above the carriageway in the pavement clearance gauge width, and lower than 7.0 m above the carriageway highest level.

On long-distance roads such as motorway and expressways, public utility installations must not be placed in the road body within the clearance gauge area, except those ducts and conduits, which are indispensable for the individual road operation, irrespective of the fact whether they are provided for other needs or not.

On roads arranged for conceptual speeds of > 70 km/h, shaft covers must not be located on the carriageway. This rule does not apply to roads in settlements, except to rapid urban roads.

In plan view, public utilities run longitudinally along the road space, or they are shifted away from the carriageway. Exceptionally, they can also run in the road carriageway, however on urban roads only. In such cases, conditions by the road managing authority shall be considered.

14.3.2 Road operation obstruction

On a road carriageway, where the conceptual speed exceeds 60 km/h, it is not allowed to place shafts of public utility installations, except in settlements, taking account of conditions by the road managing authority.

Where shaft covers or valves are placed on the carriageway, they shall be situated between the ruts of an individual traffic lane, considering the requirements by the road managing authority. The location of a cover in the pavement cross-section shall be so selected as to allow provisional driveability of the road during maintenance works carried out on the particular public utility installation as well. The only exception is roads within settlements, on condition that the carriageway width amounts to less than 5.0 m.

14.3.3 Depth of placing public utility infrastructure

Unless no other technical provisions apply to an individual public utility installation, ducts, conduits, cables, etc. running below the carriageway shall be placed into the road body at depths indicated in Table 1.

A water main must not be placed below the height level of a faecal or mixed sewage system.

14.3.4 Road – public utility infrastructure intersection, distance between public utilities and pavement elements

Intersection of public utility infrastructure and a road is admissible under conditions preliminarily specified, and considering the technical conditions for each individual public utility separately.

A water pipe measuring up to 100 mm in diameter shall be protected by additional pipe of diameter above 100 mm, and shall be placed in a concrete pipe if intersecting a road. In such a case the concrete pipe shall be located below the pavement at a minimum depth as indicated in Table 45.

Crossing of a road and public utility installations may be carried out at angles between 45° and 135°. Individual ducts or cables can run in open air or in the ground below the pavement. On roads where piping is not protected by an additional pipe, the intersecting angle shall amount to 60° to 90°.

Hot water network running below the pavement in a settlement shall be placed in a protective concrete kinete, which upper edge is situated below the carriageway as directed by the road managing authority (Table 45).

A gas main of operating pressure more than 16 bar shall run along a long-distance road at minimum spacing of 10 m from the carriageway outer edge. Where such a gas main runs along a connecting and collecting road, the distance to the outer carriageway edge shall amount to 5.0 m from the lower edge of the road fill slope. In case of an access road, or a road of low traffic volume, this distance shall be at least 2.0 m.

A gas main of operating pressure less than 16 bar shall be moved away from the carriageway edge by at least 2.50 m.

High-voltage and low-voltage power cables shall run at least 1.50 away from the carriageway edge. In addition, the protected pipe for a 110 kV cable shall be placed at a depth of at least 1.0 m below the carriageway, whilst in case of a 10 kV cable this depth shall amount to 0.80 m minimum.

Telecommunication cable network shall run at least 1.00 m away from the carriageway edge at a minimum depth as indicated in Table 45.

Power cables running freely in the air along a road outside settlements shall be situated at least 10 m from the carriageway edge.

Crossing of a road and an open air power cable shall be carried out at a minimum height of 7.50 m above the carriageway at the maximum admissible sag of the transmission line cable of up to 400 kV of voltage. For low-tension cables this height shall not be less than 4.70 m.

Table 45: Minimum depths of placing public utility installations

Public utility type	Installation type	Minimum depth of the installation top
Sewage system	MD – main drains WWC – waste water channel PWC – precipitation water channel DP – drainage pipe	1.50 m 0.90 m 0.60 m
Water supply	MC – main conduit DN – distribution network	1.20 m 0.90 – 1.50 m
Heating and gas supply	HWS – hot water supply, steam supply GM – gas main PM – product conduit	1.0 m (0.5 m concrete kinete) 1.0m
Power cables	ECH – high-voltage ECL – low-voltage PL – public lighting	0.60 – 1.20 m
Telecommunications	TT – telephone TV – television CATV – cable television *Suffix „C" for control cables*	0.60 – 1.00 m

Note: in case of an installation running above ground the suffix _AG (above ground); if an installation runs underground it shall receive a suffix _UG (underground)

14.4 TRANSPORT DEVICES

Transport devices are ropeways and belt conveyors located along a road or crossing a road either above ground or in a structure below the carriageway.

Crossing of a road and a permanent transport device may be carried out at angles between 75° and 105°, at a minimum height of the lower edge of a device or load amounting to 5.0 m above the pavement, taking account of the maximum sag.

The supporting structure of a transport device shall be placed at a minimum distance of 10 m from the carriageway edge. Exceptionally, on roads of conceptual speed of up to 50 km/h this distance can by reduced to 1.50 m if the supporting structure is protected from motorcar impact.

The structure for a transport device below the road pavement shall be designed taking account of the traffic load imposed to the road.

14.5 AIRPORTS

Situating a road body within or outside an airport zone shall be in accordance with the provisions, standards, and recommendations by ICAO (International Civil Aviation Organization).

Road clearance gauge must not extend into the space intended exclusively for the airport use, and must not break through areas of restricting planes as specified by the particular reference code, and by the category of an airport.

At the border of the exclusive airport use the road clearance gauge shall amount to at least 4.80 m (Figs. 320 and 321).

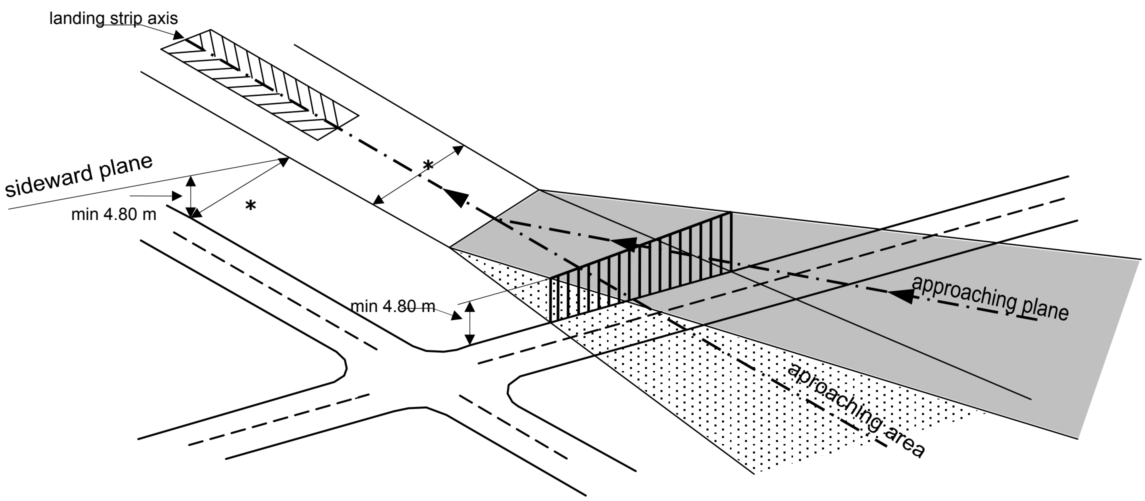
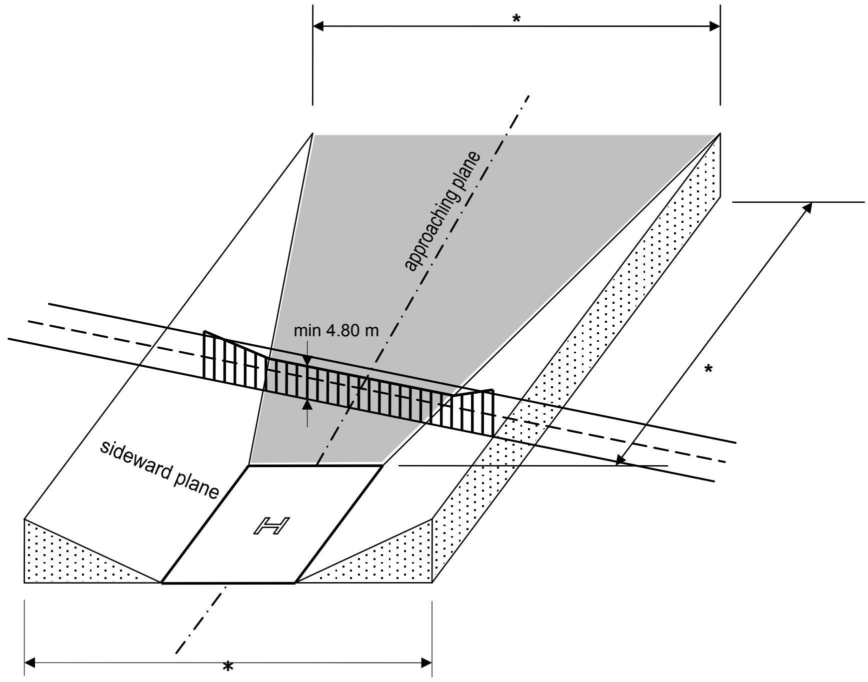


Figure 320: Road clearance gauge in the airport or runway area with landing strip



*** depending on the airport reference code and category**

Figure 321: Road clearance gauge in helicopter take-off areas

14.6 LOCATION OF NATURAL MATERIALS (QUARRIES, STONE PITS)

A road running at a location of natural materials (quarry, sand pit, clay pit, gravel pit) shall be so shifted away from such a location as to prevent any impact of the location on the road body stability, and/or not to affect the road traffic safety (blasting, dust).

During periodical blasting, roadblocks of short duration may be carried out introducing adequate provisions. Roadblocks are not admitted on roads of the technical groups A and B, which permanent operation shall be ensured without any restrictions.

At the excavation edge, and at the edge of a structure for processing with deposited material, a protective barrier shall be foreseen, if the location boundary is situated in the road protective area. Placing of the protective barrier shall obligatorily take account of the required spacing to enable sight distance field at the carriageway.

The technology of winning or processing natural materials within a location at the road shall not affect both visibility and roughness of the carriageway, and shall prevent scattering the blasted-off stone material into the road area, and onto the carriageway.