



Technische
Universität
Braunschweig

Carolo-Cup



Carolo-Cup Regulations 2017

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Legend:

- The regulations contain fundamental changes compared to the **last year's** version. Thus, only changes in already existings paragraphs are marked in **red**. Passages which did not exist in the previous version are not explicitly highlighted.
- Chapter 5 (Description of the dynamic events) has changed fundamentally. Please read it carefully.



1 Overview

1.1 Objectives

The student competition "Carolo-Cup" provides a platform for student teams to get involved with the conceptualization and implementation of automated model vehicles. The challenge is to realize the best performing vehicle guidance system for different scenarios, which have been derived from requirements arising from a realistic environment.

In the annual competition, the students can present their know-how in front of judges from industry and academia while competing with teams from other universities.

1.2 Tasks

The student team is put in charge of developing, producing and demonstrating a cost- and energy-efficient 1:10 concept for an automated vehicle by a fictional OEM. During the competition several driving tasks have to be executed as fast and precise as possible. In addition, the developed concept must be presented and explained.

1.3 Scoring

Each concept and its realization will be assessed in comparison to the results of the other participating teams. For this, the teams compete in different static and dynamic events, while being awarded at most 1050 points.

The maximum amount of points per event is distributed as follows:

Static Events:	
S1: Presentation and Overall Concept	150 Points
S2: Technical Approaches	150 Points
Dynamic Events:	
D1: Parking parallel	200 Points
D2: Free Drive (w/o obstacles)	250 Points
D3: Obstacle Evasion Parcours	300 Points
Maximum Score:	1050 Points



1.4 Competition

1.4.1 Organization

The student competition "Carolo-Cup" is organized and presented by the Technische Universität Carolo-Wilhelmina in Braunschweig.

1.4.2 Dates

The "Carolo-Cup" annually takes place in February. If possible, the "Carolo-Cup" will be held as a preceded event to the "Automatisierungs-, Assistenz- und eingebettete Systeme für Transportmittel (AAET)" symposium. (Due) dates will be published on the website.

1.4.3 Venue

The venue will be published on the website.

1.4.4 Language

Until further notice, the official "Carolo-Cup" language is German. Presentations, communication with the teams (e-mails, phone calls, etc.) are also possible to be conducted in English. **The English regulations are a translation of the German regulations. In case of doubts or translation-errors, the German rules are effectual.**

1.5 Regulations

1.5.1 Commission

The "Carolo-Cup" Regulations Commission is the only responsible party which is allowed to modify rules and obligations of the Carolo-Cup. In case of disputable events the statements of the Commission are the only effectual statements.

1.5.2 Validity of Regulations

Only the regulations which have been published on the official website are valid for the competition. Old Regulations are invalidated as soon as a new version of the regulations is published.

1.5.3 Questions

Every participant is obliged to thoroughly read, understand and accept the regulations. In case of questions, the commission is to be consulted. Questions can either be directly posed to the commission or be published in the official thread board on the Carolo-Cup website. Studying the thread board on the website is recommended, as questions are being publicly discussed there on a regular basis.



1.5.4 Authority

The commission can change the schedule or the regulations of the event at any time. All participants are obliged to cooperating with and following the instructions of the commission at any time.



2 Prerequisites for Attending

Only students fulfilling the following conditions are allowed to participate in the "Carolo-Cup" competition.

2.1 Status of Enrollment

Every participant must either be currently enrolled in a Bachelor's, Master's or a comparable degree program or the respective degree must not have been obtained more than six months before the competition. A corresponding registration number / certificate of enrollment has to be presented with the registration for the competition. There is no restriction concerning the subject of study. Research staff and PhD students may not participate actively in conceptualization or development of the vehicle. They may not participate actively in the competition (cf. 3.11).

2.2 Minimum Age

Every participant must be 18 or older.

2.3 Number of Teams per Institution

The number of teams per Institution is not limited. However, the development of the vehicles must be strictly separated. Soft- and hardware architectures of the respective teams must differ significantly.

2.4 Registration

Details concerning the registration will be published on the Website.

2.4.1 Date of Registration

Due dates for the registration can be found on the website. An early-bird registration is possible, resulting in a reduced admission fee. Early-bird due dates are also published on the website.

2.4.2 Admission Fee

An admission fee of 200 Euros per team is issued for the "Carolo-Cup". The admission fee is not refundable and covers entry fee, on-site catering expenses as well as organisational expenses. Accommodation, catering expenses apart from on-site catering, as well as travel expenses are **not** covered. The discounted early-bird fee is 100 Euros per team. In case of a desired participation in the AAET symposium, a protective charge of 50 Euros is issued. It will be refunded after



participation in the AAET symposium and its evening event.

2.4.3 Registration Form

Registration is only possible using the **online web form published on the Website**. The registration will be revoked in case of falsely filled information.

2.5 Publication Rights

By registering, every team and every participant declares her/his agreement with the publication of image, video and audio recordings. This also includes the recording of team presentations. This agreement might be revoked until the day of the competition.



3 Vehicle Requirements and Limitations

The observance of the following regulations will be monitored during the competition. Violating these regulations will lead to a deduction of points or exclusion from the competition. The same vehicle must be used for all events.

3.1 Drivetrain

The vehicle must be equipped with (an) electrical drive(s). The number of driven wheels is not limited (torque vectoring is allowed). Alternate drives (e.g. chain drives) are not permitted.

3.2 Energy Supply

Energy must be supplied in the form of batteries. Changing the batteries between single events is allowed.

3.3 Physical Dimensions

The vehicles must be based on four-wheeled 1:10 scale chassis. Only two axles are permitted. The wheel base must measure at least 200 mm. The track width (measured from the center of the wheels) must measure at least 160 mm. **The vehicle, including possible extensions and bodywork, must not be wider than 300 mm.** The height of fixed installations must not exceed a height of 300 mm above the track surface. Flexible antennae are allowed. These physical dimensions will be checked before the competition during the acceptance test executed by the head referee. The car must be driven through a fixed gate (inner dimensions: height 300 mm, width ~~400 mm~~ **300 mm**) in RC-mode.

3.4 Steering / Chassis

The front axle must be steerable. An additional steerable rear axle is allowed. Apart from this, the design of the chassis is subject to the teams creativity, as long as it adheres the maximum physical dimensions. The steerable axle(s) must feature ackermann steering.

3.5 Sensor Setup

The sensor setup can be arbitrarily chosen by the teams. Laser sensors are allowed only up to class 2 devices.



3.6 Data Transmission

No data or signals must be transferred from the vehicle to the outside world during the dynamic events, except for those signals necessary for the remote control (cf. Chapter 3.8).

3.7 Bodywork

The teams must be able to quickly disassemble the vehicles' bodywork, so that the inner parts of the vehicle can be inspected at any times. The bodywork must conform to **IP-11 IP 10** (EN 60529).

3.8 RC-Mode

In emergency situations, the vehicle must be stopp- and maneuverable using a remote control. This can become necessary due to faults or errors in the data processing or due to other problems so that the vehicle cannot continue to execute its automated driving task.

3.8.1 Activating RC-Mode

RC-mode is activated with the remote control. An active RC-mode must be signaled by utilizing a sufficiently bright, flashing, blue light, which is visible from any position on the track. The light must be fixed at the highest point of the vehicle. The light must flash with a frequency of 1 Hz, showing a duty cycle of 50 %, beginning with the status "on" when activating RC-mode. RC-mode must only be activated after a clear misbehavior of the vehicle. This means e.g. completely leaving the designated course of the track.

3.8.2 Driving in RC-Mode

Activation of RC-mode must instantly bring the vehicle to a complete halt **without further steering maneuvers**. The vehicle must be in **standstill** for 1 s before it may be controlled with the remote control. During the events, the vehicle must not drive faster than 0,3 m/s forward and backward when RC-mode is engaged. During the training sessions a maximal velocity of 1,0 m/s is to be adhered for safety reasons. In this case the vehicle may be controlled again directly after having stopped. Additional functionality is not allowed in RC-mode.

3.8.3 Transmission Frequencies

In order to limit interference between the vehicles of the different teams, each team must inform the commission about the used transmission frequency of their remote control when registering. Frequencies are issued on a first-come-first-serve basis. Additionally frequencies in the 2.4-GHz-band are already occupied by Wifi networks, or other infrastructure. Thus they may not be used for RC-mode. Exceptions need to be confirmed by the commission.



3.9 Handling of the Vehicle

The vehicle must provide three mechanic pushbuttons, which start the different modes for the different events. The buttons must be uniquely identifiable and easily reachable in order to allow non-teammembers (e.g. Judges, Referees) to start the vehicle.

3.10 Lights

As in real traffic, lights shall signal different driving maneuvers.

3.10.1 Braking Lights

Three clearly visible and differentiable braking lights must be installed at the rear of the vehicle. Active braking must be signaled.

3.10.2 Indicators

Each corner of the vehicle must be equipped with a yellow/orange light. The respective lights at the correct side must be flashed at a frequency of maximal 2 Hz (50 % duty-cycle, initial state "on") when overtaking, turning or parking.

3.10.3 RC-Mode-Indicator

A clearly visible blue light is to be installed at the highest point of the vehicle, which flashes to signal the activation of RC-mode (cf. Section 3.8).

3.11 Development Know-How

The basic concepts of the vehicles must be conceptualized and implemented by the students themselves. They must not accept direct help of professional engineers or suppliers. The students are encouraged to do research and/or discuss their problems with professional engineers or suppliers. Ready-made solutions may never be included in the vehicle. **This particularly concerns the usage of predesigned algorithms which may be part of a hardware platform, which serve the purpose of providing a fully functional system for perception, behavior generation or control for automated vehicles or robots. The final decision on acceptable components is taken by the commission. The teams are encouraged to contact the commission in case of doubts or questions about a particular component. In case of violating these guidelines or intentional fraud, the commission has the right to exclude the respective team from the competition.**

3.12 Safety Regulations

During the competition, safety instructions issued by the commission members are to be followed. Ignorance of notes or guidelines can be punished by excluding the respective team from the training sessions or the competition. Each individual shall take care at all times so that neither other participants are injured, nor other vehicles are damaged due to careless



behavior.

As far as the sensor setup is concerned, the following requirements and restriction arise: All components withing the vehicles must adhere to established guidelines for safe public usage. Particularly the usage of active sensors can be limited by this rule. The teams must make sure that no third parties are subject to possible injury due to installation or handling of the sensors.

In case of questions concerning particular sensors, the admission must be discussed with the commission prior to the begin of the training sessions. Violations of these regulations lead to an immediate exclusion from the competition. Compensation demands to the commission are not applicable.

3.13 Modification of the Vehicle

During the dynamic events, the hardware of the vehicle must not be modified except in case of supervised repair. The software must not be modified during the dynamic events. Changing and charging batteries is allowed.



4 Static Events

During the static events, the teams must present and defend their concepts in front of a jury. Each team is awarded an individual grade between 1 (maximum score) and 5 (0 points) individually for each key aspect of the presentation. The judges are experts from industry and academia. The maximum attainable number of points is described in chapter 1.3.

4.1 Overall Concept Presentation

Each team has the possibility to explain the overall concept behind their vehicle, independent from the different events. The overall concept covers hard- and software architecture. Additionally, each team shall present how energy- and cost efficiency have been considered during the design phase. Finally, the teams shall explain how obtained knowledge and know-how is preserved for future team generations (knowledge management).

4.2 Presentation of Technical Approaches

Each team must present their concepts for each key aspect of the dynamic events. These dynamic aspects are: Lane detection and lateral control, parking, obstacles/intersection. Each key aspect is divided into the aspects of perception and control.

4.3 Deliverables: Presentations

All presentation must be digitally available (ppt, pptx or pdf) and sent to ***konzepte@carolo-cup.de*** prior to the competition. The files must not exceed a file size of 10 MB. The due date for the presentation files will be announced on the website.

4.4 Agenda

There is a time budget of 20 minutes for the presentation. After this budget, the presentation will be interrupted by the jury. Afterward the team's qualification video will be presented, followed by a panel discussion with the jury of about 10 minutes. The length of the presentation is subject to change in case of a large number of participating teams. In this case the teams will be informed sufficiently early.



5 Dynamic Events

During the dynamic events, the actual performance of the automated model vehicles will be challenged in three different events.

5.1 Leagues

In order to being able to offer new challenges for experienced Carolo-Cup teams without excluding new teams, leagues with two classes have been introduced.

5.1.1 Description of the Classes

The participating Carolo-Cup teams are divided into two classes in which they will encounter different challenges. Prizes and scoring will be separated for both classes. Each class contains all three dynamic events (Free Drive (w/o obstacles), Parking, Obstacle Avoidance Parcours). However, complexity of the three events differs between the classes.

Basic Class The basic class corresponds to the dynamic events of the past Carolo-Cups. The competing teams must park in parallel to a straight part of the track and successfully complete both circuits (Free Drive, Obstacle Avoidance). Both circuits correspond to a rural road scenario and contain the respective elements.

Advanced Class The advanced class contains additional elements and challenges on the track. These additional elements extend the existing events, there will be no additional events. The challenges are more versatile and there will be a gradual change from a rural road scenario toward suburban scenarios, which will, for example, confront the teams with more complex intersection scenarios. Additionally, the parking event will be extended from parallel parking to perpendicular parking on the other side of the track. This offers new flexibility with regard to the different parking strategies of the teams. In total, the advanced class shall impose higher requirements on the perception, decision and control algorithms of the participating teams.

5.1.2 Team Classification

During registration, the teams obligatory declare in which class they would like to compete. The classes consist of the following events:

Basic Class

D1: Parallel Parking

D2: Free Drive (w/o obstacles)

D3: Obstacle Avoidance Parcours (rural road scenario)

Advanced Class



D1: Parallel and Perpendicular Parking

D2: Free Drive (w/o obstacles)

D3: Obstacle Avoidance Parcours (rural road and suburban scenario)

The teams are free to choose their appropriate class. Apart from this the following exceptions apply:

1. Participating teams who came in on third to first rank in the advanced class will automatically register for the advanced class again for the next Carolo-Cup.
2. Participating teams who came in on first or second rank in the basic class will automatically register for the advanced class for the next Carolo-Cup.
3. First time participating teams may only register for the basic class. This also applies to teams who participated in the Junior-Cup the year before.

Teams will not be automatically nominated. I.e. if teams which were automatically registered for the advanced class do not participate, subsequently ranked teams will not be automatically registered for the advanced class. However, the subsequently ranked teams may choose to register for the advanced class. Exceptions from these regulations need to be discussed with the commission. Exceptions may apply, if a majority of team members has changed over the year. In this case, please contact the commission to allow a registration for the basic class.

As an exception for the initial introduction of the classes, the first three teams from 2016 are automatically registered for the advanced class in 2017. This does not invalidate other regulations.

5.1.3 Assignment of Elements to the Classes

The following table presents an overview over the elements in the different classes. Each element is listed with its corresponding class. Additionally a reference to the description of the element in the regulations is listed.



Element	Basic Class	Advanced Class	Section
Parking Spot	Parallel	Parallel or Perpendicular	5.2.1 5.2.2
Double Center Marking	yes	yes	5.3.1.2
Side Road Junction	yes	yes	5.3.1.2
Missing Markings	max. 1 m	max. 1 m	5.3.1.2
Guiding Elements	yes	yes	5.3.1.3
Static Obstacles	yes	yes	5.4.1.1
Dynamic Obstacles	Vehicles	Vehicles Pedestrians	5.4.1.2 5.4.2.4
Intersections	Stop Line	Stop Line Give-Way Line Priority to Right	5.4.1.3 5.4.2.5 5.4.2.5
Direction of Crossing	Straight	According to visible Traffic Signs	5.4.2.6
No-Passing-Zone	no	yes	5.4.2.8
30 Zones	no	yes	5.4.2.1
Barred Areas	no	yes	5.4.2.3
Crosswalks	no	yes	5.4.2.4

5.2 Parking

In this event, the automated vehicle must automatically find a suitable parking spot and maneuver into it. Depending on the chosen class, there are either parking spots in parallel only or in parallel and perpendicular orientation to the track. Both areas for parking are located on a straight part of the track with a dashed center line without missing lane markings. Additional elements (intersections, crosswalks, dynamic obstacles, etc.) are not present during this event.

5.2.1 Parallel Parking

In both classes, there is a 300 mm wide area next to the right lane. White cardboard boxes represent other vehicles. The boxes can be fixed to the ground. There is a space of 20 mm - 200 mm between the right lane marking and the side of the obstacle which faces the track. The obstacles are spaced apart from each other up to 400 mm. The obstacles measure at least 100 mm in height and length. The parking area and the track are located in the same ground plane. **The track is blocked by two obstacles directly after the end of the parking area.** In the advanced class parts of the parking area can be marked as no parking areas (cf. Appendix, Section 7.1). These areas may not be used for parking, but may be used for maneuvering.

The parking spots can be arranged in arbitrary order. They measure 550 mm, 630 mm oder 700 mm in length and 300 mm in width.

Depending on the targeted parking spot, a time penalty according to Chapter 5.2.4.2 will be added to the time which is required for parking. Each parking spot is present at least once. The left and right hand limits of the parking spots are defined by the right lane marking and an additional solid white line (also 20 mm width). Front and rear limits are defined either by



white cardboard boxes or by a no parking area. (cf. Section [7.1.0.1](#))

5.2.2 Perpendicular Parking

In the advanced class there is an additional parking area consisting of several parking spots with perpendicular orientation to the track. This area is located on the left hand side of the track and may also be used for parking. All spots measure 350 mm in width and 500 mm in length. The parking spots are separated and limited to the front as well as to the rear by 20 mm wide white markings. Parking spots can be blocked by obstacles or no parking zones. A parking spot is considered to be blocked, if the vehicle cannot be placed completely inside the spot. There is always at least one free parking spot. Obstacles possess the same dimensions as in the parallel parking area and can be placed at a distance of 20 mm to 100 mm from the solid left lane marking. The vehicle must keep a distance of 10 mm from the front rear marking, as well as a distance of at least 20 mm from the left and right hand side markings. The car must be parked with an angular offset of at most 5 degrees to the nominal orientation of the parking spot. Vehicles may be parked forward and backward. The left lane of the track may only be crossed during parking. When searching for a parking spot, the vehicle must use the right lane.

5.2.3 Execution of the Event

5.2.3.1 Start

Driving on the right hand side of the road, the vehicle shall find a parking spot and maneuver into it as quickly as possible, without touching the surrounding obstacles. The vehicle is started on the track at the scratch line (40 mm wide) by using a pushbutton which is operated by a judge or a referee. The start of the parking maneuver has to be signaled using the turn indicators. After finishing the parking maneuver, all turn indicators must be flashed three times. For the calculation of the net time for parking, see Section [5.3.3.1](#).

5.2.3.2 Attempts

Each team must complete 2 subsequent attempts. The teams compete one after another in a given order. All teams must be ready according to the start scheduling system described in Chapter [6.3.2](#)

5.2.3.3 RC-Mode

RC-mode must not be used in this event.

5.2.4 Scoring

5.2.4.1 Timing

The time required for parking is measured between the vehicle start at the scratch line and the last flash of all turn indicators.



5.2.4.2 Penalties

Violation	Penalty
Distance to front and rear limits < 10 mm	invalid attempt
Distance to left and right limits < 20 mm (perpendicular parking)	invalid attempt
Parking maneuver takes longer than 30 s	invalid attempt
Vehicle not placed inside the markings	invalid attempt
Vehicle parked in no parking zone	5 s
Collision with obstacle	5 s
False usage of turn indicators	5 s
Passing the right line of the parking area	5 s
Angular offset > 5° to nominal orientation of the parking spot	5 s
Maneuvering into 63 cm spot	8 s
Maneuvering into 70 cm spot	15 s

5.2.4.3 Scoring

Each attempt is scored separately. In each attempt, the fastest team is awarded the maximum number of points. The subsequent teams will be awarded points in relation to the fastest team. The final scores per team are calculated from the average of all 2 attempts.

5.3 Free Drive w/o Obstacles

In this event, the vehicle shall automatically cover the farthest possible distance in a given time. The vehicle drives in the right lane.

5.3.1 Scenario

The complexity of this scenario is limited: It consists of a road with two parallel lanes - one in each direction. This scenario shall imitate a rural road scenario, consisting of long straight sections, tight turns, intersections **and side road junctions**. The lanes are limited by different types of lane markings. All markings are white and approx. 20 mm wide, if not specified differently.

5.3.1.1 Lanewidth

Each lane has a width of 350 mm to 450 mm, measured from the inside of the respective markings. The left and right markings do not show lateral discontinuities. However, the centerline may under circumstances (e.g. because of change of marking type, cf. next Section) display discontinuities.

5.3.1.2 Lane markings

Both lanes are separated by a dashed center line. The centerline is interrupted every 200 mm for another 200 mm. This shape continues until reaching an intersection or the scratch line, so that the center line might end with a gap at these points.



Alternatively to the dashed centerline, a double solid line can be present. In this case the solid lines are spaced approx. 20 mm apart, yielding a total marking width of approx. 60 mm. A combination of a solid and a dashed line is possible. In both cases, the inner edges of the markings define the width of the lane. Marking types can occur in arbitrary order. Marking types will persist for a distance of at least 1000 mm. There will be immediate changes between marking types. For the Free Drive event, these marking types are to be treated as regular dashed markings.

The left and right track boundaries are given by solid white lines. On straight sections of the track, the outer track boundaries can also mark side road junctions. In this case, the outer track boundaries are marked with 100 mm long dashed, interrupted by 50 mm long gaps. These markings are to be treated as solid lines and must not be crossed, as the vehicle is assumed to have the right of way. Side road junctions may be at most 960 mm long. The junction is only marked by the change in marking types, there are no further markings for the side lane.

Neighboring sections of the track are spaced at least 50 mm apart, measured from the outer edges of the markings. The minimal distance of the track to the end of the parcour area is 300 mm. The sharpest turn has an inner radius of 1000 mm (cf. Chapter 7.2.1)

The circuit is mostly planar. Parts of the track can show slopes of up to 10 % (10 cm difference in height on a length of 1 m). All of the lane markings can be missing at arbitrary locations for a maximum of 1000 mm. Except for intersections, no more than two markings are missing at the same time. An example scenario is depicted in Chapter 7.5 in the Appendix.

In this event, no obstacles are located on the track. Possible stop lines and regulations concerning the right of way are to be ignored.

5.3.1.3 Traffic Signs

In order to mark sharp turns, there will be supporting traffic signs at the roadside. They mark a curved section of the track with radii below 1.2 m, if this is located after a straight section of at least 3 m length. The supporting traffic signs will be placed 1.5 m before the transition to the turn. They will be repeated every 400 mm until reaching the apex of the turn.

Additional traffic signs can be present at the roadside. They are located on the right hand side of the lane. For an exact specification see Section 7.3. In this event, traffic signs can be ignored.

5.3.1.4 Artifacts

The design of the area outside of the road is not defined. Artifacts in the form of objects or remainders of lane markings might be located outside of the road area. The minimal distance between artifacts and valid lane markings is 100 mm.

5.3.2 Execution of the Event

5.3.2.1 Start

At the beginning of the event, the vehicle must be ready to start and it must be placed in the start box, which is located next to the track (cf. Section 7.5). The start box can be separated from the track by a solid white line. This line may be crossed to enter the track.



The attempt is started by a judge or a referee by pressing the respective pushbutton. The attempt may be canceled up to 30 s after the pushbutton has been pressed. The starting order of the teams will be announced by the commission, visualized using the start scheduling system (cf. 6.3.2) during the competition.

5.3.2.2 Attempts

An attempt can be cancelled by the team representative within 30 seconds. The team is then allowed a second attempt, after all other teams have completed their first attempt. Cancelling an attempt is penalized (cf. Section 5.3.3).

5.3.2.3 RC-Mode

In case the vehicle is not able to return to the track on its own after leaving the track, the team is allowed to activate RC-mode in order to guide the vehicle back to the track. Each activation of RC-mode is penalized. RC-mode is subject to the regulations in Section 3.8. Activating RC-mode without having left the track is considered a non-permitted use of RC-mode and will be penalized accordingly.

5.3.3 Scoring

5.3.3.1 Timing

Each team has 2 minutes to complete this event. Timing for the event starts with crossing the scratch line, or 30 seconds after the start button has been pressed.

5.3.3.2 Penalties

Violation	Maximum Count	Penalty
Allowed activation of RC-mode	∞	5 m
Non-permitted activation of RC-mode	∞	25 m
Faulty activation of brake light	3	5 m
Cancelled attempt / second attempt	1	40 m
Leaving the right lane with more than one wheel	∞	5 m

5.3.3.3 Scoring

The longest covered distance under consideration of penalties will be awarded the maximum number of points. The subsequent teams will be scored in relation to the best team.

5.4 Obstacle Evasion Parcours

The event "Obstacle Evasion Parcours" extends the Free Drive w/o Obstacles with additional elements which need to be considered during the driving task. The event is separated into two classes (cf. Section 5.1). The rural road scenario is geared toward the participants of the basic class. For the teams in the advanced class, the rural road scenario is, amongst others, extended



with a suburban section of the track. The advanced class is an extension of the basic class: All elements which are present for the basic class must also be considered in the advanced class. The following sections describe the different elements.

5.4.1 Basic Class: Scenario "Rural Road"

The following scenario is based on the event "Free Drive w/o Obstacles", thus the assumption of a rural road scenario is maintained. All definitions concerning the course of the road maintain validity.

5.4.1.1 Static Obstacles

During this event, a number of static obstacles will be placed in the right lane, in the left lane and outside of the track. The body of each obstacle consists of white cardboard with dimensions as specified in the appendix (Chapter 7.4.1). Obstacles can be fixed on the ground and are spaced at least 1000 mm apart. The obstacles cannot always be attributed to a single lane, however under no circumstance can both lanes be blocked. Static obstacles outside the track are no artifacts in the sense of Section 5.3.1.4, thus the described minimum distance to lane markings for artifacts does not apply.

Obstacles may force the vehicle to change lanes. Lane changes must be indicated using the turn indicators. Passing maneuvers must be executed without touching an obstacle. They must be completed after a maximum distance of 2 m after having passed the obstacle.

5.4.1.2 Dynamic Obstacles

Apart from static obstacles, at least one dynamic obstacle is present on the track. Its shape resembles the static obstacles ("driving white cardboard box") and it can be encountered in both lanes and in combination with any other element, as long as this is not explicitly excluded. It moves at a speed of 0.6 m/s. Dynamic obstacles do not pass and do not execute lane changes.

Dynamic obstacles can stop temporarily and in turn block the right lane. It may be passed. Under no circumstance can a dynamic obstacle block both lanes in combination with a static obstacle. Passing maneuvers can be executed without encountering an obstacle on the left lane. The passing maneuver is subject to the same regulations as when passing a static obstacle.

5.4.1.3 Intersections

Sections of the track can be part of intersections with other parts of the track. The respective lanes cross perpendicularly. An intersection possesses four entries or exits respectively. Design and layout are shown in the appendix (Chapter 7.2.2.1). **In addition to the perpendicular cross section of the respective left and right lane boundaries, the intersection can display a round shape with a radius of about 100 mm. Intersections must be crossed driving straight.**

Intersections are displayed with stop lines to opposing entries. These lines are 40 mm wide and cross one lane completely. Additionally, a stop line is complemented by a traffic sign (stop sign, cf. Section 7.3). Entries without a stop line are not marked separately. The right of way is only announced by the respective traffic sign.

If a stop line is located in the own lane, the vehicle must stop for at least 3 seconds. The front of



the vehicle must be located in front of the stop line, however the distance must not be greater than 15 cm. The right of way of an dynamic obstacle must be respected at an intersection, if the dynamic obstacle is located within the defined area (cf. 7.2.2.6). If the vehicle does not possess the right of way, it must wait until the dynamic obstacle has completely crossed the intersection. Only one dynamic obstacle at a time can be present at an intersection.

5.4.2 Advanced Class: Suburban Scenario

In addition to the rural road scenario, the advanced class contains a suburban section of the track ("Suburban Scenario"). Apart from the elements mentioned above, this scenario contains additional elements which must be respected. As for obstacles, the additional elements are spaced at least 1000 mm apart. Elements do not overlap. Oncoming traffic is not to be expected, except for the case of a diagonally marked island.

5.4.2.1 Beginning and Ending of Scenario

The suburban area is a defined section of the track which is otherwise designed according to the rural road scenario. Beginning and ending of the suburban area are defined by according traffic signs (cf. Section 7.3 / 7.3) as well as by markings on the road surface (cf. Section 7.3 / 7.3). Within the suburban section, the speed limit is indicated by respective traffic signs (cf. Section 7.3)

5.4.2.2 Traffic Signs

In addition to the traffic signs defined in Section 5.3.1.3 and 5.4.1.3, the suburban scenario contains several other traffic signs which must be respected. Each traffic sign defines the beginning of the connected elements as defined in the following sections. Traffic signs can only occur in combination with their connected element. The exact dimensions and positioning are defined in the appendix of this document. Distances for longitudinal distances are measured on the right hand lane marking with a tolerance of ± 50 mm. Each Traffic Sign is complemented with an additional marking on the road surface, which must not have the same distance as the traffic sign to the corresponding element. See the following sections for the according specifications.

5.4.2.3 Diagonally Marked Islands

In addition to obstacles, the suburban scenario can contain diagonally marked islands on straight sections of the track. These areas block one lane for a length of max. 2000 mm, measured along the outer lane marking. These areas must be passed just as a regular obstacle. Diagonally marked islands are marked with a 20 mm wide trapezoidal outline. They are filled with 40 mm wide white markings with black spacing. For shape and dimensions see Section 7.2.3. Islands are at least 15 cm wide and always start at the right hand side of the lane.

Oncoming traffic has the right of way at islands, indicated by a corresponding traffic sign (cf. Section 7.3), which is located 50 cm before the beginning of the island. If a dynamic obstacle is located within 1 m of the beginning of the island, the vehicle has to wait. Before passing the island, oncoming traffic must have completely passed. The desired passing maneuver has to be indicated while waiting by flashing the left turn indicators. Only one dynamic obstacle



can at a time can occur in at islands. If the vehicle is able to pass the island without leaving the own lane and driving over the island markings, the vehicle may continue along the island even in case of oncoming traffic.

5.4.2.4 Crosswalks

In the suburban area, one ore more crosswalks may be present. These are marked with several 40 mm wide and 400 mm long white markings parallel to the direction of travel which are spaced 40 mm apart (see Section 7.2.4). On the roadside at each crosswalk "pedestrians" may wait to cross the road. For this purpose two areas are defined which may contain relevant pedestrians. A "pedestrian" is depicted by a small white cardboard box in analogy to the static obstacles. In addition, each pedestrian is marked with a picture in order to facilitate its detection (cf. Section 7.4.2). Apart from crosswalks, pedestrians are not to be expected on the track.

Multiple pedestrians can be located on the right as well as on the left hand side of the crosswalk. They are always located such that they can explicitly be differentiated at any time. The vehicle must stop in front of the crosswalk, if at least one pedestrian is present in the defined zones. Stopping must be performed with the same regulations as at intersections. Pedestrians start crossing the street only after the vehicle has stopped. If all relevant pedestrians have crossed the street, the vehicle may continue.

A crosswalk is indicated by a corresponding traffic sign (cf. Section 7.3) which is located 50 cm in front of the crosswalk.

5.4.2.5 Extended Regulations at Intersections

In addition to the requirements arising from stop lines, there can be different regulations for the right of way at intersections in the advanced class. Three types of intersections have to be considered:

- Intersections with stop lines (cf. Basic Class)
- Intersections with give-way lines
- Intersections without lines (priority to right)

Dimensions and layout of the intersections are displayed in the appendix (cf. Section 7.2.2.2 and 7.2.2.3). Stop and give-way lines are also announced by traffic signs (cf. Sections 7.3, 7.3). A give-way line is 40 mm wide and consists of 80 mm long dashes. Stop and give-way lines occur in pairs at opposing intersection entries. At a stop line, the vehicle must stop for at least 3 seconds. At a give-way line, the vehicle must stop for at least 1 second. Dynamic obstacles must be considered in both cases.

If an intersection does not contain any traffic regulation devices, priority to right is to be applied. Such intersections will not be announced by traffic signs. In this case, all four arms of the intersection will display a give-way line and the right of way of a possible dynamic obstacle must be respected. Scenarios which yield ambiguous regulations of the right of way will not be encountered.



5.4.2.6 Turning

In addition to the intersections described above, intersections in the advanced class can have a required direction to cross the intersection. This will be announced by a corresponding traffic sign and a marking on the road surface (cf. Section 7.3 und 7.2.2.4). Vehicles will have to turn left or right according to these regulations. In the intersection, dashed turn lines will be replace the dashed lane center line. Turn lines cannot be missing.

5.4.2.7 Speed Control

Within the suburban area, the vehicle has to adhere to the given speed limit. Devices for controlling the speed of the vehicle might be present.

5.4.2.8 No-Passing Zones

For the advanced class, sections of the track, not only in the suburban area, can be defined as no-passing zones. Corresponding traffic signs and lane markings will indicate such sections (cf. Section 5.3.1.2). In sections with a solid lane center line (either a single line or a solid line facing the ego lane) obstacles must not be passed.

However, if a passing maneuver has been started before a no-passing zone, the vehicle is allowed to return to the right lane in any case. In a no-passing zone, the dynamic obstacle must be followed at a distance of at least 300 mm until the end of the zone. Static obstacles will not block the right lane in no-passing zones. In combination with a dynamic obstacle, the whole track can be temporarily blocked. The vehicle must stop in these situations until it is allowed continue. No passing maneuvers are allowed in intersections.

5.4.3 Execution of the Event

5.4.3.1 Start (Additions)

The starting order of the teams will be visualized using the start scheduling system (cf. 6.3.2) during the competition. The same start box as for the Free Drive w/o Obstacles must be used.

5.4.3.2 Attempts

An attempt can be cancelled by the team representative within 30 seconds. The team is then allowed a second attempt, after all other teams have completed their first attempt. Cancelling an attempt is penalized (cf. Section 5.3.3).

5.4.3.3 RC-Mode

In case the vehicle is not able to return to the track on its own after leaving the track or after a collision, the team is allowed to activate RC-mode in order to guide the vehicle back to the track. Each activation of RC-mode is penalized. RC-mode is subject to the regulations in Section 3.8. Activating RC-mode without having left the track is considered a non-permitted use of RC-mode and will be penalized accordingly.



5.4.4 Scoring (Additions)

5.4.4.1 Timing

Each team has 2 minutes to complete this event.

5.4.4.2 Penalties

Penalty	Maximum Number	Penalty
Stopping outside of the 15 cm area at intersections	∞	5 m
Violating right of way	∞	20 m
Ignoring Crosswalks	∞	30 m
Collision with an obstacle	∞	5 m
Driving over a diagonally marked island	∞	5 m
Speed limit violation	once per section	10 m
Passing in no-passing zone	∞	10 m
Violating safety distance to dynamic obstacle	∞	5 m
Too long passing maneuver	∞	5 m
Falsely using turn indicators	3	5 m

5.4.4.3 Scoring

The longest covered distance under consideration of penalties will be awarded the maximum number of points. The subsequent teams will be scored in relation to the best team.



6 Competition Schedule

In this section, the general schedule execution of the competition is described.

6.1 Training

In order to guarantee safe and fair training conditions, the training sessions are divided into time slots. The number of teams allowed on the track at the same time and the length of the slots will be announced on the Website before the competition. The commission might change the slots and the number of teams on the track without further notice. In case of repetitive violation of training slots, the commission may issue penalties which will be subtracted from the final score of the respective teams. **In case of repetitive violations of slots or if team members endanger other teams or their equipment, the commission may expel single team members or whole teams from the competition.**

6.2 Qualifying

In order to compete in the dynamic events, the vehicle must fulfill the following requirements in addition to the technical regulations in Chapter 3:

1. The vehicle must be able to follow the road for at least 30 seconds.
2. One out of three parking attempts must be successful.

The fulfillment of these requirements will be checked by the referees during the training sessions. The parking attempts as well as the test drive will be recorded and cut to a 60 s video clip. This video will be shown to the judges during the static events.

6.3 Competition

6.3.1 Preparations

30 minutes before the beginning of the competition, the teams must hand in their vehicles at the parc fermé. No modifications of the vehicles must be made after this point. Batteries must be separated from the system, the vehicle must be switched off. All external tools must be removed from the vehicle, all wireless communication on board the vehicles except for the remote control (Wifi, Bluetooth, etc.) must be switched off or removed. The remote control must be placed next to vehicle in switched off state. When handing in the vehicle, the teams must make a definite statement to the head referee in which events they would like to participate. This is to ensure a smooth execution of the competition.



6.3.2 Start Scheduling System

A traffic-light-like start scheduling system will signal the teams when to pick up their vehicle at the parc fermé and when to begin to prepare for starting. The traffic light will show the following stages:

1. Red: No preparation necessary
2. Yellow: The vehicle must be prepared for start. The team picks up their vehicle at the parc fermé. Time budget for preparation is 5 minutes.

The teams may change to fully charged batteries in this context. However, no additional tools must be used at this stage. The idle but ready vehicle must be placed inside the start box or at least brought to the scratch line at this point. Timing will start, regardless whether the vehicle is ready or not.

3. Green: When showing "green" the teams have 30 s to start their vehicle. The vehicle will be started by a judge or a referee by pressing the pushbutton for the respective event.

After each event, the vehicle must be returned to the parc fermé.

6.3.3 Order of Events

The first event is Parking: One team after another starts their parking event according to the regulations in Chapter 5.2. The order is fixed, **grouped by the two classes. Teams in the basic class start first, followed by the teams in the advanced class.** The calls for preparation and start are made according to the above mentioned start scheduling system.

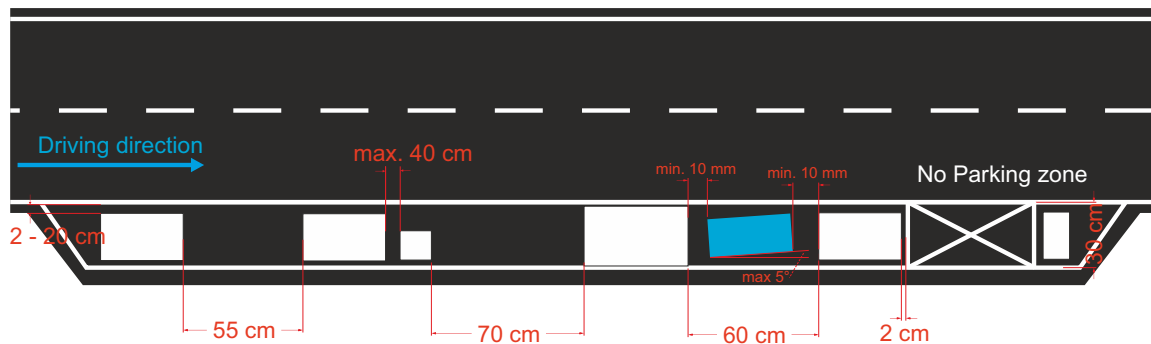
The events "Free Driving w/o Obstacles" and "Obstacle Evasion Parcours" will follow in the given order. **All teams first start in the event "Free Driving w/o Obstacles" in the same order as during the "Parking" event.** An attempt can be cancelled according to the regulations in Chapter 5.3.2.2. The respective team is moved to the end of the schedule and will be called again to attempt a second run.

Eventually, the event "Obstacle Evasion Parcours" will be executed. The teams in the basic class start first. After adaption of the track, the teams in the advanced class start their event.

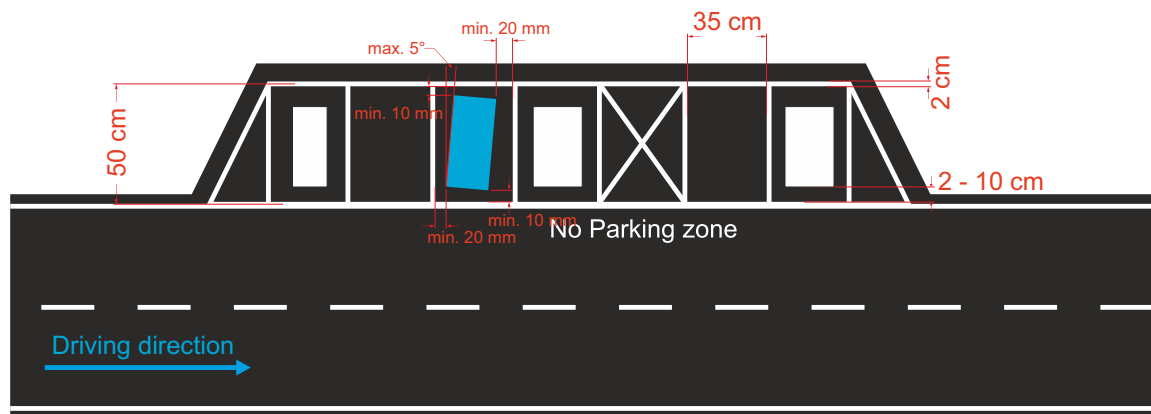
7 Appendix

7.1 Possible Parking Lot layouts

7.1.0.1 Parallel Parking



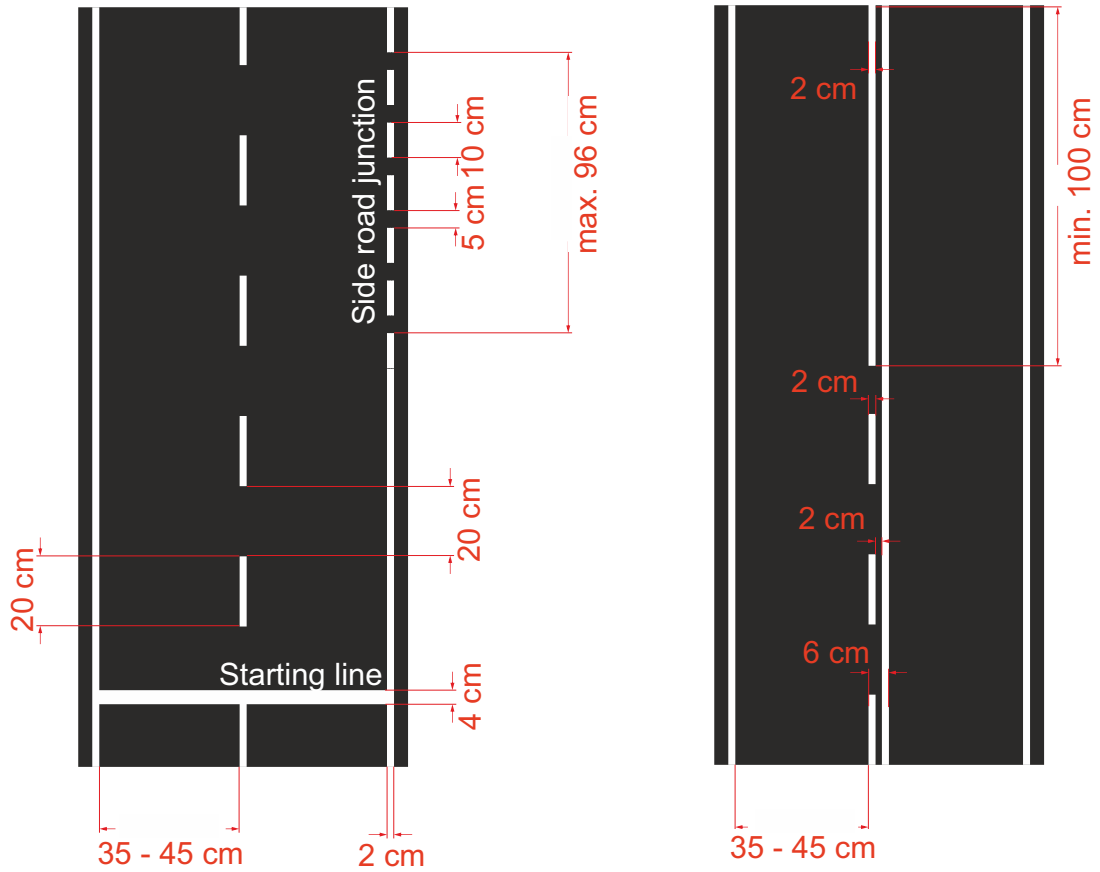
7.1.0.2 Perpendicular Parking





7.2 Road description

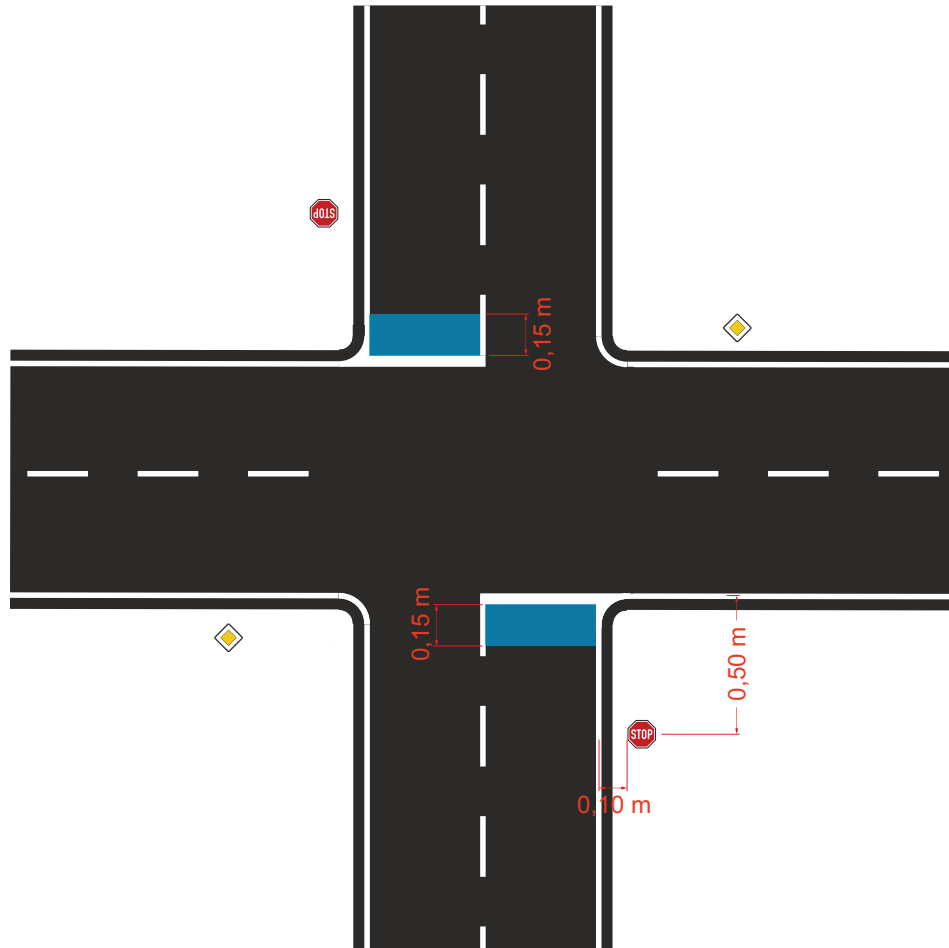
7.2.1 Road layout and lane markings



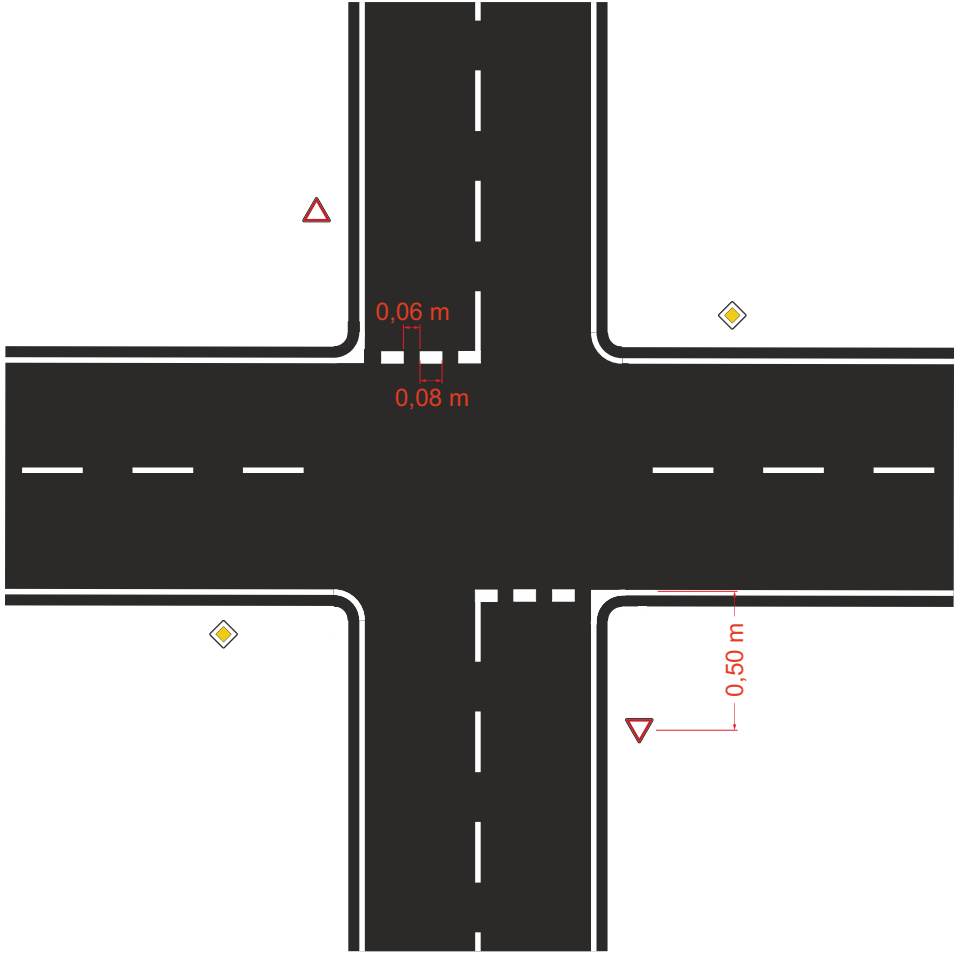


7.2.2 Intersections

7.2.2.1 Intersections with stop lines

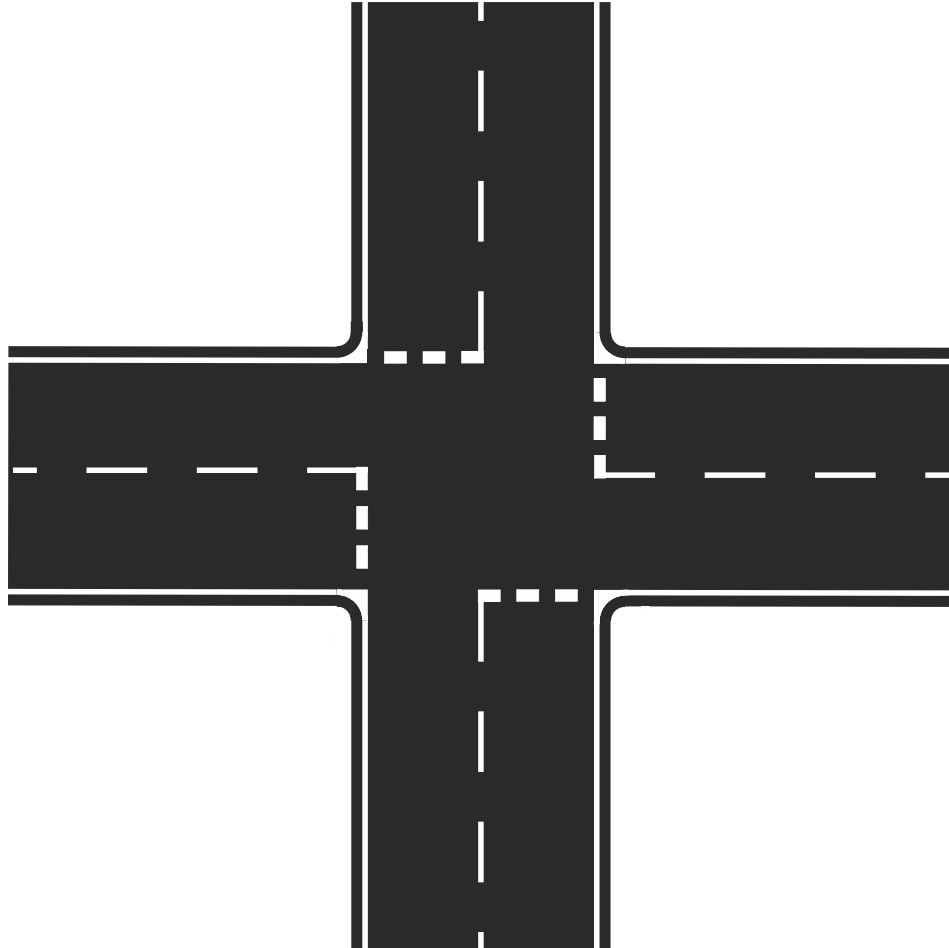


7.2.2.2 Intersections with give-way lines



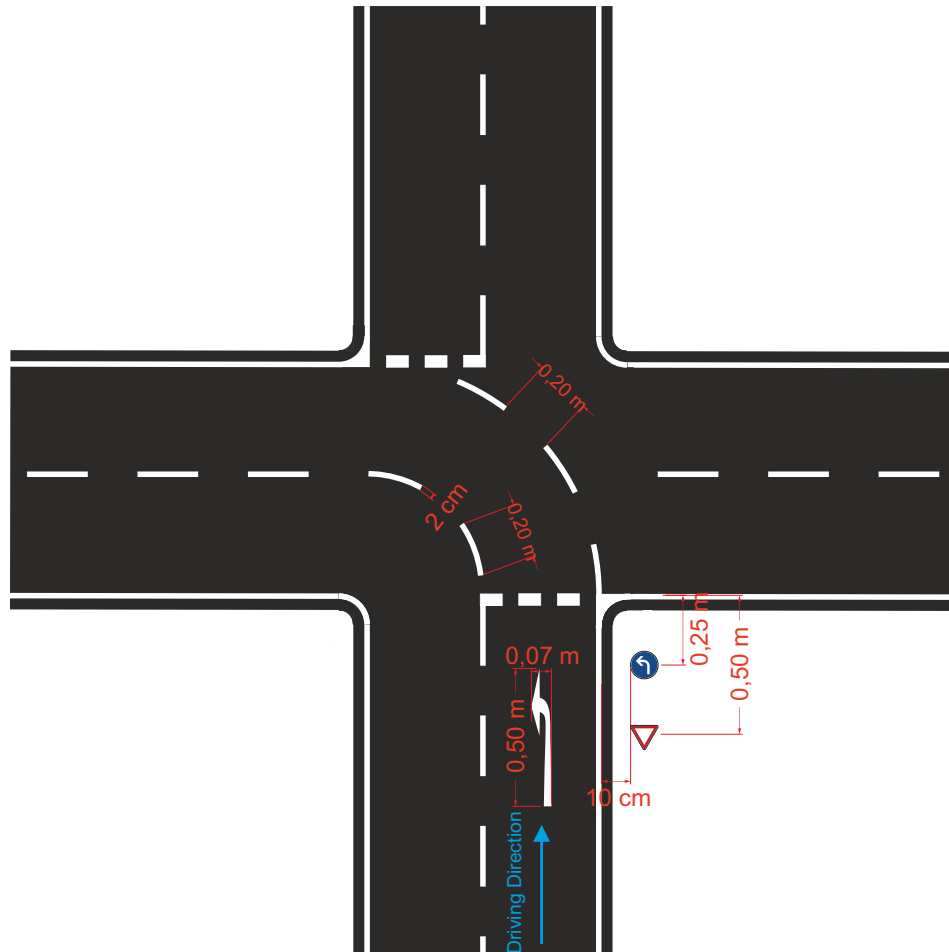


7.2.2.3 Intersections with priority to right



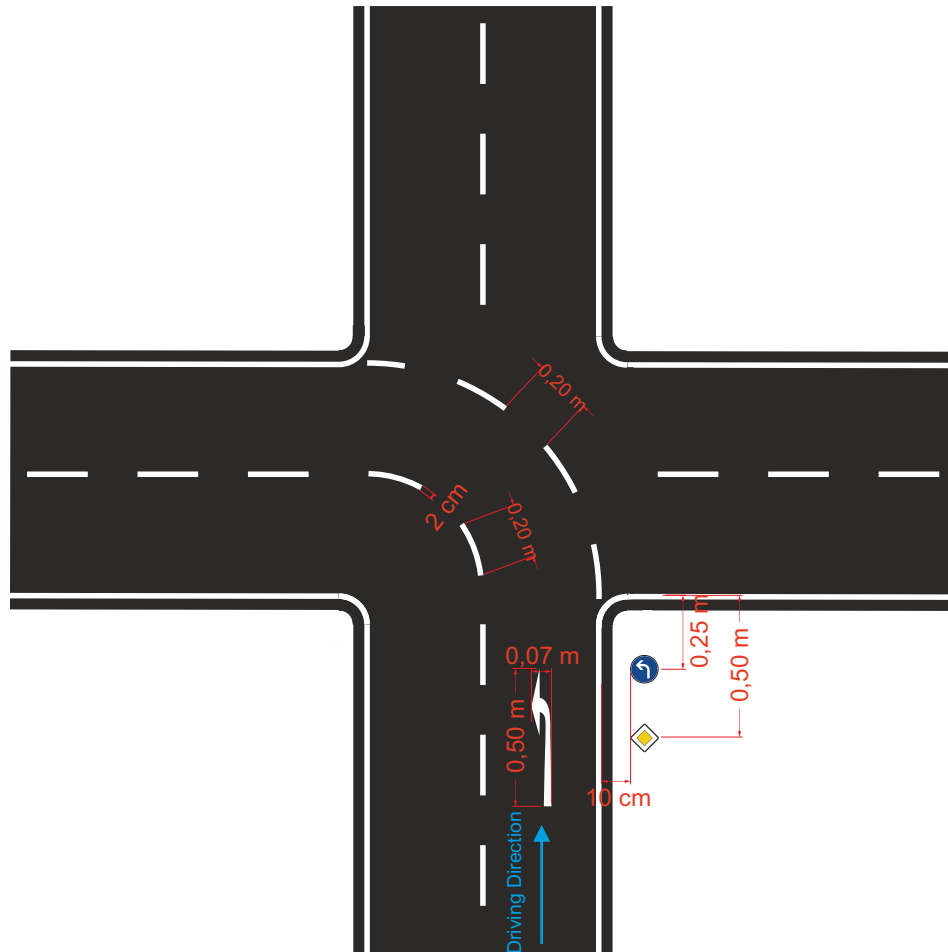


7.2.2.4 Enforced crossing direction - give-way condition



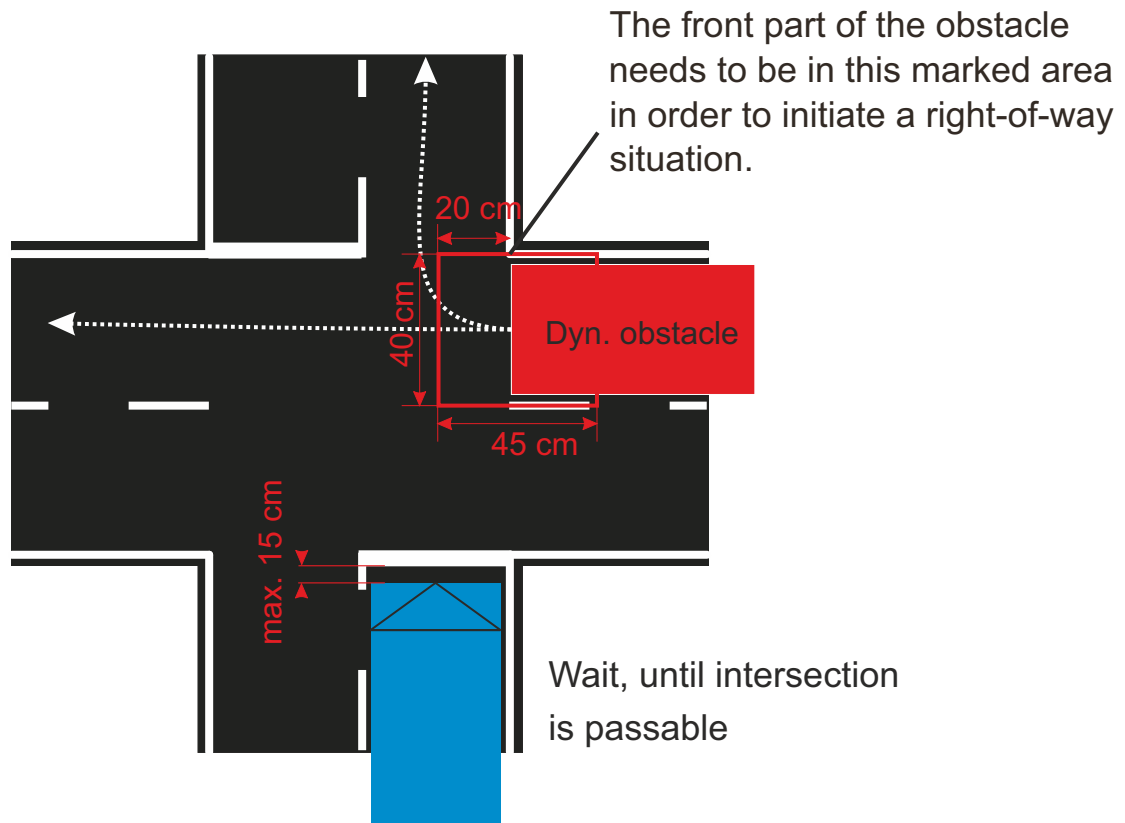


7.2.2.5 Enforced crossing direction - right of way condition



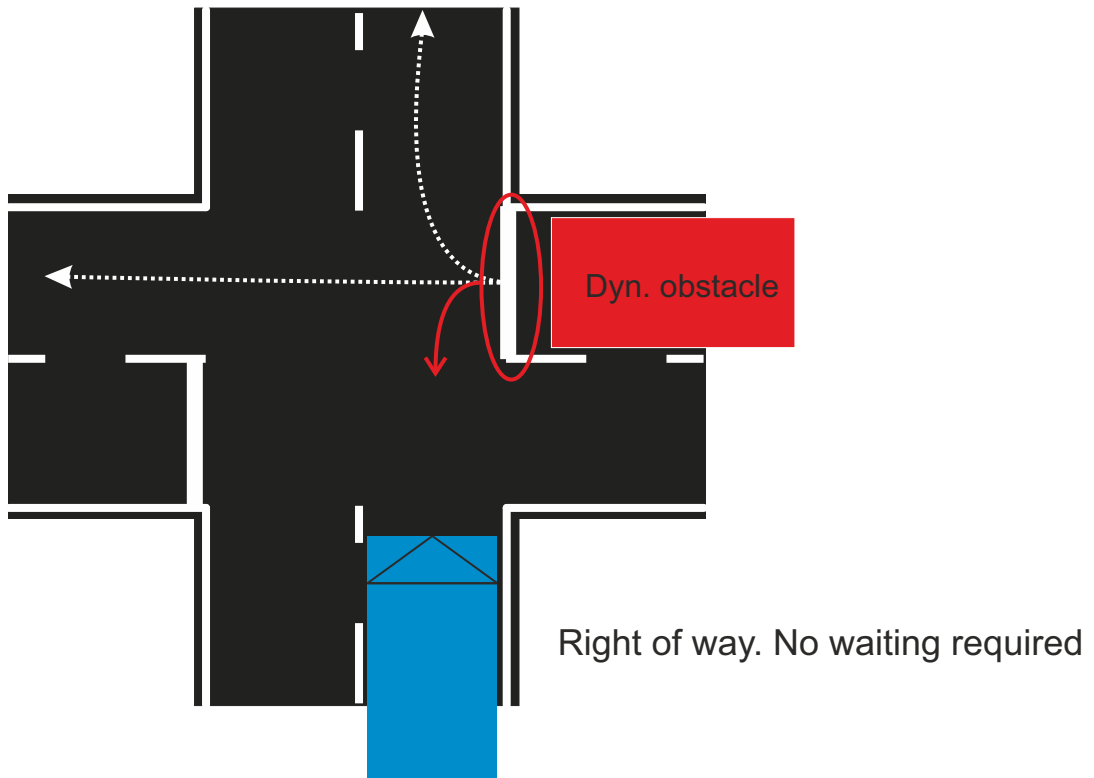


7.2.2.6 Dynamic obstacles at intersections - Give way condition

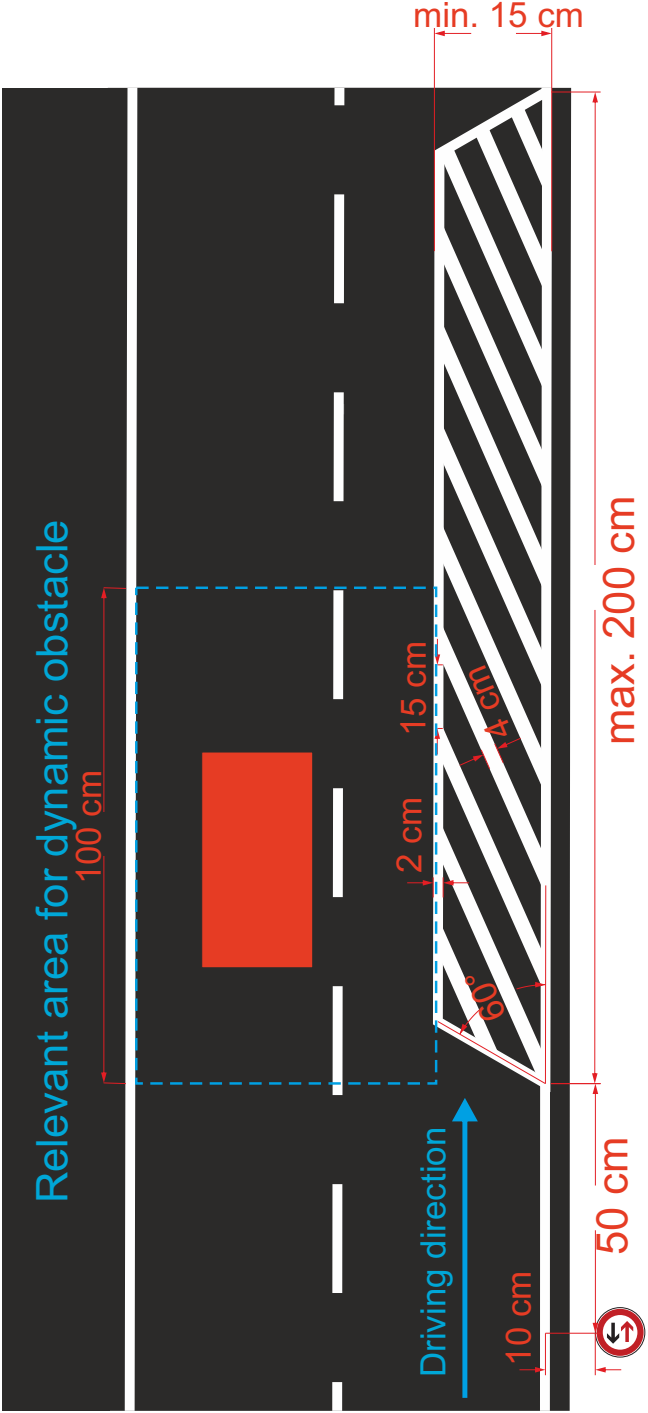




7.2.2.7 Dynamic obstacles at intersections - Right of way condition

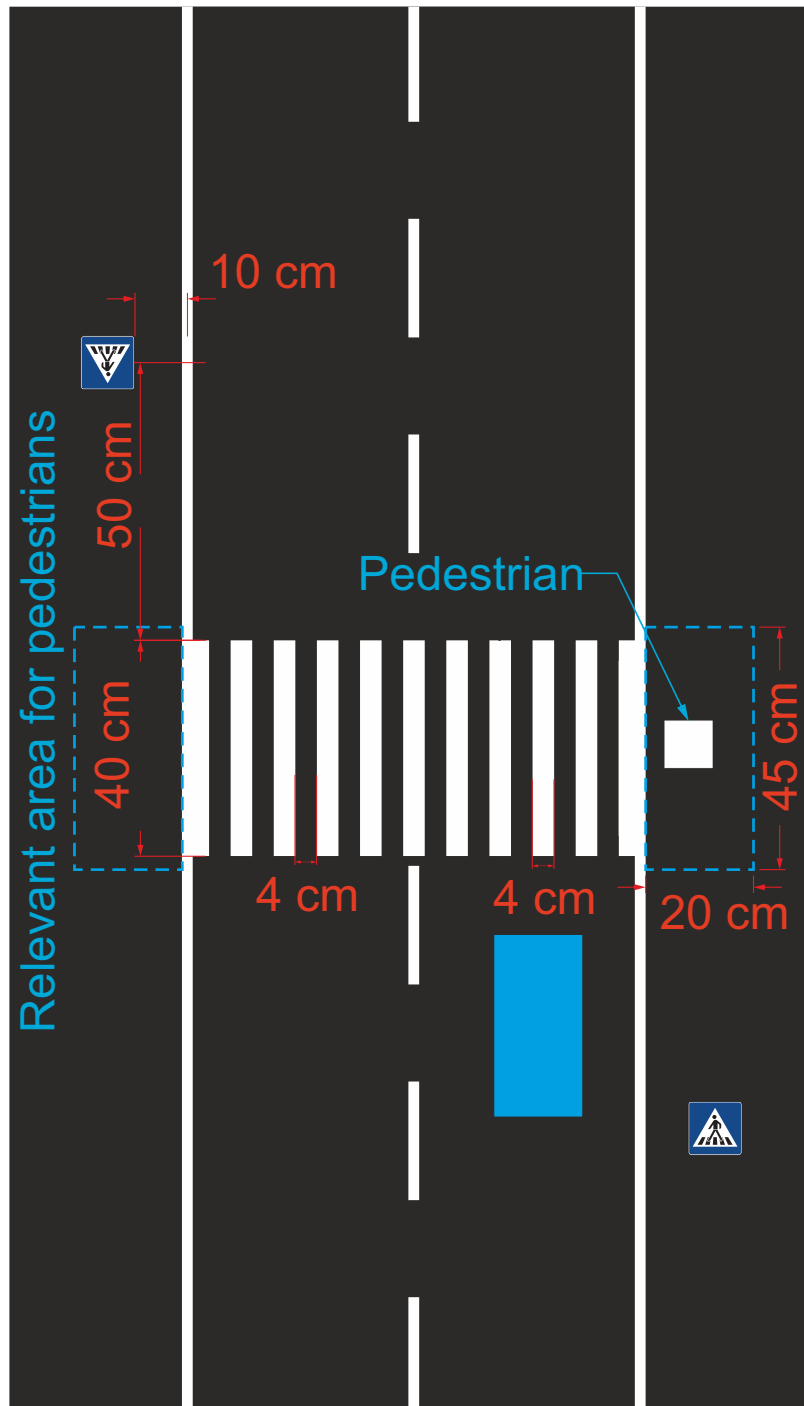


7.2.3 Blocked areas



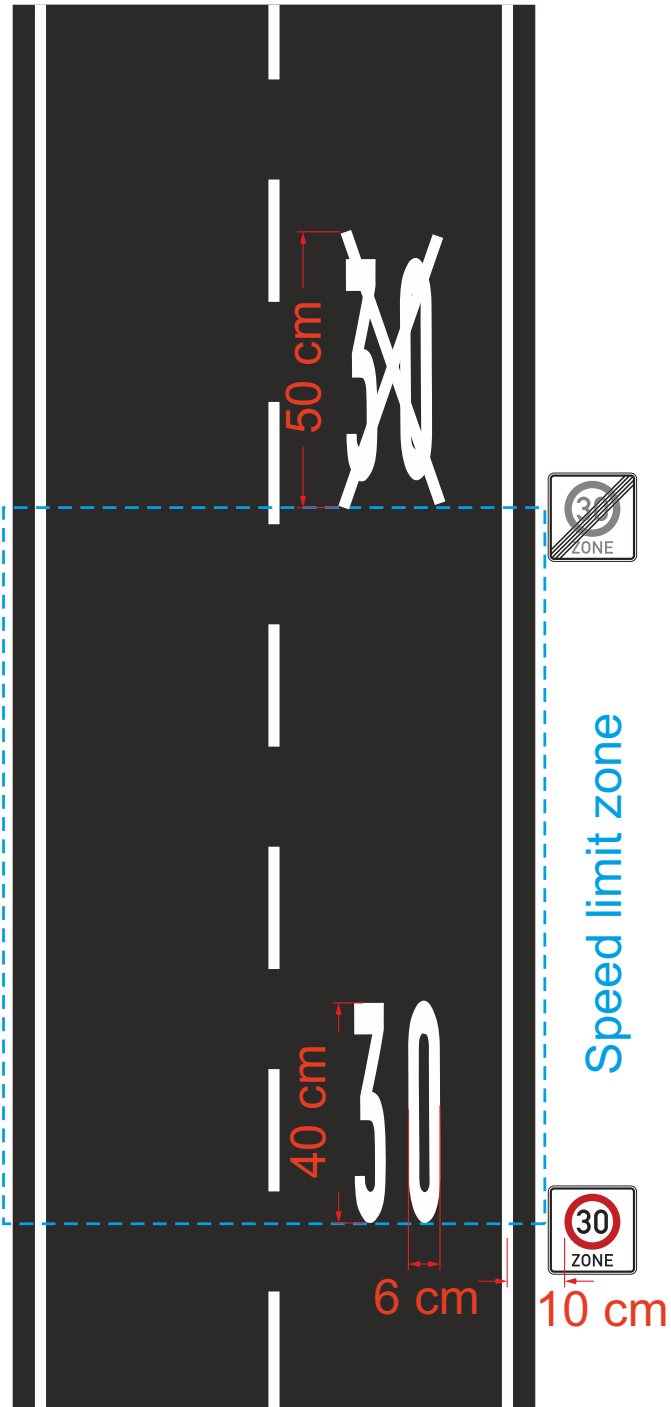


7.2.4 Crosswalks





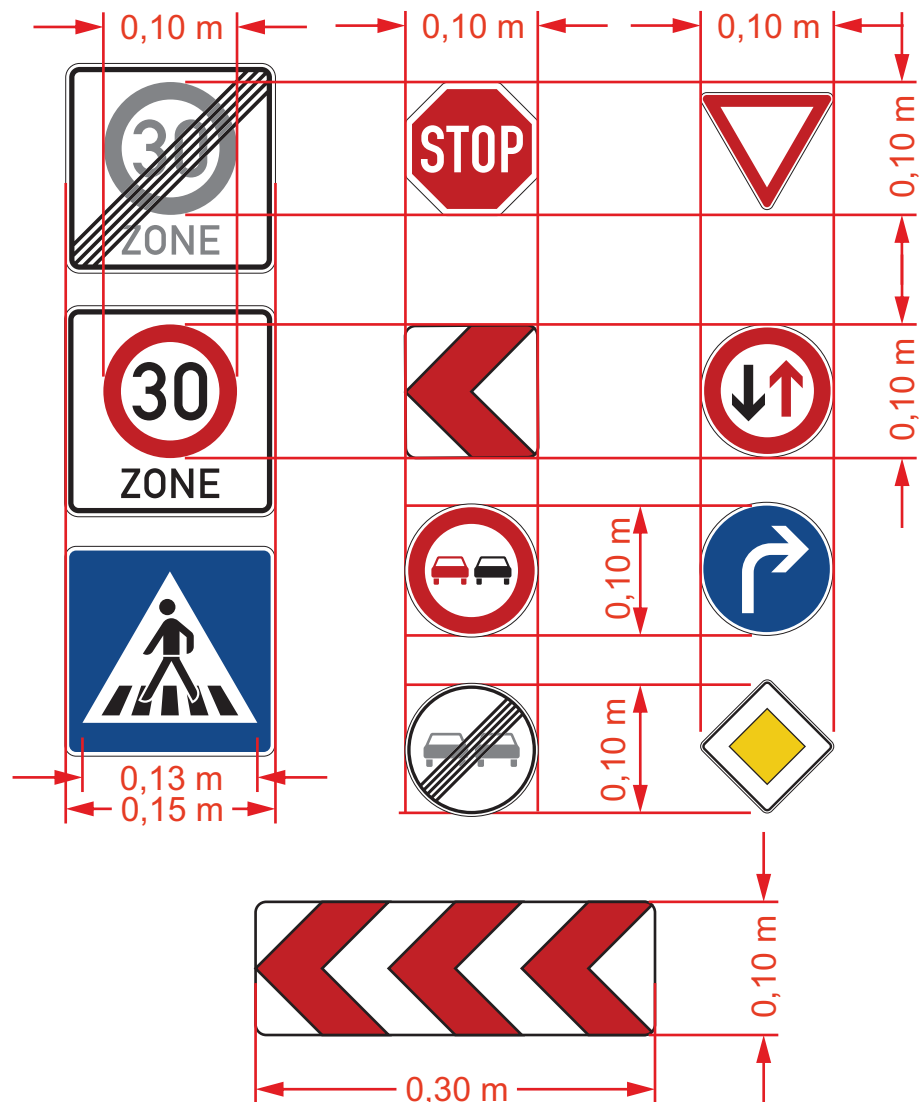
7.2.5 Speed limit zone





7.3 Traffic signs and guidance symbols

7.3.1 Definition of traffic signs

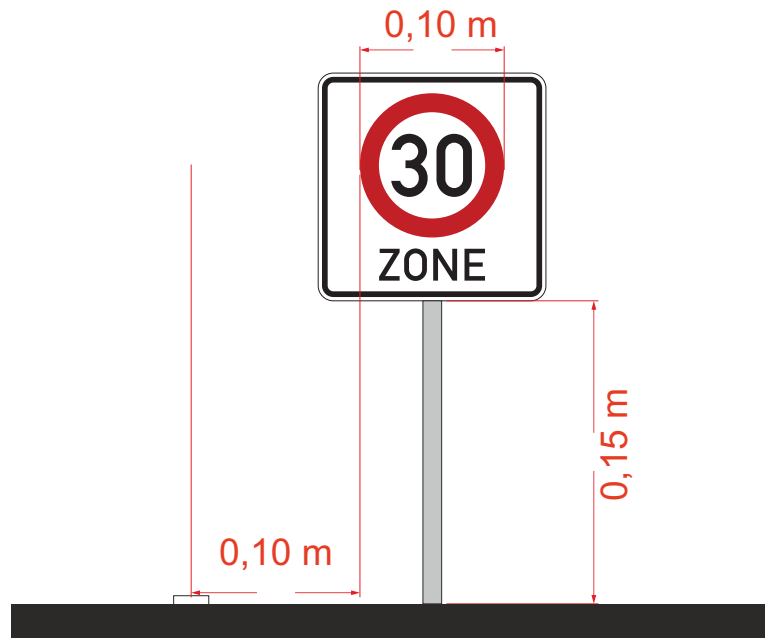


The traffic signs are defined according to StVO (Legal definition of traffic rules) and are applied as described there, except otherwise defined in this regulations. Additional information about the dimensions can be scaled based on this source. In addition to the speed limits depicted in the above signs, other numeric signs might appear (e.g. a speed limit of 20 km/h). The speed limit is stated in steps of 10 and have to be scaled by 1:10 (i.e. a speed limit of 30 km/h corresponds to 0,83 m/s).

Traffic signs might appear in their mirrored version as well, i.e. guidance symbols may also show to the right side.

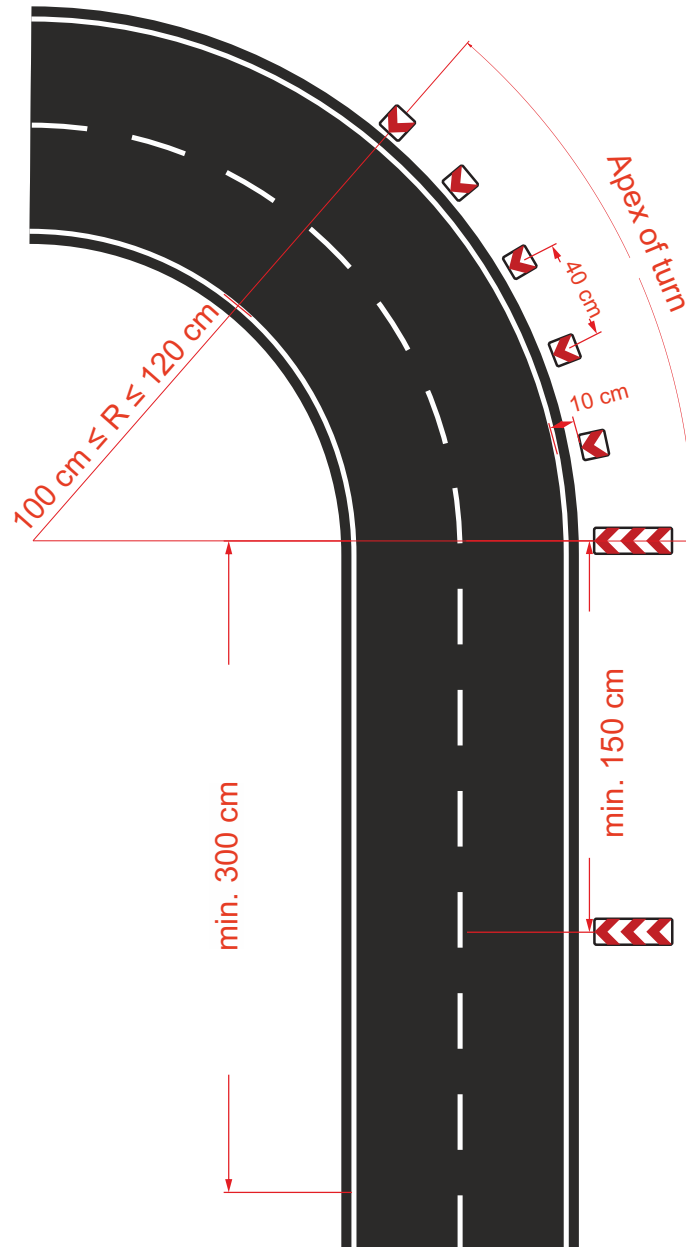


7.3.2 Positioning of traffic signs (example sign)





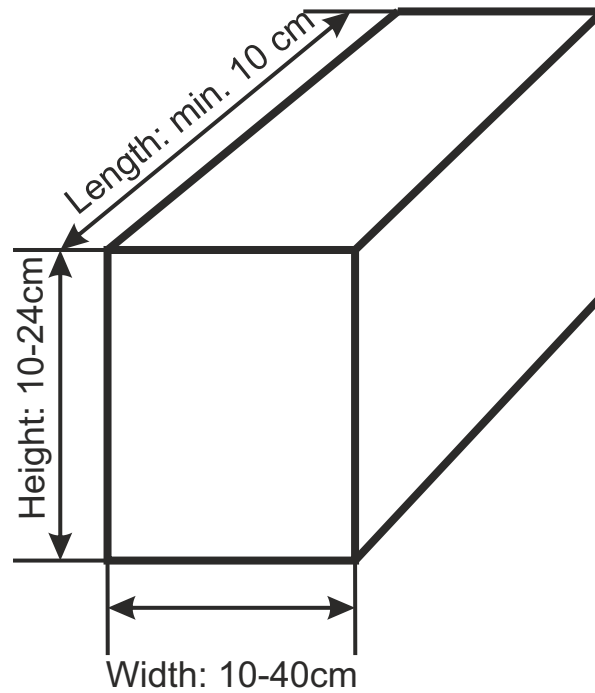
7.3.3 Markings for sharp turns



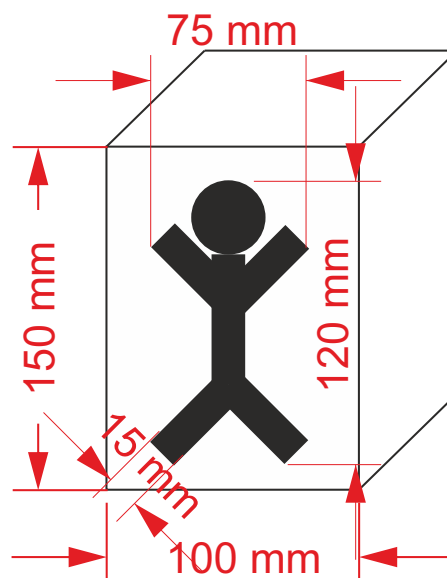


7.4 Dimensions of obstacles

7.4.1 Vehicles



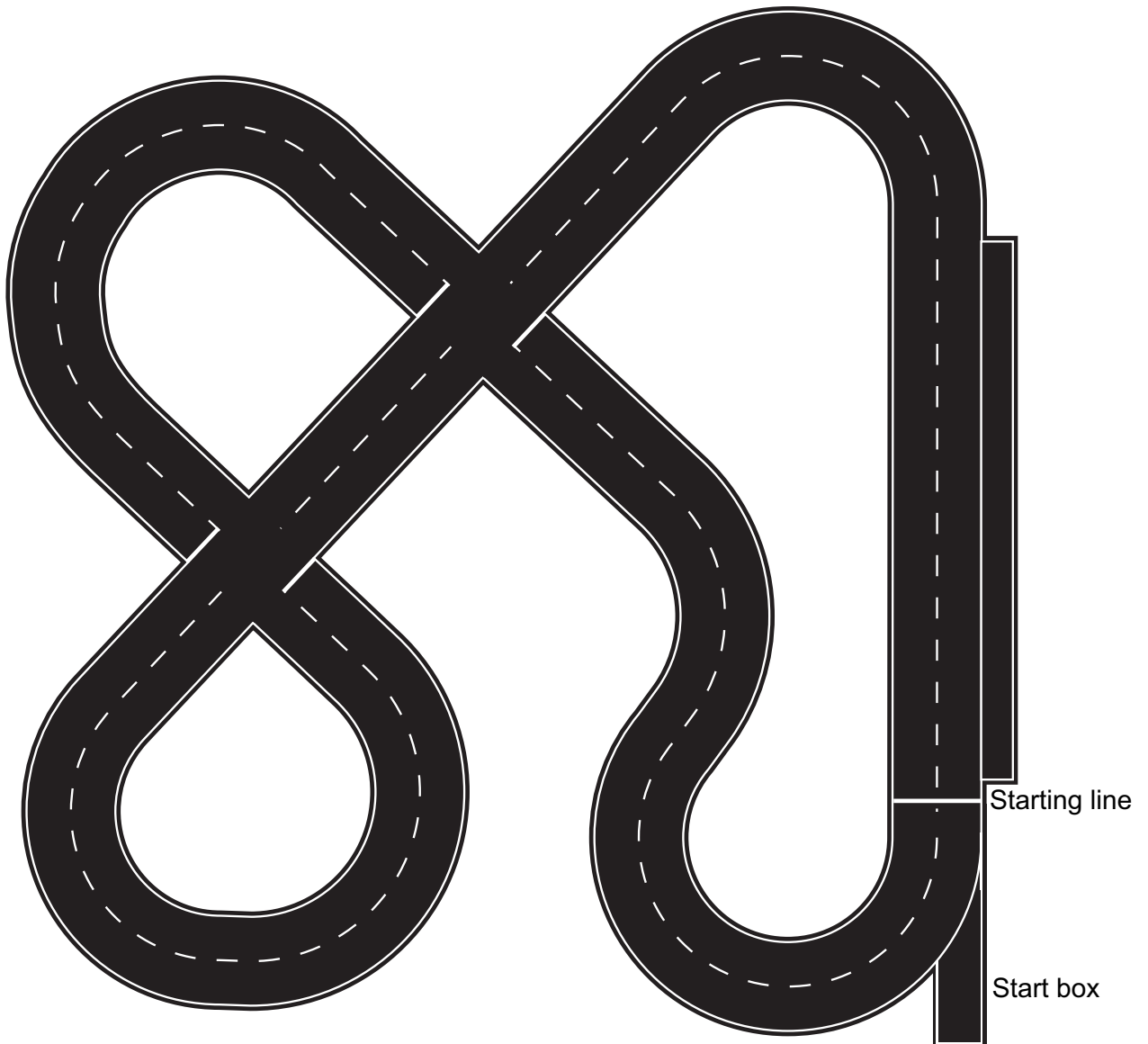
7.4.2 Pedestrians





7.5 Example Circuits

Example circuit - Without missing lane markings:





Example circuit - With missing lane markings and obstacles:

