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Safety in Non-Urban Areas for VRU (SANA-4U)

WP4 Preparation of Guidelines for Selection of Design of VRU Infrastructure

Deliverable No D4.1

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VTI (Sweden)

BRRC (Belgium)

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CEDR Call Safety 2016

Safety in Non-Urban Areas for VRU (SANA-4U)

Deliverable 4.1: Draft version of Guidelines for Selection of Design of VRU Infrastructure

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Glossary of Terms

AADT	Average annual daily traffic (measure of traffic volume).
CEDR	Conference of European Directors of Roads
CPiJ	Crossing Points in Junctions
HF	Human factors (HF) is the application of psychological and physiological principles to the design of products, processes, and systems. The goal of human factors is to reduce human error, increase productivity, and enhance safety and comfort with a specific focus on the interaction between the human and the thing of interest (from Wickens et al., 2004).
MV	Motorised vehicles
NMU	Non-motorised users
NRA	National road authority
NUA	Non-urban areas: Specifies a transition zone which can comprise a road length which is designed between the rural and urban areas.
VRU	Vulnerable Road User: The road user groups defined as vulnerable road users in this project comprises pedestrians and cyclists. Electric bicycles are classes as bicycles if the effect does not exceed 0.250 kW (and speed restricted to 25 km/h). Motorised wheelchairs are included. Electric bicycles with an engine effect > 0.25 kW are classed as mopeds (class 1 or 2 depending on power) or motorcycles if they exceed 4 kW. Neither of these types are classed included in the projects definition of VRU. Equestrian transport or hackneys are not included in this project's definition of VRU.

1 Introduction

The promotion of active transport (cycling and walking) for everyday physical activity is a win-win approach; it not only promotes health but can also lead to positive environmental effects, especially if cycling and walking replace car trips. Cycling and walking can also be more readily integrated into people's busy schedules than, for example, leisure-time exercise. However, of course, we must ensure that these activities by cyclists and other vulnerable road users (VRU) can be done in a safe environment.

Promoting safety for VRU is an item that comes back in several initiatives, on national and European levels. Many European Road Authorities focus their design standards on VRU's. However, those standards have been developed to be implemented in new road projects and are unfortunately not always implemented on the existing road network outside urban areas.

Over the course of this project, we have reviewed VRU standards across member states, analysed them and developed a "good practice guide" with focus on self-explaining systems for VRU in non-urban areas. It is worth noting that this work focuses on the development of guidance for design of cycle facilities to be used primarily by commuter and tourists rather than higher speed exercise/race biking.

The next and almost last step in the project is the creation of guidelines. This document, ***Deliverable 4.1 Draft version of guidelines***, is created during WP4 Preparation of Guidelines for Selection of Design of VRU Infrastructure.

2 Project & WP 4 objectives

The objectives of this project are to identify improvements to existing standards and guidelines for the design of self-explaining road systems that promote safety for vulnerable road users (VRU) especially in non-urban areas. The non-urban areas of main interest comprise existing legacy road networks in CEDR member states.

Work package 1 (WP1) reviewed available VRU Standards across CEDR member states and these were summarised in *D1.1 "Review of Standards and Practices for VRU on non-urban roads"*.

Work package 2 (WP2) collected and presented a number of examples, both good and bad (or rather less good), for implemented cycle and pedestrian schemes in non-urban areas. The examples collected were done through road authority contacts made during WP 1 as well as through internet searches for relevant examples.

Examples for various elements of non-urban VRU design were collected and presented in the WP2 report, *D2.3 Final version of the Good Practice Guide*. The report reviewed the following cycle and pedestrian design elements:

- Crossing points;
- Junctions (which have good visibility and poor visibility);
- Continuous road segments, including curves (which have good visibility and poor visibility);
- School Zones;
- Small linear settlements, small numbers of houses/buildings alongside the road which are not indicated/characterised as a city or town, but does result in VRU's walking and cycling along or across the road;
- Roundabouts (rural roundabouts).

For each of the design elements reviewed, a list of good practice principles was established.

Work package 3 (WP3) focused on 3 worked examples. This WP 3 led to Deliverable *D3.1: "Report on three Worked Examples of Good Practice"* and presents sample concept designs, based on existing standards across Europe collected during Work Package 1, and the good practice principles identified in Work Package 2. The purpose of the worked examples was to test the applicability of the good practice identified on roads in different countries with different characteristics and constraints.

The present Deliverable 4.1 is part of WP 4 Preparation of Guidelines for Selection of Design of VRU Infrastructure. The final objective of WP 4 is to come to well-founded guidelines concerning VRU's which can be implemented on the existing legacy road network, in particular in non-urban areas.

Those established guidelines are the result of the good practices, prepared in WP 2 (= rather a theoretical approach), combined with findings and recommendations after analysing the "worked examples" (= a practical approach, in the field) which were carried out in WP 3.

3 Methodology

The guidelines in this document can be subdivided into the following topics:

- Crossing points;
- Junctions (which have good visibility and poor visibility);
- Continuous road segments, including curves (which have good visibility and poor visibility);
- School Zones;
- Small linear settlements, small numbers of houses/buildings alongside the road which are not indicated/characterised as a city or town, but does result in VRU's walking and cycling along or across the road;
- Roundabouts (rural roundabouts).

Sometimes it is difficult to make a clear distinction between crossing points and junctions, since several consulted documents take them together as one concept. The distinction becomes more and more difficult to make especially with bicycle infrastructure, since bicycle infrastructure can also be a "cycle street", the 'crossing point' with a (car) street looks more like a junction than a 'crossing point'.

For this reason, in these guidelines there is sometimes a vague border between crossing points and junctions.

Small linear settlements can also include crossing points, junctions, school zones or roundabouts. The other topics can therefore also be included.

To make a good recommendation, which is quickly readable, traffic lights-icons are used.

Legend: Traffic light metaphor

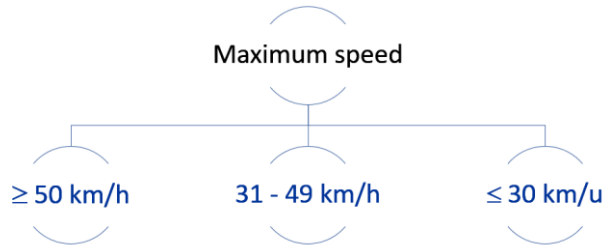
A traffic light metaphor using the red-amber-green colours to indicate appropriateness or level of the good practice-recommendations. The green hue being the most recommended and the red hue being the least appropriate (or used as a cautionary note). The amber hue could be advisable in certain circumstances given contextual considerations such as AADT.

	Items indicated with a green traffic light are much recommended as a good guideline, this should be the starting point, it may only be deviated for good reasons.
	Sometimes, the ideal situation cannot be achieved. Those recommendations – indicated with an amber traffic light- could also be effective, but sometimes have limitations, that we have to take into account.
	Short-term adjustments, but which must be thoroughly adjusted in the case of redesigns, are indicated with a red traffic light. Those solutions cannot be recommended on the long term.

4 Crossing points

As a starting point, one can state that the higher the permitted speed on the road to be crossed, the 'more secure' the safety of the crossing must be.

4.1 Guidelines for Crossing Points



High speed (> or = 50km/h) :

level crossing (pedestrian/cycle tunnel or bridge), since allowed speed on the road to cross is too high to be able to cross safely

bridge: a safe way to cross a major road, a gentle slope is necessary

tunnel:

reduce the speed locally at the height of the crossing (+ see guidelines below, by 50km/h)

be sure that traffic cannot stop or overtake in the immediate area of the crossing, this preserves forward visibility for approaching drivers so they can see people who are about to cross, or who are crossing

use traffic lights to protect the crossing

Speed between 31 and 49 km/h:

Ensure **good visibility** on the crossing, by:

using vertical elements to emphasize the crossing (and ensure recognisability with vertical elements and public lighting)

Lighting placed on the pole over the crossing

Clear signage on approach to the crossing warning motorists of presence of crossing, but also vice versa: cyclists and pedestrians yield to MV traffic with clear signage and marking denoting this

Flashing speed limit sign grabs motorists' attention.

Multiple warnings (zig-zag edge line, horizontal stripes) help increase awareness of a crossing.

be sure that traffic cannot stop or overtake in the immediate area of the crossing, this preserves forward visibility for approaching drivers so they can see people who are about to cross, or who are crossing

Ensure **good readability** on the crossing, by:

Indicate right of way situation in an unambiguous way;

if pedestrians/cyclists have priority, provide an adequate radius (4m min) on bend to allow comfortable movement of cyclists

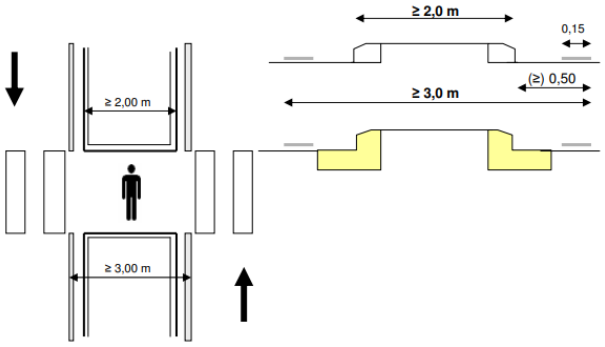
if pedestrians/cyclists do not have priority, this must be visible in the design and markings/signs

Reduce the crossing length, by:

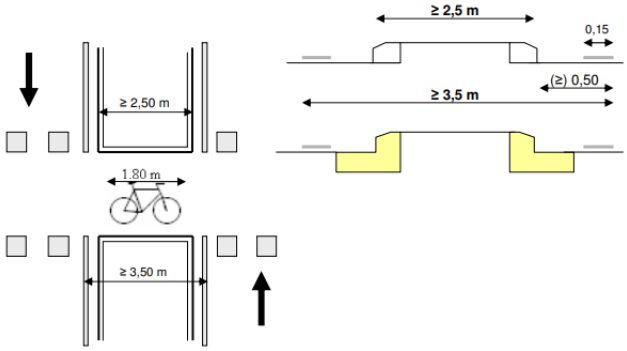
Using a traffic island: the provision of a traffic (refuge) island allows the user to cross the road in two halves, thus only requiring concentration on one direction of traffic flow at a time. Furthermore, the introduction of a refuge island can lead to reduced pedestrians and cyclist delays, thus improving convenience. It constitute the cheapest form of crossing facility. They can be introduced quickly without the need for formal administrative procedures.

Good dimensions of traffic islands are important!

For Pedestrians:



For Cyclists:



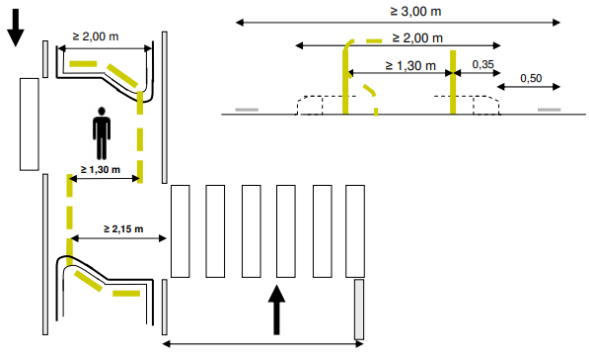
reduce the number of lanes at the height of the crossing to a maximum of one lane per driving direction

Visual and physical narrowing can help reduced MV speed (at the crossing)

Use of high-friction surfacing at sites where speeding is an issue, can help

Nudge the pedestrian/cyclist by oblige **them to look in the right direction**:

Staggered pedestrian crossing, especially when unregulated, i.e., without traffic lights, supports pedestrian safety by nudging the pedestrian into looking in the direction of oncoming traffic.



Staggered crossings for cyclist require more space for stopping, turning and stacking.

Low speed (< or = 30km/h) :

30km/h zones will not be common used outside urban area.

But if so, in general, pedestrians and cyclists should cross the road wherever they want, so marked crossings aren't necessary.

Of course, the infrastructure must comply with the maximum speed permitted (it has to be clear (= visible in the infrastructure) that 30km/h is the maximum speed allowed).

4.2 Schematic overview for Crossing Points for pedestrians

Qualitatively

On the short term

	Local road	**Secondary road**	**Primary road**
Max speed limit **> 90km/h**	No pedestrian crossing	No pedestrian crossing	No pedestrian crossing OR Traffic lights with conflict-free left and right turns and camera
Max speed limit **< or = 90km/h** and V_{85} < or = 100 km/h	Zebracrossing (supplemented with vertical elements (posts))	Junction with major road: Traffic lights or roundabout Junction with priority: Zebracrossing with traffic lights	Zebracrossing supplemented with vertical elements (posts) + flashing light when pedestrian is detected OR Traffic lights with conflict-free left and right turns
Max speed limit **< or = 70km/h** and V_{85} < or = 80 km/h	Junction without priority: Zebracrossing On a 2x2 road: Zebracrossing supplemented with vertical elements (posts)	Junction without priority (with major road): Zebracrossing with traffic lights or roundabout Junction with priority: Zebracrossing supplemented with vertical elements (posts)	Zebracrossing supplemented with vertical elements (posts) + flashing light when pedestrian is detected OR Traffic lights with conflict-free left and right turns
Max speed limit **< or = 50km/h** and V_{85} < or = 60 km/h	zebracrossing On a 2x2 road: Zebracrossing supplemented with vertical	Junction without priority (with major road): Zebracrossing On a 2x2 road:	Exceptional OR Zebracrossing supplemented with vertical

	elements (posts)	Supplemented with vertical elements (posts)	elements (posts) OR No pedestrian crossing
Max speed limit = **30km/h**	In general: no marked crossing point needed If anyway: only zebracrossing	No pedestrian crossing	No pedestrian crossing

Source: Guidelines Flanders Region, "Voetgangersvademecum"

On the long term (target for the future)

	Local road	**Secondary road**	**Primary road**
Max speed limit **> 90km/h**	*No pedestrian crossing*	*No pedestrian crossing*	Split level interchange
Max speed limit **< or = 90km/h** and V_{85} < or = 100 km/h	Outside urban area: Zebracrossing with traffic light or roundabout	Junction with major road: Traffic lights or roundabout Junction with priority: Zebracrossing with traffic lights or roundabout Crossings: Zebracrossing with traffic light	Zebracrossing with traffic light + camera OR Split level interchange
Max speed limit **< or = 70km/h** and V_{85} < or = 80 km/h	Outside urban area: Zebracrossing and gateway On a 2x2 road: Zebracrossing supplemented with vertical elements (posts)	Junction without priority (with major road): Zebracrossing with traffic lights or roundabout Junction with priority: Zebracrossing supplemented	Zebracrossing with traffic light OR Split level interchange

		with vertical elements (posts)	
Max speed limit **< or = 50km/h** and V_{85} < or = 60 km/h	zebracrossing On a 2x2 road: Zebracrossing supplemented with vertical elements (posts)	Junction without priority: Zebracrossing on speed bump On a 2x2 road: Zebracrossing supplemented with vertical elements (posts) Junction with priority: zebracrossing and gateway crossings: zebracrossing and gateway	*No pedestrian crossing*
Max speed limit = **30km/h**	In general: no marked crossing point needed If anyway: only zebracrossing	*No pedestrian crossing*	*No pedestrian crossing*

Source: Guidelines Flanders Region, "Voetgangersvademecum"

Quantitatively

	Local road	**Secondary road**	**Primary road**
Transition zone	**> 900 pcu/h**: Distance between two zebracrossings = 180 till 360 m **Between 700 and 900 pcu/h:** Distance between two	**> 900 pcu/h**: Distance between two zebracrossings = 270 till 540 m **Between 700 and 900 pcu/h:** Distance between two	If (n of pedestrians/h) x (n of vehicles/h)^2 = 5 x 10^7 And n of pedestrians in one hour is equal or more than 40

	zebracrossings = 180 till 270 or 360 till 540 meters **< 700 pcu/h**: Zebracrossing if n pedestrians/h > 40 or near school, hospital, retirement home, public transport stop,	zebracrossings = 270 till 400 or 540 till 700 meters **< 700 pcu/h**: Zebracrossing if n pedestrians/h > 40 or near school, hospital, retirement home, public transport stop,	OR Separate traffic lights for pedestrians If (n of pedestrians/h) x (n of vehicles/h)^2 = 9 x 10^7 And n of pedestrians in one hour is equal or more than 50
Outside urban area	If (n of pedestrians/h) x (n of vehicles/h)^2 = 3 x 10^7	If (n of pedestrians/h) x (n of vehicles/h)^2 = 5 x 10^7	If (n of pedestrians/h) x (n of vehicles/h)^2 = 7 x 10^7

Source: Guidelines Flanders Region, "Voetgangersvademecum"

5 Junctions

Type of road crossing (primary/secondary) described in this section cover secondary road junctions only. I.e. a crossing point that traverses a secondary road that joins a primary road.

Traffic volume thresholds, expressed as average annual daily traffic (AADT), are an area for discussion and should not be seen as a prescriptive. Moreover, the bicycle AADT is often an elusive measure. Acquiring accurate/representative bicycle data for particular roads/paths may be difficult. The bicycle AADT can in practice be viewed as high or low levels of bicycle traffic if reliable data is not available. Note that bicycle traffic is often affected by e.g. weather, in a way that motor vehicle traffic is not.

Signposted speed limits of ≤ 30 km/h are not included in the scope of this chapter where these speed zones are predominately found in urban areas and not in non-urban areas.

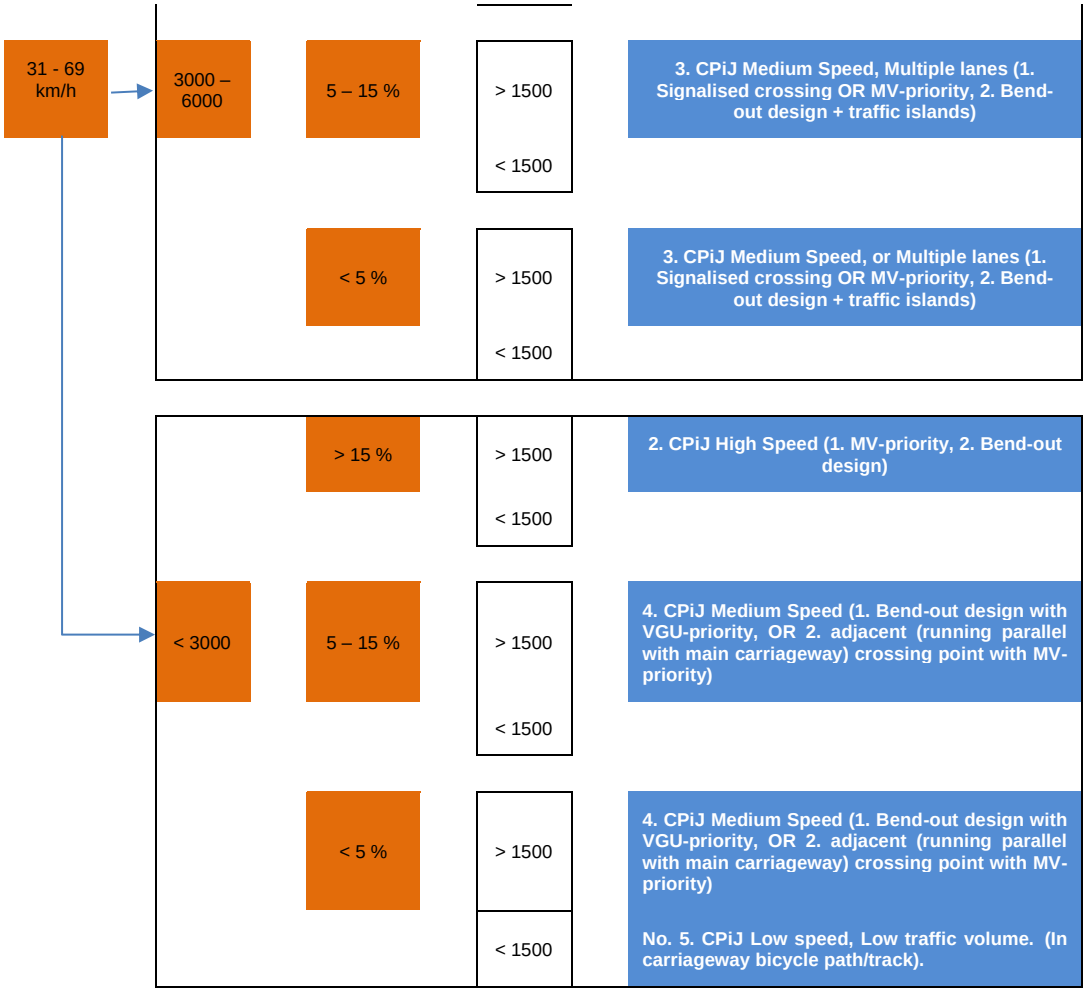
5.1 Decision-tree table – Crossing Points in Junctions (CPiJ) ≥ 70 km/h

Speed (km/h)	MV-AADT	% HGV AADT	Bicycle AADT	Recommended design	*Link to descriptions*
≥ 70 km/h	> 6000	> 15 %	> 1500	1. CPiJ High Speed, High Traffic volume (1. Signalised crossing, 2. MV-priority, 3. Bend-out design)	
			< 1500		
		5 – 15 %	> 1500	1. CPiJ High Speed, High Traffic volume (1. Signalised crossing, 2. MV-priority, 3. Bend-out design)	
			< 1500		
		< 5 %	> 1500	2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)	
			< 1500		
	3000 – 6000	> 15 %	> 1500	1. CPiJ High Speed, High Traffic volume (1. Signalised crossing, 2. MV-priority, 3. Bend-out design)	
			< 1500		
		5 – 15 %	> 1500	2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)	
			< 1500		

	< 5 %	> 1500		2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)
		< 1500		
	> 15 %	> 1500		2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)
		< 1500		
< 3000	5 – 15 %	> 1500		2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)
		< 1500		3. CPiJ Medium Speed, or Multiple lanes (1. Signalised crossing OR MV-priority, 2. Bend-out design + traffic islands)
	< 5 %	> 1500		2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)
		< 1500		3. CPiJ Medium Speed,or Multiple lanes (1. Signalised crossing OR MV-priority, 2. Bend-out design + traffic islands)

5.2 Decision-tree table – Crossing Points in Junctions (CPiJ) 31 – 69 km/h

Speed (km/h)	MV-AADT	% HGV AADT	Bicycle AADT	Recommended design	*Link to descriptions*
		> 15 %	> 1500	1. CPiJ High Speed, High Traffic volume (1. Signalised crossing, 2. MV-priority, 3. Bend-out design)	
			< 1500		
	> 6000	5 – 15 %	> 1500	1. CPiJ High Speed, High Traffic volume (1. Signalised crossing, 2. MV-priority, 3. Bend-out design)	
			< 1500		
		< 5 %	> 1500	2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)	
			< 1500		
		> 15 %	> 1500	2. CPiJ High Speed (1. MV-priority, 2. Bend-out design)	
			< 1500		



Description of *Recommended Crossing Points in Junctions* (CPiJ) that are alluded to in the decision tree tables above.

No. 1. CPiJ High Speed, High Traffic volume

(1. Signalised crossing, 2. MV-priority, 3. Bend-out design).

No. 2. CPiJ High Speed

(1. MV-priority, 2. Bend-out design).

No. 3. CPiJ Medium Speed, or Multiple lanes

(1. Signalised crossing OR MV-priority, 2. Bend-out design + traffic islands).

No. 4. CPiJ Medium Speed

(1. Bend-out design with VGU-priority, OR 2. Adjacent (running parallel with main carriageway) crossing point with MV-priority).

No. 5. CPiJ Low speed, low traffic volume.

(In carriageway bicycle path/track. Not for pedestrians or other VRU-groups).

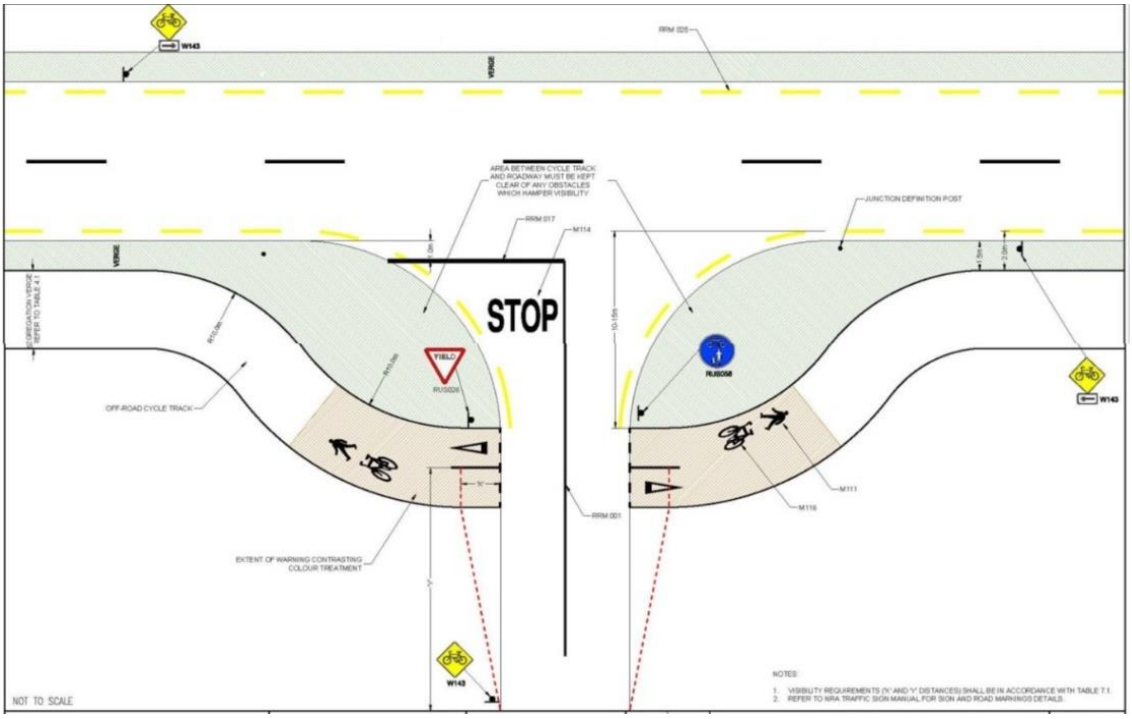
5.3 Detailed description of No. 1. CPiJ High Speed, High Traffic volume.

Design specification	Solution	Possible next best solution
Geometric considerations	Bend-out design. Crossing point min. 10 m from main carriageway.	
Orientation of priority	Signalised crossing	MV priority
Visibility	Road markings, Traffic lights Clear sightlines Road/street lighting	
Direction	Two-way possible	
Width	Minimum 2.5 meters	

Remarks: Highlights to consider for junctions:

- Lower speeds at junctions reduce risk of injuries
- Cycle lane crossing/across side roads should be a minimum of 2 m wide
- Designers should ensure good visibility between cyclists/pedestrians on a side road crossing

5.3.1 Bend-out design



- Bicycle and pedestrian (on a separate path parallel with a main road) crossings a secondary road that joins the main road and that is set back ≥ 10 m (a car length) from the main road intersection. Thus, facilitating the MV driver space and time to complete their turning manoeuvre when turning off the main road or alternatively when entering the main road, there is space and time to observe VRUs before having to prepare for the main road manoeuvre; thus, using road design to reduce goal-conflict for MV drivers.
- Signage on all approaches to the crossing warning motorists of presence of crossing.
- Adequate radius (4m min) provided on bend to allow comfortable movement of cyclists.

Source: Infrastructure Ireland standard, (2014). National Roads Authority Design Manual for Roads and Bridges. Rural Cycle Scheme Design (including Amendment No. 1) DN-GEO-03047.

5.4 Detailed description of No. 2. CPiJ High Speed.

Design specification	Solution	Possible next best solution
Geometric considerations	Bend-out design. Crossing point min. 10 m from main carriageway.	
Orientation of priority	MV priority	
Visibility	Road markings, Traffic lights Clear sightlines Road/street lighting	
Direction	Two-way possible	
Width	Minimum 2.5 meters	

Remarks: Highlights to consider for junctions:

- Lower speeds at junctions reduce risk of injuries
- Cycle lane crossing/across side roads should be a minimum of 2 m wide
- Designers should ensure good visibility between cyclists/pedestrians on a side road crossing

5.4.1 Bend-out design

See section 5.3.1 for details.

5.5 Detailed description of No. 3. CPiJ Medium Speed, or Multiple lanes.

Design specification	Solution	Possible next best solution
Geometric considerations	Bend-out design. Crossing point min. 10 m from main carriageway.	Traffic islands for multiple lane-crossings
Orientation of priority	Signalised crossing	MV priority
Visibility	Road markings, Traffic lights Clear sightlines Road/street lighting	
Direction	Two-way possible	
Width	Minimum 2.5 meters	

Remarks: Highlights to consider for junctions:

- Lower speeds at junctions reduce risk of injuries
- Cycle lane crossing/across side roads should be a minimum of 2 m wide
- Designers should ensure good visibility between cyclists/pedestrians on a side road crossing

5.5.1 Bend-out design

See section 5.3.1 for details.

5.6 Detailed description of No. 4. CPiJ Medium Speed.

Design specification	Solution	Possible next best solution
Geometric considerations	Bend-out design. Crossing point min. 10 m from main carriageway.	Adjacent crossing point (running parallel with main carriageway) crossing point with MV-priority
Orientation of priority	MV priority	VRU priority (when speed and AADT is low)
Visibility	Road markings, Clear sightlines Road/street lighting	
Direction	Two-way possible	One-way crossing (with VRU priority)
Width	Minimum 2.5 meters	

Remarks: Highlights to consider for junctions:

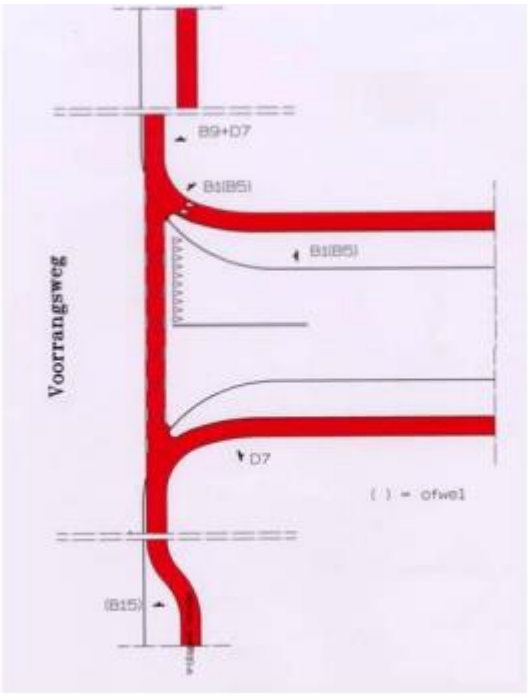
- Lower speeds at junctions reduce risk of injuries
- Cycle lane crossing/across side roads should be a minimum of 2 m wide
- Designers should ensure good visibility between cyclists/pedestrians on a side road crossing

5.6.1 Bend-out design

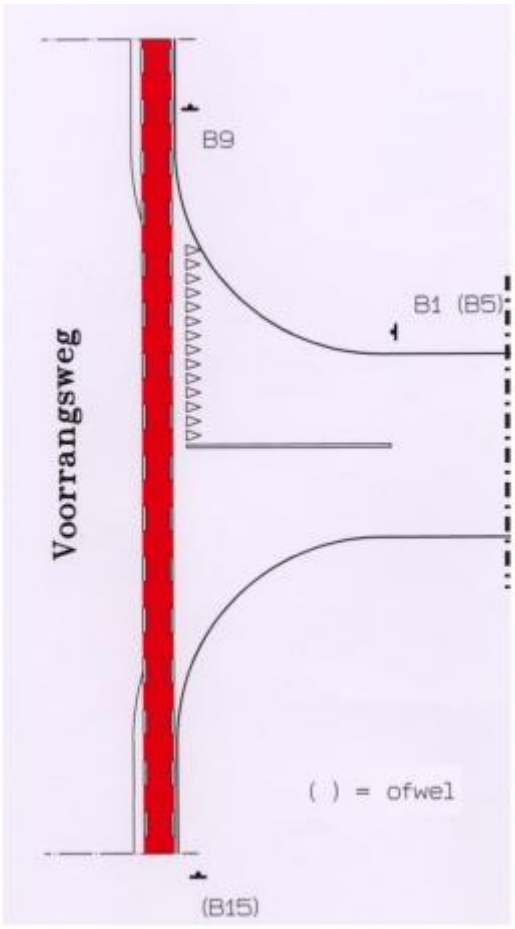
See section 5.3.1 for details.

5.6.2 Adjacent crossing point design

a)



b)



If the bicycle path on the priority road is separated from the main road (often occurring in traffic areas) it preferably bends inwards (abutting). As a rule, this happens from about 30 meters for the connection. It is recommended to maintain a narrow safety zone here as well between road and bicycle path.

Source: https://www.mobielvlaanderen.be/pdf/vademecum/hfdst4.pdf

& https://www.mobielvlaanderen.be/vademecums/fiets-praktijkvoorbeelden.pdf

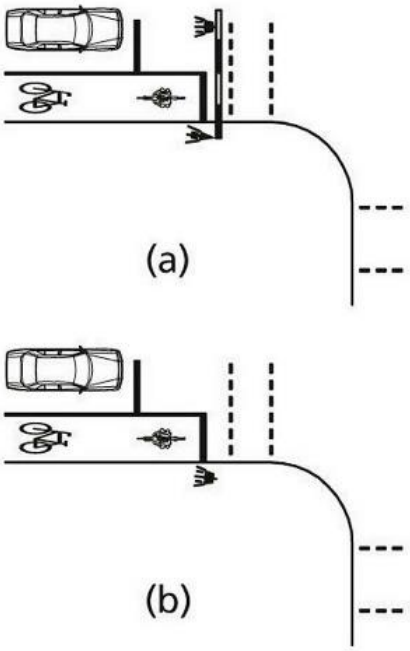
5.7 Detailed description of No. 5. CPiJ Low Speed. (Not for pedestrians).

Design specification	Solution	Possible next best solution
Geometric considerations	Crossing point in junction for in-carriageway bicycle path/track.	
Orientation of priority	Shared priority (conflict may occur when right-turning vehicles intersect with cyclist going straight-on). Signalised crossing	VRU priority (when speed and AADT is low)
Visibility	Protruding bicycle lane Road markings, Clear sightlines Road/street lighting	
Direction	One-way only	
Width	Minimum 2.5 meters	

Remarks: Highlights to consider for junctions:

- Lower speeds at junctions reduce risk of injuries
- Cycle lane crossing/across side roads should be a minimum of 2 m wide
- Designers should ensure good visibility between cyclists/pedestrians on a side road crossing

5.7.1 In-carriageway crossing point design (cyclists only)



Protruding bicycle lane (in-carriageway crossing point in junction) to provide an early start for cyclists in a signalised junction. This design alternative is mostly applicable in urban areas and partially falls out of the study's scope.

- Improving visibility (safety) of cyclists on shared carriageways.
- Early start in such a way that cyclists arrive at the conflict point before the right-turning motorised traffic arrives there.
- Early start not too long, as cyclists wanting to turn left will otherwise come into conflict with quickly accelerating motor vehicles from the opposite direction.
- Type a: bicycle direction given green light before light for other traffic.
- Type b: early start by moving stop line, simultaneous green light for cyclists and other traffic.
- Critical analysis of green light and clearance times are necessary.

Source: http://kennisbank.crow.nl/zoeken/search

5.8 General summary of good practice design elements for junctions

Good visibility at the crossing, no objects or greenery is in the way of the bicycle path. That allows for the car driver to see the cyclists from a distance.

Colour can be used to indicate that there is a crossing point for cyclists to the MV drivers but should be avoided because colours are irregularly used and have an ambiguous meaning in terms of priority. [This may not work well in e.g. Nordic countries due to the winter climate.]

Arrows can be used to indicate that the cyclists can approach from either direction.

Ensure adequate inter-visibility between motorists and cyclists at junction crossing points e.g. clear and maintain vegetation.

Provide sufficient space for a car between the bicycle crossing and the perpendicular road. This allows sufficient time for motorists to react and slow to allow a cyclist which has already started to cross the road.

Avoid wide crossing (e.g. crossing 2 or more lanes) which exposes cyclists for a substantial length; separate with traffic islands (with an adequate mid-way area) where possible, e.g. if width to be crossed is greater than 8 à 9 m.

Make sure that the priority for crossing in the junction is clear and sensible/logical. In non-urban areas (with speed > 50 km/h) would mean that cyclists always yield to MV traffic.

Use signage reinforcing message to yield.

Provide clear signage for both motorists and cyclists such that the layout is self-explaining.

Avoid complex intersection for MV drivers with multiple crossing points, signalling and yielding rules.

Use separate bicycle/pedestrian paths running parallel with a main road and at junctions/crossing points, set them back, e.g. ≥ 10 m (a car length) from the main road intersection. This will facilitate space and time for the MV driver to complete their turning manoeuvre when turning off the main road or alternatively when entering the main road. Providing space and time to observe VRUs before having

to prepare for the main road manoeuvre. This road design will reduce goal-conflict for MV drivers and increase safety for VRU.

Good *communication* in the road design can provide clarity on what may be expected and what the expectations are on the road user in any given part of the road infrastructure.

6 Continuous road segments

6.1 Guidelines for Continuous Road Segments

Continuous road segments in a rural setting are often high-speed environments. For a safer environment, the higher the speed, the more separation should be made between vehicles and VRU's.

There are some general best practice measures which important for all continuous road segments, regardless of the speed.

	All speeds:
	Ensure adequate maintenance, clearing loose gravel, and de-icing during winter periods. Ensure that vegetation is maintained so it does not encroach on the cycle path or obstruct visibility.
	Provide adequate connection points for the bicycle lane to a road of lower speed and lower volume.
	Provide adequate signage indicating the presence of vulnerable users.
	Ensure connection points are provided and that cycle paths do not end abruptly resulting in an unsafe environment for VRU's. 
	**High speed (> or = 50km/h):**
	For speeds greater than 50km/h, separation should be made between cyclists and vehicles.

The preferred cycle facility for non-urban areas are one-way cycle facilities on each side of the road. The cycle facility should be wide enough to accommodate the volume of cyclists (minimum 2.5m).

Provide adequate connection points for the bicycle lane to a road of lower speed and lower volume.

Adequate separation between carriageway and bicycle lane should be provided (2m minimum where there is no vertical separation). Separation should ideally be a different material to carriageway (i.e. grassed verge). Care should be taken to ensure secluded sections pose no safety/security risks. The below example shows no horizontal separation, but vertical separation is provided.

Vertical separation (120mm kerb) should be considered particularly where separation between the carriageway and cycle/shared facility is not feasible. Minimum of 0.5m horizontal separation is recommended.

Speed between 31 and 49 km/h:

Ensure there is good protection, visibility and awareness of cyclists on road.

Using signage to warn of the potential for cyclists to be on the road.

Ensure adequate width of the bicycle lane. There are different specifications depending on the number of vehicles, speed limits etc. A single bicycle lane within the carriageway should be ≥2.0m give a speed limit of 50km/h, and for higher speeds a higher width is required.

Provide differentiation between the driving lane and the cycle lane, using bright colours for the cycle lanes if they are within the carriageway. The below example illustrates a 2-1 arrangement which is suitable on roads with low traffic volumes. Shared rural carriageways such as this should avoid blind bends which could prove potentially hazardous.

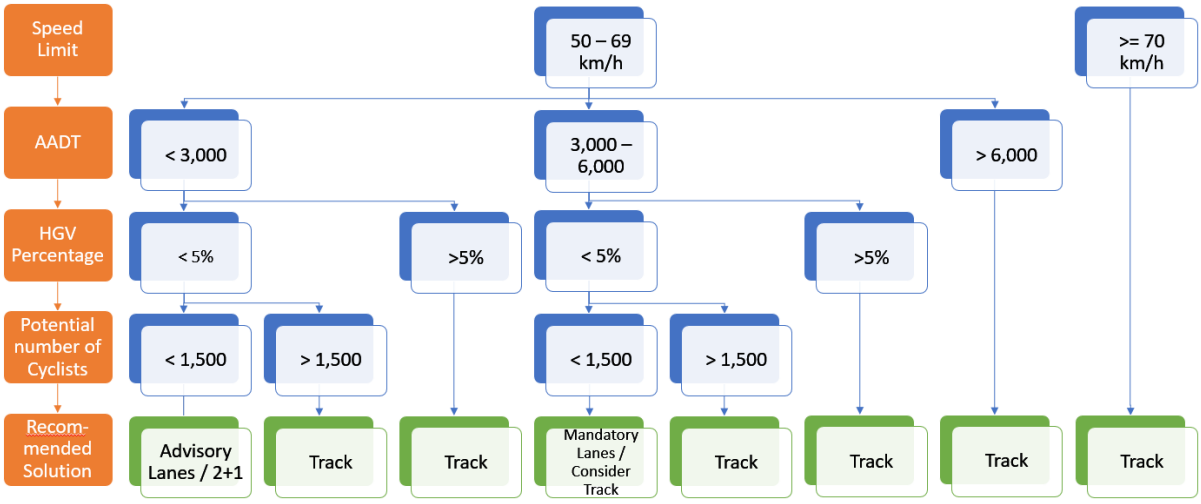
Provide adequate carriageway widths to accommodate two-way traffic movements without the need for motorists to drive in cycle lanes (if provided on carriageway).

Low speed (< or = to 30 km/h):

Low speed zones in this range will not be commonly used outside urban areas.

But if so, vulnerable users should be provided for with good protection, visibility and awareness from other road users. It is advised that urban design guidance is applied in these scenarios.

6.2 Schematic overview



6.3 Continuous road segments decisions, TRACK

Aspect	Recommendation	solution	Possible next best solution
Segregation	Required	Required	Required
Type and width	One way either side	Two way one side	Two way one side
	Minimum 2.5 meters	Minimum 3.0 meters	Minimum 3.0 meters
Vertical separation and horizontal segregation	Ditch / open drain	No vertical separation	Minimum 120 mm kerb
	Minimum 3 meters	Minimum 2 meters	Minimum 0.5 meter
Signage	Indicate cycle track	Indicate cycle track	Indicate cycle track

6.4 Continuous road segments decisions, MANDATORY LANES

Aspect	Recommendation
Segregation	Preferred; not required[1]
Type and width	One way either side mandatory
	Minimum 2.0 meters
Vertical separation and horizontal segregation	Solid line markings
	Not required
Signage	Warning traffic that cyclists are on road

1 if provided, go to Track table for requirements

6.5 Continuous road segments decisions, ADVISORY LANES

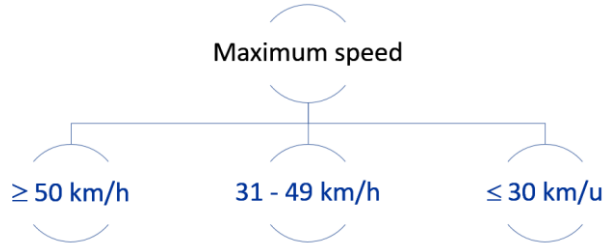
Aspect	Recommendation	Possible next best solution
Segregation	Not required	Shared Street
Type and width	One way either side advisory	
	Minimum 1.0 meters	
Vertical separation and horizontal segregation	Dashed line markings	
	Not required	
Signage	Advanced warning signage	Cycle symbols on road Shared street signage

7 School zones

7.1 Guidelines for School Zones

School zones are places where we can expect many children/young people. Those places have to be safe for them. Safe means adapted speed and safe infrastructure.

As a starting point one can state that having a school zone “outside urban area” is maybe not the best location, since roads outside urban area are roads where traffic flow is important. School zones must be relocated to areas where the residential function prevails (not an easy/cheap solution), as for instance could be the case in small linear settlements.



High speed (> or = 50km/h):

School zones and 70km/h are not compatible with each other

School zones must be relocated to areas where the residential function prevails (not an easy/cheap solution)

If the school cannot be relocated, maybe the main school entrance can be relocated. E.g. the main entrance can be moved to an access from a side street, where less traffic passes and the maximum allowed speed can be reduced

If the school cannot be relocated, there must be a gradual decrease in speed, first to 50km/h and then to 30km/h in the school zone.

Use high visibility signage (including variable message signs) to make MV users aware of the possible presence of school children.

If a carriageway needs to be crossed, provide a median. Provide zebra or pelican crossings where appropriate. (see also guidelines for Crossing Points)

Speed between 31 and 49 km/h:

In a 50km/h zone, the speed must be reduced until 30km/h in the school environment.

Use a low, maximum speed limit (30 km/h) during school hours (e.g. Monday to Friday, 08-15 hrs.) = variable speed display

The speed limit of 30 km/h should be supported by infrastructural measures, e.g. chicanes, adaptive speed humps (programmable and variable.

Consider the provision of adequate and safe drop-off areas for school buses and parents' cars, but not too close to the school entrance to avoid chaos at the school gate

Use high visibility signage (including variable message signs) to make MV users aware of the possible presence of school children.

Crossing could be raised to reduce vehicle speeds.

	Good public lighting including at pedestrian crossing is necessary.
	**Low speed (< or = 30km/h) :**
	The speed limit of 30 km/h should be supported by infrastructural measures, e.g. chicanes, adaptive speed humps (programmable and variable.
	Crossing could be raised to reduce vehicle speeds.

7.2 Schematic Overview for School Zones

Additional information:

Benefits:

- School zones and crossing supervisors can reduce pedestrian risk.
- School zones help to moderate traffic speeds which can reduce injury severity.
- It has been shown that school zones can reduce crashes involving bicyclists.
- School crossing supervisors can help to control pedestrian crossing movements.
- School crossing supervisors provide a safe place to cross.

Implementation issues:

- Traffic signs and road markings must make it clear to motorists that they have entered a school zone.
- Consider incorporating flashing beacons to compliment the school zone signs and markings.
- Operating times and any speeds limit changes must be clearly signed and understood.
- Through traffic must be able to see pedestrian crossing points in time to stop for them.
- Advanced warning signs should be located on approaches with adequate forward visibility.
- Parking provision should be carefully considered within school zones with adequate sight distances at pedestrian crossings.

Source: http://toolkit.irap.org/default.asp?page=treatment&id=59

8 Small linear settlements

8.1 Guidelines for Small Linear Settlements

Small linear settlements are in rural settings with the presence of VRU's and possibly high speeds. For a safer environment, the higher the speed, the more separation should be made between vehicles and VRU's.

In general, the guidance set out in other sections of this report will apply when designing facilities for vulnerable road users in small linear settlements e.g. continuous road segments in high speed linear settlements should be segregated vertically and horizontally. As such, flow charts for each individual design element should be followed in small linear settlements. In addition, the following table presents some considerations that are particular to small linear settlements.

	All speeds:
	Small linear settlements may contain bus stops serving local or regional bus services. The interface between bus stops and facilities for VRUs will require consideration in order to safely accommodate bus users and VRUs using the shared facility. The specific arrangement will depend on the type of facility provided on that particular road section (dependent on speed and flow conditions). It is recommended that urban design guidance for treatment at bus stops is utilised at these locations. Provide buffer zones between bus stops and cycle lanes if they converge. Examples such as the below may be suitable depending on cycle volumes and bus passenger volumes. Where high volumes are anticipated, it is recommended that cycle track runs behind the bus shelter. 
	There is likely to be more of a desire for crossing activity in small linear settlements, particularly if bus stops are present or there are amenities located within the village (shops, restaurants, churches etc.). Crossings which align

with anticipated desire lines should therefore be considered in small linear settlements.

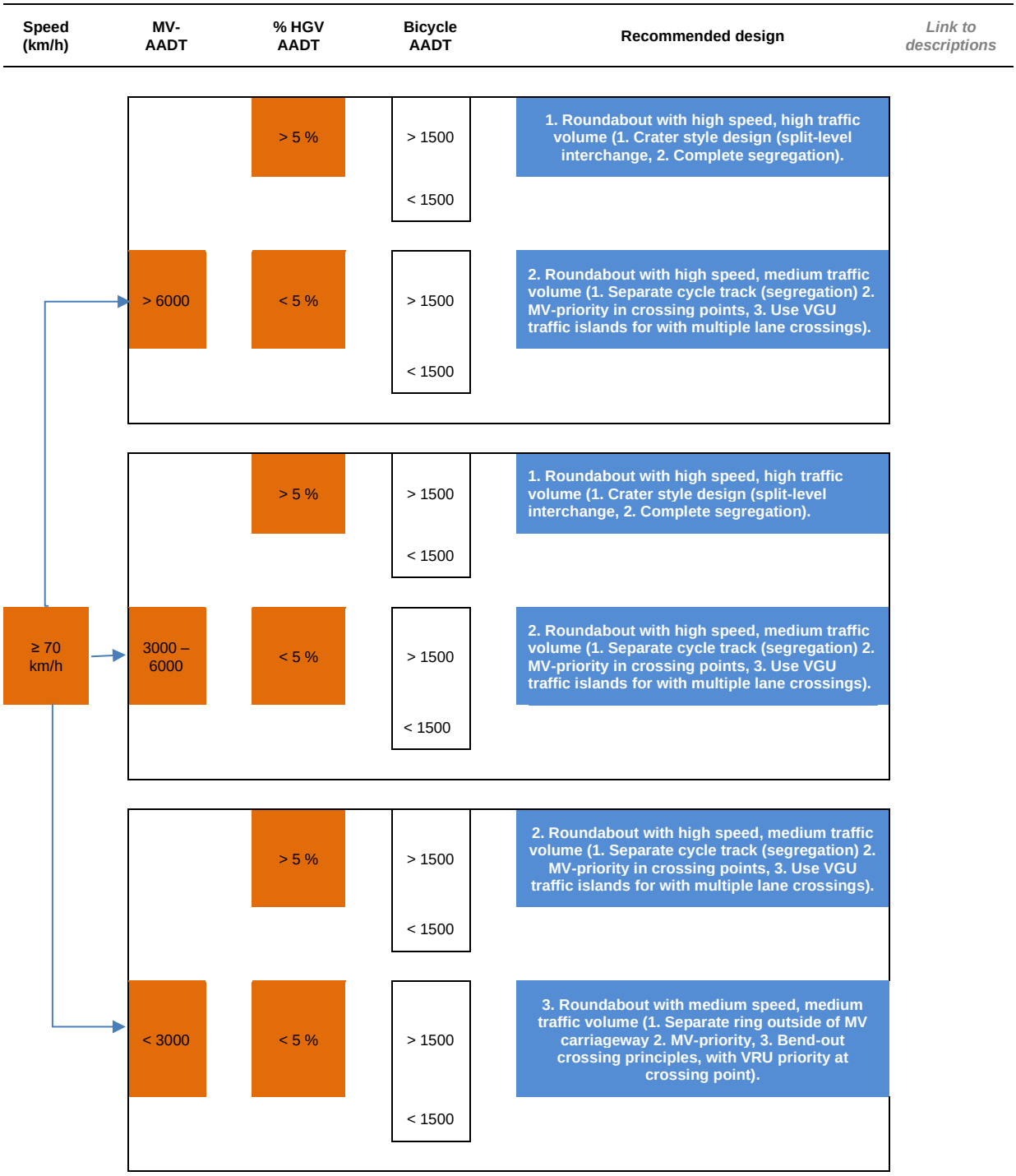
Small linear settlements may contain community facilities such as shops, restaurants, and churches which may have car parking located on the road edge. Similar to bus stops, the treatment of the interface between car parking and facilities for VRUs will be dependent on the type of facility provided on the road on approach to the car parking. It is recommended that urban design guidance for treatment at car parking is utilised at these locations.

Linear settlements tend to generate more pedestrian and cycle activity along rural roads. In order to promote a safer environment for VRUs in linear settlements, it is recommended that lower speed limits (50km/hr or less) are introduced at these locations. Reduced speed limits may need to be complemented with traffic calming measures to self-regulate speed restrictions.

Ensure adequate maintenance, clearing loose gravel, and de-icing during winter periods. Ensure that vegetation is maintained so it does not encroach on the cycle path or obstruct visibility.

9 Roundabouts (rural roundabouts)

9.1 Decision-tree table – Roundabouts Vmax ≥ 70 km/h



9.2 Decision-tree table – Roundabouts Vmax 31 – 69 km/h

Speed (km/h)	MV-AADT	% HGV AADT	Bicycle AADT	Recommended design	*Link to descriptions*
31 - 69 km/h	> 6000	> 5 %	> 1500	1. Roundabout with high speed, high traffic volume (1. Crater style design (split-level interchange, 2. Complete segregation).	
			< 1500		
		< 5 %	> 1500	2. Roundabout with high speed, medium traffic volume (1. Separate cycle track (segregation) 2. MV-priority in crossing points, 3. Use VGU traffic islands for with multiple lane crossings).	
			< 1500		
	3000 – 6000	> 5 %	> 1500	2. Roundabout with high speed, medium traffic volume (1. Separate cycle track (segregation) 2. MV-priority in crossing points, 3. Use VGU traffic islands for with multiple lane crossings).	
			< 1500		
		< 5 %	> 1500	3. Roundabout with medium speed, medium traffic volume (1. Separate ring outside of MV carriageway 2. MV-priority, 3. Bend-out crossing principles, with VRU priority at crossing point).	
			< 1500		
	< 3000	> 5 %	> 1500	3. Roundabout with medium speed, medium traffic volume (1. Separate ring outside of MV carriageway 2. MV-priority, 3. Bend-out crossing principles, with VRU priority at crossing point).	
			< 1500		
		< 5 %	> 1500	No. 4. Roundabout with low speed, low traffic volume (1. Separate track for cyclists in roundabout. 2. Use raised segregation or buffer distances from MV-carriageway).	
			< 1500	No. 5. Roundabout with low speed, low MV & bicycle traffic volume (1. Mixed traffic, single carriageway roundabout).	

Description of recommended roundabout designs that are alluded to in the decision tree tables above.

No. 1. Roundabout with high speed, high traffic volume

(1. Crater style design (split-level interchange, 2. Complete segregation).

No. 2. Roundabout with high speed, medium traffic volume

(1. Separate cycle track (segregation) 2. MV-priority in crossing points, 3. Use VGU traffic islands for with multiple lane crossings 4. Bend-out crossing principles).

No. 3. Roundabout with medium speed, medium traffic volume

(1. Separate ring outside of MV carriageway 2. MV-priority, 3. VRU priority at crossing point if speed ≤ 50 km/h, 4. Bend-out crossing principles).

No. 4. Roundabout with low speed, low traffic volume

(1. Separate track for cyclists in roundabout. 2. Use raised segregation or buffer distances from MV-carriageway).

No. 5. Roundabout with low speed, low MV & bicycle traffic volume

(1. Mixed traffic, single carriageway roundabout).

9.3 Detailed description of No. 1. Roundabout with high speed, high traffic volume.

Design specification	Solution	Possible next best solution
Geometric considerations	Crater style design (split-level interchange)	
Orientation of priority	Complete segregation (i.e. no priority)	
Visibility	Orientation signage important Road/street lighting	
Direction	Two-way only	
Width	Minimum 4 meters (cyclists & pedestrians)	

Remarks: Highlights to consider for junctions:

- Cycle lane crossing/across side roads should be a minimum of 2.5 m wide
- Designers should ensure good visibility between cyclists/pedestrians

- Consider possible conflict points (and remove/mitigate)

9.3.1 Crater style design

- Outside urban area
- Safe for cyclists & pedestrians
- Split level interchange

Source:
https://www.google.com/maps/@51.2884199,4.8547974,3a,60y,56.55h,81.12t/data=!3m6!1e1!3m4!1s-2vqteRqVrY-a-PV6dSyww!2e0!7i13312!8i6656

9.4 Detailed description of No. 2. Roundabout with high speed, medium traffic volume.

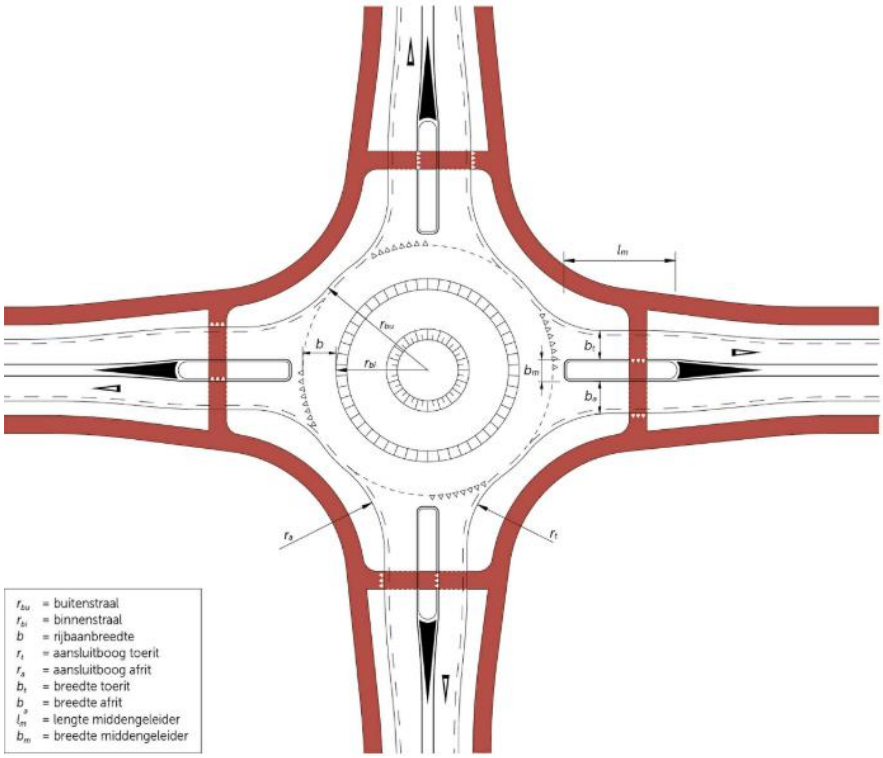
Design specification	Solution	Possible next best solution
Geometric considerations	Separate cycle track (segregation) Use VGU traffic islands for with multiple lane crossings Bend-out crossing principles	
Orientation of priority	MV-priority in crossing points with VRU	If the bicycle AADT has periodic peaks, from e.g. nearby schools, consider signalised crossings.

		Evaluation of affected routes necessary.
Visibility	Orientation signage important Road/street lighting Bend-out crossing design for increased visibility Use VGU traffic islands for with multiple lane crossings	
Direction	Two-way possible	
Width	Minimum 4 meters (cyclists & pedestrians)	

Remarks: Highlights to consider for junctions:

- Cycle lane crossing/across side roads should be a minimum of 2.5 m wide (single)
- Designers should ensure good visibility between cyclists/pedestrians
- Consider possible conflict points (and remove/mitigate)

9.4.1 Separate cycle track



An example of some of the specifications from the Netherlands for No. 2 Roundabout are found below.

- Outside urban area, cyclists have to give priority on roundabouts.
- Implementation:
- No block marking at the cycle crossing location
- No continuous pavement on cycle track
- Central traffic islands sufficiently wide in connection with stacking space for cyclists
- Equal right of way regime for cyclists and pedestrians
- Vertical elements on elevated central traffic island
- Guarantee recognisability by means of public lighting
- Dimensions:
- R1 = 12,50 to 20 m
- R2 = 6,50 to 15 m
- ra = 12 m, with central traffic island
- = 8 m, without central traffic island
- rb = 15 m, with central traffic island
- = 12 m, without central traffic island
- B = 5 to 6 m (depending on R1 and R2)
- b1 = 1,50 (1,00) m
- b2 = 2 to 2,50 m
- b3 = as large as possible
- L = 5 m
- C = 2 m
- Length of central traffic island (b1) > = 6 m
- Stacking space on cycle track (b2) 2,10 to 3 m
- Width of central traffic island (b3) 2,50 to 3 m (2,10 m)

Source: http://kennisbank.crow.nl/zoeken/search

9.5 Detailed description of No. 3. Roundabout with medium speed, medium traffic volume.

Design specification	Solution	Possible next best solution
Geometric considerations	Separate cycle track (segregation) outside of MV carriageway Use VGU traffic islands for with multiple lane crossings	
Orientation of priority	MV-priority in crossing points	VRU priority at crossing point if speed is ≤ 50 km/h
Visibility	Orientation signage important Road/street lighting Bend-out crossing design for increased visibility	
Direction	Two-way possible	

Width	Minimum 4 meters (cyclists & pedestrians)

Remarks: Highlights to consider for junctions:

- Cycle lane crossing/across side roads should be a minimum of 2.5 m wide
- Designers should ensure good visibility between cyclists/pedestrians
- Consider possible conflict points (and remove/mitigate)

9.5.1 Separate cycle track

- Outside urban area
- Cyclists have no priority on roundabouts.
- Flexible application possibilities (for local needs)

Source: https://www.mobielvlaanderen.be/pdf/vademecum/hfdst4.pdf

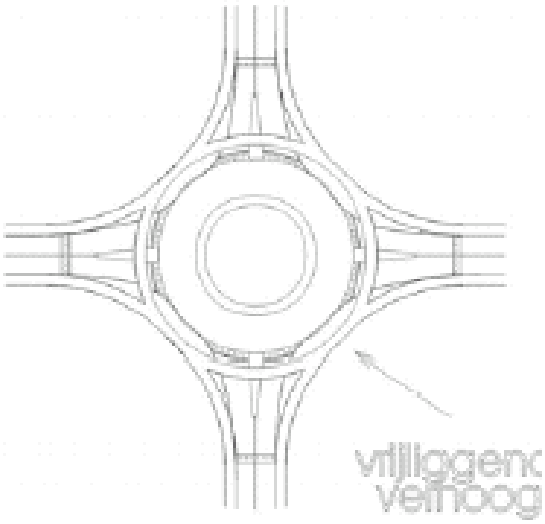
9.6 Detailed description of No. 4. Roundabout with low speed, low traffic volume.

Design specification	Solution	Possible next best solution
Geometric considerations	Separate track for cyclists in roundabout. Use raised segregation or buffer distances from MV-carriageway	
Orientation of priority	VRU-priority in crossing points	
Visibility	Orientation signage important Road/street lighting necessary Vegetation etc. if used in raised buffers should not exceed 0.5 m in height above the carriageway	
Direction	One-way only	
Width	Minimum 2.5 meters	

Remarks: Highlights to consider for junctions:

- Cycle lane crossing/across side roads should be a minimum of 2.5 m wide
- Designers should ensure good visibility between cyclists/pedestrians
- Consider possible conflict points (and remove/mitigate)

9.6.1 Separate cycle track with raised segregation



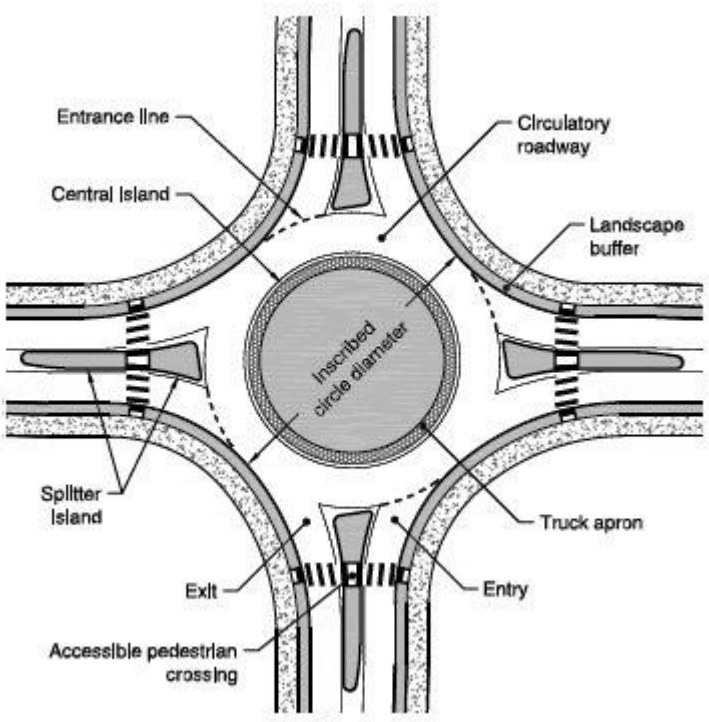
9.7 Detailed description of No. 5. Roundabout with low speed, low MV & bicycle traffic volume (1. Mixed traffic, single carriageway roundabout).

Design specification	Solution	Possible next best solution
Geometric considerations	Mixed use, low speed, single-lane design.	
Orientation of priority	MV-priority in crossing points	
Visibility	Orientation signage important Road/street lighting	
Direction	Two-way possible	
Width	Minimum 4 meters (cyclists & pedestrians)	

Remarks: Highlights to consider for junctions:

- Designers should ensure good visibility between cyclists/pedestrians
- Consider possible conflict points (and remove/mitigate)

9.7.1 Low speed mixed traffic single-lane roundabout



Source:

https://safety.fhwa.dot.gov/intersection/innovative/roundabouts/fhwasa10006/

9.8 Good practice summary for Roundabouts (rural roundabouts)

Split-level interchanges (e.g. 'crater' roundabouts) are advisable on high MV traffic volume areas, where possible.

Outside urban areas, cyclists and pedestrians should not have priority on non-signalised roundabout crossings due to higher MV speeds.

Dedicated facilities provided for cyclists are recommended.

Consider use of signalised crossing points for cyclists and pedestrians if VRU and traffic volumes are high. If MV speeds are high, use traffic islands (with an adequate streaming area mid-way) where possible to shorten the crossing time for VRU.

Use street lighting to make the VRU crossing points conspicuous.

Avoid placing the crossing located too close to the gyratory at the roundabout exits. At least 6-8 m (one car length) is advisable (also avoid placing crossing too far away from the roundabout, or else it would be used).

Central traffic islands sufficiently wide in connection with stacking space for cyclists (minimum of 2.5m).

Use clear road markings and signs to alert MV drivers of the VRU crossing points.

Consider that motorists arriving at the roundabouts may be burdened by navigating or orientation tasks; therefore, avoid mixing route guidance signs with (VRU) awareness or warning signs.

Ensure that foliage and shrubs do not restrict VRU visibility and MV driver sight-lines.

Suburban setting with lower MV speeds (≤ 50 km/h) could employ characteristics that:

Shared cycle/pedestrian facility around entire roundabout. Could be better if separated facility provided although facility appears wide and speeds are low (if in rural areas the pedestrian/cyclist volumes are be small, shared facility could even though be a solution).

Dedicated raised pedestrian / cycle crossings with priority given to pedestrians and cyclists.

The crossing points, for safety reasons, need to be moved away from the complexity of the inner section of the roundabout to accommodate at least one car length (≥ 6-8 m).

Consider MV and VRU AADT when dimensioning the crossing/roundabout design.

10 Next step

This Deliverable 4.1, *Draft version of Guidelines for Selection of Design of VRU Infrastructure* will be the starting point for Work Package 5 (WP 5).

The objective of WP5 is to harmonise the WP1 - 4 reports and compile a usable set of best-practice guidelines. The improvements on existing standards and guidelines are for the design of self-explaining road systems that promote safety for vulnerable road users (VRU), especially in non-urban areas.

This present Deliverable 4.1 will be fine-tuned and will lead to D 5.1; the Final Report of this SANA-4U project.

11 References

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