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

WP2 Final version of the "Good practice guide"

Deliverable No D2.3
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VTI (Sweden)
BRRC (Belgium)
Arup (Ireland)

CEDR Call Safety 2016

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

Deliverable number 4: Final version of the "Good practice guide"

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Version: 1.0

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Glossary of Terms

AADT	Average annual daily traffic (measure of traffic volume).
CEDR	Conference of European Directors of Roads
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.
SER	Self-explaining roads
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 included in the project's definition of VRU. Equestrian transport or hackneys are not included in this project's definition of VRU.

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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 will review VRU standards across member states, analyse them and develop a "good practice guide" with focus on self-explaining systems for VRU in non-urban areas. Since those roads outside urban areas are increasingly being used to transport goods and services between the larger urban areas while at the same time still being used by local communities, including pedestrians and cyclists, these good practice guidelines will give illustrated examples of self-explaining systems that have proven to be effective in this type of environment.

2 Project & WP 2 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".

This work package, Work package 2 (WP2) seeks to collect a number of examples, both good and bad, for implemented cycle 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 are presented in this report. The report is structured under these headings as set out below:

- 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 along or across the road;
- roundabouts (rural roundabouts).

The current deliverable D2.3 "Good Practice Guide" shows good and less-good examples of non-urban cycle and pedestrian facilities.

This deliverable is the result of a process, started with Deliverable D2.1 Preliminary Good Practice Guide, created by the SANA-4U partners with the help of the CEDR members. This Preliminary Good Practice Guide is discussed during a Workshop (more information available in D2.2 Proceedings of Workshop), which took place on Thursday the 6th of December 2018, in Brussels. The purpose of the workshop was to discuss the draft version (Preliminary) of the Good Practice Design Guide for VRU facilities with stakeholders and determine whether current best practice in their countries were reflected in our work to date. We were also keen to discuss the stakeholders' experiences of road design for VRU in all CEDR countries as well as the success, or otherwise, of implemented schemes.

After that workshop, the D2.1 Preliminary Good Practice Guide is completed with comments and additions from the workshop participant.

Deliverable D2.3 is the last phase of Work Package 2.

3 Good practices

3.1 Examples from CEDR member countries

There are 27 CEDR member countries. In WP 1 a questionnaire was sent to all 27 members which asked them for their willingness to be interviewed in greater depth after the initial questionnaire. There were 13 countries that replied of which only 7 countries were willing to participate in a follow-up interview.

As a reminder; the interviewees were NRA staff (except the Flanders region) that had elected to participate or nominated colleagues to participate in follow-up interviews after having completed the questionnaire on road design.

The aim of the interviews was to gain in-depth information on the infrastructural practices of CEDR members concerning VRU outside urban areas. The objectives were:

1. Provide an overview of the respective country's guidelines/standards regarding VRU on inter-urban roads. (as a task for WP 1)
2. Help find good examples of guidelines/standards regarding VRU on inter-urban roads that can be used in WP2.

As WP 2 builds on WP 1, the "Good practices" described in this Deliverable 2.3 are examples initially coming from those 7 countries, added with other examples from other countries.

Table 1 lists the CEDR countries which replied and who were willing to participate in a follow-up interview and that have public access for their respective design standards or guidelines.

	Country
1	Estonia
2	Flanders/ Belgium
3	Germany
4	Ireland
5	Netherlands
6	Sweden
7	UK

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3.2 Good and less good examples

We cannot only learn from good examples (how we can do it), but also less-good examples can show us why we should not opt for certain solutions. For this reason, less good examples are also included.

This "good practice guide" is an illustrated guide of possible solutions in certain circumstances under certain conditions. It can help to gather ideas, but these ideas cannot simply be taken over, as they always have to be seen in their context, taking into account national guidelines.

In the examples provide in the following chapter (four) by the responding CEDR members, the good characteristics are preceded by ☺ emoji; the less good characteristics by the ☹ emoji; and the summary of respective good practice guidance with the checked-box ☒ symbol.

3.3 General Human Factors design considerations and SER

The purpose of this section is to provide an overview of the factors that influence the users (MV drivers and VRU) in a technical system (road network) thus facilitating and supporting a user-friendly and self-explaining road (SER) design.

The three general principles of SER design state that roads should be:

- *Easily recognizable*: roads that have the same function, the same speed profile and the same mix of road users, should look similar
- *Easily distinguishable*: roads of different categories should look different, the layout between the different categories should be different.
- *Easily interpreted*: desired driver behaviour should be clear and the characteristics to differentiate the different road categories should induce this behaviour.

Drivers must comprehend a measure and understand what is expected of them. They must be able to perform the desired behaviour. Afterwards the driver must be willing to perform the task. Behavioural options decrease due to limited comprehensibility of the measure, local alternatives and individual interests.

The following general design considerations for road safety in non-urban areas are incorporated in the good practice guidelines in this document.

- Human expectations and perception
    - Human expectations influence and even muddle our visual perception, i.e., what we see, in any given dynamic situation is steered not by what we "see" but by what we *expect* to see (Plous, 1993). The design implications are profound and architects of e.g. road networks need to carefully consider the selective nature of expectations on perception.

- Human signal detection, specifically vigilance, performance and judgement.
    - The primary factors that can shape the level of performance for a task (such as driving, riding a bicycle or walking in a specific environment) create a

performance window that will vary in size throughout the tasks' duration. The human's ability to deal with various stages of task execution (e.g. information acquisition; information analysis; decision making and action selection; action implementation) will depend on experience, training and knowledge.
    - Human performance focuses on the quality of the human performance in terms of **speed** where faster is better; and **accuracy**, where higher is better (Wickens, et al., 2016).

- Attention in perception.
    - Driving requires a lot of attention and in particular visual attention and perception. Moreover, failures in attention are attributed to approximately half of all fatal road accidents (in the USA), Lee et al. (2009).
    - The critical parts of attention are selecting, focusing, dividing (attention between tasks) and sustaining attention long enough to complete the task at hand (Wickens et al., 2016).
    - Multitasking in driving is therefore necessary part of driving, cycling and walking in all aspects of using the road infrastructure. (distraction, situation awareness).
    - The implications are for road network designs are that the need to accommodate the delicate nature of human attention and not create complex environments with very slim margins in time and space.

- Working memory.
    - Working memory is highly vulnerable to disruption when, for instance, attention resources are diverted to other mental tasks. The human working memory limitations influence our ability to successfully perform complex tasks in dynamic environments such as driving.
    - Working memory is severely limited in making absolute judgements when conceptualised in situations where observers assign stimulus into multiple categories along a sensory dimension (Wickens & Hollands, 2000). When studying the ability of observers to discriminate, on a single dimension, using four discrete levels along a stimulus continuum (representing 2 bits of information), performance is usually perfect. However, when the number of stimuli is increased and performance is mapped with five, six, seven or more discrete stimulus levels, errors tend to start occurring at about the five to six stimuli level, and the situation worsens increasingly with additional stimuli.

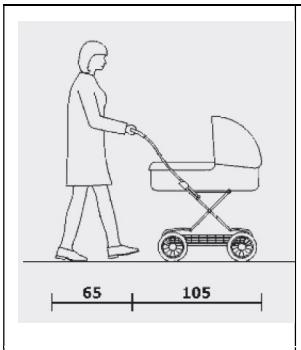
- Mental workload and stress.
    - Mental workload is defined as "the demands of tasks imposed on the limited information processing capacity of the brain…" p. 346 Wickens et al. (2016). Stress, however, is often seen as an emotional state that can impair performance. Stress can be induced by many factors such as loud noise, vibrations, heat, limited time, anxiety, fatigue etc. These stressors impair our ability to process information and reduce our performance. When this happens, humans tend to start making (more) errors in the form of skill-based slips and lapses; and rule and knowledge-based mistakes (Reason, 1990).

- Automation and human performance.
    - Principal benefits of automation in a complex environment is that it can reduce the human user's mental and physical workload if it is carefully designed. If the system is not carefully designed, there is an abundance of hazards and/or areas of concern.

- Future challenges involve accommodating the road network design so that autonomous vehicle-systems can more easily detect cyclists and/or pedestrians. A human driver is more adept at *reading* intentions of e.g. a child walking adjacent to and nearing a crossing point to an obvious (for the human) destination, e.g. a school on the other side of the road. Writers of algorithms find this complexity difficult. Predicting and executing appropriate actions relevant to the task-situation are also challenging for autonomous systems.

3.4 Anthropomorphic properties of vulnerable road users

Pedestrians:

<table>
<tr>
<td> 
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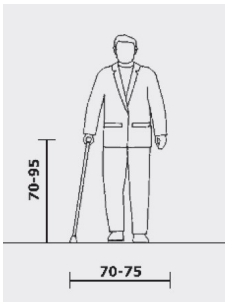
<td> 
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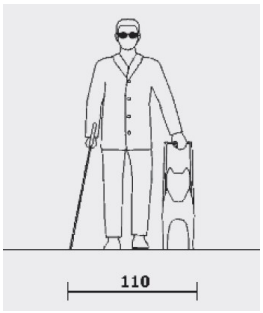
<td> 
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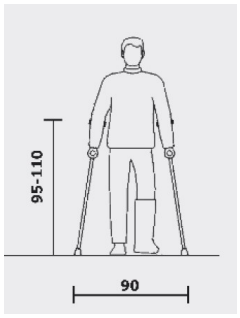
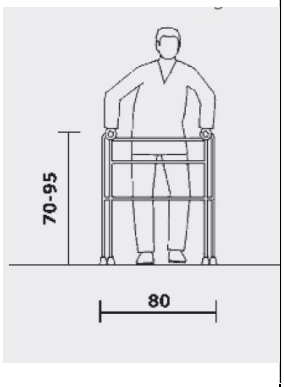
<td> 
</td>
</tr>
<tr>
<td>Person with pushchair</td>
<td>Person with walking stick</td>
<td>Blind person with walking stick and guide dog</td>
<td>Person with crutches</td>
</tr>
<tr>
<td> 
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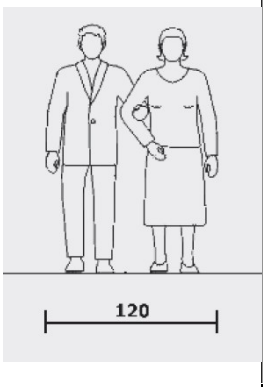
<td> 
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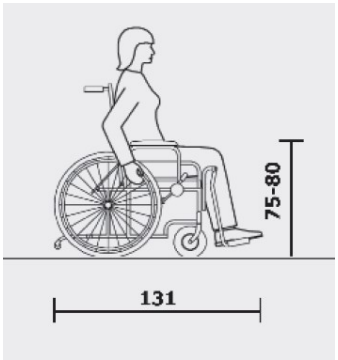
<td> 
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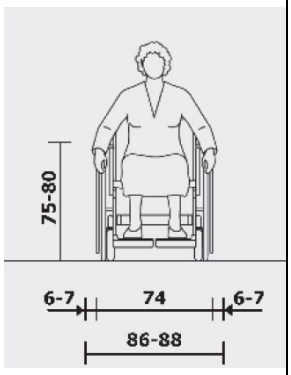
<td> 
</td>
</tr>
<tr>
<td>Person with walker</td>
<td>Supervised person</td>
<td colspan="2">Person in manual wheelchair</td>
</tr>
</table>

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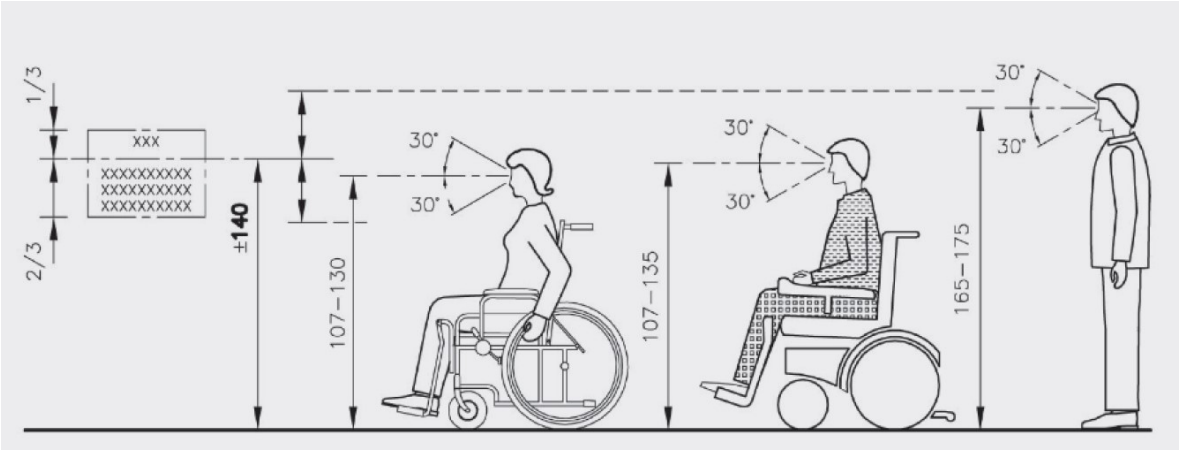
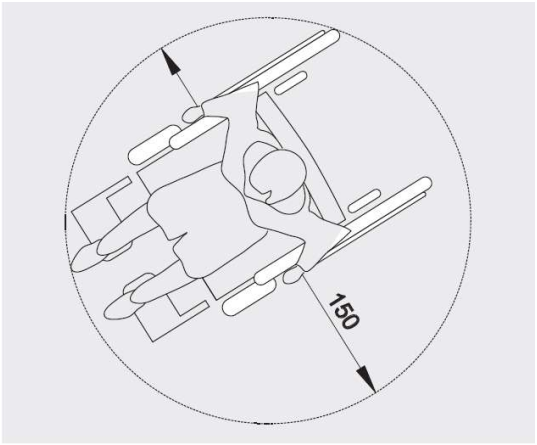
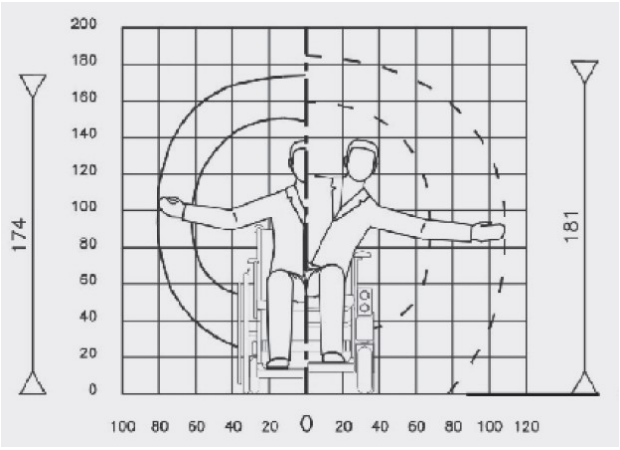


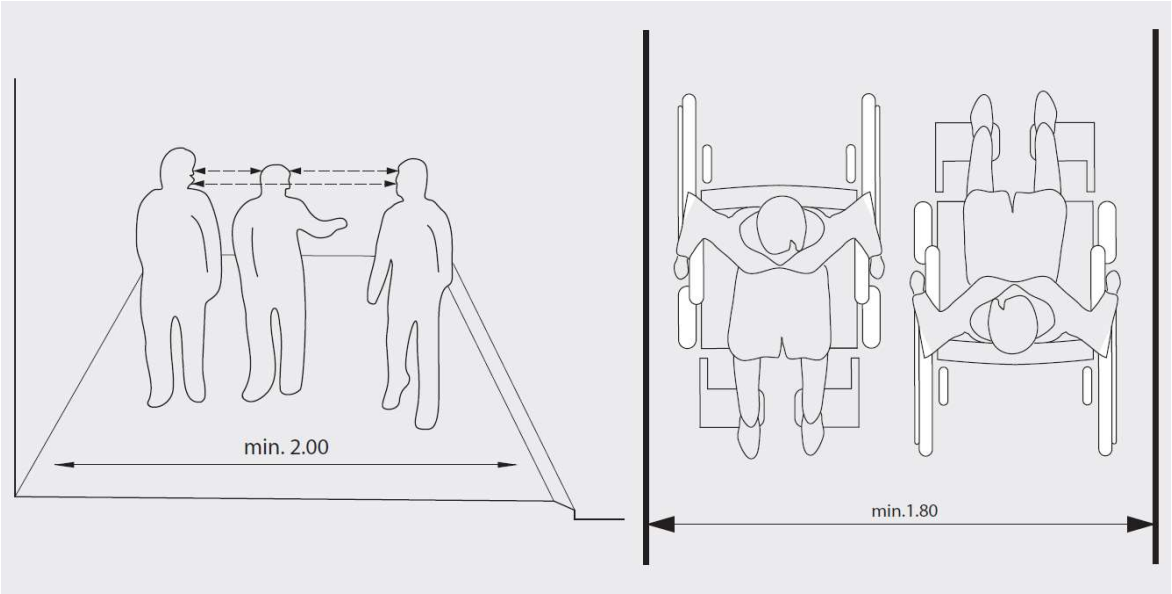
Visibility range (in cm)



Turning radius (in cm)



Scope (in cm)



Pass space (in cm)

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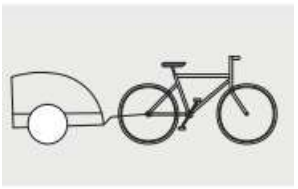
Source: Cahier voetgangerstoegankelijkheid, Richtlijnen voor de inrichting van voor iedereen toegankelijke openbare ruimte, Voetgangersvademecum Brussels Hoofdstedelijk Gewest, juni 2014

Cyclists:

		Global dimensions (cm)			Eye level	Particularities
		Length	Width	Height		
Bicycle/ speed pedelec		165-180	40-75	90-110	140-185	Folding bicycles have smaller tires
Children's bicycle		100-150	40-50	60-90	90-140	Small dimensions
Tandem		275	40-75	90-110	140-185	Length + loaded weight
Tricycle for adults		165-180	80	90-110	140-185	
Recumbent bike		165-200	40-75	110-130	110-130	Height
Handbike / tricycle		165-180	80	80-100	110-130	Turning radius = 4m
Cargo bike		165-180	80	90-110	140-185	Length + loaded weight
Bicycle with child trailer		300	Max 100	90-110	140-185	Length + loaded weight

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Bicycle with half bicyle		300	40-75	90-110	140-185	Length + loaded weight
Bicycle with child seat		165-180	40-75	120-140	140-185	Higher centre of gravity

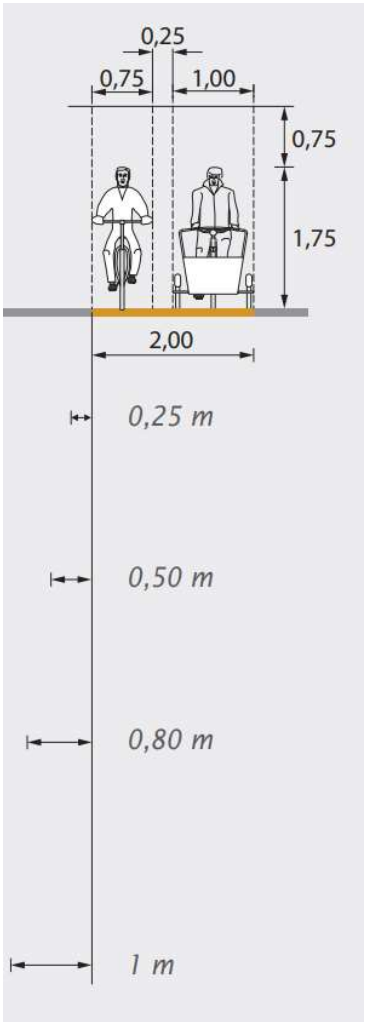
Source: **Source**: Cahier Van de rijbaan afgescheiden fietsinfrastructuur, DEEL I Aanbevelingen voor ontwerp en uitvoering, Fietsvademecum Brussels Hoofdstedelijk Gewest, oktober 2018

= fear of obstacles regarding median or border with a height difference of maximum 7 cm

= fear of obstacles regarding median or border with a height difference > 7 cm

= fear of obstacles regarding fixed objects (lighting columns, traffic signs, posts, trees etc.

= fear of obstacles regarding closed wall

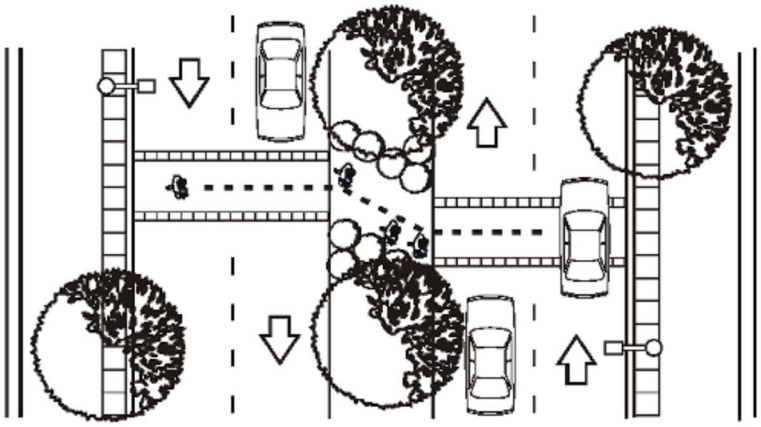


Section of free space for the bicycle

Source: **Source**: Cahier Van de rijbaan afgescheiden fietsinfrastructuur, DEEL I Aanbevelingen voor ontwerp en uitvoering, Fietsvademecum Brussels Hoofdstedelijk Gewest, oktober 2018

4 Crossing points

4.1 Estonia

What?	**Staggered pedestrian crossing**
	 Fig. 4.1.a. Staggered pedestrian crossing regulated with traffic lights.  Fig. 4.1.b. A two-lane drawing of a staggered unregulated pedestrian crossing.
Remarks	☺ 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.
Source:	INSENERIBÜROO STRATUM, Estonia (2009).

4.2 Flanders / Belgium

What?	**Pedestrian crossing with vertical element to increase visibility**
	
Remarks	☺ vertical elements to increase visibility ☺ accent lighting placed on the pole ☺ pedestrians can cross the road in 2 phases, thanks to the middle island
Source:	Google street view (Haachtsesteenweg, Steenokkerzeel, België)

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What?	**Bicycle crossing**
Before/ after	*Before:*  *After:* 
Remarks:	☺ better visibility ☺ smaller ☺ shorter crossing length for cyclists
Source:	http://www.fietsberaad.be/Kennisbank/Paginas/kontich_wegversmalling.aspx

What?	**Bicycle crossing**
	 
Remarks	☺ Good crossover that increases the attention among motorized road users. ☺ It also ensures that cyclists can cross safely and 'seamlessly'. ☹ the red colour is not allowed in this situation and is inconsistent with the Flanders guidelines (the colour red may only be used where cyclists have priority)
Source:	https://www.mobielvlaanderen.be/vademecums/fietsroutesvlaanderen.pdf

What?	**Bicycle crossing**
	 
Remarks	Bicycle crossing outside urban area, max speed allowed 70km/h Location: N763 Maasmechelen ☺ good visibility ☹ not totally following the principles of forgiving road, for motorised traffic
Source:	https://www.google.com/maps/@50.9857569,5.6335494,3a,31.2y,145.26h,84.76t/data=!3m6!1e1!3m4!1sXg3NemiKvrHkpnv4sc9G_w!2e0!7i13312!8i6656

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What?	**Bicycle crossing and public transport stop**
	 More in detail: 
Remarks	Location: N20, Hasselt Outside urban area, maximum speed allowed 70km/h ☺ cyclists cross the street in 2 times
Source:	https://www.google.be/maps/@50.8973553,5.3556141,3a,75y,182.31h,84.11t/data=!3m6!1e1!3m4!1sMAAd6HHzV_plEx7dedFtPA!2e0!7i13312!8i6656?hl=nl&authuser=0

What?	**Bicycle crossing, and reducing 2x2 road into an 2x1 road with median**
	 
Remarks	Outside urban area, maximum speed limit allowed: 70 km/h Location: N78 Dilsen-Stokkem ☺ Transformation of a 2x2 road into a 2x1 road, with median and bicycle crossing. ☺ Possibility for pedestrians to cross comfortable (no difference in level) at the public transport stop, but intentionally not providing a zebra crossing (this means that pedestrians have to give way).
Source:	https://www.google.com/maps/@51.0585553,5.7449926,3a,74y,42.34h,85.31t/data=!3m6!1e1!3m4!1sFWvhKkN-dtVk_5nT2nAAxw!2e0!7i13312!8i6656

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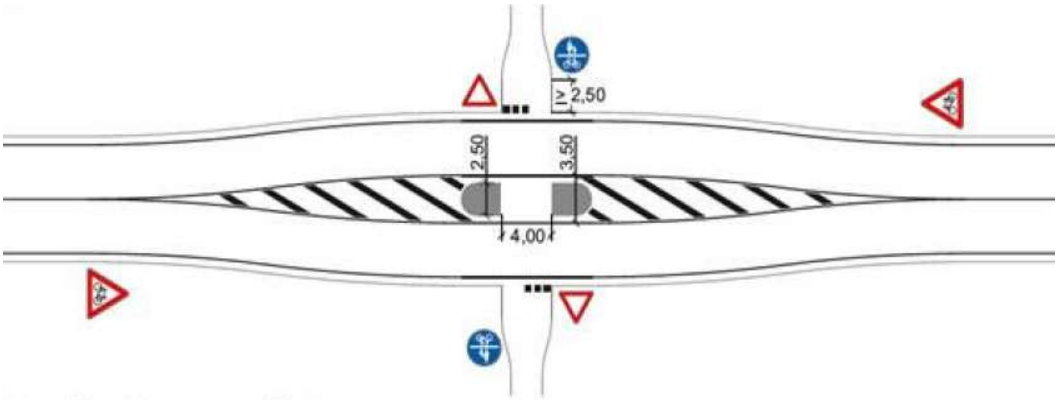
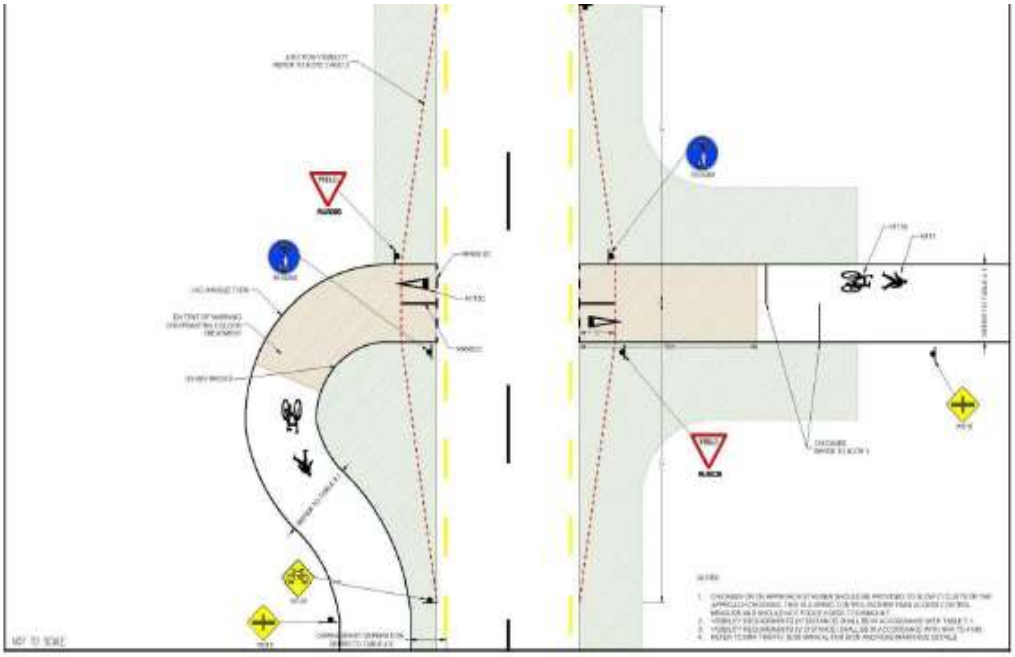
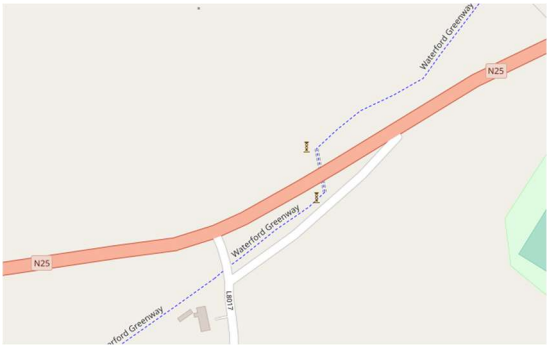
4.3 Germany

What?	**Bicycle crossing with central traffic island**
	 Systemskizze, Abmessungen in [m])
Remarks	☺ Cyclists and pedestrians yield to traffic with clear signage and marking denoting this; ☺ Signage on approach to the crossing warning motorists of presence of crossing ☺ Central refuge provided
Source:	Richtlinien für die Anlage von Landstraßen, RAL 2012

4.4 Ireland

What?	**Bicycle crossing with central traffic island**
	
Remarks	☺ Cyclists and pedestrians yield to traffic with clear signage and marking denoting this; ☺ Signage on approach 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.

What?	**Cycle underpass, at Kildermody on N25 in Waterford**
	 

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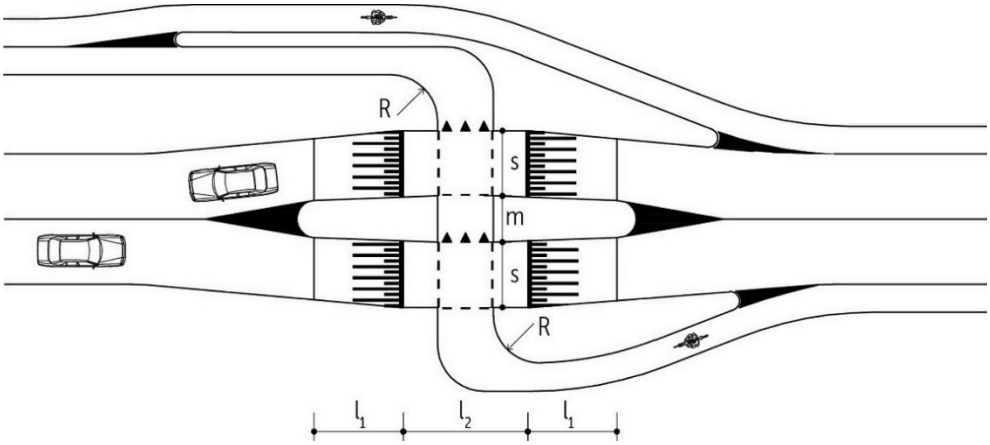
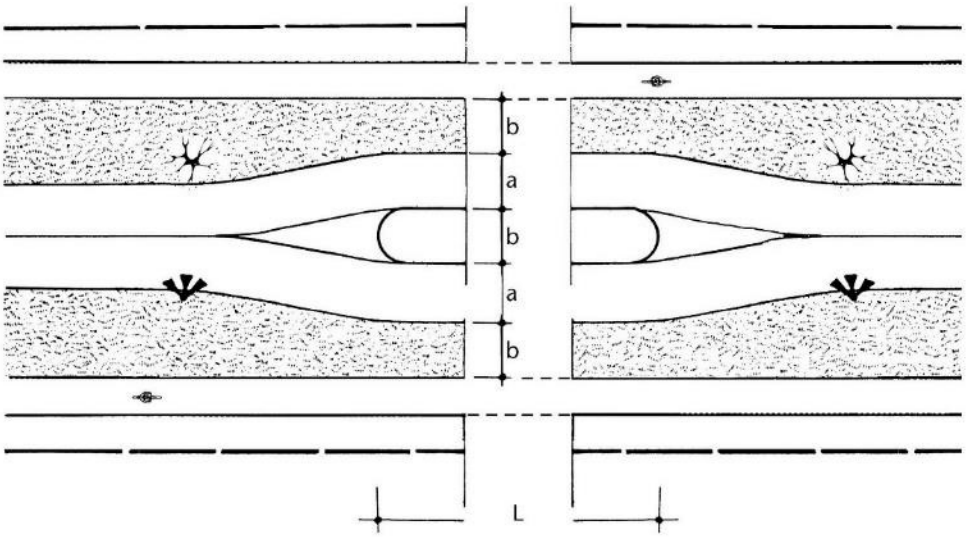
Remarks	☺ it removes cycle & pedestrian traffic from the road and gives them a safe route ☹ width is too narrow ☹ approach is at an angle, so there is no clear line of vision from start to finish ☹ gradient is too steep ☹ because of narrow width and angle of approach daylight can't penetrate into the middle 2 remedial measures were implemented after it had been in use for a few months: • Half-width fencing has been placed across the cycle path on the approach to the underpass to reduce speed of cycles • A brightly coloured mural has been painted on the approach walls to improve light reflection, and also to deter vandalism.
Source:	Google Street View https://goo.gl/maps/eh6SrVbQBPv

4.5 Netherlands

What?	**Crossing with transverse central island, with transition from two-way cycle track to one-way cycle track**
	
Remarks	Implementation: - Ensure recognisability with vertical elements and public lighting - Ensure good visibility of cycle traffic - Cyclists out of have right of way - Indicate right of way situation, no block marking, no red traffic path - Elevated construction preferable Dimensions: - B_3 = 2,75 to 3,50m - B_4 > = 2,50m - L_1 = depending on design speed - L_2 = 5,00 to 10 m - L_3 = 10 to 20 m - R = 5,00 m
Source:	http://kennisbank.crow.nl/zoeken/search

What?	**Bicycle crossing with central traffic island**
	
Remarks	Implementation: - Central traffic island preferably symmetrical in centreline of carriageway - Ensure recognisability with vertical elements and public lighting - Vegetation on central traffic island possible if dimension b is large enough - Ensure good eye contact - Central traffic island not elevated at cycle crossing location Dimensions: - a = 2,75 to 3,5m, depending on the function of motorised traffic - width of central traffic island (b) - at V_{max} < = 50mk/h > 3,00 (2,10) m - at V_{max} > 50km/h > 3,50 (3,00) m - if b = 10 to 20m: carriageway division - L = 5,00 to 20m L = 35 to 50m, at b > 10m - Chamfer of outward bends depending on design speed, but at least 1:5 - R = 30 to 40m, depending on manoeuvring room of design vehicle - Height of any vegetation on central traffic island < 0,60m
Source:	http://kennisbank.crow.nl/zoeken/search

What?	**A bicycle bridge: A non-level crossing for bicycles**
	
Remarks	☺ safe way to cross a main road ☺ gentle slope
Source:	From pictures-data-bank Fietsberaad The Netherlands, http://www.fietsberaad.nl/?section=fotos&lang=nl

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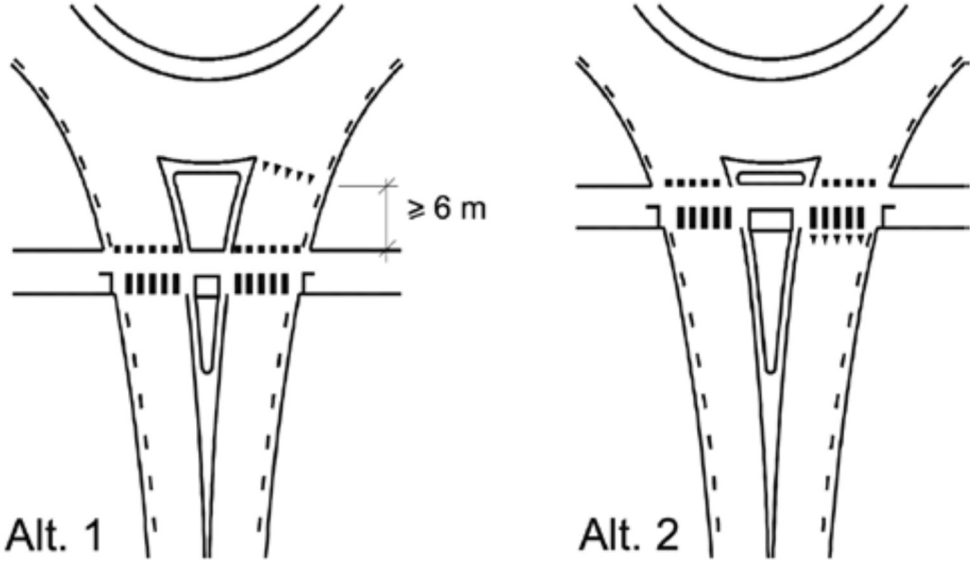
4.6 Sweden

What?	**Bicycle crossing (better example)**
	
Remarks	In Sweden, both examples are permitted, however, alternative 1 is a better solution because it places the crossing away from the complexity of the junction. This makes it easier for the motor vehicle driver to focus on the crossing without being required to watch out for dangers to his/her self (i.e. collisions with other motor vehicles). ☺ Alternative 1 places the crossing away from the complexity of the junction and reduces complexity and workload for MV drivers thus facilitating an increase in cyclist and pedestrian detection and the likelihood of MV giving way.
Source:	Modified by VTI, from VGU 2016:083 (Trafikverket), Sweden.

4.7 UK

What?	**Crossing point in Campusbarron, Dundee and Stornoway**
	
Remarks	Photos a) and c) show a crossing point in Guernsey from both directions. Photos b) and d) show the good/not good design characteristics of the same pictures: ☺ The division between cyclists and pedestrians on the path is clear and the cycle path has a generous width. ☺ Pavement colour at the crossing indicates to car users that there is crossing traffic. ☺ The right of way rules at the junction is clear. There is a yield sign on the road for cars, a sign indicating it and the paving is different visually assisting the right of way situation. ☹ There is no indication that cyclists are using the cycle path in both directions. The signs should indicate this for the cyclists and the car users, possibly assisted by road markings. ☹ Pavement marking prompting the cyclists to slow down is used only on one side of the crossing making it confusing for the cyclists. The question is also whether or not these should be used for cyclists, or perhaps for the cars that approach the junction. ☹ Tactile paving across the cycle path is not comfortable to ride over, and the question is if it is needed across the whole cross section.
Source:	Arup

4.8 Hungary

What?	**Crossing point**

	
Remarks	A good example, where more than one experimental design feature can be seen is rural road 2, marker 53+570. Here, due to frequent pedestrian crossing activity because of a bus stop, a centre island has been built, with a gap for pedestrians to stand in. No pedestrian crossing has been marked, but horizontal tactile striping warns cars of a dangerous situation. Furthermore, a solar powered system has been installed, consisting of push buttons and VMSs. If a pedestrian wishes to cross, they need to push the button, which activates a temporary 60 km/h speed limit (flashing sign). ☺ flashing speed limit sign grabs motorists' attention ☺ center island makes it possible for VRUs to cross in two steps ☺ VRUs are made cautious by the information sign, and the lack of pedestrian crossing marking ☹ Only works if pedestrians actively push the button ☹ zig-zag edge line could have been used ☹ no illumination
Source:	Google Street View https://www.google.hu/maps/@47.9186628,19.1193737,3a,75y,60.87h,85.65t/data=!3m6!1e1!3m4!1sPvkO4_r1t0Gj-lGvQrON5A!2e0!7i13312!8i6656?hl=hu source last picture: Gyula Orosz

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What?	**Crossing Point**
	
Remarks	**rural road 1, mark 11+200**. Here, the crossing is traffic light controlled, and zig-zag edge lines, as well as a centre island were employed. ☺ multiple warnings (zig-zag edge line, horizontal stripes) ☺ reduced speed ☺ centre island ☺ visual environment of road permits signalized traffic control ☹ Expensive ☹ requires power and communications lines
Source:	Google Street View https://www.google.hu/maps/@47.4678143,18.8756441,3a,75y,306.28h,79.84t/data=!3m6!1e1!3m4!1sLtTCG9Z19TjVjjET931xvw!2e0!7i13312!8i6656?hl=hu

4.9 Good practice summary for Crossing Points

☒ 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.

☒ Vertical deflections to increase visibility.

☒ Lighting placed on the pole over the crossing.

☒ Using a traffic island shortens crossing length.

- ☒ Good crossing points increases the attention among motorized road users.
- ☒ It also ensures that cyclists can cross safely and 'seamlessly'.
- ☒ The width of the traffic island should have the length of a bicycle as a minimum, if that's not possible a staggered crossing is recommended.
- ☒ Improves VRU visibility.
- ☒ Pedestrians can cross the road in 2 phases.

☒ Cyclists and pedestrians yield to MV traffic with clear signage and marking denoting this.

☒ Clear signage on approach to the crossing warning motorists of presence of crossing.

☒ Adequate radius (4m min) provided on bend to allow comfortable movement of cyclists.

- ☒ Ensure recognisability with vertical elements and public lighting.
- ☒ Ensure good visibility of cycle traffic.
- ☒ Indicate right of way situation, no block marking, no red traffic path.
- ☒ Elevated construction preferable.

☒ The division between cyclists and pedestrians on the path should be clear and the cycle path has a generous width.

☒ Pavement colour at the crossing is not recommended because it can easily be misconstrued as indicating a cyclist priority or have an ambiguous meaning; used inconsistently and lack universal deployment; and is often prone to lower carriageway friction when wet.

☒ Use clear right of way rules at the junction. For safety reasons, it is advisable to require VRU to yield.

☒ Setting back the crossing point from the junction (or roundabout) reduces the complexity of the junction and reduces complexity and workload for MV drivers thus facilitating an increase in cyclist and pedestrian detection and the likelihood of MV giving way (if required).

☒ Flashing speed limit sign grabs motorists' attention.

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

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

☒ Signalized traffic control maybe advisable if MV or VRU traffic flow is significant.

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A non-level crossing for bicycles: a bicycle bridge

☒ A safe way to cross a major road.

☒ A gentle slope is necessary.

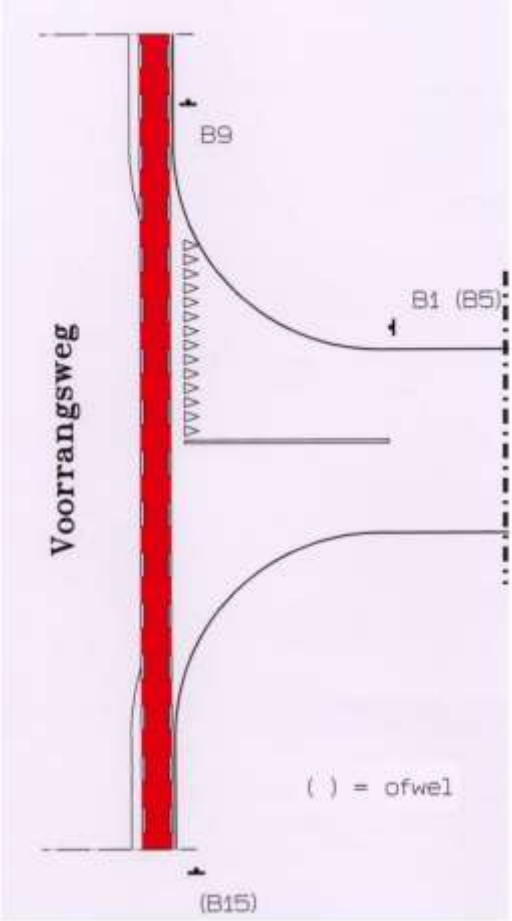
5 Junctions

Note: As roundabouts can be seen as a special type of junction, they are treated in a separate chapter, see further.

5.1 Flanders / Belgium

Four types of junctions:

- Priority road
- Priority to the right (no standard solution on regional roads outside built-up areas)
- Junction with traffic lights
- Roundabouts (separate chapter, see further)

What?	**Cycle lane on priority road, at a junction**
	

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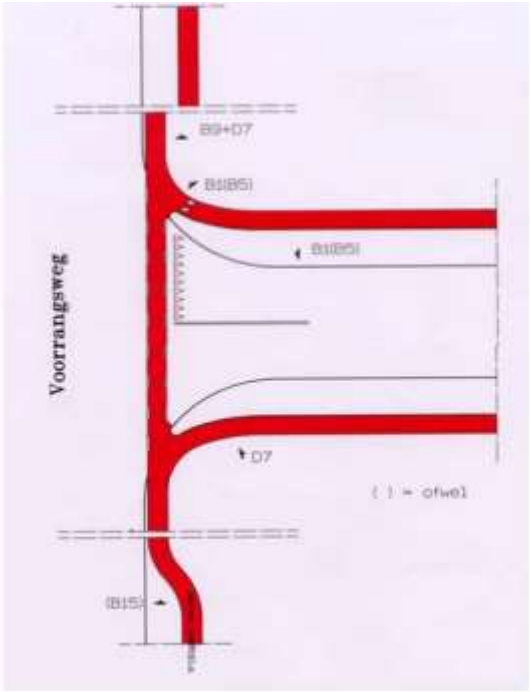
Remarks	☺ Comfortable cycle lane, no height differences, cyclists have priority even as the motorised traffic on the main road.
Source:	https://www.mobielvlaanderen.be/vademecums/fiets-praktijkvoorbeelden.pdf

What?		**Separated cycle lane on priority road, at a junction.**
		
Remarks		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

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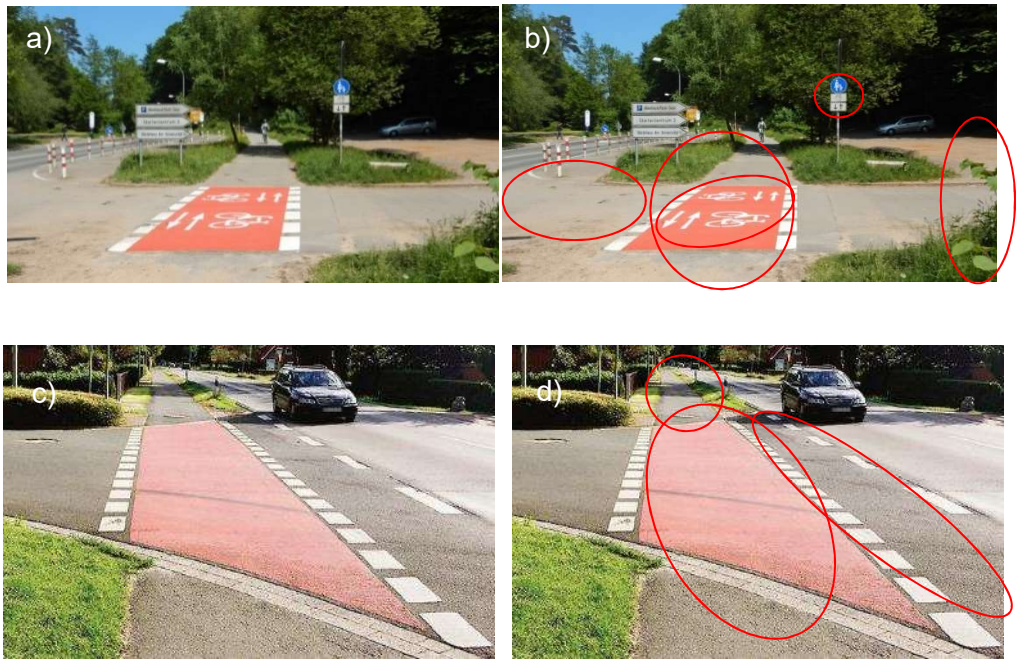
5.2 Germany

What?	**Bicycle crossing**
	
Remarks	Photo a) shows a bicycle path in Saarbrücken. Photo b) identifies the areas with good design elements as well as design flaws or areas of concern at the location. Photos c) and d) show a same analysis for a location in Edewecht. In photo **a**, there are four good design characteristics and three areas of concern: ☺ The colour indicates that there is a crossing point for cyclists to the car drivers. ☺ The arrows indicate that the cyclists can approach from either direction. ☺ There is 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. ☺ There is sufficient space for a car between the bicycle crossing and the perpendicular road. This allows for a car to slow down and come to a complete stop without causing unsafe situation on the main road. ☹ The crossing is shared with pedestrians without indication of where each user group needs to cross. ☹ The symbols and arrows to both directions on the crossing make it confusing where cyclists can be expected to cross. ☹ It is unclear who has to give way at this junction. The colour at the junction suggests the car has to give way to the cyclist, but there are no signs or markings to support that suggestion. In photo **c**, there is one good design characteristic and three areas of concern:

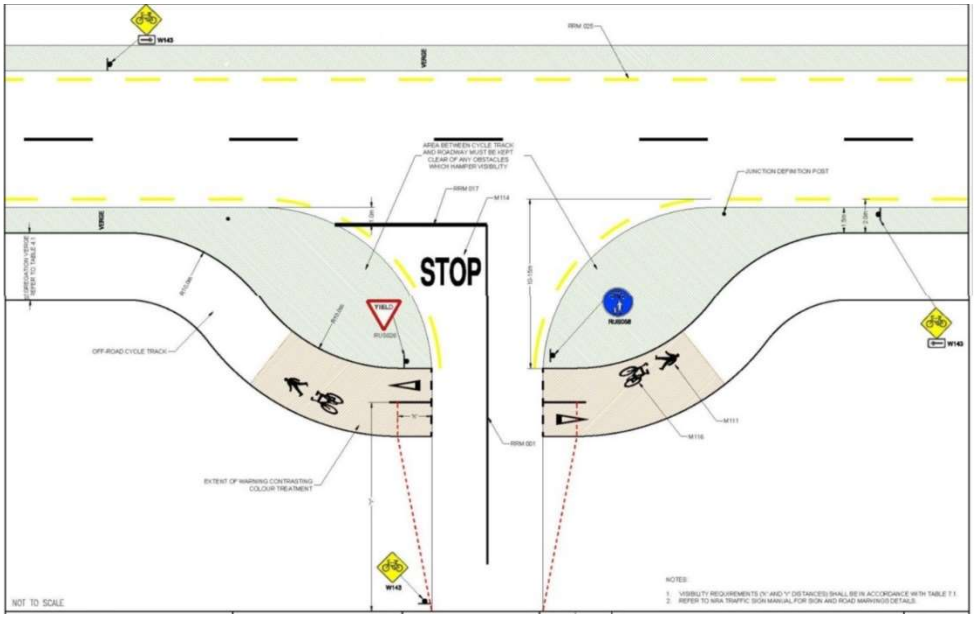
	+ Coloured pavement to indicate to car traffic that there is a crossing movement of cyclists. ☹ No indication if cyclists are approaching from both directions or just one direction. There are also no signs to indicate if cyclists are allowed to use the cycle path in one or two directions. ☹ Not sufficient space for cars between the cycle path and the perpendicular road. This may lead to rushed turning movements by car drivers to get off the main road, who might overlook cyclists as a result of the rushed turning movement. That might lead to unsafe situations. ☹ The pavement quality is not good on either side of the crossing.
Source:	a (Municipality of Saarbrücken, 2018) c (Edewecht, 2017)

5.3 Ireland

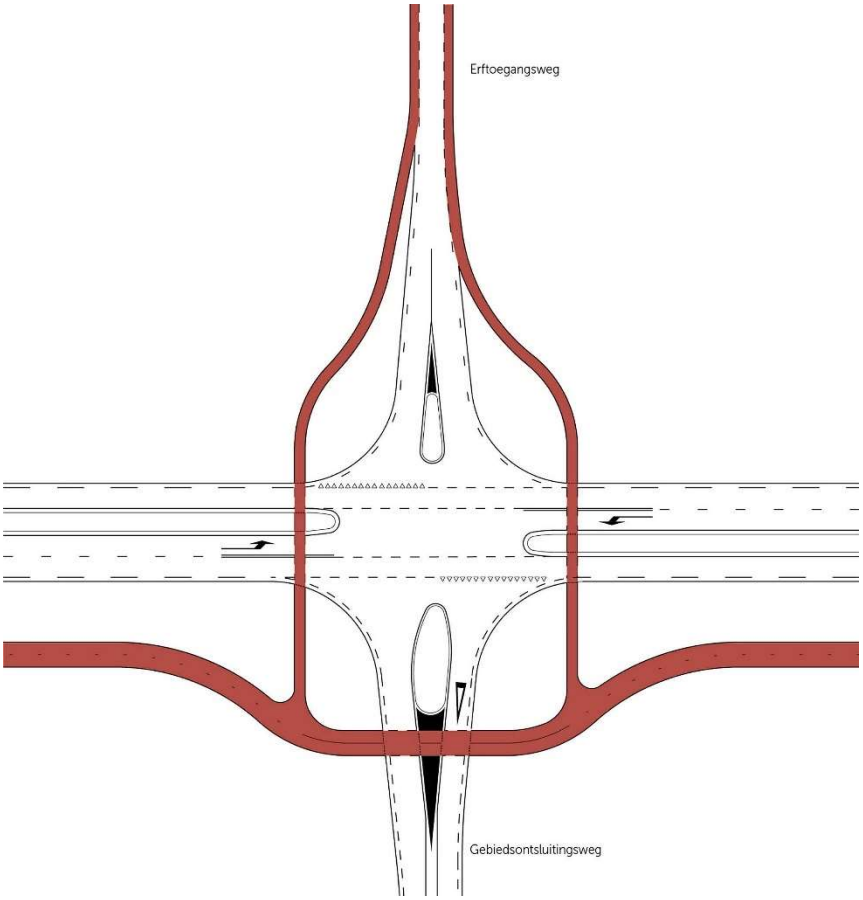
What?	**Junction in Labane, County Galway**
	 
Remarks	☺ Clear markings and coloured surfacing delineating crossing point – makes crossing very clear to cyclists and motorists ☹ Crossing is very wide (c. 18m) which exposes cyclists for a substantial length ☹ Cyclists do not have a priority for crossing although this is made clear to cyclists ☹ No signage reinforcing message to cyclists to yield ☹ No cycle facility provided on side road ☹ No dropped kerb provided on shared pedestrian/cycle path opposite the junction meaning any cyclists that enters from the side road cannot easily access the cycle facility

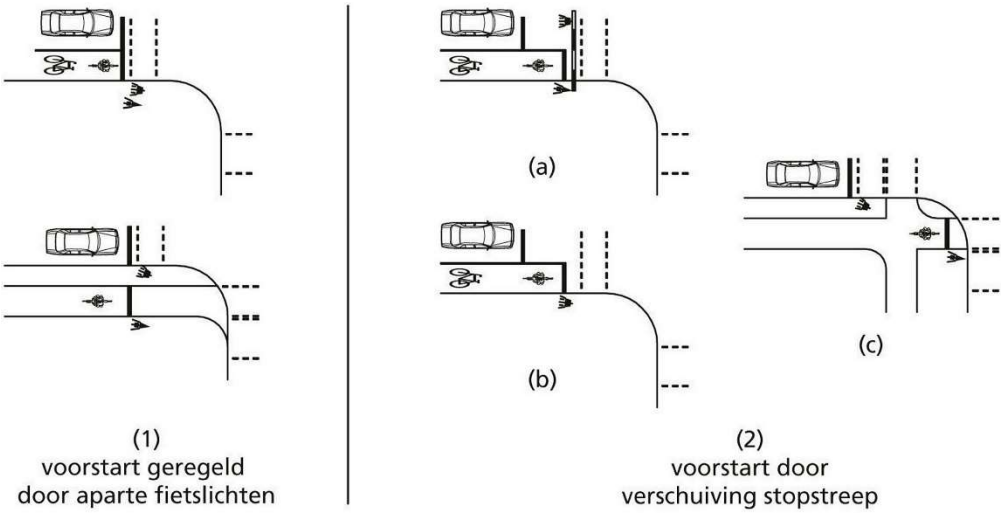
Source:	https://goo.gl/maps/UgFteHPyWvR2

What?	**N59, North of Westport County Mayo**
	
Remarks	Crossing location along greenway route in the west of Ireland ☹ Small 'stop' sign highlighting priority is with vehicular traffic. This could easily be missed by cyclists. ☹ Poor visibility for cyclists to the right due to vegetation ☹ Poor forward visibility of crossing for vehicles turning in from the main road ☹ Sign on gate is misleading – suggests a 'shared space' type environment is ahead
Source:	https://goo.gl/maps/UgFteHPyWvR2

What?	**Bicycle crossing**
	
Remarks	☺ 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 ☺ Central refuge provided ☺ 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 Netherlands

What?	**Cycle lane on priority road**
	
Remarks	Cyclists on a separated cycle/moped lane, parallel to the priority road, do not have priority. A separate priority regulation is set for the regulation of the priority between the (moped) bicycle traffic and traffic on the side road. The design must support the priority regulation as much as possible: • The cycle / moped path must be extended at a distance of 10 meters to 15 meters from the main carriageway. • A block mark may not be used on the crossing of the side road because the cyclist associates this marking with priority.
Source:	http://kennisbank.crow.nl/zoeken/search

What?	**Early start for cyclists at intersection with traffic control system**
	
Remarks	Function: - Improving visibility (safety) of cyclists Implementation: - 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 1: bicycle direction given green light before light for other traffic - Type 2: early start by moving stop line, simultaneous green light for cyclists and other traffic - Preferably implement types 2a and 2b with ECSL (> expanded cycle streaming lane) or with physical separation - Critical analysis of green light and clearance times
Source:	http://kennisbank.crow.nl/zoeken/search

5.5 Sweden

What?	**Junctions/intersections**

Fig. 5.6.a Hornsgatan-Långholmsgatan in Stockholm. This is a very complex intersection for motor vehicle drivers.

☹ The complexity has been increased by adding bicycle/pedestrian paths and crossing in every direction.

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	Fig. 5.6.b Hornsgatan-Långholmsgatan in Stockholm. The location of this photo is marked with a red arrow in Fig. 5.6.a. The cyclists have just received a green traffic light to enter the main intersection.
Remarks	☹ This is a very complex intersection for motor vehicle drivers. The complexity has been increased by adding bicycle/pedestrian paths and crossing. Moreover, there is a mixture of regulated and unregulated crossings as shown in the photo in Fig. 5.6.b. ☹ An exacerbating factor is that the regulated crossings (i.e. with traffic lights) in Sweden allow for motor vehicles and VRU (cyclists and/or pedestrians) to have a green light at the same time and with traversing paths. The occurrence of traffic light schemes that give a green-light to MV drivers and VRU users in the same crossing and at the same time is found in urban and inter-urban junctions. The Eriksson et al. (2017) study of this crossing observed multiple hazards.
Source:	Fig. 5.6.a. Google Maps (2018). Fig. 5.6.b. from Eriksson et al., 2017, VTI report, Sweden.

5.6 Hungary

What?	**Junction**
	
Remarks	The safest solution for VRUs to move in junctions is to establish signalized pedestrian crossings (e.g. rural road 5, marker 77+800). Other connecting roads of the junction are ☺ not signalized. It is furthermore illegal to establish a rural pedestrian crossing without illumination. ☺ no ambiguity regarding right of way and method of crossing

	☺ illuminated ☺ visual environment does not contradict traffic light control ☹ limited applicability (requires power and communications lines) ☹ connecting inferior roads not controlled, sudden mind set shift required from motorists ☹ installing traffic signals in a rural area (with no speed limit, presumably) can create a collision problem ☹ installing traffic signals are not expected by the driver (= not self-explaining) ☹ expensive
Source:	Google Street View https://www.google.hu/maps/@46.9641551,19.6409472,3a,75y,327.38h,81.98t/data=!3m6!1e1!3m4!1skB8K2CX8O9ftAhGH_5xU3g!2e0!7i13312!8i6656?hl=hu

5.7 Good practice summary for Junctions

☒ 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 (0.5 m) here as well between road and bicycle path.

☒ The 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.

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

☒ There is 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.

☒ 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.

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

☒ 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.

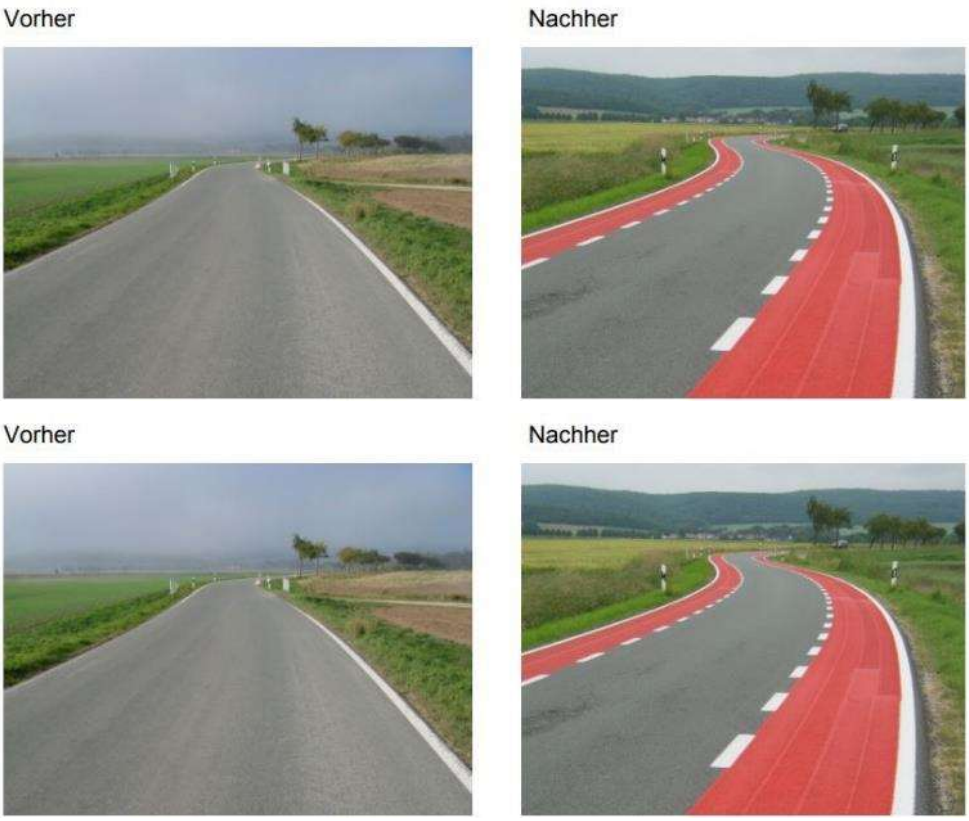
☒ Use separate bicycle/pedestrian paths running parallel with a main road and at junctions/crossing points, set them back, e.g. ≥ 10 m (a car length) from the main road intersection. This will facilitate space and time for the MV driver to complete their turning manoeuvre when turning off the main road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

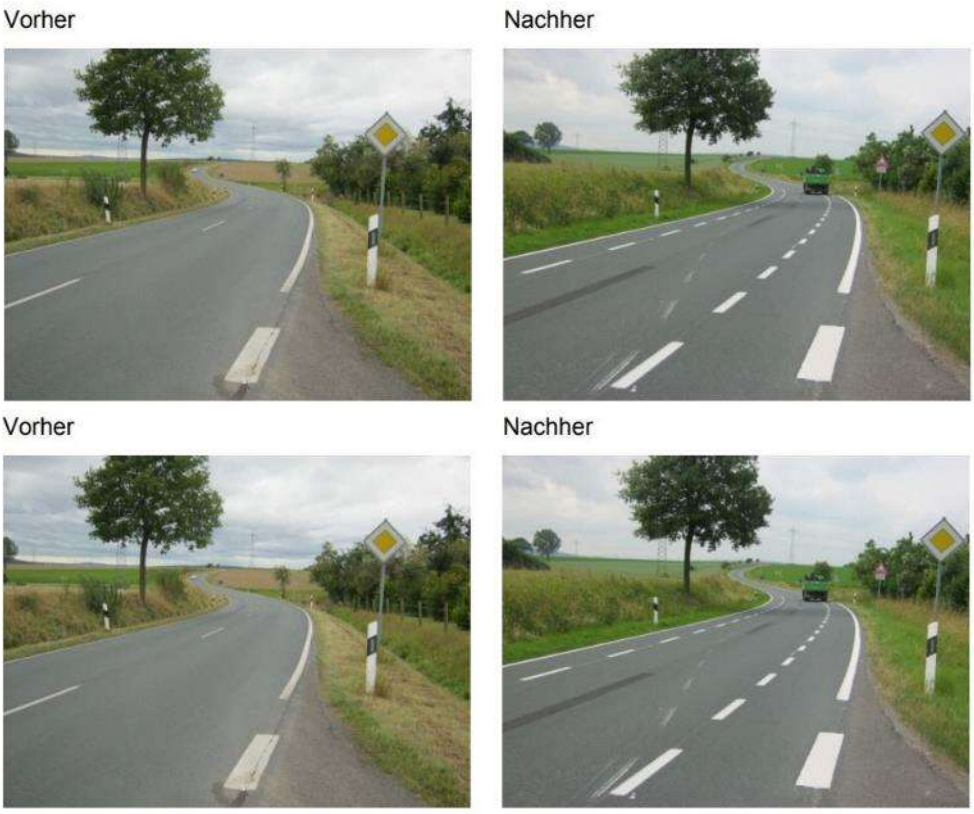
☒ Good *communication* in the road design can provide clarity on what may be expected and what the expectations are on the road user in any given part of the road infrastructure.

6 Continuous road segments, including curves

6.1 Germany

What?	One of 15 test road segments





Remarks	The first four images portray a road in Eilensen before and after improvements that were made to the road surface in order to improve the cycling safety.

	The same applies to a location in Northeim where the second four images show the before and after situation and pictures. The final image shows the termination of a cycle facility in Stolpe **Eilensen** ☺ Differentiation between the driving lane and cycle lane has been made clear with the bright colour ☺ The width of the cycle lane is appropriate ☹ The width of the road is insufficient to accommodate two-way traffic movements and as such motorists are required to drive in cycle lanes. ☹ There is no sign indicating that cyclists might be on the road. ☹ Cars drive rather fast on such roads (~80km/h) and therefore, the cycle lane does not provide adequate safety. There should be a physical barrier between the cars and cyclists ☹ Such marking of roads can be slippery in wet conditions **Northeim** ☺ The dotted line on the road surface makes the road appear narrower than it actually is which has the potential of encouraging car users to drive slower ☹ The cycle lane is less visible and therefore car drivers are less likely to anticipate cyclists on the road ☹ No signs warning of cyclists on the road ☹ In situations where the road has such high speeds, cyclists should be separated from the cars for safety reasons **Location in Stolpe** ☹ The cycle path ends abruptly without a warning (at the red and white barrier) ☹ There is no priority for cyclists to cross ☹ No indication for car drivers that there might be cyclists crossing
Source:	(Ministerium für Energie, Infrastruktur und Digitalisierung, 2018)

6.2 Ireland

What?	**Continuous Road Section on the N2 Monaghan - Corracrin**
	 
Remarks	☺ Good quality pavement ☺ Separated from the carriageway by a verge and in some locations by thick vegetation. Positive but could lead to personal security/safety issues. ☹ Poor visibility due to overgrown bushes arching over the bicycle path ☹ Path appears to be narrow ☹ Some gravel on the bicycle path ☹ Infrequent signage and road markings defining use

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Source:	https://goo.gl/maps/YBg7QqmydwK2

What?	**Continuous road segment on the N20 in Lahinch, Co. Clare**
	
	
Remarks	**N67 Lahinch in County Clare**

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	☺ Continuous two-way cycle lane on one side of the road ☺ Physical separation (kerb) between carriageway and cycle facility ☺ Width of the cycle lane appears appropriate ☹ Lateral separation between carriageway and cycle facility could be better (i.e. verge)
Source:	https://goo.gl/maps/31zGFYZUeau

6.3 Sweden

What?	Continuous road segments [Better]
	 Fig. 6.6. Cycle path between Falun & Grycksbo
Remarks	A 3385 m long pedestrian and cycle path was built in 2014 between Grycksbo and Bergsgården (Falun). The path is 2.5 m broad and cost 18 MSEK. Prior to the building of the path adjacent to Road 69, pedestrians and cyclist were forced to use the 0.5 m narrow hard-shoulder. The road has an AADT >8000 with approx. 10 % comprising heavy goods vehicles (often timber lorries). The speed limit is 90 km/h. ☺ The path improved travelling by bicycle in terms of safety and comfort immensely as well as increasing the number of cyclists.
Source:	Google Maps (2018).

6.4 UK

What?	**Bicycle path along Highway A1 in Morpeth, Northumberland, England**
	 
Remarks	☺ Dedicated cycle facility separated by verge ☺ Leads to other road parallel to main road with lower traffic volumes ☹ Cycle facility and verge appears to be narrow. Evidence of rutting suggesting that cars drive in the verge when exiting the A1 to the left. ☹ Facility on offline route (second image) could be better - currently mix of on and off-road with poor pavement surface. ☹ Little signage or road markings along route to identify use/priority.

Source:	https://goo.gl/maps/DuEULLtMZY62

What?	**Contra flow cycle lane in Barra**
	
	

	
Remarks	☺ Good attempt at providing for vulnerable road users in a rural area with restricted width ☹ Contra-flow facility with no physical separation ☹ Narrow width provided for both cyclists and pedestrians. A shared facility would have been a better solution
Source:	https://goo.gl/maps/qPw5S7EoKpn

6.5 Good practice summary for Continuous Road Segments, including Curves

☒ Two-way cycle facilities (of minimum width 2.5m) provided on one side of the road is the preferred layout for cycle facilities in non-urban areas.

☒ Adequate separation between cycle facility and the carriageway should be provided (0.5m minimum). Separation should ideally be a different material to the carriageway (e.g. grassed verge).

☒ Differentiation between the driving lane and cycle lane has been made clear with the bright colour if cycle lanes are provided within the carriageway.

☒ The width of the cycle lane is appropriate. There are different specifications depending on e.g. MV and cycle AADT, speed limits etc. A single bicycle lane within the carriageway should ≥ 2.0 metres wide given a speed limit of 50 km/h (30 mph). If the speed limit is higher, the lane width should also increase.

☒ In situations where the road has speeds greater than 50-60 km/h, cyclists should be separated from the cars for safety reasons.

☒ Provide adequate carriageway widths that accommodate two-way traffic movements without the need for motorists to drive in cycle lanes.

☒ Provide signs warning of potential for cyclists to be on the road

☒ Separate the cycle lane from the carriageway by a verge and in some locations by vegetation. (Also consider effects of secluded sections leading to personal security/safety issues).

☒ Consider winter road maintenance needs and give priority to VRU path over carriageway to reduce bring cyclist and pedestrians on to the winter carriageways.

☒ A contra flow cycle lane maybe a viable way of providing for vulnerable road users in a rural area with restricted width and low AADT.

☒ Contra-flow facilities should where possible, be provided with physical separation or MV meeting points (if in two-way traffic).

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7 School zones

7.1 Flanders / Belgium

What?	**School zones located on busy fast roads, use of variable message sign**
	 © Photo News
Remarks	☺ maximum speed is during school period (= normally 30 minutes before school start and 30 minutes after school is out), limited to 30 km/h ☹ the maximum allowed speed of 30 km/h cannot be supported by infrastructural measures, because outside the school hours a maximum allowed speed of 50 or 70 km / h applies
Source:	Flemish Region Photo: internet

What?	**School zone, outside urban area**
	 
Remarks	Location: N133, Wuustwezel, Flanders. ☺ separated cycle track, bi-directional ☺ median, gives the possibility to cross in two times ☺ dynamic zone 30 (= zone 30 during school hours) ☺ The cycle paths also connect to local roads that are frequently used as a school route, wherever crossing facilities are constructed.
Source:	https://www.google.com/maps/@51.4043789,4.5465702,3a,43y,321.42h,89.17t/data=!3m6!1e1!3m4!1satixPsSBy2FUurdcJrEJJQ!2e0!7i13312!8i6656

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What?	**School zone, outside urban area**
	
Remarks	Location: N285, Eizeringen, Flanders ☺ coloured traffic poles indicate the possible presence of children ☺ coloured octopus post emphasizes the crossing ☺ separated cycle lane
Source:	https://www.google.com/maps/@50.8267504,4.1407887,3a,75y,27.46h,92.52t/data=!3m6!1e1!3m4!1skM1Qwiv855ltuTcyx3tsxg!2e0!7i13312!8i6656

7.2 Ireland

What?	School zone Labane Co. Galway
	
Remarks	☺ Cycle lane/track on each side of the road. ☺ Physical separation (kerb) between carriageway and cycle facility (bollards on one side of the road, vertical separation on other side). ☺ Zebra crossing across road ☺ Integration with bus stops ☺ Good public lighting including at pedestrian crossing ☹ Width through the bus stop could be increased ☹ Crossing could be raised to reduce vehicle speeds
Source:	https://goo.gl/maps/HXZk1UDYPNR2

7.3 Netherlands

Almost all schools are located inside built-up area.

7.4 Sweden

Not specified in Swedish VGU/guidelines although 30 km/h zones are usually adopted in these urban areas.

7.5 UK

What?	**School zone in Stirling**
	 
Remarks	☹ Pavement only to one direction ☹ No hard shoulder to cycle on, ☹ Footpath only on one side of the road

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	☹ Poor quality pavement
Source:	https://goo.gl/maps/1ud9Csa2mUz

7.6 Good practice summary for School Zones

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

☒ The speed limit of 30 km/h should be supported by infrastructural measures, e.g. chicanes, adaptive speed humps (programmable and variable. Source: https://www.youtube.com/watch?v=KxpvwKiOpag), standard speed humps.

☒ School zones inherently have large numbers of particularly vulnerable road users (i.e. children) who often walk or cycle, therefore the school zone should accommodate for periodically high AADT levels.

☒ If a carriageway needs to be crossed, provide a median. Provide zebra or pelican crossings where appropriate.

☒ Consider the provision of adequate and safe drop-off areas for school buses and parents' cars.

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

☒ Good public lighting including at pedestrian crossing is necessary.

☒ Crossing could be raised to reduce vehicle speeds.

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8 Small linear settlements

8.1 Flanders / Belgium

What?	**A separated cycle path along small linear settlements**
	
Remarks	When a maximum speed of 70km/h is allowed, cyclist must have a separate cycle path.
Source:	https://www.mobielvlaanderen.be/vademecums/fietsroutesvlaanderen.pdf

What?	**Diverted cycle lane at the bus stop**
	
Remarks	☺ smooth diverted cycle lane ☺ buffer space between bus stop and cycle lane
Source:	https://www.mobielvlaanderen.be/vademecums/fietsroutesvlaanderen.pdf

8.2 Germany

What?	**Off Road Cycle Lane**
	

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Remarks	Suburban setting but it is a fitting example of a poor cycle path: ☹ The cycle path has been painted on the footpath as an afterthought. This means that the cycle lane keeps its width at all times, but it is not linear and, hence, it doesn't take into consideration cycling trajectories.
Source:	Tagesspiegel, 2018: https://www.tagesspiegel.de/berlin/zehlendorf-das-ist-berlins-absurdester-radweg/22894002.html

8.3 Ireland

What?	**Linear Settlement on N20 in Rathduff, Co. Cork**
	
Remarks	**N20 Rathduff County Cork** ☺ Cyclists have a dedicated part of the shoulder that has been clearly marked ☺ Horizontal separation provided in the form of hatched line-marking ☹ The width of the shoulder is not sufficient (because of poor maintenance, the grass has crept across the cycle path. ☹ The quality of the paving is poor: it is covered in gravel/debris and the surface is not smooth making for poor cycling conditions
Source:	https://goo.gl/maps/qfZ1jJ3Xz682

8.4 Sweden

What?	**Low-speed linear settlement with a speed reduction alternative. (Better example)**
	 Fig. 8.6.a. The 'village neighbourhood road' has a recommended speed limit of 30 km/h but the formal speed limit is 50 km/h.

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Fig. 8.6.b. The 'village neighbourhood road'. There is not enough room for two vehicles to meet head-on.

	 Fig. 8.6.c. The 'village neighbourhood road' has multiple bottlenecks with bus stops that also double as traffic calming applications.
Remarks	This "Bymiljöväg" (direct translation: 'Village neighbourhood road') in Bonäs in the county of Dalarna has been in existence since 2006. The road is 6 m wide in total, the hard-shoulder is 1,25 m and the centre lane is 3.5 m wide. The village is 4.2 km long. The AADT is ≤ 2000 vehicles. The original purpose of this road design was to improve safety for pedestrians and cyclists in the village, increase their mobility and reduce motor vehicle speeds through the village. The design concept is originally from Denmark. ☺ The concept reduced the motor vehicles' speed which is a safety improvement per se. However, actual safety benefit not related to the design are more in question because the motor vehicles are continuously required to use the hard shoulder when they encounter oncoming traffic and thereby jeopardising VGU safety. The benefits of this design are realised because the speed limits are low, i.e. ≤ 50 km/h.
Source:	VTI, Sweden

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What?	**Low-speed linear settlement VRU alternative applied in a high-speed inter-urban context (less good example).**

Fig. 8.6.d. This road design type is referred to as a *2-1 rural road*.

Fig. 8.6.e. The speed limit varied between 60-70 km/h.

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	 Fig. 8.6.f. The centre lane is 3.5 m wide and the tractor mowing the verge occupies the whole road.
Remarks	This type of road is called a "Bygdeväg" (2-1 rural road) which is very similar to the "Bymiljöväg" ("Village neighbourhood road") mentioned above. The design concept is originally from Denmark. ☹ The motor vehicle speeds tended to be too high to accommodate a safe environment for pedestrians and cyclists. The route in the photographs from the south of Sweden also included numerous blind bends which could prove potentially hazardous for car drivers driving in the centre lane if they encountered an on-coming car who is also driving in centre lane (as prescribed). ☹ In the same blind bend, as many drivers do, they driver could elect to use the hard shoulder. Unfortunately, the cyclist/pedestrian could also be there. ☹ This type of road design requires that the motor vehicle driver behaves in a certain manner. For the first-time user, the only hint available is the pictogram on the road sign in Fig. 8.6.d. There are no formal traffic rules for this type of road type.
Source:	VTI, Sweden

8.5 Good practice summary for Small Linear Settlements

☒ A maximum speed limit of exceeding 60km/h warrants a separate cycle path.

☒ Smooth curves should be adopted on cycle lanes.

☒ Provide buffer zones between bus stops and cycle lanes if they converge.

☒ Cyclists should have a dedicated part of the shoulder that has been clearly marked when cycle traffic is within the carriageway.

☒ Provide sufficient width on the shoulder relevant to the AADT and MV speeds.

☒ The quality of the paving must be high and e.g. gravel and debris on the surface needs to be removed regularly to avoid poor cycling conditions.

☒ Carriageways that are too wide, long and straight tend to lead to high MV speeds; traffic calming measures maybe be required to accommodate a safe environment for pedestrians and cyclists.

☒ Shared rural carriageways that have been narrowed, e.g. 2-1 roads, should avoid blind bends which could prove potentially hazardous for car drivers driving in the centre lane if they encountered an on-coming car who is also driving in centre lane (as prescribed). In the same blind bend, as many drivers do, they driver could elect to use the hard shoulder. Unfortunately, the cyclist/pedestrian could also be there. Therefore the 2-1 design on rural road should be abandoned

☒ Unique road designs often require that the motor vehicle drivers behave in a certain manner. Information and instructions must be clear especially for the first-time user, particularly if there are no formal traffic rules for this unique/prototyped type of road segment. Priority/right-of-way issues must be clearly stated and logical.

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9 Roundabouts (rural roundabouts)

9.1 Flanders / Belgium

What?	**Roundabout in a transition zone. Separated cycle lane, cyclists have priority**
	
Remarks	
Source:	https://www.mobielvlaanderen.be/pdf/vademecum/hfdst4.pdf

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What?	**Roundabout outside an urban area. Separated cycle lane, cyclists have to give priority**
	
Remarks	☺ Outside urban area, cyclists have no priority on roundabouts.
Source:	https://www.mobielvlaanderen.be/pdf/vademecum/hfdst4.pdf

What?	**Roundabout "crater roundabout"**
	
Remarks	Outside urban area, entrances and exits complex on a highway ☺ safe for cyclists, split level interchange
Source:	https://www.google.com/maps/@51.2884199,4.8547974,3a,60y,56.55h,81.12t/data=!3m6!1e1!3m4!1s-2vqteRgVrY-a-PV6dSyww!2e0!7i13312!8i6656

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9.2 Germany

What?	**Cycle lane around roundabout**
	  
Remarks	☺ Dedicated facilities provided for cyclists ☹ Narrow infrastructure shared between cyclists and pedestrians ☹ Priority is given to vehicles at crossing points ☹ Central island doesn't seem quite wide enough to fit a cyclist waiting. ☹ Cycle path only to one direction, shared with pedestrians.
Source:	Photo 1: JugendstilBikes (Blog), Cycling in Roundabouts, 2014 : http://jugendstilbikes.de/radfahren-im-kreisverkehr/ Photo 2+3: Allgemeiner Deutscher Fahrrad-Club (ADFC) (German Cyclist's Association), Cycle Paths in Roundabouts, 2014: https://www.adfc-hessen.de/public_downloads/dokumente/ADFC-Hessen_2014_Kreisverkehre_www.pdf

9.3 Ireland

What?	**Roundabout in Castleisland, County Kerry**
	 
Remarks	☺ Two- way facility provided on one side of the road ☺ Surface in need of repair and upgrade ☺ High vehicle speeds likely make it difficult to cross the traffic lanes ☺ No efforts to reduce vehicle speeds on approach to the roundabout (speed limit is 100kph)

	☺ At the roundabout exit, crossing is located too close to the gyratory placing crossing cyclists in danger
Source:	https://goo.gl/maps/Fe9PLdR62KT2

What?	**Roundabout in Naas, County Kildare**
	 

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Remarks	Suburban setting but many characteristics that could be employed at rural roundabouts: ☺ Shared cycle/pedestrian facility around entire roundabout. Could be better if separated facility provided although facility appears wide ☺ Dedicated raised pedestrian / cycle crossings with priority given to pedestrians and cyclists ☺ Crossings well-lit with targeted light. Presence of crossings further enhanced by flashing lights either side of crossing ☹ Requires reduced speed environment which may be undesirable on national road network
Source:	https://goo.gl/maps/yAyGe9PQW2C2

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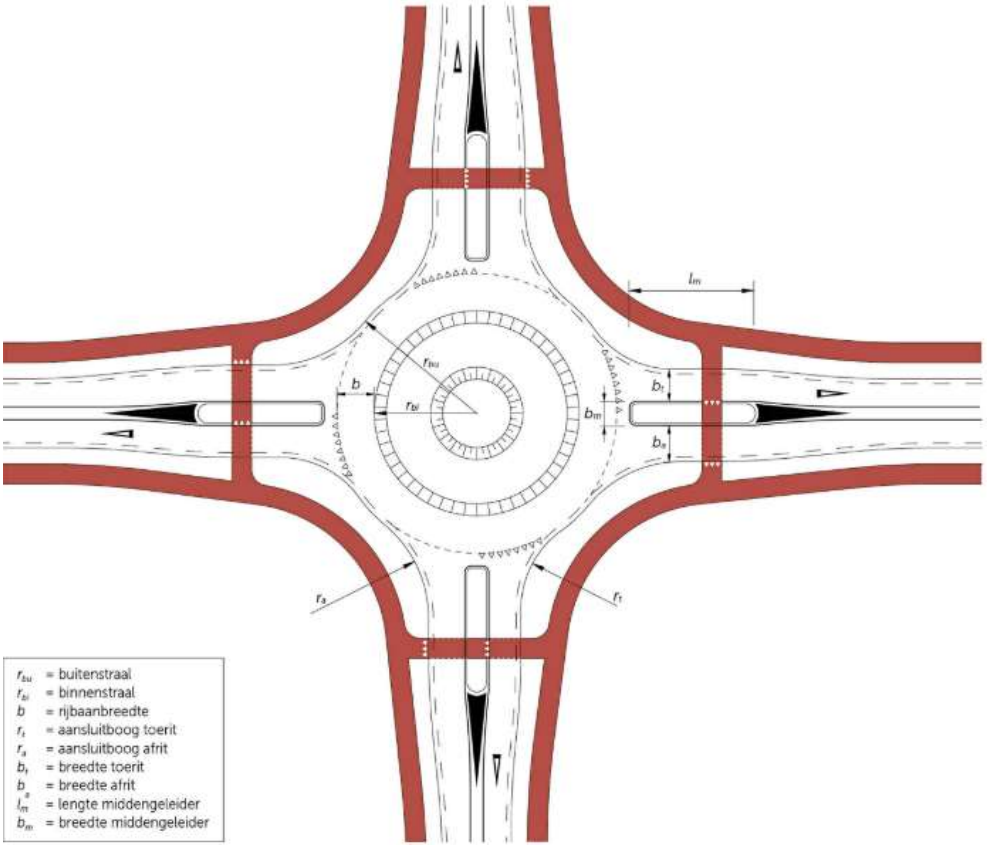
9.4 Netherlands

Single-lane roundabout with separate cycle track and cyclists not having right of way

What?	**Cycle path (cyclist have no priority) on roundabouts outside urban area**
	 Example: 
Remarks	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

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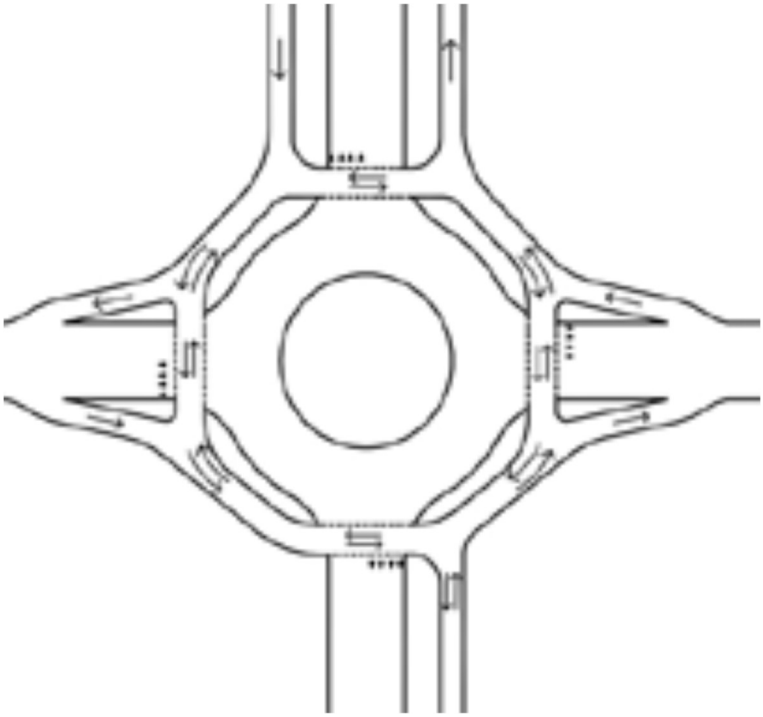
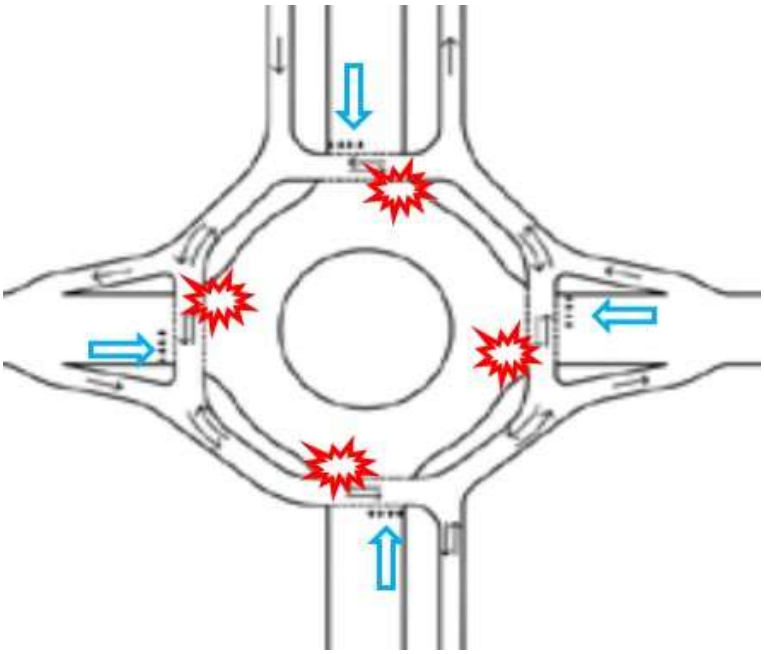
	- Central traffic islands sufficiently wide in connection with stacking space for cyclists - Equal right of way regime for cyclists and pedestrians - Vertical elements on elevated central traffic island - Guarantee recognisability by means of public lighting Dimensions: - R_1 = 12,50 to 20 m - R_2 = 6,50 to 15 m - r_a = 12 m, with central traffic island = 8 m, without central traffic island - r_b = 15 m, with central traffic island = 12 m, without central traffic island - B = 5 to 6 m (depending on R_1 and R_2) - b_1 = 1,50 (1,00) m - b_2 = 2 to 2,50 m - b_3 = as large as possible - L = 5 m - C = 2 m - Length of central traffic island (b_1) > = 6 m - Stacking space on cycle track (b_2) 2,10 to 3 m - Width of central traffic island (b_3) 2,50 to 3 m (2,10 m)
Source:	http://kennisbank.crow.nl/zoeken/search Picture example: https://www.google.be/maps/@52.0781132,4.587958,3a,75y,172.26h,85.63t/data=!3m6!1e1!3m4!1sNMadn0RcgK22qLVqvtQOQw!2e0!7i13312!8i6656

9.5 Sweden

What?	**Low speed roundabout on roads with a high AADT.**
	 Fig. 9.6.a.  Fig. 9.6.b.
Remarks	The figure 9.6.a above is one of a number of design-examples that are "recommended" in the VGU voluntary guidelines but does not provide satisfactory safety margins for the cyclists. The areas of conflict are indicated in figure 9.6.b with red starbursts.

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	☺ 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 m).
Source:	Modified by VTI, from VGU 2016:083 (Trafikverket), Sweden.

9.6 UK

What?	**Roundabout with cycling facilities on the A47 near Leicester**
	 
Remarks	This is located in a market town but still a good example of a bicycle facility that is in place but that could be improved. ☺ Shared pedestrian / cycle lane provided around the gyratory

	☺ Presence of crossing points highlighted by thick road markings ☺ While priority is given to vehicles, the priority is clear to cyclists ☺ Tactile paving provided for pedestrians ☹ Limited signage for all road users ☹ The shared facility appears narrow
Source:	https://goo.gl/maps/7ueCGejA4ak

9.7 Hungary

What?	**Roundabout: Routing bicycle traffic through a roundabout**
	 

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Remarks	An example where VRUs have to cross a two-lane entry and a two lane exit branch is rural road 21, mark 11+1000. Here, two safety methods were employed: first, pedestrians have red surface painting rather than a marked pedestrian crossing. Second, on the centre island dividing the entry and exit branch, pedestrians are directed to face approaching traffic. ☺ centre island which directs VRUs to face approaching traffic ☺ roundabout illuminated ☺ horizontal stripes to warn motorists of an unusual situation ☺ "hazard of pedestrian traffic" signs posted on both entry and exit branches ☹ motorists arrive to the situation already burdened by navigating or preparing to navigate the turbo roundabout ☹ ambiguity for VRUs, whether or not they have the right of way ☹ red surface paint employed when crossing traffic does not have right of way ☹ dangerous situation when crossing the exit branch for two reasons: exiting traffic is accelerating, crossing two lanes without an island
Source:	Google Street View https://www.google.hu/maps/@47.7705373,19.6619592,3a,75y,346.17h,99.99t/data=!3m6!1e1!3m4!1se5XIMDy9ITGs7Viex0-mPA!2e0!7i13312!8i6656?hl=hu

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What?	**Routing bicycle traffic through a roundabout**
	 
Remarks	An example of routing bicycle traffic through a roundabout is the junction between rural roads 4244 and 4219. Here, bicycle traffic enters and exits the roundabout as a standalone branch. ☺ paving stone rumble strips at all entry branches for motorists ☹ no advanced warning of bicycle traffic for motorists approaching the roundabout ☹ bicycle traffic not regulated at entry/exit ☹ trees restricting visibility for bicyclists ☹ no further guidance for bicyclists once in roundabout
Source:	Google Street View https://www.google.hu/maps/@46.7173349,21.3316147,3a,75y,35.74h,75.99t/data=!3m6!1e1!3m4!1szg6l1v5HhcWea4ffKkHiGg!2e0!7i13312!8i6656?hl=hu

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What?	Bicycle suggestion markings inside a roundabout: An example of bicycle suggestion markings inside a roundabout is Dugonics square in the city of Szeged. Here, cyclists are encouraged to merge with motor vehicles. Two roundabouts can be found in rapid succession, both crossed by tram traffic as well.
	 
Remarks	☺ cyclists guided inside roundabout ☺ "hazard of bicycle traffic" signs posted and bicycle suggestion markings painted on entry branches for motorists ☹ merging with motor traffic can be deterring ☹ already complex situation due to tram crossing the roundabout ☹ if cyclists keep to the right inside the roundabout, they can easily conflict with exiting motor vehicles
Source:	Google Street View https://www.google.hu/maps/@46.2501067,20.1444135,3a,77y,49.76h,73.69t/data=!3m6!1e1!3m4!1slQ_uYy9Qtte2q-ArB8nLhw!2e0!7i13312!8i6656?hl=hu

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9.8 Good practice summary for Roundabouts (rural roundabouts)

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

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

☒ 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 faf 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.

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10 Next steps

The next steps of the SANA-4U project will continue with WP3: Worked Examples of Best Practices. The worked examples comprise three routes (from Ireland, Belgium and Sweden) where *good practice* is applied in illustrated examples.

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- www.mobielvlaanderen.be
- Google street view