

Cycling in mixed traffic

Examine bicycle markings





Fietsberaad Vlaanderen is the knowledge center for bicycle policy. Sharing good practices and investing in new and practice-oriented research are the focus. In this way, Fietsberaad Vlaanderen stimulates and supports the dynamics in cities and municipalities that want to accelerate their bicycle policy.



This report was produced in collaboration with Vias institute, MINT and Goudappel Coffeng.



Colophon

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Research report
Markings of cycling infrastructure in mixed traffic

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1 Executive summary

Until now there is little knowledge about the effectiveness and impact of markings for cycling in mixed traffic. This makes it difficult to use them optimally. Fietsberaad Vlaanderen, Vias Institute and Mint nv have observed the behavior of road users to get an idea of the effectiveness of markings for bicycles in mixed traffic. We have investigated the effects of markings on driving behavior in order to determine the impact on road safety.

1.1 Longitudinal markings for cyclists in Flanders, the Netherlands and Germany

We started a benchmark study to get an overview of all common markings of cycling infrastructure in Flanders, together with a comparison with the Netherlands and Germany. The legal meaning, the priority situation, the legibility and the possible advantages and disadvantages of the markings were examined.

In Belgium, a bicycle path can be indicated with a traffic sign or by means of the double broken line marking. According to the Vademecum Bicycle Facilities, a separate or adjacent elevated cycle path is desirable, but an adjoining level cycle path that is separated from the roadway only by interrupted parallel white lines is still possible according to the highway code. Motorized traffic is not allowed to cross the broken lines, and standing still and parking on the bike path is prohibited.

Suggested bicycle lanes have no legal significance in Belgium, they only form a visual element. Cars can just drive over it and park on it. Within built-up areas, they are marked as an ochre yellow strip with a recommended minimum width of 1.70 m according to the Vademecum Bicycle Facilities.

Most comparable to the Belgian adjacent non-elevated cycle path are 'cycle lanes with a continuous line' in the Netherlands and 'Radfahrstreifen' in Germany, because they also form part of the road surface without motorized traffic being allowed to drive or park on it. A bicycle lane and a Radfahrstreifen are marked with a continuous line.

A Dutch bicycle lane with a broken stripe marking and a German Schutzstreifen – in contrast to the visually comparable bicycle lane in Belgium – do have a legal meaning. Parking is prohibited and cars are only allowed to drive over it if there is no other option and if they do not hinder cyclists. The Dutch bicycle lanes (without legal significance) are much less conspicuously marked than their Flemish counterparts.

1.2 Research question

The bicycle is gaining ground and requires more space. But many roads do not meet the conditions for constructing fully-fledged cycle paths. It is often not even spatially desirable to construct cycle paths, and certainly not financially feasible. In built-up areas, a bicycle lane is a possibility to make the position of the cyclist on the roadway more visible in mixed traffic. That strip is a visual element, but unlike a bicycle path, it has no legal significance. Many municipalities are also looking for a solution for roads with mixed traffic outside built-up areas. They want to indicate the place for cyclists more emphatically. Installing bicycle lanes everywhere with an ochre-yellow slurry layer is a major financial effort or not desirable due to the spatial context. An alternative is the **mid lane marking (MRM)**. A strip is marked on both sides of the road that is approximately as wide as a bicycle lane and leaves room for cyclists. Motorists are allowed to drive on the marked strip, just like with the bicycle suggestion lane. The question is whether such an MRM gives cyclists more space and whether it leads to safer behavior on the part of all road users. To find out, the MRM was compared with a situation without marking and with a marking by an ochre yellow slurry layer.



Center lane marking Kannaertsstraat Hasselt

1.3 Method

The observations or measurements were carried out in Bornem and in Hasselt. A baseline measurement without marking was performed at both locations, followed by a measurement with an MRM. In Bornem, there was also a measurement where the suggestion strip was marked with an ochre yellow slurry layer. Both the municipality of Bornem and the city of Hasselt have

applied the markings with its own resources and thus invested in this research.

Speed radars and video recordings registered the behavior of the road users. Based on the video recordings, the nature of interactions between cyclists and motorized traffic was coded (overtaking and crossing), as were the distances to the edge and between road users themselves.

1.4 Results





Type of interaction: We distinguish whether motorists who drove in the same direction as a cyclist overtook them (within the camera's view) or stayed behind them. Ideally, motorists will lag behind the cyclist longer with markings on the road surface than with the baseline measurement (without markings). In all measurements, the majority of motorists overtook the cyclist. In Bornem, MRM and slam layer ensured that cyclists were ridden slightly more often. In Hasselt the effect was just the opposite and motorists overtook slightly more often at an MRM.

Lateral distances: the distance between cyclist and motorist was measured. For safety, it is especially important that interactions with a small distance (<1.5 m) take place as little as possible. In Bornem there were no significant differences between the three measurements. Descriptively, there were even slightly more overtaking maneuvers with short distances, which lowers safety and comfort. In Hasselt, the average distances between cyclist and motorist with an MRM were greater than without markings, and there were also fewer maneuvers with small distances. This positive result in Hasselt mainly occurred for vehicles that crossed a cyclist.

Cyclist position: The distance from the cyclist to the edge was measured. An MRM makes cyclists ride more on the edge of the roadway. This effect was more pronounced with motorists or when no other intersecting vehicles were present at all. Moreover, it seemed to occur mainly among cyclists who cycle in groups (two or more cyclists). This suggests that cyclists with an MRM will cycle closer together – probably in an effort not to cross the lines. In vehicles, the difference between baseline measurement and MRM was smaller and not statistically significant. It is possible that cyclists in this measurement do not stay as close as possible to each other. With an other yellow slurry layer, we see this tendency to drive closer to the edge only when no other vehicles are present.

Vehicle Position: The distance from the vehicle to the edge was measured. The differences in vehicle position were minor and unsystematic. Also, the few significant differences did not always occur in the expected direction. In Bornem, the vehicles that crossed a cyclist where there was a sludge layer drove more to the center (and therefore closer to the cyclist they crossed) and in Hasselt, if there was no cyclist, the vehicles drove more to the edge if there was an MRM while the hope was that an MRM would make motorists drive in the middle of the road by default.

Vehicle speed: The speeds driven increased when a marker was added. This was the case for both an MRM and an other sludge layer and it was also observed at both locations (Bornem and Hasselt). The differences can partly be explained by the fact that more road users were present in the baseline measurement. But there is still an increase in speed from 2 km/h to 4 km/h, even after adjusting for the frequencies of the different road user types.

		MRM Hasselt	MRM Bornem	Slam Bornem
	% of vehicles that stay behind the cyclist	-	+	+
	Overtaking with a short distance	-	+	+
	Short distance crosses	-	+	+
	Cyclist position			
	To catch up	-	-	=
	crosses	-	-	=
	Free flow	-	-	-
	Vehicle position			
	To catch up	=	-	=
	crosses	-	+	+
	Free flow	-	+	+
Speed	km/h	+	+	+

Overview results.

Significant increases (+) or decreases (-) are marked in black or red. Trends that are not statistically significant are shown in gray or pink. Red and pink stand for undesirable trends, black and gray stand for desirable trends.

1.5 Conclusion

The study shows that the results of the five indicators studied – do motorists stay behind a cyclist or overtake them; what is the lateral distance between car and cyclist; how far does the cyclist ride from the roadside; what is the distance from the car to the edge of the road; how fast do the cars go? – are not unequivocal. It is not the case that one situation (no marking, MRM, slam layer) scores significantly better on all indicators. There are only minor effects of the marking and they are not always the same at both locations (Bornem and Hasselt).

In Hasselt, slightly fewer interactions were counted with motorists who passed cyclists at too close a distance, which is positive in principle. But it was not the motorists who changed their behaviour, but the cyclists: especially when they rode together in a group, they cycled closer to the edge of the road. Together with the increased speed of motorists, the effect can therefore not be called positive.

In Bornem, the markings mean that the car stays behind the cyclists longer, in Hasselt it is just the opposite. As far as the lateral distance is concerned, the number of close-distance interactions in Bornem even increases slightly. In general, the MRM causes the cyclist to drive more to the edge of the roadway, which is less the case with the slam layer. There is also no clear effect for the position of the car. In Bornem, the vehicles move more towards the center when crossing, so closer to the crossing cyclist, which is negative. In Hasselt they drive more to the edge at the MRM, especially if there is no other traffic (while you would expect and hope just the opposite). And finally the speed: it is increasing at both locations!

Based on this study, neither the MRM nor the ocher yellow slurry layer appears to have any positive effects on road safety when cycling in mixed traffic.

If you want to mix, don't get divorced!

2 Introduction

Flanders is the third largest cycling region in Europe and we make more than one sixth of our trips by bicycle. But there is certainly still room for growth. In the Netherlands, for example, one in three journeys is made by bicycle and in Denmark one in four. Fietsberaad Vlaanderen wants to support the Flemish government, the provinces and the cities and municipalities in their ambition to focus even more strongly on the use of the bicycle as a lever for resilient mobility policy.

As the bicycle takes up more of a position as a mobility solution, there is also more discussion about the space that cyclists should be given. You think of a bicycle path, but it is not practically possible to build one everywhere, because many roads do not meet the conditions for constructing bicycle paths with safe dimensions. It is often not even spatially desirable to build bicycle paths, and often it is not financially feasible at all. Within built-up areas, the choice often falls on a bicycle lane to make the position of the cyclist on the roadway more visible in mixed traffic.

Many municipalities are also looking for a solution for roads with mixed traffic outside built-up areas. They want to indicate the place for cyclists more emphatically. Installing bicycle lanes everywhere with an ochre-yellow sludge layer is financially a tough one, and it may also be undesirable because of the spatial context. Fietsberaad is also regularly asked about the advantages and disadvantages of alternative markings, often variants of a central lane marking (MRM). But there is still little knowledge about the effectiveness and impact of markings for bicycle traffic, which makes it difficult to use them optimally. That is why Fietsberaad Vlaanderen, Vias Institute and Mint nv have now observed the behavior of road users at different types of markings for bicycles in mixed traffic. We have investigated the effects of markings on driving behavior in order to determine the impact on road safety.

To investigate the different possibilities of longitudinal markings in mixed traffic, we first performed a benchmark in Belgium and then compared the different types of markings in the Netherlands and Germany. We then carried out a field experiment to investigate whether a mid lane marking (MRM) gives cyclists more space and leads to safer behavior by all road users. The MRM was compared with a situation without marking and also with a marking through an ochre yellow slurry layer.

2.1 Reading guide

[Chapter 3](#) describes the different types of cycling infrastructure with associated markings and regulations in Flanders, the Netherlands and Germany .

[Chapter 4](#) describes how we came from the general question of which markings give cyclists more space and safety to a concrete research design . We also explain which considerations have led us to designate the MRM with a bicycle logo connection marking, as it is already used for marking bicycle crossings transverse to the right of way at intersections in Flanders.

We describe the research methodology in detail in [Chapter 5](#). We discuss the selection of the locations, the measuring equipment (cameras and radars), the processing of the video images and the planning of the measurement moments.

The results are discussed in detail in [chapter 6](#) . All findings are summarized at the beginning of [chapter 7](#) , where we discuss a number of aspects in light of the results found. [Chapter 8](#) provides the conclusions of this study again.

3 Benchmark

In this chapter we discuss the current legislation and guidelines regarding the marking of bicycle facilities. We provide an overview of the common markings in Flanders, the Netherlands and Germany.

3.1 Flanders

3.1.1 Bicycle path

3.1.1.1 Definition

A cycle path is defined in the Belgian highway code as that part of the public road that is demarcated by two parallel longitudinal white broken stripes. It is not wide enough for car traffic.

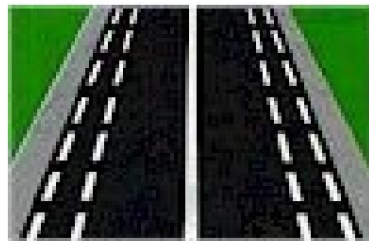


Figure 1: Longitudinal markings indicating a cycle path (source: highway code - article 74)

When the public road includes a cycle path suitable for use, indicated by road markings as described above, cyclists and drivers of class A two-wheeled mopeds must follow this cycle path as far as it lies to the right in their direction of travel. They are not allowed to follow such a bicycle path if it is on the left in their direction of travel. A cycle path can also be indicated by a traffic sign D7 or D9.

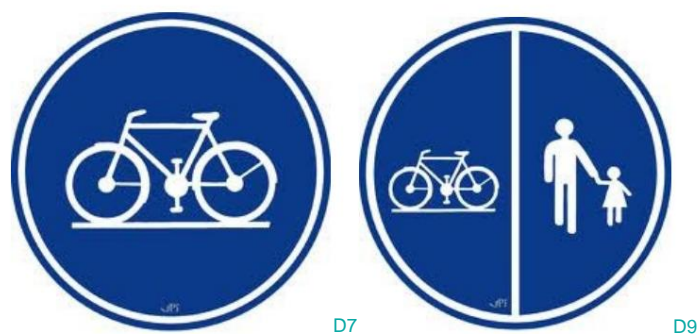


Figure 2: Traffic signs cycle path (D7 and D9)

The cycle path can run adjacent or separate from the roadway.

3.1.1.2 Adjacent cycle path

The pavement of the adjacent cycle path connects almost immediately with that of the roadway. A distinction is made here between an elevated or level cycle path. The adjacent elevated cycle path is physically separated from the roadway by a level difference of at least 5 cm. The adjacent at-grade cycle path is separated from the roadway by a gutter, interrupted parallel white lines or a different color or material. Note that an adjacent at-grade cycle path is not a desirable design according to the Vademecum Bicycle Facilities, even if this is in line with the highway code.



Adjacent elevated bike path port of Antwerp

3.1.1.3 Separate cycle path

A separate cycle path is a cycle path whose pavement is physically separated from the roadway by a safety strip of at least 1 m that may not or cannot be used by moving traffic. This safety strip can also be less wide if there is a clear vertical physical separation.

According to the Flemish Cycling Vademecum, two-way cycle paths must always be separate.



Detached one-way cycle path Veurne - Koksijde

3.1.1.4 Marking

The broken stripe marking of the bicycle path is white and consists of lines approximately 0.15 m wide and approximately 1.25 m long, with intervals of approximately 1.25 m.

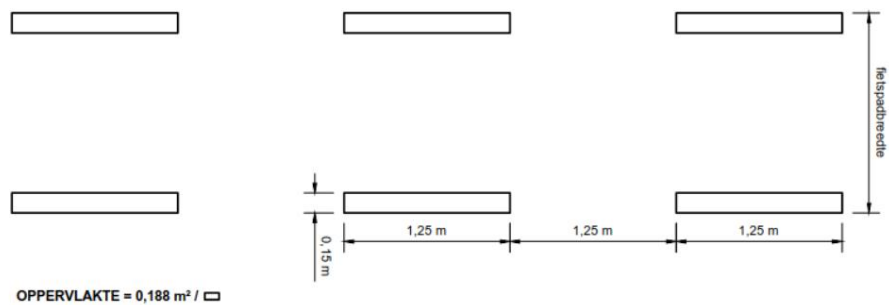


Figure 3: Marking one-way cycle path (source: General circular on road signalling)

In practice, on Flemish (regional) roads, cycle paths that are marked in this way and that are adjacent, not elevated in relation to the roadway, are often additionally demarcated with a continuous white line. But this arrangement is still not a desirable situation. Adjacent unelevated cycle paths are not recommended in the Vademecum Bicycle Facilities.



Marked cycle path with broken line marking supplemented by a continuous line marking (not a recommended arrangement according to the Vademecum Bicycle Facilities)

The circular on road signaling also mentions edge markings for cycle paths. An edge marking of a one- or two-way bicycle path is optional.

If applied, it is carried out using a continuous marking. This has a width of preferably 0.10 m (at least 0.05 m) and is placed 0.10 m from the physical edge of the cycle path.

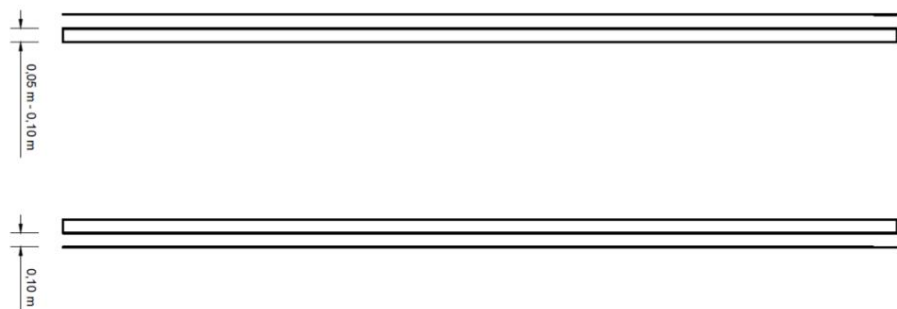


Figure 4: Edge marking of one-way cycle path (source: General circular on road signalling)

In principle, a two-way cycle path is not indicated with markings¹, traffic sign but with D7. The application of a continuous axis marking is optional on two-way bicycle paths. If the continuous line is drawn, it is placed in the middle of the cycle path and has a width of 0.10 m. A broken axis marking is mandatory on cycle highways and optional on two-way cycle paths. The axis marking pattern is spaced 2.70 m apart and is 0.30 m long and 0.10 m wide. In curves (from 15.00 m before to 15.00 m after the curve) the spacing of the axis marking is reduced to 0.30 m and the strokes of the broken marking are 2.70 m long. The width is 0.10 m.

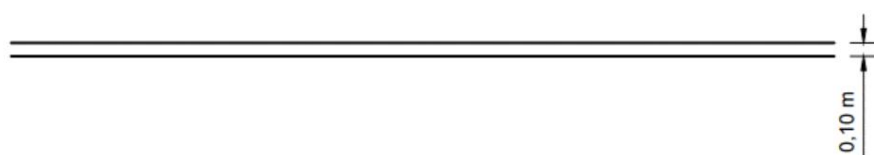


Figure 5: Continuous axis marking of two-way bicycle path (source: General circular regarding the road signalling)

¹ Road code article 9.1.2 states that “If the public road includes a cycle path that is passable, indicated by road markings as stipulated in article 74, then cyclists and drivers of class A two-wheeled mopeds must follow this cycle path insofar as it is on the right in their direction of travel. lies. They are not allowed to follow such a bicycle path if it is on the left in their direction of travel.” This does appear to occur in practice and is, for example, also included in the [Flemish service order MOW/AWV/2017/6](#) as a marking for continuous two-way cycle paths at intersections.

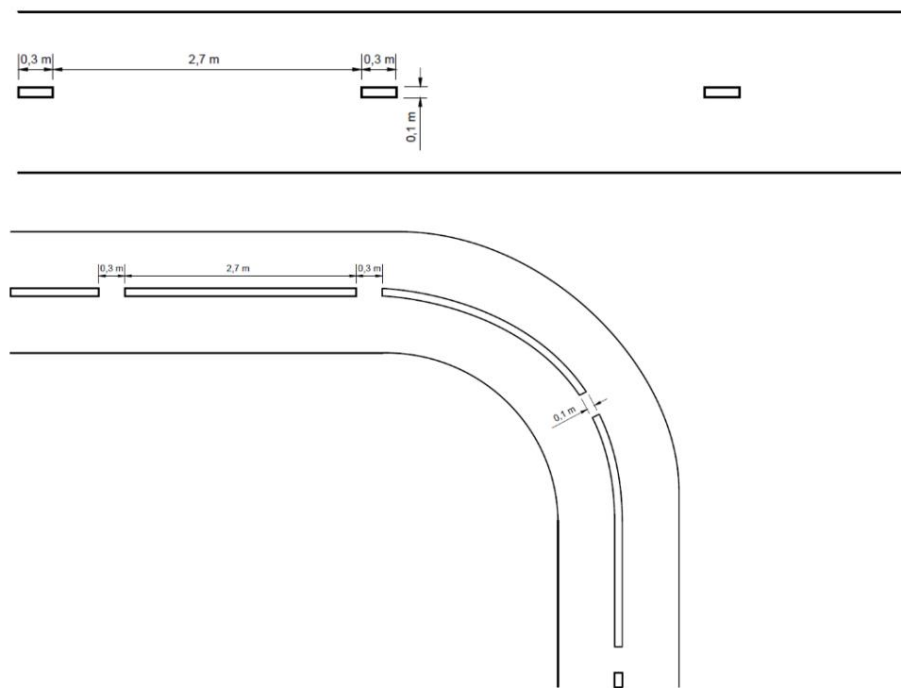


Figure 6: Interrupted axis marking of two-way bicycle path (source: General circular on road signalling)

Bicycle paths can be executed in a red color. This increases recognizability and readability.

3.1.2 Suggested bicycle lane Definition A

3.1.2.1

suggested bicycle lane is not included in the traffic regulations, so it has no legal significance. The bicycle lane is part of the roadway and is therefore a form of mixed traffic. Bicycle lanes indicate the cyclist's position on the roadway, have an attention-enhancing effect on other traffic and visually narrow the roadway.

Cars may park in a bicycle lane. To avoid conflict situations with parking cars, bicycle lanes are best combined with demarcated parking lanes next to the road or a parking ban (indicated by traffic signs or road markings).

Because bicycle lanes are used for mixed traffic, it is recommended that they are only installed in places where a speed limit of 50 km/h or less applies and if the intensities of motorized traffic allow safe and comfortable mixing. No distinction is made between roads inside and outside built-up areas.

3.1.2.2 Marking A

bicycle lane as included in the Flemish Vademecum Bicycle Facilities can be marked with an other colored strip or by means of another materialisation.

- Other colored strip: If the bicycle suggestion strip is indicated by means of a colored strip, it must be other colored. Suggested cycle lanes may therefore not be marked in red, as this may cause confusion with cycle paths.
- Materialisation: Suggested bicycle lanes can also be indicated by using a different materialisation than the central lane. This materialization may be other (e.g. asphalt or concrete).



Cycle suggestion strip with other yellow slurry layer in Kruibeke

3.1.2.3 Width

The width of the bicycle lane is a minimum of 1.70 m and a maximum of 2 m. No bicycle lanes are used on roads with a pavement width of less than 5.40 m or more than 6.60 m. If the roadway is wider than 6.60 m, it must be narrowed to a maximum of 6.60 m. This can be done, for example, by applying a border line.

3.1.3 Bicycle logos

3.1.3.1 2 Definition

Bicycle logos indicate the position of the cyclist. This alerts other traffic to shared use of the roadway by cyclists. Bicycle logos, however, have no legal basis. They are much less noticeable than a bicycle lane. Bicycle logos are a punctual marking, cycle suggestion lanes are continuous.

The use of bicycle logos as an alternative to bicycle lanes is especially useful in places where the use of color of bicycle lanes clashes with the spatial image of the road and its surroundings. Bicycle logos can also be applied to narrow streets or streets with low traffic volumes. Because bicycle logos are a mixed traffic application, it is recommended that they are only applied at a maximum speed limit of 50 km/h or less. No distinction is made between roads inside and outside built-up areas.

3.1.3.2 Marking

The bicycle logo measures 1.53 m x 0.90 m or 0.765 m x 0.45 m (small variant). It should be installed every 30 meters, and in any case after every side street. The use of other markings, such as a single broken line or sergeant's line, is not recommended as it could cause confusion with the marking of a cycle path and it is best to limit the number of markings in any case.

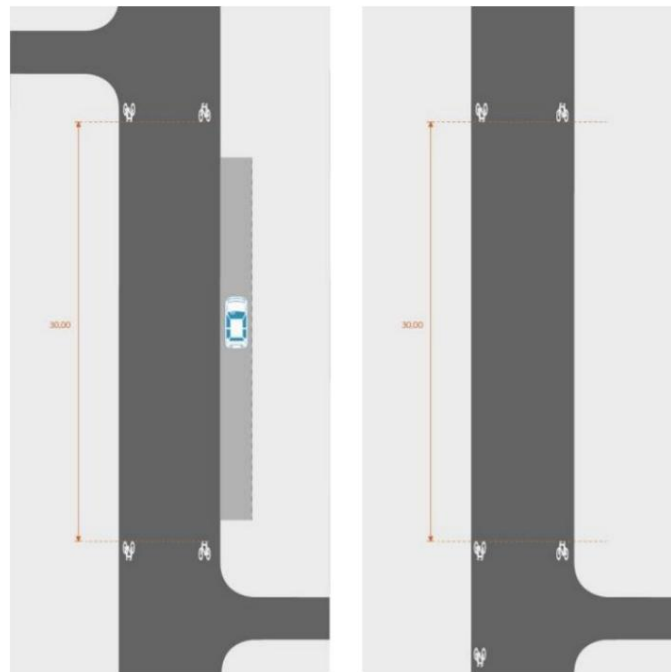


Figure 7: Placing bicycle logos on the roadway (Source: Vademecum Bicycle Facilities)

2 Bicycle logos are no longer included in the most recent revision of the Vademecum bicycle facilities, chapter 4 Design guidelines.

3.1.4 Passing distance

In Belgium drivers of a car or a motorcycle must leave a lateral distance of at least 1 meter between their vehicle and the cyclist or driver of a two-wheeled moped. Outside built-up areas, the minimum lateral distance is 1.5 m.

3.1.5 Application of bicycle facilities Along

the main road network (or the primary roads according to the old road categorization), according to the Vademecum Bicycle Facilities, a bicycle road is recommended, possibly an alternative route or the use of a service road. Separate cycle paths are designated on roads with a speed limit of 70 km/h. On roads with a speed limit of 50 km/h, adjacent elevated cycle paths are recommended, unless traffic intensity is low. In that case it can also be done safely with mixed traffic or bicycle lanes. At 30 km/h, cyclists in principle use mixed routes (possibly with cycle lanes) unless the high traffic intensities or the continuity of the cycle network require a cycle path.

3.1.6 Sources •

www.mobielvlaanderen.be/vademecums/vademecumfiets01.php#gsc.tab=0 • <https://wegcode.be/wettexts/sections/kb/wegcode/> • www.mobielvlaanderen.be/overheden/artikel.php?nav=10&mbnr=146&id=1454 • https://wegenenverkeer.be/sites/default/files/uploads/documenten/MOW_AWV-2019-2-appendix_0.pdf • www.mobielvlaanderen.be/pdf/vademecum/extra02.pdf

3.2 Netherlands

3.2.1 Bicycle path

3.2.1.1 Definition

A cycle path is a cycle path if the G11 traffic sign (the blue sign with the white bicycle) is on the right side of the path. Then cyclists are obliged to ride there. There are also non-compulsory cycle paths, which are provided with a rectangular sign saying 'cycle path' in letters (sign G13). Because mopeds have to use the roadway in built-up areas, there is also a bicycle/moped path, with a blue sign with a bicycle and moped symbol (sign G12a). Mopeds and cyclists must then drive here.



Figure 8: Traffic signs cycle path in the Netherlands

A difference with Belgium is that in the Netherlands a cycle path is always defined by means of the traffic sign. Only the correct marking, without a traffic sign, is not enough to define a cycle path.

Cycle paths are always physically separated from the roadway. This involves sufficient spacing or a vertical separation between the roadway and the bicycle path. Adjacent elevated cycle paths are not common in the Netherlands. Where they are applied, there are no marking guidelines or recommendations. Usually a different color is used between the bicycle path and the band between the roadway and the bicycle path.

A cycle path is therefore never separated from the main road by a marking alone (as is the case with adjacent non-raised cycle paths in Belgium). In that case there is a bicycle lane (see below).



Separated cycle path in the Netherlands (Eindhoven)

3.2.1.2 Marking For

markings of cycle paths, a distinction is made between the edge marking and the axis marking.

3.2.1.3 Edge marking

For cycle paths in built-up areas, edge markings on the outside of bends are recommended if a cycle path curves along a road or if there is no street lighting. For bicycle paths outside built-up areas, edge markings (on both sides) can be used in, for example, the following situations: sudden changes in route, slopes, relatively high intensities, missing public lighting and relatively unsafe verges. The width of the edge marking is at least 0.05 m and preferably 0.10 m. Furthermore, the edge marking is preferably placed at some distance from the edge (at least 0.10 metres), so that cyclists can still correct if they exceed the marking.



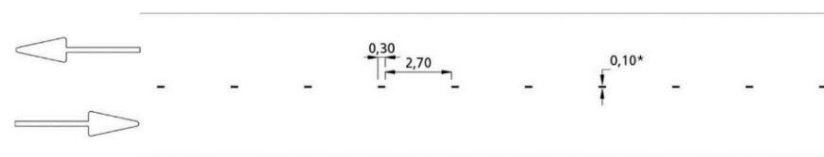
Bicycle path with axis marking and edge marking, Source: Goudappel

3.2.1.4 Axis marking

A good center marking can prevent frontal collisions between cyclists. On a two-way cycle path, an axis marking is made that consists of a broken line with a width of 0.10 meters and a length of 0.30 metres.

The space between two consecutive stripes is a maximum of 2.70 metres. On cycle paths with a tiled surface, the white stripe may be replaced by a white tile with a width of 0.15 or 0.30 metres.

At places where crossing the axis entails a more than normal risk, for example in bends, the axis marking is executed as a warning marking with a space of 0.30 metres (see Figure 9).



*) bij open verharding mag de breedte een afwijkende maat zijn

maten in m

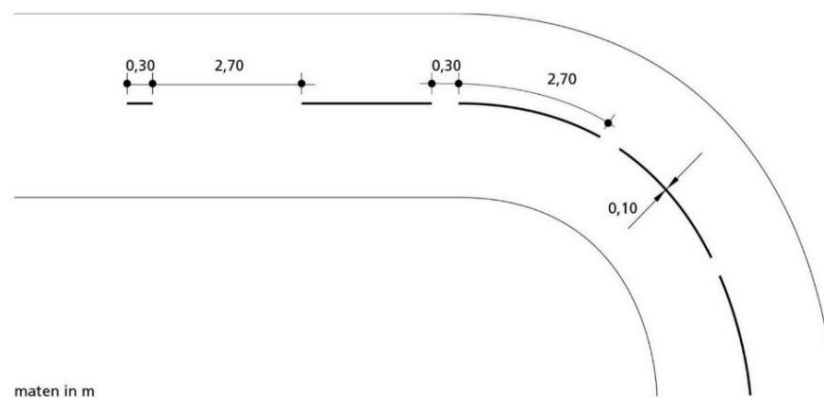


Figure 9: Axis marking (top) and warning marking (bottom) on a two-way road

bike path (source: CROW)

3.2.2 Bicycle lanes

3.2.2.1 Definition

According to the traffic rules and traffic signs regulations (RVV 1990), a bicycle lane is a section of the road marked by continuous or broken lines on which images of a bicycle have been applied. These lanes are intended for bicycle traffic and disabled vehicles. With a continuous line along the bicycle lane, other drivers are not allowed to enter the bicycle lane. In case of a broken line, other drivers are allowed to cross it, but only if they do not hinder cyclists.

Drivers may not park their vehicle in a bicycle lane or on the roadway adjacent to a bicycle lane. This applies to bicycle lanes with a broken line as well as to bicycle lanes with a continuous line.

The bicycle symbols and the longitudinal markings make the bicycle lane into a bicycle lane. The (usually red) color is optional. Bicycle lanes with interrupted markings are by far the most common in the Netherlands compared to continuous markings.



Bicycle lane demarcated with an interrupted marking and red coloring in Eindhoven

3.2.2.2 Marking At

exits, parking bays and bus stops next to the roadway, the bicycle lane is locally separated by a broken line (even if the line is continuous), unless a difference has already been indicated due to different paving. Both the solid and the broken line have a width of 0.10 metres. The broken stripes are 1.00 meters long with a space of 1.00 meters in between. The image of the bicycle on the road surface is placed at the beginning of the bicycle lane and after each paved side road. On the intermediate road sections, the symbol is repeated at regular intervals (50 to 100 m). The pavement of a bicycle lane is often provided with a different (red) color to accentuate the difference with the adjacent lanes. This is also recommended by the Dutch knowledge center for infrastructure CROW.

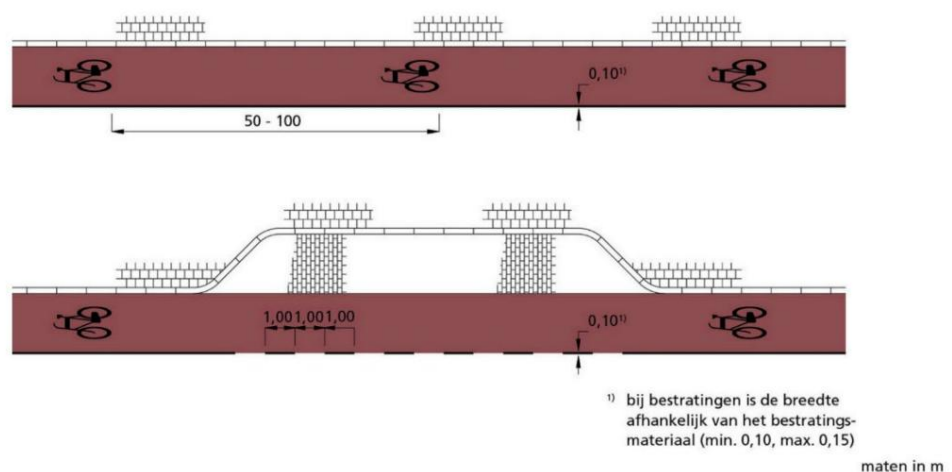


Figure 10: Bicycle lane markings (source: CROW)

3.2.2.3 Width

There is no absolute minimum width for bicycle lanes. Fietsberaad Nederland gives recommendations for the application and width of bicycle lanes. The starting point of Fietsberaad Nederland is that bicycle lanes must always be wide enough for two cyclists next to each other (minimum 1.70 metres). Three situations are distinguished:

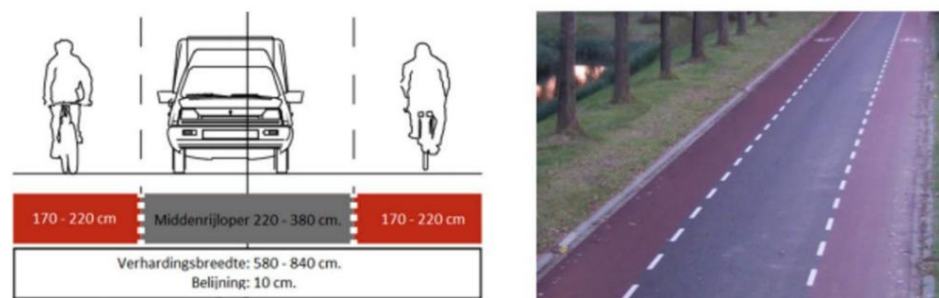


Figure 11: Bicycle lanes with a narrow driving lane in the middle, applicable at 30 km/h and < 6000 motor vehicle movements (mvt)/day (source: Fietsberaad.nl)



Figure 12: Bicycle lanes with a wide driving lane in the middle, applicable at 30 or 50 km/h and < 10,000 mvt/day (source: Fietsberaad.nl)

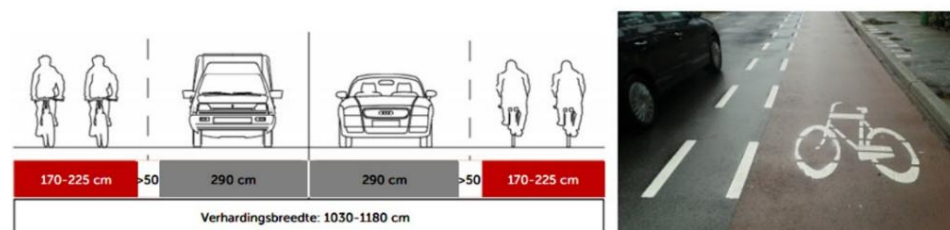


Figure 13: Bicycle lanes with their own space for bicycles (including safety strip) and cars, applicable at 50 km/h and < 20,000 mvt/day (source: Fietsberaad.nl)

3.2.3 Bicycle suggestion lane

3.2.3.1 Definition

A suggestion strip is a section of road at the edge of the roadway separated from it by a broken line. Cyclists may drive outside the suggestion lane (for example when overtaking) and drivers of other vehicles may also leave the

use suggestion lane. In principle, a suggestion strip is only used on access roads.



Bicycle suggestion lane (without red color or bicycle logo) in the Netherlands. Source: Cyclomedia

3.2.3.2 Legal status of bicycle lane and suggestion lane

A suggestion lane has no legal status and therefore offers no protection for the cyclist. All other traffic may use it, just like the cyclist. This is not the case with a bicycle lane. It is essential here that images of a bicycle are applied to the bicycle lane, which is not the case with a bicycle lane.

Parking on a bicycle lane is also allowed. The traffic law does state that you may not park on the road outside built-up areas on priority roads (article 24).

However, these priority roads are usually distributor roads on which, in principle, no bicycle lanes are desirable.

In the past, the Institute for Scientific Research into Road Safety SWOV has carried out research into edge strips/shoaling effects of the lanes. This study concluded that motorists from other countries seem to accept them. No behavioral effects

The cyclists use their 'own' lane and usually ride further away from the edge of the road than before there was a lane. Free-driving motorists also generally drive slightly further from the edge of the road in the presence of a driving lane. When passing a cyclist, they often choose not to drive on the opposite lane. On the other hand, when overtaking a cyclist on a suggestion lane, motorists usually take less lateral distance from the cyclist. It is not known to what extent this decrease of a few centimeters on average is serious. The average driving speed in most cases decreases slightly as a result of the lanes (a few kilometers per hour).

3.2.3.3 Marking

The broken line has the same dimensions as the bicycle lane. However, no different color is used for the paving of the suggestion strip and no images of bicycles may be placed on the road surface.

There are no minimum requirements regarding the width of a bicycle lane. Usually the width is between 1.00 and 1.50 m.

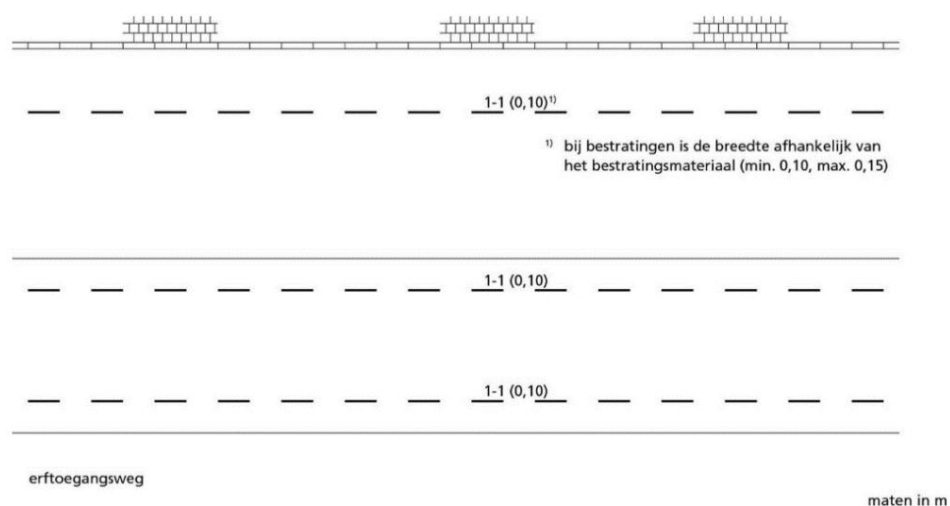


Figure 14: Cycling suggestion lane marking (source: CROW)

3.2.4 Application of bicycle facilities When

which bicycle facilities are recommended depends on the location (in built-up areas or outside), the road category, the speed regime, the traffic intensities and the role of the route in the cycling network. The table below shows

the recommended bicycle facilities inside and outside the built-up area. Note that bike lanes are not included here. Suggested bicycle lanes are rather regarded as a sub-optimal solution. It is recommended to make a clear choice: either a fully-fledged bicycle lane (of sufficient width and with markings), or a completely mixed profile. In practice, bicycle lanes are usually used if bicycle lanes do not fit (because of the width) or are not desired, because it must be possible to park on them incidentally.

On a well-designed access road within built-up areas, bicycle lanes are not necessary for reasons of road safety. Therefore, no bicycle lanes are installed on most access roads. However, there may be other reasons to do so, for example to design a main cycle route through a residential area.

Weg-categorie	Maximumsnelheid gemotoriseerd verkeer (km/h)	Intensiteit gemotoriseerd verkeer (mvt/etm)	Fietsnetwerkcategorie		
			Basisstructuur (I fiets <750/etm)	Hoofd fietsnetwerk (I fiets 500-2.500/etm)	Snelle fietsroute (I fiets > 2.000/etm)
Erf-toegangsweg	stapvoets of 30	< 2.500	gemengd verkeer	gemengd verkeer of fietsstraat	fietsstraat (met voorrang)
		2.000-5.000		gemengd verkeer of fietsstrook	fietspad of fietsstrook (met voorrang)
		> 4.000	fietsstrook of fietspad		
Gebieds-ontsluitingsweg	50	2x1 rijstrook	fietspad		
	70	2x2 rijstroken			
		niet relevant	fiets-/bromfietspad		

Figure 15: Selection scheme for bicycle facilities in built-up areas (source: Design guide for bicycle traffic)

Wegcategorie	Maximumsnelheid gemotoriseerd verkeer (km/h)	Intensiteit gemotoriseerd verkeer (mvt/etm)	Fietsnetwerkcategorie	
			Basisstructuur	Hoofd fietsnetwerk of snelle fietsroute (I fiets > 500/etm)
Erf-toegangsweg	60 (of 30)	< 2.500	gemengd verkeer	fietsstraat als I auto < I fiets ¹⁾ ; fietspad of gemengd als I auto > I fiets
		2.000-3.000	fietspad, eventueel fietsstroken	
		> 3000	fietspad	
Gebieds-ontsluitingsweg	80	niet relevant	fiets-/bromfietspad	

1) plus eventueel aanvullende eisen op het gebied van de snelheid

Figure 16: Selection scheme for bicycle facilities outside built-up areas (source: Design guide for bicycle traffic)

3.2.5 Sources •

- www.fietsersbond.nl
- www.verkeersregel.vwn.nl
- CROW Guidelines for road markings and markings • <https://wetten.overheid.nl/•www.fietsberaad.nl/getmedia/68d3ad2c-88d2-4634-8279-d33349ae5c74/Fietsberaadnotitie-Recommendation-bicycle-and-side-strips.pdf.aspx?ext=.pdf>
- www.bsabv.nl/difference-cycling-stroke-and-cycling-suggestie-strip/
- www.swov.nl/publicatie/enkele-gedragseffecten-van-suggestiebanden-op-narrow-rural-wegen
- CROW bicycle design guide

3.3 Germany

3.3.1 Bicycle path (Radweg)

3.3.1.1 Definition

A bicycle path in Germany can be mandatory or non-mandatory. If it is indicated with a traffic sign 237, 240 or 241, it is mandatory to use it. If none of these signs are present, cyclists may also cycle on the roadway. In that case, the cyclist can decide whether he wants to cycle on the road or use an existing (non-compulsory) cycle path.

If a lower sign 'Radfahrer frei' is attached to traffic signs, this means that cyclists may also use the street or part of the street to which the traffic sign refers.



Figure 17: Cycle path traffic signs (Germany)



Figure 18: Bottom plate 'Radfahrer frei'

As a rule, a cycle path is separated from the street either from the sidewalk or from the roadway by markings, a special surface or a curb. Cycle paths

can therefore be constructed with colored or gray asphalt, special covers or with red or dark gray concrete blocks.

If cycle paths are only separated by a white marking on the road, this is referred to as cycle lanes (see chapter 3.3.2).



Bicycle path with continuous dashed line and red marking in Bremen (Source: Photo by Ulamm, distributed among a CC BY-SA 3.0 license)



Two-way cycle path with red marking in Berlin (Source: Photo by W.-D. Haberland, distributed under a CC BY-SA 3.0 license)

3.3.1.2 Marking

Cycle paths can optionally be marked with a white bicycle icon on the road surface. Cycle paths must always have a signpost and they may not be used in the other direction. The direction of travel can be indicated with traffic signs or with a marking on the cycle path itself.

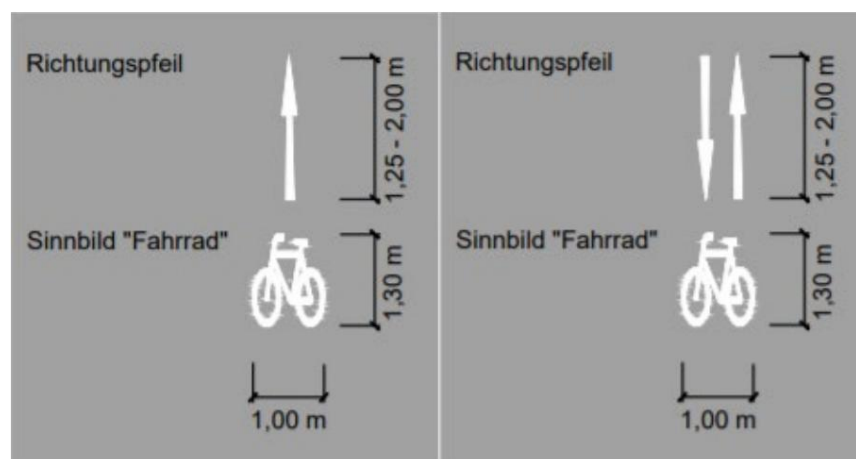


Figure 19: Cycle path marking: one-way (left), two-way (right) (Source: Musterlösungen für Radverkehrsanlagen in Baden-Württemberg)

3.3.1.3 Width

According to the Empfehlungen für Radverkehrsanlagen (ERA), the standard width of a cycle path is 2.00 metres. With little bicycle traffic, a width of 1.60 meters can be used. There is a safety strip of 0.75 meters between the cycle path and cars parked alongside. If the cycle path is directly adjacent to the road, a 0.50 meter safety strip must be provided.

A two-way cycle path has a standard width of 3.00 metres. If the bicycle traffic intensities are low, a width of 2.50 meters is sufficient.

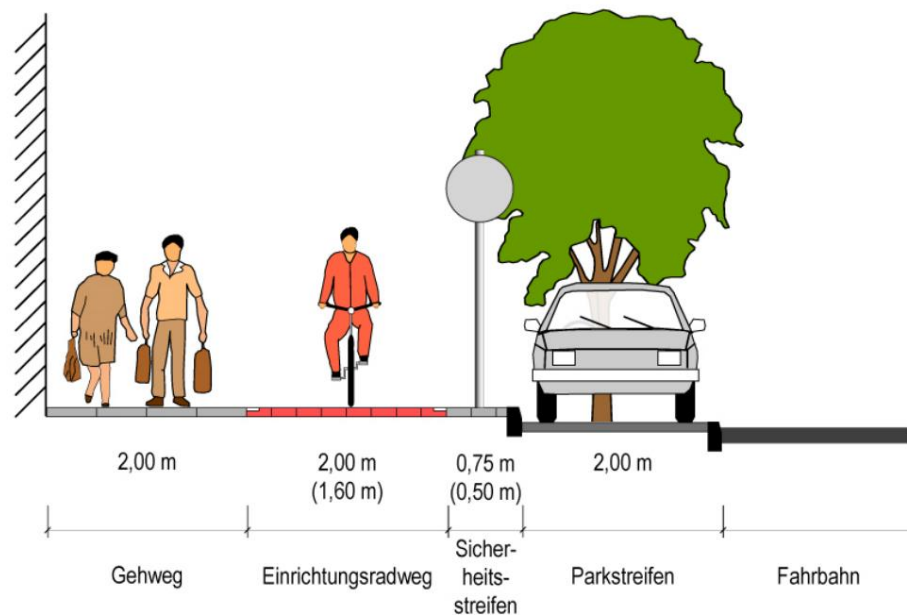


Figure 20: Width of cycle path (Source: ADFC)

3.3.2 Bicycle lane (Radfahrstreifen)

3.3.2.1 Definition

A bicycle lane is a separate part of the road reserved for cyclists.

Bicycle lanes are usually on the edge of the road. They must be indicated by the traffic sign 237 (possibly painted on the road surface). It is therefore always mandatory to use existing bicycle lanes. Other vehicles are not allowed to use it. Stopping and parking in bicycle lanes is also not allowed. You are allowed to cross them to reach a driveway or parking space, for example; in that case the bicycle lane is locally indicated with a broken stripe marking.



Bicycle lane with continuous line marking in Hamburg. At the intersection, the road becomes continuous line marker replaced by a broken dash marker. (Source: Photo by Florlan, distributed among a CC BY-SA 3.0 license)

3.3.2.2 Marking

The bicycle lane is separated from the other lanes by a white continuous line with a width of 0.25 metres. In addition, a white bicycle icon is also used on the road surface. At the beginning of the bicycle lane and after each junction of another street, the bicycle icon must be displayed on the ground. Afterwards, the pictogram is placed approximately every 60 meters.

At bus stops, ramps and intersections, this continuous white line is replaced by a broken line, so that other vehicles can also cross the bicycle lane here. The broken line also has a width of 0.25 meters, a length of 0.50 meters and a space of 0.20 meters.

3.3.2.3 Width

A bicycle lane has a minimum width of 1.85 metres, including the continuous white line. In addition, a scare strip of 0.50 to 0.75 meters must be constructed between the bicycle lane and cars parked alongside. If the bicycle lane runs alongside cars parked at right angles, the shock strip must be 0.75 meters wide. In specific circumstances, bicycle lanes can also be wider. This may be the case, for example, with high traffic intensities and heavy traffic or near schools and cycling destinations.

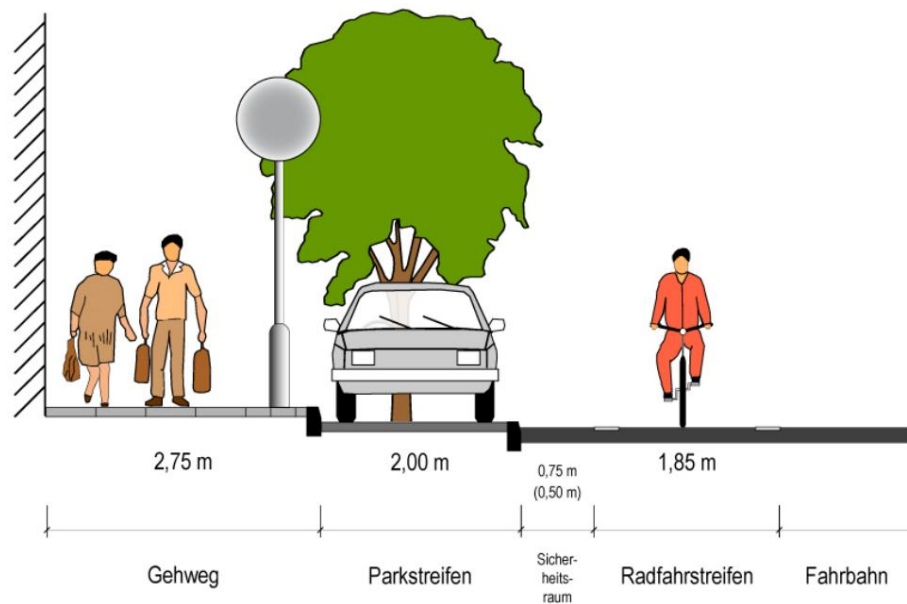


Figure 21: Width of bicycle lane (Source: ADFC)

3.3.3 Protective strip (Schutzstreifen)

3.3.3.1 Definition

A protective strip is a strip on the edge of the roadway marked with a broken white line and the image of a bicycle. Cyclists are not required to use this lane. In exceptional cases, vehicles may drive over the protective strip, if this does not endanger bicycle traffic. Two-way traffic for cars must be able to take place without the protective strip having to be used for this. Cars are not allowed to stop or park on protective strips.

According to the Allgemeine Verwaltungsvorschrift zur Strassenverkehrs-Ordnung (VwV StVO), protective strips may only be used in built-up areas, in streets with a maximum speed of 50 km/h.



Protective strip demarcated with a broken marking in Metzingen (Source: Photo by Ulamm, distributed under a CC BY-SA 3.0 license)

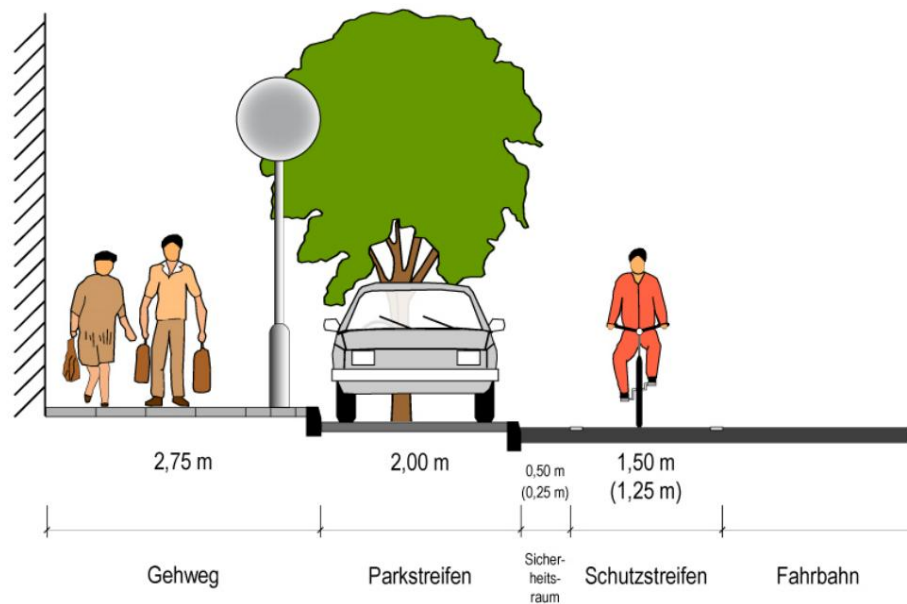
3.3.3.2 Marking

The broken line has a width of 0.12 meters, a length of 1.00 meters and a space of 1.00 meters. To make it clear that this part of the roadway is reserved for cyclists, the image of a bicycle is placed on the road surface at regular intervals.

3.3.3.3 Width

Protective strips are at least 1.25 meters wide. The standard width is 1.50 metres, including the width of the protective strip marking. In addition, a scare strip of 0.25 to 0.50 meters will be constructed for cars parked alongside. For cars parked at right angles, the safety strip must be 0.75 meters wide.

In case of a speed limit of 30 km/h and an intensity of less than 800 motor vehicles at a peak hour, the roadway for motor vehicles has a minimum width of 4.50 meters (minimum space between the 2 protective strips).



Protective strip width (Source: ADFC)

3.3.4 Passing distance

In Germany, drivers of motorized vehicles must maintain a lateral distance of at least 1.5 meters between their vehicle and the cyclist. Outside built-up areas, the minimum lateral distance is 2.00 metres. Anyone who overtakes children must also keep a minimum distance of 2.00 metres.

3.3.5 Sources •

- www.stvo.de/strassenverkehrsordnung/90-2-strassenbenutzung-durch-carriage •
- www.bussgeldkatalog.org/radweg •
- www.aktivmobil.com
- bw.de/fileadmin/user_upload/fahrradlandbw/Downloads/Musterloesungen_RadNETZ.pdf
- www.verkehrswende-darmstadt.de/infothek/breite-von-radwegen/ •
- www.bussgeldkatalog.org/radfahrstreifen/ • www.adfc-nrw.de/kreisverbaende/kv-wesel/adfc-vor-ort/dinslaken-Voerde/gut-zu-wissen/angebotsstreifen.html • https://de.m.wikipedia.org/wiki/Datei:Zweispuriger_Radweg_f%C3%BCr_beide_Richtungen_Treskowallee_Berlin.jpg www.politik.starnberg.thosch.com/Leitfaden-Rad-Ausgabe-2016-Stadt-Muenchen
- www.erfurt.de/ef/de/leben/planen/verkehr/vep/120687.html •
- www.stvo2go.de/schutzstreifen-voraussetzungen/

3.4 Synthesis of bicycle path marking/suggestion lane

The markings for cycle paths and cycle lanes in Flanders, the Netherlands and Germany show strong similarities. Yet there are specific nuances that mean that the markings are not always comparable one-to-one.

Figure 22 and Figure 23 try to give an overview of the different types of marking per country in combination with a 'hierarchy' (most 'mandatory' at the top, most 'compulsory' at the bottom).

In Belgium you can indicate a cycle path with a traffic sign or by means of a double broken line marking. In the Netherlands and Germany it is not possible to designate a bicycle path without an accompanying traffic sign. In the Netherlands and Germany, the concept of 'bicycle lane'/'Radfahrstreifen' does exist, which in itself is comparable to our adjacent unelevated cycle paths. Motorized traffic may not drive or park on a bicycle lane with a continuous line or Radfahrstreifen. The requirements for a bicycle lane or Radfahrstreifen are stricter than those for our adjacent cycle paths (for example, minimum width).

In terms of design and visual impact, our bicycle lanes (yellow ochre strip with a minimum width of 1.70 metres) are at first sight comparable to, for example, the bicycle lane with broken stripe markings in the Netherlands (with a red coloring and a minimum width of the bicycle lane of 1.70 metres).), but they have a different legal meaning. The bicycle lane in Belgium is only a visual element, it has no legal significance. Cars are allowed to drive over and park on it. The visually somewhat similar bicycle lane with broken stripe marking in the Netherlands does have a legal meaning. Parking is prohibited and cars may only drive over it if they do not hinder cyclists. The dimensions of the roadway for motorized traffic centrally between the two bicycle lanes are also generally wider, so that cars are less forced to speed over the bicycle lane. The design guidelines for bicycle lanes in Flanders call for a narrow central driving lane, as a result of which cars are virtually obliged to drive on the bicycle lane in the event of intersecting traffic. The legally comparable bicycle lanes in the Netherlands are much less conspicuously marked compared to the Flemish bicycle lanes.

Do both bike lane marker types have a similar effect?

While in the Netherlands the focus is mainly on spacious, well-defined bicycle facilities of good quality, in Belgium and Germany additional legal protection is offered to cyclists by imposing a minimum passing distance between a cyclist and an overtaking/passing car. The question then is whether this has the same effect in terms of perception and accentuation of the cyclists, the actual intermediate distance between the cyclist and motorized traffic and therefore ultimately the comfort and road safety of the cyclist.

Bicycle path and bicycle lane				
		Belgium/Flanders	The Netherlands	Germany
	day	Traffic sign D7 or D9	Traffic sign G11 or G12a	Radweg: traffic sign 237, 240 or 241
				
	evening	Traffic sign D7 or D9	Traffic sign G11 or G12a	Radweg: traffic sign 237, 240 or 241
				
		Double broken stripe marking		
				
			Continuous stripe with bike logos	Radfahrstreifen: Traffic sign 237 and continuous stripe and bicycle logos
				
			Broken stripe with bicycle logos Schutzstreifen: Broken stripe with bicycle logos	







			
	Ocher stripe	Interrupted line	
			
	Different materialization		
			
	Bicycle logos		
			

Figure 22: Overview of bike path/suggestion lane markings (Sources: Stefan Dewickere, Cyclomedia and Ulamm, W.-D. Haberland, distributed under a CC BY-SA 3.0 license)













Bicycle path and bicycle lane: consequences						
Belgium/Flanders		The Netherlands		Germany		
	Traffic sign D7 or D9		Traffic sign G11 or G12a		Traffic sign 237, 240 or 241	
	<ul style="list-style-type: none">Not passable for car trafficIt is forbidden to park on it		<ul style="list-style-type: none">Not passable for car trafficForbidden to park on it		<ul style="list-style-type: none">Not passable for car trafficIt is forbidden to park on it	
	Double broken stripe marking		Continuous stripe with bike logos		Road sign 237 and continuous stripe and bicycle logos	
	<ul style="list-style-type: none">Only one-way cycle pathsNo wider than car trafficNot passable for car trafficForbidden to park		<ul style="list-style-type: none">Not passable for car trafficIt is forbidden to park on it		<ul style="list-style-type: none">Not passable for car trafficIt is forbidden to park on it	
			Broken stripe with bike logos			Broken stripe with bicycle logo
			<ul style="list-style-type: none">Can be driven over by car traffic, but must not hinder cyclistsForbidden to park on it			<ul style="list-style-type: none">Car lane ≥ 4.5 mPassable for car trafficIt is forbidden to park on it
	Ober colored strip Different materialization Bicycle logos		Interrupted line			
	<ul style="list-style-type: none">Can be driven over by car trafficParking allowed		<ul style="list-style-type: none">Can be driven over by car trafficParking allowed			
	Passing distance car - cyclist				Passing distance car - cyclist	
	<ul style="list-style-type: none">At least 1m within built-up areasAt least 1.5m outside built-up areas				<ul style="list-style-type: none">At least 1m within built-up areasAt least 2m outside built-up areas (or when overtaking children)	

Figure 23: Overview of bike path/suggestion lane markings: consequences

4 Research design

4.1 Previous research

4.1.1 Wallonia

In Wallonia there are many rural roads outside built-up areas, with rather low traffic volumes but high driving speeds (speed regime 90 km/h). The high driving speed makes these roads unattractive to cyclists. Many Walloon municipalities are therefore looking for a solution to share space in a safe way. A road with edge strips (a road composed of a central carriageway for motorized traffic with edge strips on both sides intended for the soft modes or with center lane markings) was a solution according to several Walloon municipalities. At the request of the Walloon Region, the BRSI therefore conducted a study in 2012 into the effect of the central lane marking (MRM) or CVCB (Chaussée à voie central banalisée).

This evaluation was done on five roads with edge strips. Tests were carried out to determine whether the new situation leads to a decrease in the speed driven and whether there is a more respectful attitude of the vehicle drivers towards soft road users.

The analysis of the measurements shows that there was rather a slight increase in the observed speed, although the difference was not significant. The average intermediate distance when overtaking a cyclist decreased: the number of overtaking maneuvers in which a distance of more than 2.75 meters was maintained fell sharply, but a minimum intermediate distance of 1.50 meters was guaranteed. The minimum passing distance had increased. The category of overtaking by less than 1.50 meters has disappeared.

Source: 'La Chaussée à voie central banalisée' : une réponse intéressante à la sécurité des modes doux ?, Houdmont A., Chalanton I., Janssens I., Institut Belge pour la sécurité routière.

4.1.2 The Netherlands

SWOV has carried out two observational studies on road sections with and without edge strips. In the first study (Van der Kooi & Heidstra, 1999) roads with and without edge strips were compared. It turned out that cars on roads with edge strips drove slightly slower on average than on roads without edge strips. At the same time, however, it turned out that the space between cyclists and passing cars was slightly smaller on roads with lanes than on roads without them.

The second study (Van der Kooi & Dijkstra, 2003) was a before and after study into the effect of edging. Before and after the construction of the side strips, the driving speed of cars and their position on the road (perpendicular to the direction of travel) were examined. It appears that a driving lane with side strips has a 'channelling' effect and that both cyclists and motorists seem to accept this. The cyclists use their 'own' lane and usually ride further away from the edge of the road than before there was a lane. Free-driving motorists also generally drive a little further from the edge of the road on a road with side strips. When passing a cyclist, they often choose not to drive on the opposite side lane. At the same time, this means that when overtaking a cyclist on a side lane, motorists usually take less distance from the cyclist. The average driving speed in most cases decreases slightly as a result of the edge strips (a few kilometers per hour).

Apart from the specific case of edge strips on 60 km/h roads, much research has been conducted in the world into the effect of lines and markings on driving behavior of motorized traffic. Based on a meta-analysis of this type of study (Davidse et al., 2004), it can be concluded, among other things, that edge markings have a positive effect on the lateral position of cars on the road, and that they reduce the chance of driving off the road and cause roadside damage. An undesirable effect is that due to the good visual guidance of lines, drivers are inclined to drive faster.

Broken lines provide (slightly) less visual guidance than solid lines, and also give a better impression of the speed driven. If the aim is speed reduction, such as on access roads, broken lines are preferred.

Source: SWOV Fact sheet 'Edge strips on access roads outside built-up areas'

4.1.3 France

The French road authority CEREMA has carried out six evaluations of experimental center lane markings (MRM). In general, the effect of the French MRM or la chaussée à voie central banalisée (CVCB) on vehicle speeds is small to nil or insignificant or due to other measures being implemented at the same time. The cyclists' subjective feeling of safety increased due to the construction of the MRM. Systematic quantitative behavioral/conflict observation during the evaluations was limited and no quantitative analyzes of overtaking behavior such as lateral distance or type of overtaking maneuver exist. Moreover, it turned out that the few positive effects (on perceived safety, on vehicle positioning, on speed) diminished over time. The width of the 'cyclists' section' also turned out to be important. If it is too narrow, the distance between cars and cyclists may decrease instead of increase.

4.2 The research question

Many municipalities are looking for a solution to indicate the position of bicycles more emphatically, specifically on roads with mixed traffic outside built-up areas. Installing bicycle lanes everywhere with an ochre-yellow slurry layer is a major financial effort or not desirable due to the spatial context. A possible alternative that is already being used in various places in Flanders with a variety of designs is the central lane marking (MRM). A strip is marked on both sides of the road that is approximately as wide as a bicycle lane and leaves room for cyclists. Motorists are allowed to drive on the marked strip, just like with the bicycle suggestion lane. **The question is whether such an MRM gives cyclists more space and leads to safer behavior on the part of all road users.**

To investigate this question, the MRM was compared with a situation without marking and also with a marking through an ochre yellow sludge layer. This was done using video observations. To decide whether these two types of markers led to safer behavior, a comparative study was needed. A pre- and post-measurement was performed in each case, whereby a baseline situation was first observed (without marking), and then the MRM was applied, followed by a new video observation. Subsequently, an ochre yellow slurry layer was applied to replace the MRM, followed by a third video observation. By observing all three situations (no marking, MRM and slurry layer) at the same location, a causal relationship between marking and behavior can be demonstrated. For a better generalization of the results, this procedure was performed at two locations (Bornem and Hasselt).



Middle lane marking (MRM) Barelstraat Bornem

4.3 Selection type of marking

Various marking options were investigated for the designation of the center lane marking. It was important here that the MRM (which may be run over) is clearly distinguished from the cycle path markings (which may not be run over) to avoid confusion and possible erosion of respect for cycle paths. The visualizations below give an idea of the different marking options for cycling in mixed traffic, starting from the field of view of a motorist.

Reference: Cycle path marking in Belgium

This mark is not an option for the MRM designation, but is used as a comparison reference.

Marking: length 125 cm, spacing 125 cm, width 15 cm



Figure 24: Visualization of the MRM by means of the Belgian cycle path marking

Option 1: Dutch bicycle lane marking with a broken line

From a motorist's point of view, the difference with the cycle path marking is small. Bicycle logos can be added to make it clear to the cyclist what his position is on the roadway.

Marking: length 100 cm, spacing 100 cm, width 10 cm



Figure 25: Visualization of the MRM by means of the broken line marking at a bicycle lane

The Netherlands

Option 2: Marking proposal from Wallonia research (IBSR 2012)

From a motorist's point of view, the difference with the cycle path marking is small. Bicycle logos can be added to make it clear to the cyclist what his position is on the roadway.

Marking: length 100 cm, spacing 200 cm, width 10 cm

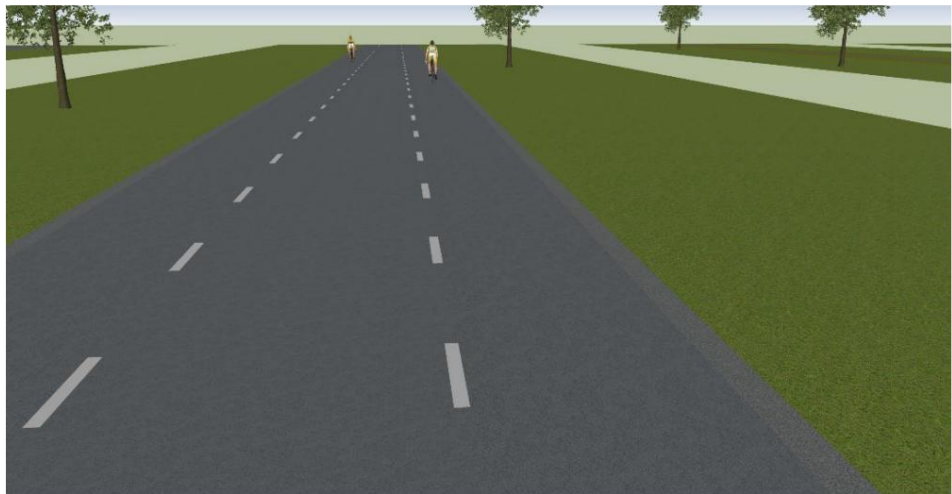


Figure 26: Visualization of the MRM through the marker line used in the study

Wallonia

Option 3: Bicycle logo connection mark (without arrows)

From the point of view of a motorist, there is a clear difference with the Belgian cycle path markings. But since this marking is very different from the bicycle path marking, there is a chance that cyclists do not understand that they can cycle within this zone.

Applying bicycle logos (at the start of the marking and each time after an intersection) is therefore

designated. This marking is already used in Flanders at intersections to indicate the bicycle crossing transverse to the right of way.

Marking: length 15 cm, intermediate distance alternately 15 cm and 30 cm, width 15 cm



Figure 27: Visualization of the MRM through the bike logo connection marker (without arrows or logos).

Since the bicycle logo connection marking clearly deviates from the Belgian cycle path marking and is not a new marking either, it was selected for the designation of the MRM.

This marking consists of two parallel white interrupted stripes consisting of square lines with a side of 15 by 15 cm, spaced alternately at 15 and 30 cm intervals. They demarcate the imaginary edges of the central lane.

A bicycle symbol may be placed on the lateral strips on the outside of those markings.

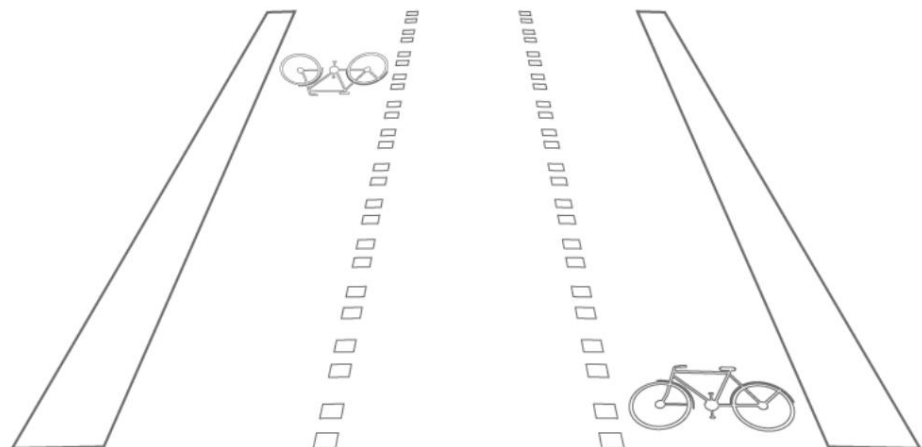


Figure 28: Preferred marker type for MRM: bicycle logo connection marker with bicycle logo at the start of the marking and each time after an intersection.

5 Method

5.1 Research design

In order to investigate the impact of a marking on driving behaviour, a before and after measurement is necessary. The research design or test set-up for cycling in mixed traffic consists of three measurements or observations:

- Baseline measurement: no marking
- Post-measurement 1: central lane marking (MRM) with the bicycle logo connection marking
- Post-measurement 2: bicycle lanes with other yellow slurry layer

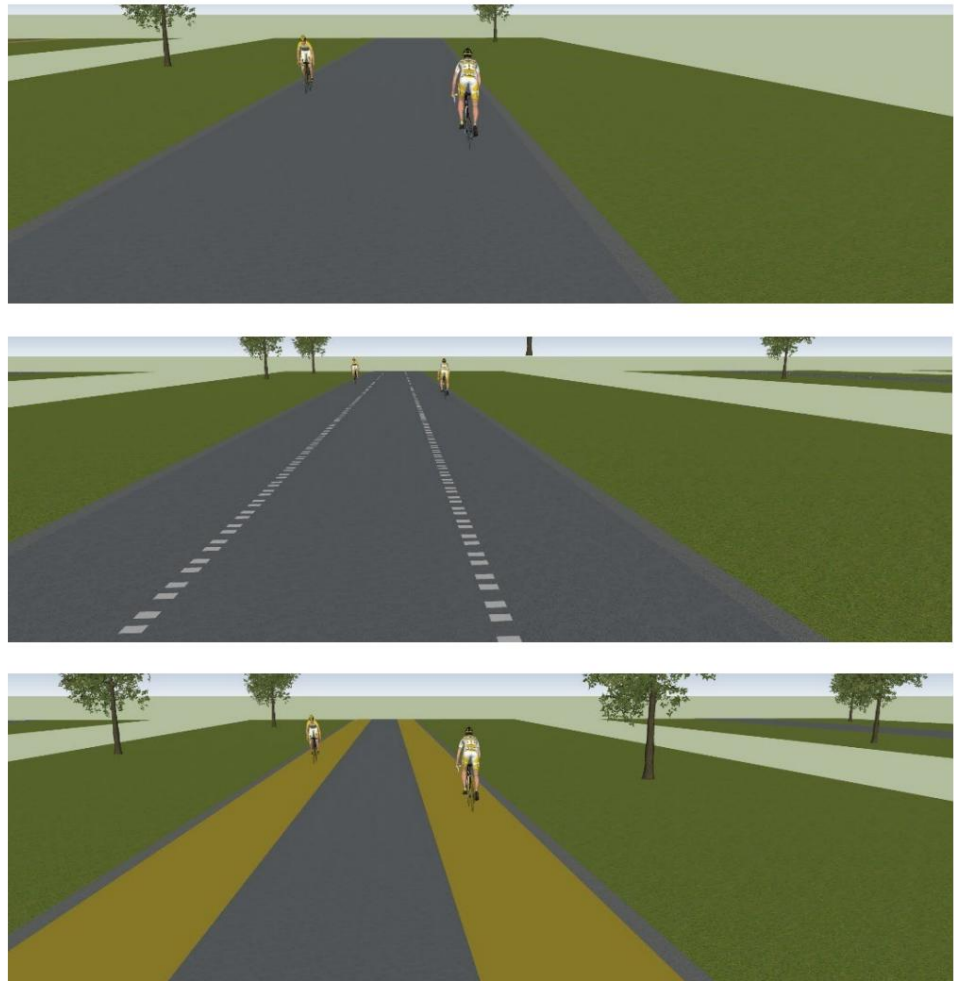


Figure 29: Research design or test setup with three measurement moments

For a reliable result, it is necessary to analyze 200 interactions between cyclists and motorized vehicles per observation. This way you get a correct picture of the driving behaviour. The measurement period will therefore always depend on the observed interactions. By default, we started from a measurement period of one week per observation.

5.2 What do we measure?

Five indicators are examined in the video observations: do motorists stay behind a cyclist or overtake them; what is the lateral distance between car and cyclist; how far does the cyclist ride from the roadside; what is the distance from the car to the edge of the road; how fast do the cars go?

Position of the cyclist on the road
Distance from right side
Depending on the type of interaction <ul style="list-style-type: none"> - Overtaking motorist - Crossing motorist - Not a driver
Depending on the number of cyclists <ul style="list-style-type: none"> - One cyclist versus 2 or more cyclists
type of interaction
Motorist overtakes cyclist
Motorist lags behind cyclist
Lateral distance between cyclist and motorist
When overtaking
When crossing
Position motorist
Distance from right side
Depending on the type of interaction <ul style="list-style-type: none"> - To catch up - crosses - Not a cyclist
Depending on the number of cyclists <ul style="list-style-type: none"> - One cyclist versus 2 or more cyclists
Speed
Motorist

Figure 30: Measured variables

5.3 Choice of locations

We were looking for two test locations for this study, because then we can compare the data from both locations in order to arrive at more general research results. At the beginning of March 2021, we launched a call to Flemish cities and municipalities to participate in this research. We looked for two locations for which the city/municipality was willing to apply the two markings (MRM and other yellow slurry layer) successively at its own expense on the entire road segment between two intersections. The following criteria applied to the test set-up:

- Local road outside built-up areas without markings • Roads with mixed traffic where it is actually not desirable to build cycle paths (because of the categorization of the road, spatial context, intensities...)
- Roadway width between 5.40 and 6.60 meters (cf. Guidelines Vademecum Bicycle Facilities for the construction of bicycle lanes)
- Maximum speed 50 km/h • Intensities of motor vehicles and cyclists as high as possible, as we aim for at least 200 interactions per test setup • Marking is applied to the entire segment between two intersections • The intersections must be several hundred meters apart.

27 cities and municipalities responded positively, but only four locations met all the criteria. The locations are shown in Table 1. Ultimately, **Bornem and Hasselt** were selected. The commitment and cooperation of both municipalities was crucial to the success of this study.

The commitment and cooperation of Bornem and Hasselt was crucial for the success of this research.

Table 1: Possible pilot locations for research into bicycle markings for mixed traffic

TEST SETUP 1 MIXED TRAFFIC	Bornem	Hasselt	Eeklo	Keerbergen
Street	Barel Street	Kannaert Street	Waaistraat	Vlieghavenlaan
Road segment	Barel Street x Bareldreef to Barel Street x Oppuursesteenweg	Between N739- Stevoortse Kiezel and dead end side street (also called Kannaertsstraat)	between Pepper Street - Sint Vincentiusstraat	between intersections with Kanarieweg and Mereldreef
Length (m)	1000	350	430	460
Width (m)	6	6.3	6.5	5.6
Bibeko/bubeko	bubeko	bubeko	bubeko	bubeko
Speed (km/h)	50	50	70	50
Intensity car	1500 vehicles / day (estimate) 100 cyclists /	100 to 130 per peak hour	rush hour 100 (estimate)	1000 vehicles / day
Intensity bike	day (estimate)	10 per rush hour	rush hour 50 (estimate)	350 cyclists / day
Own resources agreement	Yes	Yes	Yes	
Points of attention	Intensities - rough estimate based on past measurements from surrounding streets	na	Connecting road Students of Kaprijke bicycles via Waaistraat to Eeklo Ash marking can be removed by the municipality	yes axle markings and green balls on the road surface (school environment), must be removed (the municipality indicates that it wants to do so)

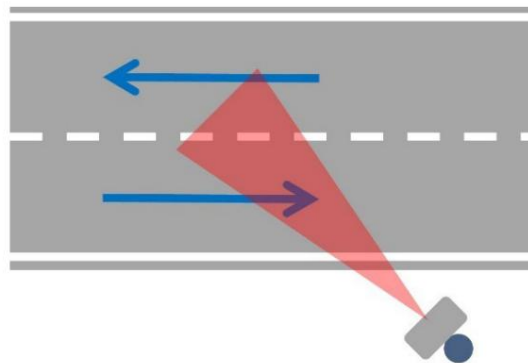
5.4 Set up measurements

5.4.1 Speed Measurements

The speed of the vehicles is measured using a roadside radar of the DataCollect SDR3 type . The speed of passing vehicles is determined by the Doppler effect. The recorded data are: date and time, direction of travel, speed and length of the vehicle.



Used radar for speed measurements



Schematic method radar for speed measurement

The radar installation is suspended from a pole. A rubber insert is fitted to prevent damage to the post. The device has a built-in battery and works autonomously.

3 <https://www.datacollect.com/sdr.html>

5.4.2 Video observation: equipment

The video images are made using a MioVision Scout4 recording system.

This is an integrated system, with a camera on an extendable mast with a length of 6.00 metres. In addition, the system includes a control module, storage capacity and battery. It is attached with tension straps to existing infrastructure such as a lighting mast or the pole of a traffic sign. The support points with which the system is attached to the existing lighting mast are covered with rubber. This way the paint of the mast will not be damaged. Due to the built-in battery, no electrical connection is required. The systems are compact and discreet, minimizing disruption to road users.

The mounting height of 6.00 meters gives us a good overview of the road. The resolution of the camera is sufficient to observe and study the relevant behaviour, but does not allow the recognition of persons or number plates. The privacy of road users is thus protected.



Miovision scout

5.4.3 Processing of the video images

The collected video images were coded in order to deliberately extract the necessary information. A distinction was made between coding interactions between cyclists and motorized traffic on the one hand, and coding freely moving motorized vehicles and cyclists that do not interact with each other (ie free-flow) on the other hand. To be able to do this as consistently as possible, a codebook was used with predefined variables that are important for the research. The following variables were included in the codebook:

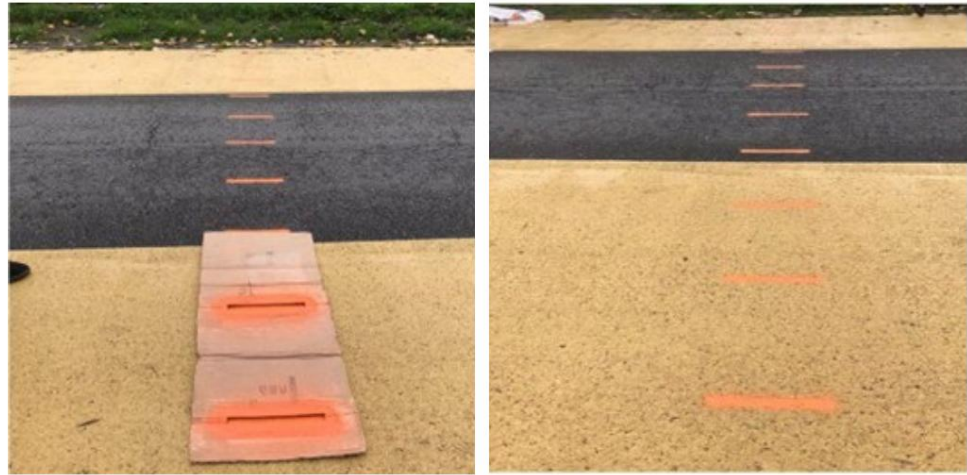
4 <https://miovision.com/scout>

Table 2: Variables from the codebook for processing the video images

Lighting conditions	ỹ Daylight ỹ Dusk ỹ Dark
Weather Conditions ỹ Dry	ỹ Rain ỹ Wet road
Cyclist type	surface ỹ 1 cyclist: o Young o Middle age o Old o Trained o With children ỹ Group: o Parents with children o Young o Middle age o Old o Trained o Mixed
Direction of the cyclist	ỹ Towards the camera ỹ Away from the camera
type of interaction	ỹ Vehicle overtakes cyclist ỹ Vehicle follows cyclist ỹ Vehicle travels in the opposite direction ỹ Other
Position of the cyclist on the roadway	ỹ See zones
Position of the vehicle on the roadway	ỹ See zones
Path of the cyclists	ỹ Unchanged ỹ To the edge of the roadway ỹ To the center of the ride away ỹ Other
Vehicle type	ỹ Moped ỹ Motorcycle ỹ Passenger car ỹ Large vehicle (Truck, agricultural vehicle, etc.)
Path of the vehicle	ỹ Unchanged ỹ To the edge of the roadway ỹ To the center of the ride away ỹ Other
Type of crossing road user (if another road user passes in the opposite direction, while already there an interaction with one vehicle takes place)	ỹ None ỹ Pedestrian ỹ Cyclist ỹ Moped rider ỹ Motorcyclist ỹ Driver car ỹ Large vehicle driver

The zones listed in the codebook were determined using 50 cm intervals marked on the roadway with chalk paint. It fades with rain or road use and does not affect the results. For example, in Hasselt 12 and in Bornem 13

demarcated zones that were traced onto the images for the analyses. In this way, the zones could also be determined after the chalk paint had disappeared and it was possible to work with continuous lines. The application of the zones on the roadway with chalk paint and the designation on the analysis images are shown in the figures below.



Application of zones (50 cm) on the road surface with chalk paint



Indication of zones (50 cm) on the road surface on the analysis images, example in Hasselt.

Coding was done by different people (coders). They had to personally view the images and then complete the codebook. To keep differences between the coders as small as possible, the predefined codebook was adhered to and the instructions and explanations were always given by the same person. In this way, an intercoder bias was avoided as much as possible. The coder also became Research Report Markings of cycling infrastructure in mixed traffic

trained on test data before starting to process the images on site to grasp the principles and reduce the chance of miscoding.

5.4.4 Measurement set-up per

5.4.4.1 location Barelstraat, Bornem

In Bornem, measurements were taken in the baseline measurement period (without marking) with four cameras (blue indication on the aerial photograph) and two radars (orange indication on the aerial photograph). There were two cameras in the north and two in the south, with one camera facing north and another facing south at each site. A radar was hung in both the north and south. Given the small marginal increase in interactions, it was decided to perform the subsequent measurements with only two cameras and two radars: one in the north facing south and one in the south facing north).



Figure 31: Bornem: measurement setup baseline with 4 cameras and 2 radars



Figure 32 Bornem: measurement setup after measurement 1 and 2 with 2 cameras and 2 radars

5.4.4.2 Kannaertsstraat, Hasselt

Two cameras and two radars were set up in Hasselt, directed to the north and south, but closer together than in Bornem. Here, too, the radars were mounted at the level of the cameras.



Figure 33 Hasselt – Kannaertsstraat: measurement setup

5.4.5 Measurement moments

Two considerations were decisive when choosing the measurement moments: the municipality had to have the opportunity to apply the markings (MRM and other sludge layer) between the observations, and the cycling frequency had to be high enough to observe a sufficiently large number of interactions. In order to obtain a correct picture of driving behaviour, it is necessary to analyze 200 interactions between cyclists and motorized vehicles per observation. The measurement period therefore depends on the observed interactions. By default, we started from a measurement period of one week per observation.

5.4.5.1 Bornem In

Bornem, the baseline measurement without markings took place in June 2021. There were some practical problems with applying the MRM, so the second measurement only took place at the end of September 2021. We will return to this in the discussion (see 7.2.5 .)

The ochre yellow sludge layer was applied in October 2021, so that the third measurement ran from the end of October to the beginning of November 2021.

Measurement period Bornem

- Baseline measurement: no marking from 18/6/2021 to 25/6/2021 • Post-measurement 1: central lane marking (MRM) by means of the bicycle logo connection marking from 16/9/2021 to 23/9/2021
- Post-measurement 2: bicycle lanes using ochre yellow slurry layer from 20/10/2021 to 2/11/2021

5.4.5.2 Hasselt

In Hasselt, a first baseline measurement took place at the beginning of July 2021. Since the Kannaertsstraat in Hasselt is mainly cycled by school students, there were too few interactions between cyclists and motorists to be observed at that time. The pre-measurement was therefore repeated at the beginning of September 2021. The MRM could be laid in October and the first post-measurement took place in November 2021. Since we had to repeat the baseline and the timing was postponed, only the MRM was tested in Hasselt, not the ochre yellow slurry layer. There was not enough time to apply the slurry layer and to measure its effects afterwards.

Measurement period Hasselt

- Baseline measurement: no marking from 1/7/2021 to 9/7/2021 • Baseline measurement bis: no marking from 30/8/2021 to 7/9/2021 • Post-measurement 1: central lane marking (MRM) by means of the bicycle logo connection marking from 8/11/2021 to 24/11/2021 • Post-measurement 2: not performed

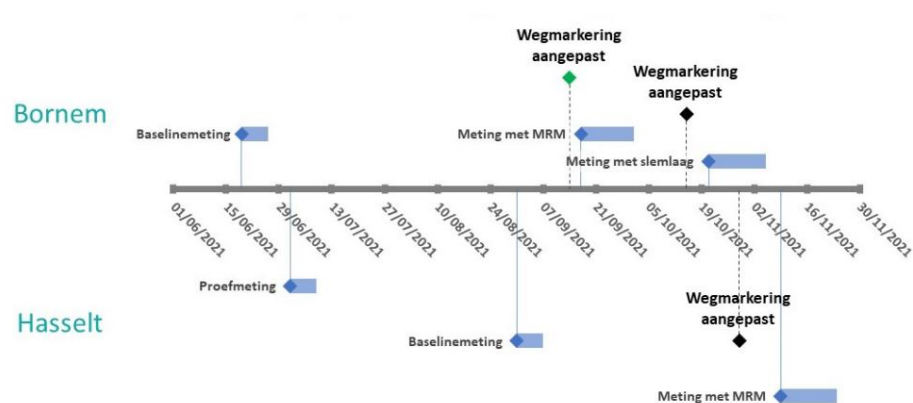


Figure 34 Timeline measurements in Bornem and Hasselt

In Bornem, measurements were therefore made with the MRM and with an ochre yellow sludge layer. The dimensions of the markings are shown in Figure 35. For the dimensions we use the guidelines from the Vademecum Bicycle Facilities for the construction of bicycle lanes⁵.



Figure 35 Bornem markings and dimensions

In Hasselt, the MRM was compared with the baseline situation without marking. The measurement with slurry layer had to be cancelled. The markings and dimensions are shown in Figure 36.



Figure 36 Hasselt markings and dimensions

5 The width of the bicycle lane is a minimum of 1.70 m and a maximum of 2 m. No bicycle lanes are used on roads with a pavement width of less than 5.40 m or greater than 6.60 m.

6 Results

As in 5.2 'What do we measure?' discussed, we examined five indicators in the video observations:

- type of interaction: overtaking or not overtaking
- lateral distances • distance cyclist from the edge of the roadway • distance vehicle from the edge of the roadway • speed motorists

Position of the cyclist on the road
Distance from right side
Depending on the type of interaction <ul style="list-style-type: none"> - Overtaking motorist - Crossing motorist - Not a driver
Depending on the number of cyclists <ul style="list-style-type: none"> - One cyclist versus 2 or more cyclists
type of interaction
Motorist overtakes cyclist
Motorist lags behind cyclist
Lateral distance between cyclist and motorist
When overtaking
When crossing
Position motorist
Distance from right side
Depending on the type of interaction <ul style="list-style-type: none"> - To catch up - crosses - Not a cyclist
Depending on the number of cyclists <ul style="list-style-type: none"> - One cyclist versus 2 or more cyclists
Speed
Motorist

Figure 37 Measured variables

In addition, we examined a number of situational characteristics or variables that influence the way interactions proceed. These variables are:

- is there an oncoming traffic;
- one cyclist or a group of cyclists;
- presence of parked vehicles;
- what type of vehicle interacts with the cyclist;
- and a characterization of the cyclists.

In all analyzes reported here, these variables were used as control variables. An example: If there was an oncoming vehicle, the distances between cyclist and overtaking vehicle were smaller. In the first measurement in Bornem, oncoming traffic was more frequent than in the post-measurement with MRM. Based purely on that, you would therefore expect the distances in the later measurements to be greater. The analysis method used (ANCOVA - Analysis of Covariance) calculates the difference that would arise if there had been an equal number of oncoming traffic in both measurements. The same goes for the other variables mentioned above. Usually these 'corrected' comparisons are not so different from the uncorrected ones. However, if there was a difference, then the corrected results are more correct than the uncorrected ones. That is why the results from the analysis are always reported with correction. A descriptive analysis of the situational characteristics can be found in appendix 1.



Center lane marking Kannaertsstraat Hasselt

6.1 Type of interaction: to overtake or not to overtake

We distinguish three types of interactions between cyclists⁶ and motorized vehicles:

- car driver crosses in the opposite direction of cyclist;
- motorist overtakes cyclist;
- motorist stays behind cyclist.

The last two interactions always involve motorists and cyclists traveling in the same direction. The hypothesis was that a marking could make motorists more likely to stay behind the cyclist.

6.1.1 Statistics used For each

location (Bornem and Hasselt), the percentage of motorists who stayed behind the cyclist and the percentage of motorists who overtook was calculated for the various measurements (baseline, MRM, slam layer). The differences were tested using a chi-square test⁷.

6.1.2 Result

As can be seen in Figure 38, the majority of motorists overtake cyclists – this applies to both locations and both with and without marking. For **Bornem** it can be noted that the proportion of motorists who stay behind the cyclist almost doubles at the first post-measurement with MRM compared to the baseline condition (24% vs. 13%; $\chi^2=7.4$; $p<0.01$). In the second post-measurement with other yellow mud layer, the proportion that lags behind the cyclist was slightly higher (25% vs. 13%; $\chi^2=6.4$; $p<0.05$). The difference between MRM and other slam was not statistically significant (24% vs. 25%; $\chi^2=0.01$; $p=0.992$).

⁶ We treat classic bicycles, e-bikes and speed pedelecs together, because they could not be reliably distinguished on the video images.

⁷ The Chi-squared independence test is a statistical hypothesis test used to determine whether or not two categorical variables are related. In this case, we test whether the type of interaction differs systematically according to the road marking

In Hasselt, in the presence of an MRM, fewer vehicles remained behind the cyclist than in the baseline condition (24% vs. 8%; $\chi^2=17.2$, $p<0.001$).

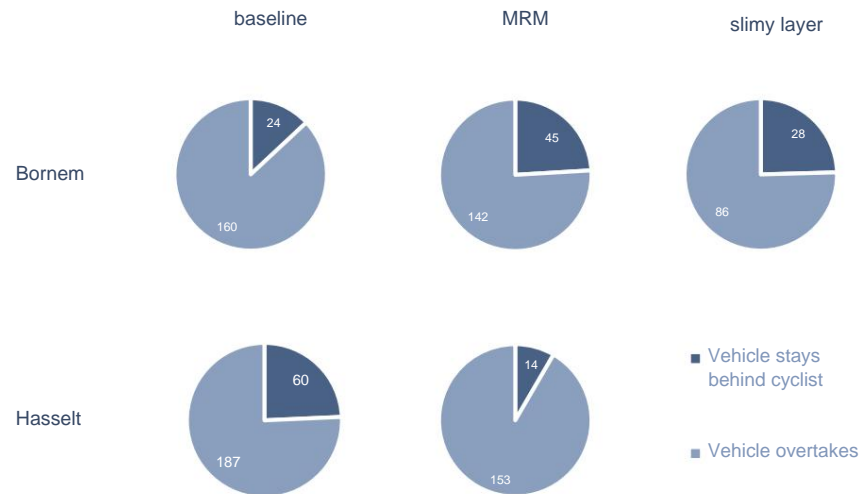
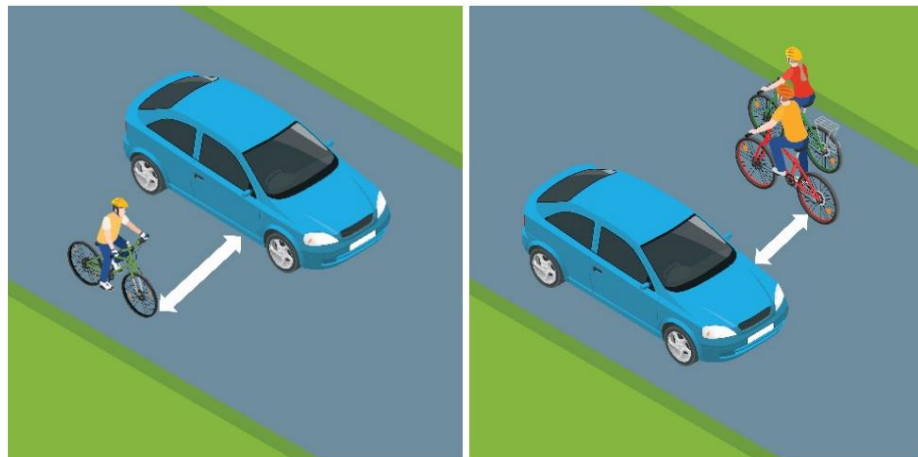


Figure 38 Interactions between cyclists and other vehicles traveling in the same direction as the cyclist.

6.2 Lateral distances

During the interactions we look at the distance between the overtaking motor vehicles and the cyclists. As we described in 5.4.3, for the interactions (which took place close enough to the camera), the position of the cyclist and that of the vehicle were determined in zones (distance between zones is 50 cm). If there were less than 3 zones (i.e. less than 150 cm) between the cyclist's wheel and the wheel of the overtaking or crossing vehicle facing the cyclist, this was considered 'overtaking with a short distance'.



Lateral distance when overtaking.

Lateral distance when crossing.

Figure 39 Examples for lateral distances

Figure 40 shows the lateral distance between cyclist and motorist during overtaking and crossing for both Bornem and Hasselt. The x-axis shows the distance in meters between the cyclist and the overtaking vehicle. The y-axis shows the percentage of interactions for each distance.

The interactions in the baseline measurement were shown with a dark blue line. The interactions in the MRM measurement were shown with a light blue line. The interactions in the measurement with slurry layer (only for Bornem) are in light grey. For each line, the percentages add up to 100%.

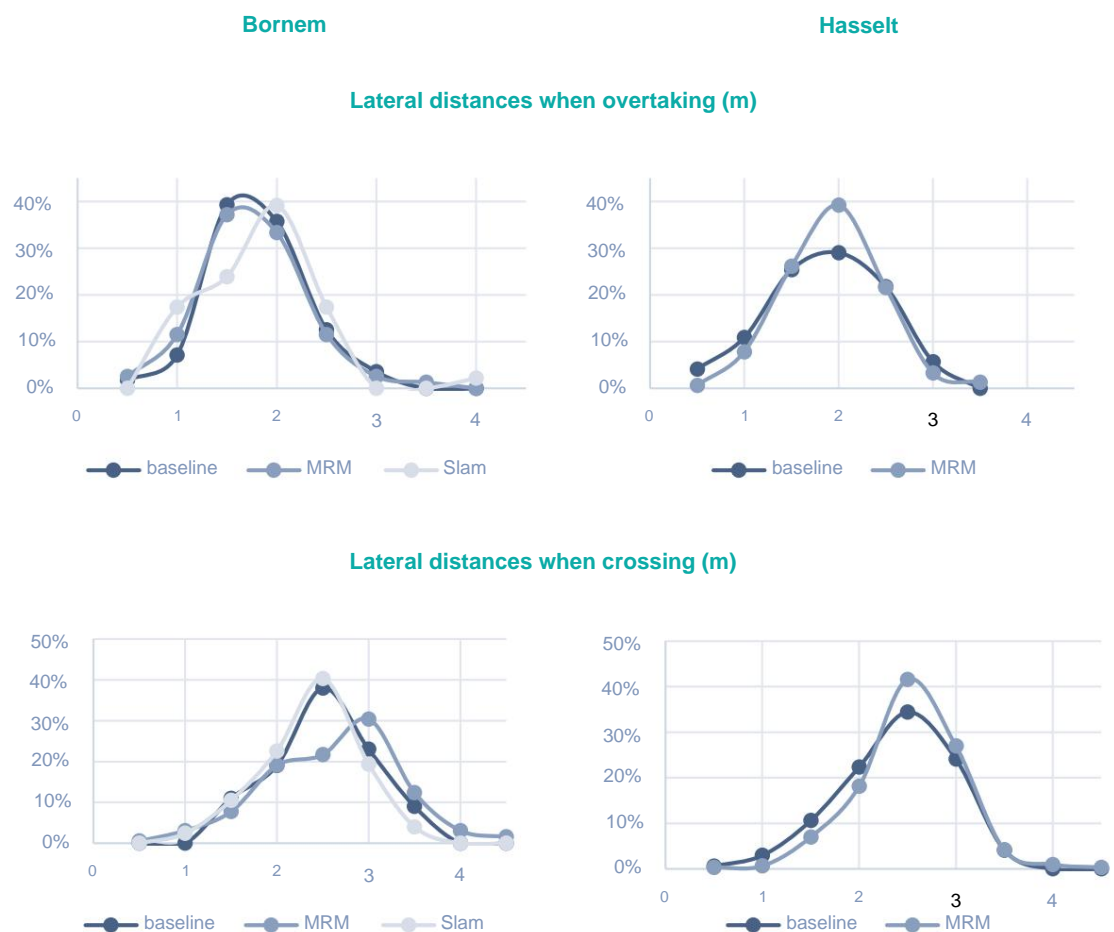


Figure 40 Lateral distances during overtaking and crossing.

In Hasselt we see that there were fewer small distances in the MRM measurement. This difference is small when overtaking and more pronounced when crossing.

In Bornem the result is less clear. At the short distances we see that the curves for MRM and slam layer are even slightly higher than those for the baseline measurement – both for overtaking and for crossing. That means more close-distance interactions occurred. On the other hand, the curve of the slam layer when overtaking and that of the MRM when crossing for the longer distances has shifted to the right. So the greater distances have become even greater in these conditions.

We tested two hypotheses:

1. The proportion of interactions with a short distance between cyclist and motorist decreases with a mark.
2. The average distance decreases with a marker.

The first hypothesis is the most important for road safety. Small distances are potentially dangerous. At greater distances, it is less relevant how large they are exactly.

Below we first explain how the average distance was calculated and analyzed – although it is therefore less important – because the analysis of the number of close-distance interactions is based on this calculation.

6.2.1 Average distance

The lateral distances were determined based on the zone in which the cyclist was located in relation to the zone in which the wheel of the vehicle facing the cyclist was located. As this pointed away from the camera in some cases, the position of the wheel pointing to the camera was encoded and then 5 zones (2.50 meters) for passenger cars were added, 1 zone (0.50 meters) for motorized two-wheelers, and 6 zones (3.00 meters) for vans. The distance is then the difference in zones $\times 0.5$.

The average distance in each measurement is shown in Table 3 (Bornem) and Table 4 (Hasselt). These distances were the dependent variable in an analysis of co-variance (ANCOVA) – an analysis of variance in which the difference between baseline, MRM, and slam layer was tested for significance. In addition, the situational characteristics or variables mentioned under 6 were included in the analysis to correct for any differences between the measurements. The results in the models with and without correction were very similar. The p-values⁸ reported here always originate from the analysis in which the situational characteristics were included as a co-variate.

6.2.2 Proportion of Close Distance Interactions

A dichotomous variable 'small distance' was coded with

- 0: distance 3 or more zones (= 1.50 m or more)
- 1: distance 1 or 2 zones (= 0.51 m to 1.49 m)

This was used as a dependent variable in a logistic regression analysis. In addition to the distinction between baseline, MRM and slam layer, the situational characteristics or variables mentioned under 6 were included in the regression model to correct for any differences between the measurements. The results between the models with correction and without

⁸ The analyzes result in whether p-value, the probability of the null hypothesis*. The null hypothesis is that there is no difference, the difference is due to a correction variable. A small p-value therefore indicates that there is probably a difference, a well large p-value indicates that the null hypothesis is maintained. We normally assume a significant difference if the probability of the null hypothesis is less than 5% ($p < 0.05$). If the probability is between 5 and 10%, we speak of a marginally significant result. Significance is indicated as follows: (*) marginally significant: $0.1 > p \geq 0.05$; * significant $0.05 > p \geq 0.01$; ** highly significant $0.01 > p \geq 0.001$; highly significant $0.001 > p$.

correction were very similar. The p-values reported here are always those from the corrected model.

Table 3 Lateral distances in Bornem according to the measurement (Baseline, MRM, and slurry layer)⁹

Type of interaction	Type of result	Measurement	Result	Significance: difference from baseline
Overtaking vehicle	Small distances (<1.5)	baseline	8.9%	
		MRM	14.1%	p=0.783 (ns)
		slimy layer	17.4%	p=0.390 (ns)
	Average distance	baseline	1.8m	
		MRM	1.8m	p=0.676 (ns)
		slimy layer	1.8m	p=0.691 (ns)
Crossing vehicle	% short distances	baseline	0.0%	
		MRM	3.6%	p=0.996 (ns)
		slimy layer	2.4%	p=0.996 (ns)
	Average distance	baseline	2.5m	
		MRM	2.6m	p=0.365 (ns)
		slimy layer	2.4m	p=0.068 (*)
Joint analysis	% small distances	baseline	3.2%	
		MRM	6.6%	p=0.216 (ns)
		slimy layer	6.5%	p=0.434 (ns)
	Average distance	baseline	2.3m	
		MRM	2.4m	p=0.365 (ns)
		slimy layer	2.3m	p=0.163 (ns)

⁹ Significance is indicated as follows: (*) marginally significant: $0.1 > p \geq 0.05$; * significant $0.01 > p \geq 0.001$; highly significant $0.001 > p \geq 0.05$; $0.05 > p \geq 0.01$;

Table 4 Lateral distances in Hasselt depending on the measurement (Baseline, MRM, and slurry layer)¹⁰

			Result	Significance: difference from baseline
Overtaking vehicle	Small distances (<1.5)	baseline	15.5%	p=0.119 (n.s.)
		MRM	8.5%	
		slimy layer		
	Average distance	baseline	1.86m	p=0.378 (n.s.)
		MRM	1.94m	
		slimy layer		
Crossing vehicle	% short distances	baseline	3.6%	p=0.052 (*)
		MRM	1%	
		slimy layer		
	Average distance	baseline	2.38m	p=0.012 *
		MRM	2.52m	
		slimy layer		
Joint analysis	% small distances	baseline	7.8%	p=0.013 **
		MRM	3.4%	
		slimy layer		
	Average distance	baseline	2.20m	p=0.033 *
		MRM	2.33m	
		slimy layer		

6.2.3 Conclusion on lateral distances In

Bornem, the differences between the three measurements were very small and not systematic.

Descriptively, the proportion of interactions in MRM and other slurry layer with small interstices was even slightly larger than without marking. The statistical analyzes do show that the differences are not significant – neither for the average distance nor for the share of short distances. There was one exception to this: with a slam layer, the average distance when crossing was greater than without marking. This difference was 'marginally significant', but that does indicate a possible difference.

In Hasselt only two measurements were made (baseline and MRM). The differences were slightly larger than in Bornem and went in the expected direction. The share of short distances was slightly reduced. This difference was significant when we analyzed the interaction types 'catch up' and 'crossing' together. For crossing the difference was marginally significant, for overtaking the difference was not significant. The average distance was also greater. This too was significant in the joint analysis and for crossing vehicles but not for overtaking ones.

¹⁰ Significance is indicated as follows: (*) marginally significant: $0.1 > p \geq 0.05$; * significant $0.01 > p \geq 0.001$; highly significant $0.001 > p \geq 0.05$; $p > 0.01$;



Center lane marking Barelstraat Bornem – lateral distance when overtaking

So we can remember: in terms of lateral distance between cyclist and vehicle, we saw no structural differences between the three measurements in Bornem, but in Hasselt there were less small distances with an MRM than without markings – especially for crossing vehicles.

6.3 Position cyclists

The position of the cyclists was also determined in terms of zones of 50 cm and then expressed as number of zones from the edge of the roadway (e.g. zones 1 or 13 mean a distance between 0 and 49 cm from the edge, zones 2 and 12 50 to 99 cm, etc.) If there were several cyclists, the position was determined by the cyclist who cycled closest to the center of the road.



Position one cyclist: distance from the edge.



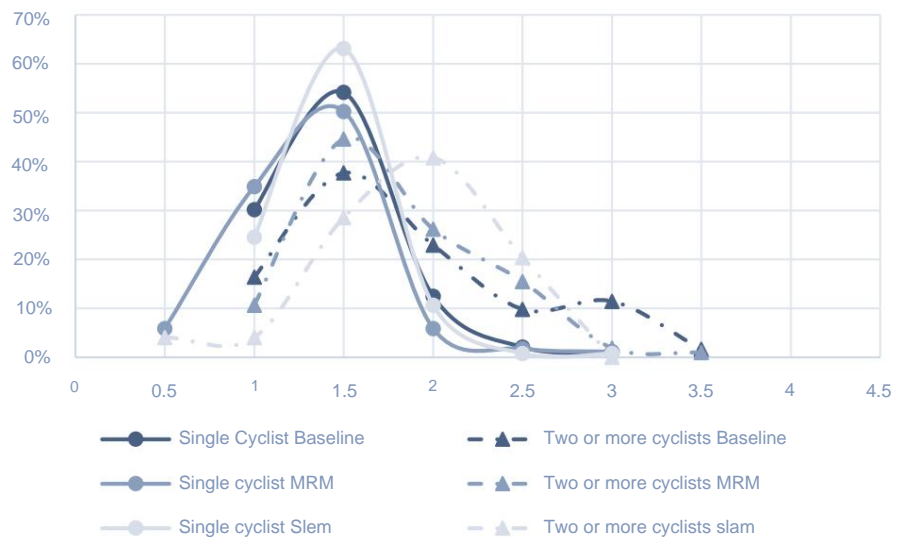
Position of multiple cyclists: Distance from the edge to the most centered cyclist drives off the road.

Figure 41 Examples for the position of the cyclist (distance from the side)

In Figure 42 the positions of the cyclists are shown in terms of distance from the edge of the road. The x-axis in these graphs shows the distance from the edge in m. The y-axis again shows the percentage of interactions for a certain position of the cyclist.

The positions for vehicles are split here according to whether the cyclists cycled together or viewed and alone or in a group (two or more).

Distance cyclist from the edge (m): overtake & cross - Bornem



Distance cyclist from the edge (m) - Hasselt

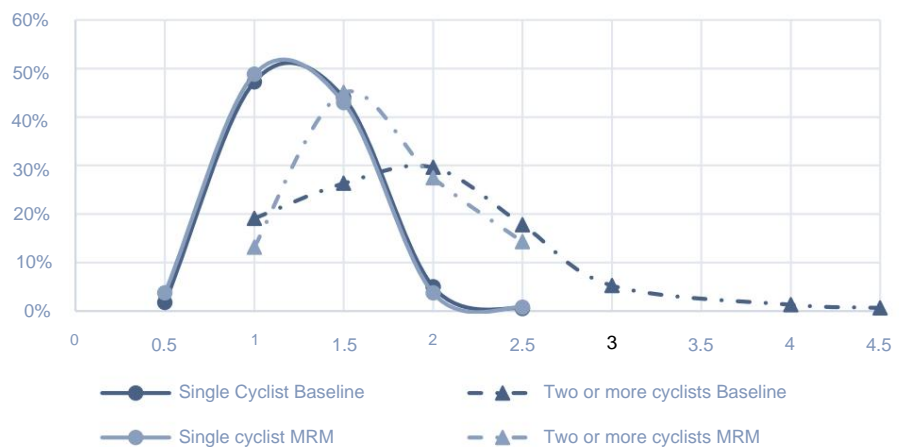


Figure 42 Position of the cyclist relative to the edge of the road.

Descriptively, we see that in Hasselt there was a clear effect on the position of cyclists riding in groups: with an MRM they kept more to the edge of the road during interactions with motor vehicles than in the baseline measurement without marking. This effect was absent for cyclists traveling alone. In Bornem, the picture is slightly less clear: cyclists keep slightly less to the right with an other yellow sludge layer and slightly more with an MRM. This trend is visible both for cyclists in groups and for people who cycle alone.

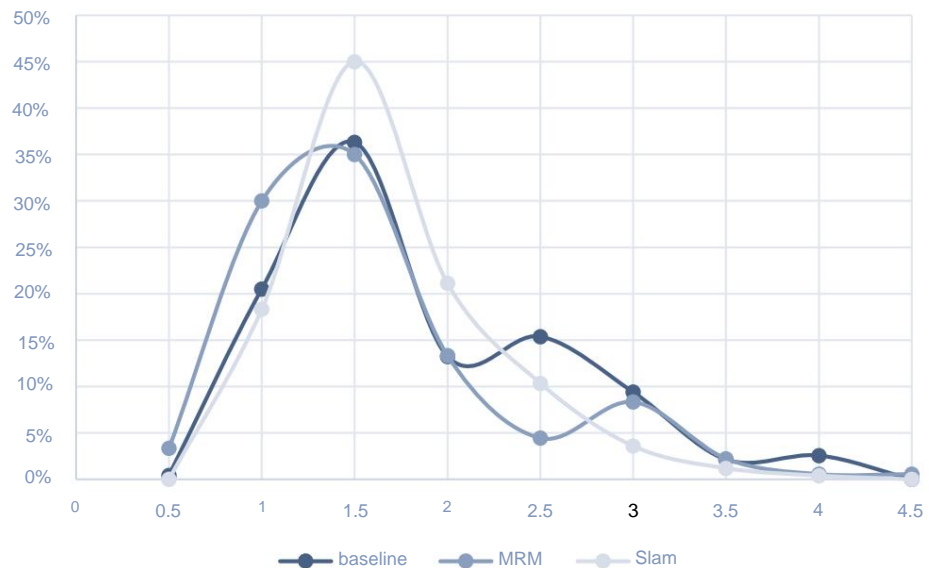
To determine whether the effect of the marker differed for cyclists in a group and cyclists cycling alone, the interaction between 'group' (alone vs. multiple cyclists)

and 'measurement' (baseline, MRM, slam) tested. This was not significant for Bornem (crossing $p=0.158$; overtaking $p=0.328$; joint $p=0.117$). This means that the effect of the marking did not differ systematically for cyclists in groups and people who cycled alone.

In Hasselt this was significant for crossing and in the joint analysis (crossing $p=0.002$; joint $p=0.081$). The smaller distance from the edge of the roadway in the MRM condition was almost entirely accounted for by cyclists cycling in groups, while for cyclists cycling alone the marking made no difference. There was no significant effect for overtaking ($p=0.441$).

Figure 43 shows the position of the cyclists who cycled without a motorist. A division according to cyclists into groups and individual cyclists was not possible here.

Distance cyclist from the edge (m): no other vehicle - Bornem



Distance cyclist from the edge (m): no other vehicle - Hasselt

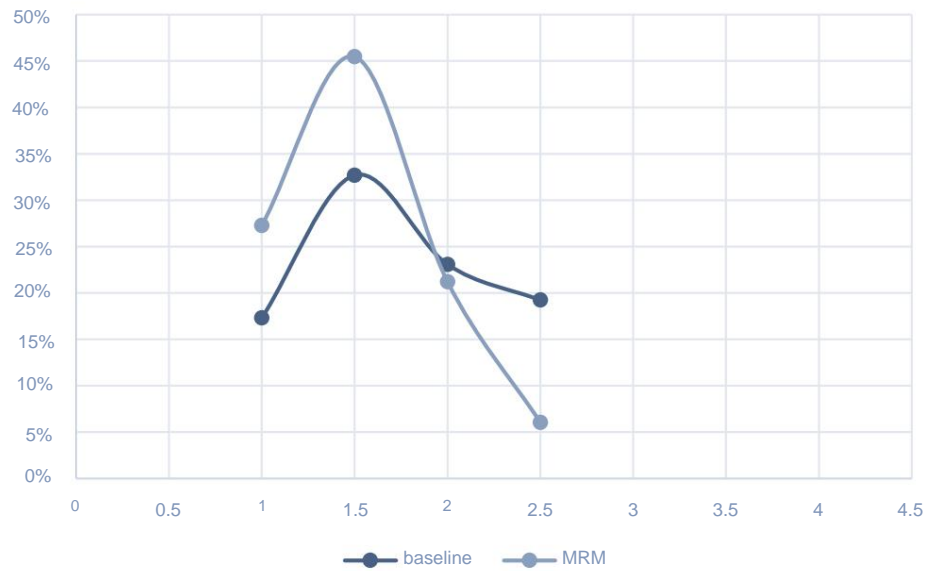


Figure 43 Position of cyclist without other vehicles present

Figure 43 shows the positions of cyclists when a vehicle was present.

Again in Hasselt there is a clear effect of the MRM where the distances to the edge are systematically smaller than in the baseline condition. In Bornem it is striking that the positions of the cyclists are more spread over the entire width of the road. Here, too, cyclists stay closer to the edge at an MRM. It is also striking that during the measurement with a slurry layer the spread was smaller. The slurry layer therefore appears to have a channeling effect. Perhaps a nudging effect due to the color.



Center lane marking Barelstraat Bornem, position of cyclists in relation to the edge of the roadway

6.3.1 Significance tests To

find out whether cyclists adhere more to the edge of the roadway at a marking, we tested whether the average distance from the edge of the roadway in the measurements with MRM and with a slurry layer is greater than in the baseline condition.

Edge distance was used as a dependent variable in an analysis of co-variance (ANCOVA) analysis – an analysis of variance in which the difference between baseline, MRM and slurry layer was tested for significance.

In addition, the situational characteristics or variables mentioned under 6 were included as co-variables to correct for any differences between the measurements. The results between the models with correction and without correction were very similar. In

Table 5 shows the average distances of the cyclist from the edge, if there was an interaction with another vehicle. Cyclists with crossing and overtaking motorists were analyzed separately. The joint analysis includes these interactions, but also those where the motorist continued to drive behind the cyclist. The reported p-values result from the analysis with situational characteristics. All analyzes were done separately for 'overtaking vehicle' and 'crossing vehicle' interaction types. The joint analysis also includes interaction types 'vehicle stays behind cyclist' and 'other'.

Table 5 Average position of cyclist in interaction with vehicle¹¹

			Mean distance cyclist difference	Significance: from baseline of side
Bornem	With overtaking vehicle	Baseline	1.03 m	
		MRM	0.95m	p=0.300 (ns)
		Slab layer	1.03 m	p=0.962 (ns)
	With crossing vehicle	Baseline	1.14 m	
		MRM	1.02m	p=0.091 (*)
		Slab layer	1.13 m	p=0.618 (ns)
	Joint Analysis	Baseline	1.11m	
		MRM	1.02 m	p=0.075 (*)
		Slab layer	1.14 m	p=0.094 (*)
Hasselt	With overtaking vehicle	Baseline	0.85 m	
		MRM	0.78m	p=0.623 (ns)
	With crossing vehicle	Baseline	0.97 m	
		MRM	0.87m	p=0.016 **
	Joint analysis	baseline	0.94m	
		MRM	0.84m	p=0.014 **
		slimy layer		

¹¹ Significance is indicated as follows: (*) marginally significant: $0.1 > p \geq 0.05$; * significant $0.01 > p \geq 0.001$; highly significant $0.001 > p \geq 0.05$; ** highly significant $0.001 > p \geq 0.01$;

Table 6 shows the average distances from the edge for cyclists who cycled without an interaction taking place. These were analyzed separately because the analysis model did not contain corrections for situational characteristics.

Table 6 Average position of cyclist without interaction with vehicle¹²

			Result	Significance: difference from baseline
Bornem	No vehicle present	Baseline 1.53 m		
		MRM 1.40m		*** p<0.001
		Slab layer 1.36 m		** p=0.007
Hasselt	No vehicle present	Baseline 1.36 m		
		MRM 1.03m		* p=0.012

6.3.2 Conclusion on position of cyclists

A central lane marking (MRM) has an effect on the position of cyclists on the roadway: they continue to ride against the edge of the road.

This difference was statistically significant (in Bornem only marginally significant) – except when the cyclist was overtaken, but when cyclists crossed a motor vehicle or without the presence of other vehicles. In the interactions with car drivers, there was almost exclusively a difference among cyclists who cycled in groups or in pairs. In situations where no other vehicles were present, we cannot distinguish between cyclists in a group and a cyclist alone.

With a slurry layer in Bornem, we saw no significant difference during interactions with other vehicles, while in the absence of other vehicles there was also more right-hand cycling than in the baseline condition.

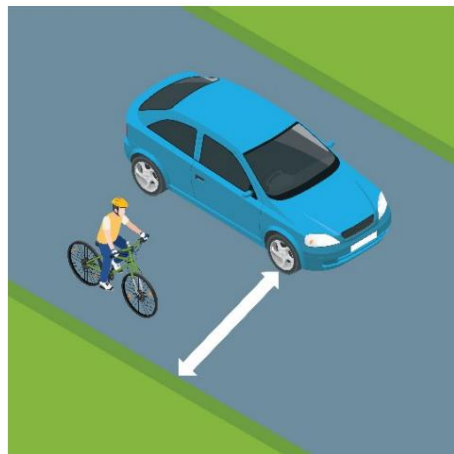
We remember that an MRM makes cyclists ride more on the edge. The effect is more pronounced with crossing motorists and without the presence of another vehicle. With a slurry layer, this effect is less clear.

¹² Significance is indicated as follows: (*) marginally significant: $0.1 > p \geq 0.05$; * significant $0.01 > p \geq 0.001$; highly significant $0.001 > p \geq 0.05$; $0.05 > p \geq 0.01$;

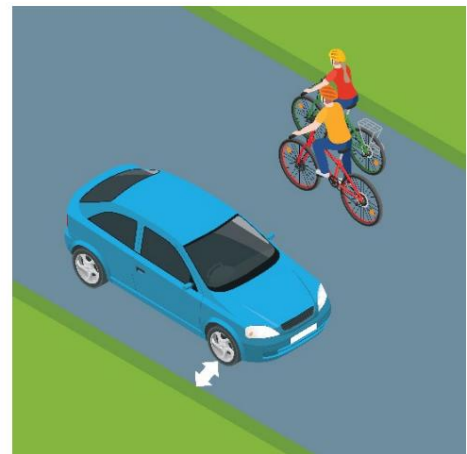
6.4 Vehicle position

Just like the position of the cyclists, the position of the vehicles was determined. All calculations below refer to the right side of the vehicle.

Because that side pointed away from the camera in some cases, we still coded the position of the wheel that pointed to the camera and added 5 zones (2.50 meters) for passenger cars, 1 zone (0.50 meters) for motorized vehicles, two-wheelers, and 6 zones (3.00 meters) for vans. The distance then amounts to the number of zones ^{*} 0.5.



Vehicle distance from edge: overtake.



Distance vehicle from edge: cross.

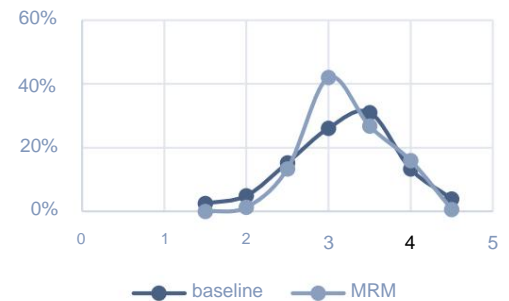
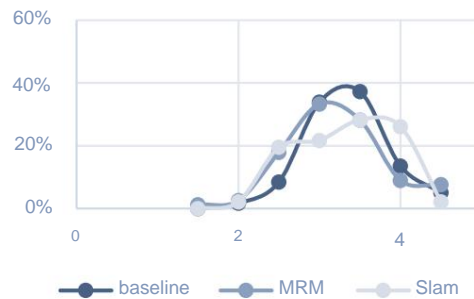
Figure 44 Examples of vehicle distance from the side

In Figure 45 the positions of the vehicles are shown in terms of distance from the edge of the road. The positions when viewed. overtake cross and of vehicles are here together

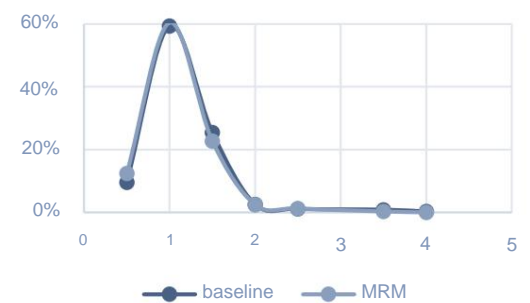
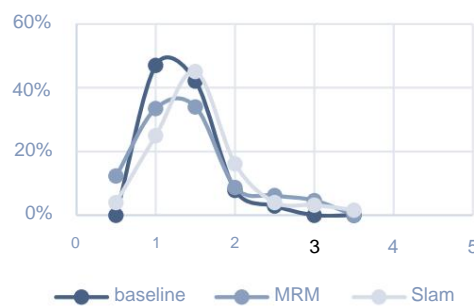
Bornem

Hasselt

Vehicle position when overtaking (m)



Vehicle position when crossing (m)



Position vehicle no cyclist (m)

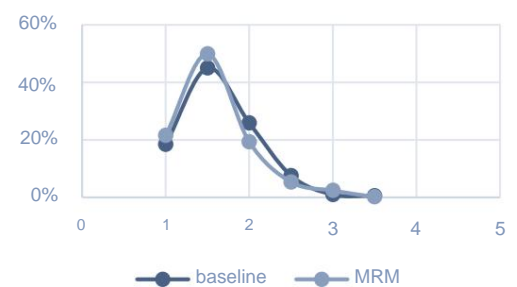
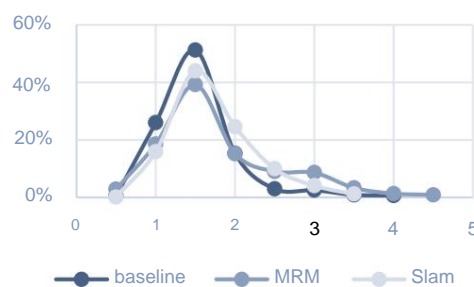


Figure 45 Vehicle position when overtaking and crossing.

In Bornem, the vehicles drove closer to the side of the cyclist during **overtaking** in the MRM measurement than in the baseline measurement. In the measurement with an ochre yellow sludge layer, a bimodal distribution was formed: a small group of motorists drove closer to the cyclists, while a slightly larger group drove further away from them. In Hasselt

during overtaking, there were fewer vehicles (relatively) close to the edge and therefore near the cyclists during overtaking than in the baseline measurement.

At the **intersection**, motorists in Bornem drove a little further to the left – and therefore closer to the cyclist. In Hasselt there was no difference.

When **no cyclists** were present, motorists at the MRM were more likely to stick to the middle of the road in Bornem, but more to the edge of the roadway in Hasselt compared to the baseline measurement.



Center lane marking Barelstraat Bornem, position of vehicles without cyclists

6.4.1 Significance testing To

know if the differences mentioned above are significant, we used the distance between the vehicles and the edge of the roadway as a dependent variable in an analysis of co-variance (ANCOVA) – an analysis of variance in which the difference between baseline, MRM and slam layer was tested for significance.

The situational characteristics or variables mentioned under 6 were also included again as co-variables. Table 7 shows the average distances of passenger cars from the edge. Cyclists with crossing and overtaking motorists were analyzed separately. The joint analysis includes these two types of interactions, but also those where the motorist continued to drive behind the cyclist. The reported p-values result from the analysis with correction for situational characteristics. The average distances from the edge for vehicles without a cyclist are shown in Table 8. The p-values result from an analysis without correction for situational characteristics.

Table 7 Average vehicle position in interaction with cyclist(s)¹³

			Result	Significance: difference from baseline
Bornem	Overtaking vehicle	baseline	2.84 m	
		MRM	2.71 m	p=0.152 (ns)
		slimy layer	2.82 m	mp=0.920 (ns) 0.83 m 0.88 m
	Crossing vehicle	baseline		
		MRM		p=0.706 (ns)
		slimy layer	1.02m	mp=0.033
	Joint Analysis Baseline	baseline	1.55m	
		MRM	1.44m	p=0.920 (ns)
		slimy layer	1.55	p=0.060 (*)
Hasselt	Overtaking vehicle	baseline	m 2.71	
		MRM	m 2.72	mp=0.555 (ns)
	Crossing vehicle	baseline	0.64m	
		MRM	0.60m	p=0.365 (ns)
	Joint analysis	baseline	1.36m	
		MRM	1.28m	p=0.645 (ns)

Table 8 Average vehicle position without cyclist interaction

			Result	Significance: difference from baseline
Bornem	No cyclist present Baseline		1.23m	
		MRM	1.47m	p=0.003 **
		Slab layer	1.39 m	P<0.001 ***
Hasselt	No cyclist present Baseline		1.12m	
		MRM	1.07m	p=0.010 *

6.4.2 Conclusion vehicle position

There are few significant differences between the measurements with regard to vehicle position. We see only one significant difference in the interactions between cyclists and motorists: with an other yellow sludge layer, motorists drove more towards the center of the roadway during crossings – and therefore closer to the cyclist they crossed.

When there were no cyclists, we did see significant differences in the position of the vehicles, but they went in different directions at the two locations: in Bornem

¹³ Significance is indicated as follows: (*) marginally significant: 0.1>p>0.05; * significant 0.01>p>0.001; highly significant 0.001>p. 0.05>p>0.01;

vehicles drove more towards the middle of the road, while in Hasselt they kept more to the edge.

We remember that the effects on the position of the vehicles were small and unsystematic.

6.5 Motor vehicle speeds

The speeds were registered by radars, which also counted the passing vehicles at the same time. In addition, a radar registers the length of the vehicles, although the measurement of the length is not always reliable - for example, a platoon of cyclists can be perceived by a radar as one large vehicle.

There is also a side note to be made with regard to the measurement of the speeds: the radars were not calibrated. So there may be a systematic measurement error. In absolute terms, the speeds shown here may therefore be higher (or lower) than the actual speeds, but for this study it was important to determine whether the speeds depend on the marking. The radars can indicate this precisely, because any systematic measurement error would occur in the same way with each measurement.

Another problem in evaluating the speeds driven is that they may be influenced not only by the marking, but also by the presence of other road users. The presence of vulnerable road users in particular could reduce the speeds driven. Hopefully it is. Due to circumstances, the measurements were carried out at different times of the year. Due to differences in the weather conditions and the measurement period (eg holiday period or not), the presence of vulnerable road users was not always the same. We have corrected for this statistically. The details of how we made that correction are described in the appendix in section 9.2.

The measured speeds and the corrected speeds are shown together in Figure 46.

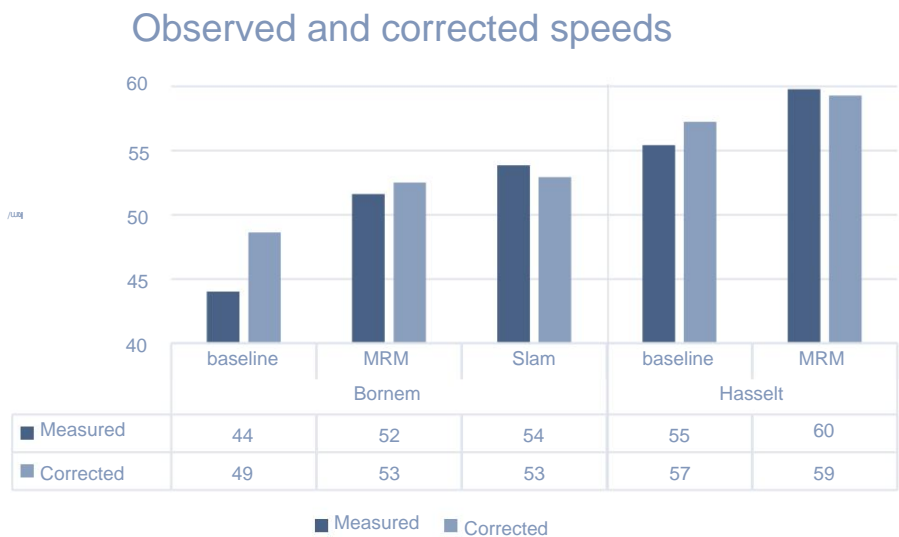


Figure 46 Measured and corrected speeds

The corrected speeds (light gray bars) are closer together than the measured speeds (dark bars). This indicates that the differences are partly due to the number of road users present, for which the light gray bars have been corrected.

In addition, there is also an effect of the marking: the velocities in the two baseline measurements are structurally lower than those in measurements with MRM or other yellow slurry layer. The ANCOVA analysis indicated that all differences between the baseline measurement and a tagged measurement were highly significant (all p-values <0.001).



Slurry layer Barelstraat Bornem, vehicle speed

6.5.1 Conclusion vehicle speed

The speeds in Bornem were higher in the MRM condition and in the slam condition than in the baseline condition. In the raw data, the difference was almost 8 km/h. This was partly due to the fact that it was much busier during the baseline measurement. There were more vulnerable road users, but also more cars. However, if we correct for this effect, we still see a difference between the baseline measurement and the measurements with MRM and slam layer. In Bornem it is still 4 km/h.

In Hasselt we observed a similar pattern. The speeds in the baseline measurement were higher than in Bornem, but here too the speed also increased in the MRM measurement. In Hasselt it was an uncorrected difference of 4 km/h, which is reduced by the correction to a difference of 2 km/h.

In summary, the speed driven by motorists increases by 2 to 4 km/h if an MRM or slurry layer is applied.

7 Interpretation results

In this study we have tried to find out what effects markings for bicycles in mixed traffic, in particular a central lane marking (MRM) and an ochre yellow slurry layer, have on road safety. To this end, we investigated different aspects of the behavior of cyclists and motorists: the type of interaction (overtaking or staying behind the cyclist), the lateral distances between cyclists and motorists, the position of the cyclists and that of the vehicles, and the speed of the vehicles. We investigated this at two locations and with different markings: in Bornem there was a baseline measurement without marking, a measurement with an MRM and a third measurement with a suggestion strip marked with an ochre yellow slurry layer. In Hasselt there was a baseline measurement without marking and a measurement with an MRM.

Below we will first summarize the results again, after which various points for attention that play a role in the interpretation of the results will be discussed.

7.1 Summary of results

Type of interaction: We look at whether motorists traveling in the same direction as a cyclist overtook them or stayed behind (within the camera's view). In all measurements, the majority of motorists overtook the cyclist. In Bornem they stayed behind the cyclist slightly more often with MRM and slurry layer. In Hasselt the effect was reversed and motorists overtook slightly more often at an MRM.

Lateral distances: For safety, it is especially important that there are as few interactions as possible with a small distance (< 1.5 m) between motorists and cyclists. In Bornem there were no significant differences between the three measurements. Descriptively there were even slightly more overtaking maneuvers with small distances. In Hasselt the lateral distances with an MRM were slightly greater than without markings and there were also fewer maneuvers with small distances. This was especially the case for vehicles crossing a cyclist.

Position cyclist: An MRM causes cyclists to drive more to the edge of the roadway. The effect is more pronounced with crossing motorists or when no other vehicles are present at all. Where we investigated this, we also saw that this effect mainly occurs among cyclists who cycle together. This suggests that cyclists with an MRM will cycle closer together – probably in an effort not to cross the lines. For overtaking vehicles, the difference between baseline and MRM is smaller and not statistically significant. It could be that cyclists in that situation also do their best in the baseline measurement to stay as close as possible to each other. With an ochre yellow

In the mud layer, we only see this tendency (driving closer to the edge) when no other vehicles were present.

Vehicle position: The differences in vehicle position were small and not systematic. Also, the few significant differences were not necessarily in the expected direction. In Bornem, the vehicles that crossed a cyclist with a layer of mud drove more to the center (and therefore closer to the cyclist they crossed) and in Hasselt, if there was no cyclist, the vehicles drove more to the edge if there was an MRM, while the hope is that an MRM will make motorists drive in the middle of the road as standard.

Vehicle speed: The speeds driven increased when a marker was added. The difference is partly explained by the fact that more road users were present in the baseline measurement. But there is still an increase in driving speed from 2 to 4 km/h, even after correction for the frequencies of the different road user types.


		MRM Hasselt	MRM Bornem	Slam Bornem
	% of vehicles that stay behind the cyclist	-	+	+
	Overtaking with a short distance	-	+	+
	Short distance crosses	-	+	+
	Cyclist position			
	To catch up	-	-	=
	crosses	-	-	=
	Free flow	-	-	-
	Vehicle position			
	To catch up	=	-	=
	crosses	-	+	+
	Free flow	-	+	+
Speed	km/h	+	+	+

Figure 47 Overview of results. Significant increases (+) or decreases (-) are marked in black or red. Trends that are not statistically significant are shown in gray or pink. Red and pink are in front undesirable trends, black and gray stand for desirable trends.

7.2 What lessons can we draw from the results?

7.2.1 MRM -> cyclists to the edge?

Even though the differences are small (around 10 cm on average), we see in Hasselt that with an MRM the lateral distances at crossings were on average greater and that there were fewer crossing maneuvers with a small distance (1 or 2 zones at 50 cm between cyclist and motorists, so motorists drive closer to cyclists) compared to the baseline measurements. For overtaking maneuvers we saw the same trend, but the differences were not significant. What is suggestive, however, is that we hardly saw any effects on the position of the motor vehicles during the interactions with cyclists, but we did see effects on the position of the cyclists. The slightly increased distances in Hasselt are therefore not caused by motorists changing their behaviour, but because cyclists stayed closer to the edge. In particular, cyclists who cycled side by side cycled closer together in order to stay between the lines.



Center lane marking Kannaertsstraat Hasselt, position cyclists

A greater lateral distance between motorized traffic and cyclist is of course positive, but if this is due to cyclists cycling closer together and closer to the edge of the road, other risks may arise. The quality of the road surface on the edge is not always optimal, dirt can accumulate and plants can be present.

Cyclists who cycle close to each other can also come into conflict with each other and as a result fall or swing, which in turn can cause them to come into conflict with a Research Report

motorist. To be clear, we have not observed this kind of problem. So with a good road surface and at least 1.70 m wide suggestion lanes, we have not identified any problems. But we cannot generalize this.

7.2.2 MRM -> faster motorists?

The increased speed at both test locations is surprising. After all, this is an optical narrowing of the roadway, which is generally assumed to reduce speed. A previous test of an MRM in Wallonia (Chalenton, et al., 2012¹⁴) also reported a slight increase in speed, which was not statistically significant at the time.

used to be.

A possible explanation is that the markings provide motorists with visual guidance, thereby reducing uncertainty and leading to higher speeds. This has mainly been found for the application of a marking that separates two lanes or for edge markings (Davidse, Van Driel & Goldenbeld, 2014¹⁵; Shackel & Parkin 2014¹⁶, Sloth-Andersen, Hegner-Reinart, & Agerholm, 2019¹⁷). It has also been found that the effect is greater with continuous marks than with broken lines. The guide marker has such small distances between the elements that they have more the effect of a

continuous line than a broken line. What speaks somewhat against this hypothesis is the fact that the vast majority of motorists simply continued to drive on the edge and therefore did not really use the lines as a guide.

Another explanation also has to do with the changed behavior of cyclists: if the MRM gives both cyclists and motorists the impression that cyclists should pull over, this may give motorists the feeling that they have to take less account of the cyclist and that they have more space to

pass.

It is clear that increased speed is not a desirable effect. Based on Elvik's calculation framework (2019¹⁸), we estimate that an increase in average speed of 3 km/h increases the risk of minor, serious and fatal injuries from road crashes by 8%, 12% and 16% respectively.

¹⁴ Houdmont A., Chalanton I., Janssens I. (2012). La Chaussée à voie central banalisée : une réponse intéressante à la sécurité des modes doux ? Institute Belge pour la sécurité routière, Brussels.

¹⁵ <https://www.swov.nl/sites/default/files/publicaties/rapport/r-2003-31.pdf>

¹⁶ <https://uwe-repository.worktribe.com/output/807348/influence-of-road-markings-lane-widths-and-driver-behaviour-on-proximity-and-speed-of-vehicles-overtaking-cyclists> ¹⁷

<https://www.diva-portal.org/smash/get/diva2:921905/FULLTEXT02.pdf> ¹⁸

Elvik, R. 2019. A comprehensive and unified framework for analyzing the effects on injuries of measures influencing speed. Accident Analysis and Prevention 125, 63-69.

7.2.3 Bicycle path, MRM, and bicycle lanes The

tendency of cyclists to drive closer to the edge and that of motorists to drive faster suggests that users have not understood the non-committal nature of the marking in that way. We have chosen the marking in such a way that it stands out visually as much as possible from the mandatory marking of a bicycle path. Nevertheless, the question arises whether lines do not automatically evoke the interpretation of fixed places on the roadway, which may not be crossed without reason.

7.2.4 MRM vs. yellow ocher sludge

layer The results for the ocher yellow sludge layer are in principle similar to those of the MRM. But the result 'cyclists stay more on the edge' we only see for the poor layer if there are no motorists. In the interactions between cyclists and motorists, we see little difference compared to the baseline, except that motorists stay behind the cyclist slightly more often and that when they cross a cyclist they drive more in the middle of the road (i.e. closer to the cyclist). The speed is also higher in a slam layer than in the baseline condition. We can conclude that a slurry layer has a similar channeling effect as an MRM – with its advantages and disadvantages.



Sludge layer Barelstraat Bornem

7.2.5 Marking MRM

Marking the MRM with a bicycle logo connection marker caused major practical problems, as it could not be automated in the software of the marking machines and was therefore very expensive. A visit to the marker showed that the following aspects must be met for an automation of the marking:

- **Fixed width, length and spacing:** no software exists yet for different spacings, which means that the automatic marking of the MRM in our

test set-up with two different intermediate distances (15 cm and 30 cm) impossible. •

Minimum length = 30 cm; minimum spacing = 100 cm; minimum width = 10 cm:

these minimum distances guarantee a certain recognisability of the marking over time.

Most markings must be reapplied annually. Since the marking machines are not yet able to automatically detect a marking, this always requires manual action. The marker must manually start remarking, which always causes a certain shift. If the marking dimensions are then too small, a continuous line will eventually form.



Test setups at marker to investigate the limitations of the marking machines

With these criteria we are forced to arrive at a marking that is difficult for most road users to distinguish from that of a cycle path. This in turn can lead to the erosion of respect for cycle paths or, conversely, to road users regarding the lines as absolute and impassable. Both are undesirable for road safety.

An other yellow sludge layer is clearly distinguishable from current cycle path markings. But then two other problems arise:

1. No rules can be attached to a paint layer (eg a parking ban).
2. To apply the other yellow color permanently, this must be done in the form of a slurry layer. This is very expensive and therefore not feasible for many municipalities in their outlying areas.

7.2.6 Marking cycle path If

we want a suggestion strip that is marked with a line and can be clearly distinguished from the marking of a cycle path, then we may have to consider changing the marking of the cycle path: in the Netherlands and Germany, lines that are not crossed may be marked as a solid line. Even though the marking of a cycle path may indeed not be driven over, a cycle path in Belgium is still provided with a broken line. A similar broken line is reserved in the Netherlands and Germany for a situation where it is allowed to drive over the line (eg for a bicycle lane). In practice, the broken line marking a bicycle path is usually accompanied by a continuous line marking the edge of the roadway. This emphasizes the impassable character for motorists and also creates extra space for cyclists.



Continuous white line next to the cycle path marking that indicates the edge of the roadway.

If it turns out that practical restrictions make it impossible to construct a central lane marking that is sufficiently distinct from a cycle path, then consideration may have to be given to adjusting the marking of a cycle path - for example by making it mandatory to place a continuous marking next to it, or bicycle path always to be colored red.

However, based on the results of this study, it is not yet recommended to use center lane markings outside built-up areas.

8 Conclusion

The study shows that the results of the five indicators studied – do motorists stay behind a cyclist or overtake them; what is the lateral distance between car and cyclist; how far does the cyclist ride from the roadside; what is the distance from the car to the edge of the road; how fast do the cars go? – are not unequivocal. It is not the case that one situation (no marking, MRM, slam layer) scores significantly better on all indicators.

The marking has only limited effects, and therefore not always the same at both locations (Bornem and Hasselt).

In Hasselt, slightly fewer interactions were counted with motorists who passed cyclists at too close a distance, which is positive in principle. But it was not the motorists who changed their behaviour, but the cyclists: especially when they rode together in a group, they cycled closer to the edge of the road. Together with the increased speed of motorists, the effect can therefore not be called positive.

In Bornem, the markings ensure that the car stays behind the cyclists longer, in Hasselt it is just the opposite. As far as the lateral distance is concerned, the number of close-distance interactions in Bornem even increases slightly. In general, the MRM causes the cyclist to drive more to the edge of the roadway, which is less the case with the slam layer. There is also no clear effect for the position of the car. In Bornem, the vehicles move more towards the center when crossing, so closer to the crossing cyclist, which is negative. In Hasselt they drive more to the edge at the MRM, especially if there is no other traffic (while you would expect and hope just the opposite). And finally the speed: it is increasing at both locations!

Based on this study, neither the MRM nor the ochre yellow slurry layer appears to have any positive effects on road safety when cycling in mixed traffic.

Further research should show which other (enforceable and/or behavior-directing) measures can be taken to improve the road safety of bicycle traffic on rural roads.

9 Appendices

9.1 The situational characteristics

In total we observed 1324 interactions in Bornem and 1067 in Hasselt. All situational features of these interactions for Bornem are shown in Table 9.

For each characteristic, a statistical test was used to check whether the distribution of the categories differs significantly over the three measurements (baseline, MRM and other yellow layer). The outcome of this test is shown in the right column for each characteristic.

Table 9 Situational characteristics of the observed interactions: Bornem

			Baseline MRM Slab Layer P (Chi2) 487		
	Total		530	294	*
Interaction	Vehicle crosses	Count 303%	340	194	0.027
		62.2% 64.2% 63.0%			
	Others	Count 0	0		
		% 0.0%	3 0.6% 0.0% 28		
	Vehicle stays behind cyclist % 4.9%	Count 24	45		
Group	Vehicle overtakes	Count 160	142		0.010
		% 32.9% 26.8% 27.9%			
	A biker	Count 282%	344	208	
		57.9% 64.9% 67.8%			
	2 or more cyclists	Count 205%	186 99		
Oncoming car		42.1%	35.1% 32.2%		0.010
	None	Count	480 273		
		411% 84.4% 90.6% 88.6%			
	Oncoming car	Count	50 35		
		76% 15.6% 9.4% 11.4%			
Overtaking Vehicle	Passenger car	Count 458 480%	94.0%	294	0.053 (*)
		90.6% 95.5%			
	Van/Truck Count 21 % 4.3%		31 9 5.8%		
			2.9%		
	Moped/Motorcycle	Count	19 5 3.6%		
Parking		8% 1.6%	1.6% 379 470		0.000***
	Parked car	Count 245 77.8%	807 807.5%		
		11.3% 20.5%	469 258		
	No parked car				
		22.2%			
Sporty	No cyclist(s) Count 417				0.159 ns

		% 85.6% 88.5% 84.0%	
	Cyclist(s)	Count 70% 61 49	
		14.4% 11.5% 16.0% 269	
Child	No child	Count 412% 423	0.009 **
		84.6% 79.8% 87.6%	
	Child or parent with child	Count 75% 107 20.2% 38	
		15.4% 12.4%	
Senior	Not a senior	Count 396% 237 115	0.000***
		81.3% 44.7% 37.5%	
	Senior(s)	Count 91% 293 192 55.3%	
		18.7% 62.5%	

Table 10 shows the distribution for the same characteristics in Hasselt. However, no vehicles were parked here, so the variable 'parking' is omitted. Again, a statistical test was performed for each characteristic to determine whether the distribution of categories differs significantly between baseline and MRM. The result is shown in the right column.

Table 10 Situational characteristics of the observed interactions: Hasselt

			Baseline MRM P (Chi2) 585 482		
	Total				
Interaction	Vehicle crosses	Count	337	315	0.000 ***
		%	57.6%	65.4%	
	Others	Count	1	0	
		%	0.2%	0.0%	
	Vehicle stays behind cyclist	Count	60	14	
		%	10.3%	2.9%	
Group	Vehicle overtakes	Count	187	153	
		%	32.0%	31.7%	
	Single cyclist	Count	424	384	0.004 **
		%	72.5%	79.7%	
	2 or more cyclists	Count	161	98	
		%	27.5%	20.3%	
Oncoming car	None	Count	526	415	* 0.010
		%	89.9%	86.1%	
	Oncoming car	Count	59	67	
		%	10.1%	13.9%	
Overtaking Vehicle	Passenger car	Count	532	466	0.001 (**)
		%	90.9%	96.7%	
	Van/Truck	Count	49	14	
		%	8.4%	2.9%	
	Moped/Motorcycle	Count		2	
		%	4	0.4%	
Sporty	No cyclist(s)	Count	0.7%	460	0.000 (***)
		%	481 82.2%	95.4%	
	Cyclist(s)	Count	104	22	
		%	17.8%	4.6%	

Child	No child	Count	530	424	0.099 (*)
		%	90.6%	88.0%	
	Child or Parent with Child	Count	55	58	
		%	9.4%	12.0%	
Senior	Not a senior	Count	436	442	0.099(*)
		%	74.5%	91.7%	
	Senior(s)	Count	149	40	
		%	25.5%	8.3%	

9.2 Speed Measurement Correction

To correct the measured speeds for a possible effect of the presence of vulnerable road users, we included the counts from the radars in the analysis in the following way: based on length and speed, we divided all passing vehicles into three classes:

- ≤ 2 m (\rightarrow probably vulnerable road user)
- > 2 m ; ≤ 4 m)
- (unclear) • > 4 m (certainly a car)

For each vehicle, we calculated how many other vehicles passed in that hour. The averages of these frequencies are shown in Table 11.

Table 11 Average number of vehicles per hour according to vehicle type and measurement condition.

	Marking	Vehicle length			Total
		≤ 2 m	> 2 ; ≤ 4 m	> 4 m	
Bornem	baseline	55	17	3	75
	MRM	20	18	51	90
	slimy layer	10	22	44	76
Hasselt	baseline	4	33	67	103
	MRM	2	68	24	94

To investigate whether the pace was slower when many other vehicles also passed within the same hour, we calculated the correlation between the speed and the counts for each of the three types of vehicles (see Table 12).

Table 12 Correlation between counts of road users per hour and measured speeds

	Vehicle category			Total
	≤ 2 m	> 2 ; ≤ 4 m	> 4 m	
Correlation with speed Bornem	-0.155**	-0.038**	0.221**	-0.090**
Hasselt	-0.215**			

For both locations there was a substantial correlation between the speeds driven and the counts for the different vehicle types. In other words: if there were many other vehicles in addition to the vehicle whose speed was measured, the pace was slower. This correlation was greatest for vehicles under two meters.

The pace was therefore particularly slower when there were many vulnerable road users.

Because not the same number of road users were present during each measurement, we corrected for this in an ANCOVA analysis: would the speeds also have been different if there were the same number of other road users?