ZEBRA

Cycle Lane Separators

User's Manual

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ZICLA

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1. Introduction

The recommendations for using the ZICLA ZEBRA cycle lane separator contained in this manual (hereinafter, ZEBRA separator) are provided with the following objectives:

A To describe the experience gathered by ZICLA since 2008 from cycle lanes where the separators have been installed.

B Comment on the most important aspects to consider when installing cycle lanes using broken line ZEBRA segregation.

The following concepts will be covered in this document: the usefulness of the product, expected safety enhancement objectives, lane design criteria, proper product installation, effective life maintenance and material recycling at the end of the product's effective life.

This manual is therefore intended for transport planners, project writers, road designers, works managers, installers, bicycle users and the general public.

2. Technical definition of the ZEBRA separator

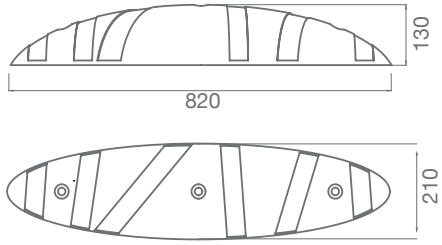
The ZEBRA separator is a robust, black median strip with reflective bands, which provide high visibility both day and night. This element is designed to enhance cyclist safety on roads where cycles share space with other users: motorcycles, cars, buses, etc. This enhanced safety is made possible by the form of the separator, which has no angles or sharp edges, is flexible and cushions possible impacts.

The design and the material used provide the ZEBRA separator with high mechanical resistance. It is anchored to the pavement at three points.

The reflective strips are available in a range of colors; yellow and white are the colours specified in the Spanish Technical Road Instruction: Standard 8.2 - I.C., Ministry of Development (1982) ZEBRA separators may also be installed with fluorescent strips in poorly lit areas.

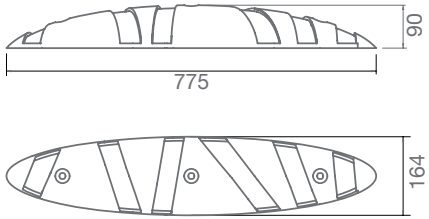
Zebra 13

Weight	9 kg	19.8 lbs
Length	820 mm	2’ 8.2”
Height	130 mm	5.1”
Width	210 mm	8.25”
Colour	Black	



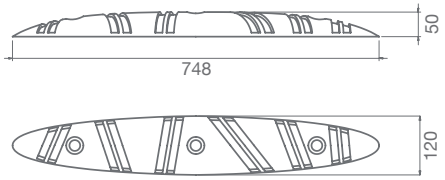
Zebra 9

Weight	4 kg	8.8 lb
Length	775 mm	2’ 6.5”
Height	90 mm	3.5”
Width	164 mm	6.5”
Colour	Black	



Zebra 5

Weight	2,5 kg	5.5lb
Length	748 mm	2’ 5.5”
Height	50 mm	2.0”
Width	120 mm	4.7”
Colour	Black	



The ZEBRA separator works as an intermittent traffic routing element, allowing for rainwater drainage and providing the possibility for cyclists to exit the lane when necessary. Separators should be used together with horizontal signage and other markings, and serve to minimize the effect of accidental impact with bicycle tires.

The elasto-plastic material absorbs kinetic energy through deformation, thus cushioning accidental impacts.

3. Traffic and transport culture

A significant number of new cycle lanes have been installed in various countries over the past several years with the aim of decreasing the use of private vehicles, reducing air pollution in cities, promoting healthy lifestyle habits and saving on transport costs.

This increment in new users sharing motor traffic or pedestrian lanes has led to new problems of coexistence and an increase in the accident rate in those places where no measures to adjust bike demand are being done. When cycle lanes are located on the pavement, pedestrians are less protected, particularly young children and the elderly. But when cycle lanes are located in the road with other motor vehicles, the less-protected user is the cyclist.

Thankfully, there is evidence that the relative rate of fatalities for cyclists is actually going down in the US. Many cities are interested in protected bike lanes and therefore to increase cycling. As a collateral effect, congestion is being reduced.

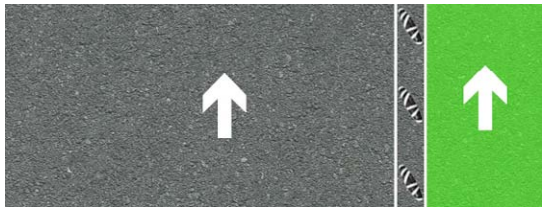
Cyclists using their bicycle as a standard means of transport hope to shorten their journey, which ideally should be uninterrupted. The ideal solution would be to install exclusive-use bike lanes, but it would be an enormous challenge to adapt existing urban roads to new infrastructures that would allow cyclists to travel in comfort and safety.

Channeling traffic according to the type of vehicle is an intelligent and effective solution from all standpoints, yet channeling with nothing more than road markings is undoubtedly insufficient from the perceived safety standpoint.

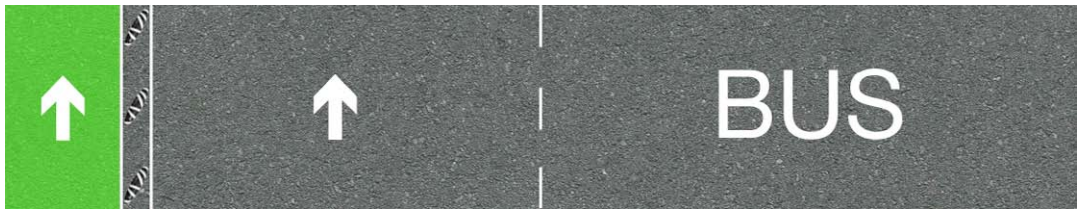
4. Types of cycle lane

4.1. Generic case study: One-way road

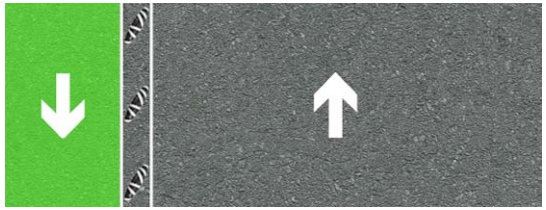
A An optimum design situates the cycle lane to the right of the carriageway, in the same direction as adjacent general traffic lanes.



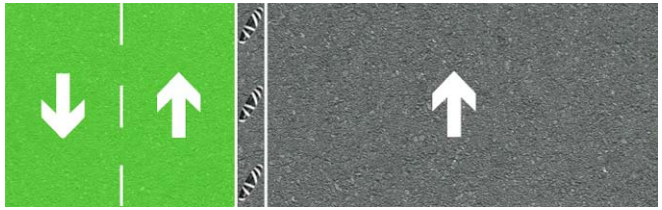
B When the road is also equipped with a bus or service lane, the cycle lane can be situated to the left of the carriageway. Further details are given in Sections 4.6 (pg. 11) and 6.5 (pg. 30)



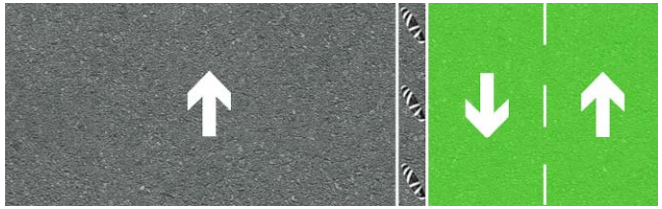
C There is also the option of installing a contraflow cycle lane to the left of the traffic lane or carriageway, so cyclists will travel on the right. National Association of City Transportation Officials (NACTO) now recognizes contraflow cycle lanes.



D Yet another possibility is to install a two-way cycle lane to the left of the carriageway such that contraflow cycle traffic will be on the left.



E The use of this solution should be limited, as it breaks with the traditional two-way traffic system. On these roads, the lanes in the direction of vehicular traffic are located on the left, with contraflow traffic on the rightt. This system can, however, be useful for certain justified cases. It is highly recommended, both by this manual and by NACTO to use segregation using separators.



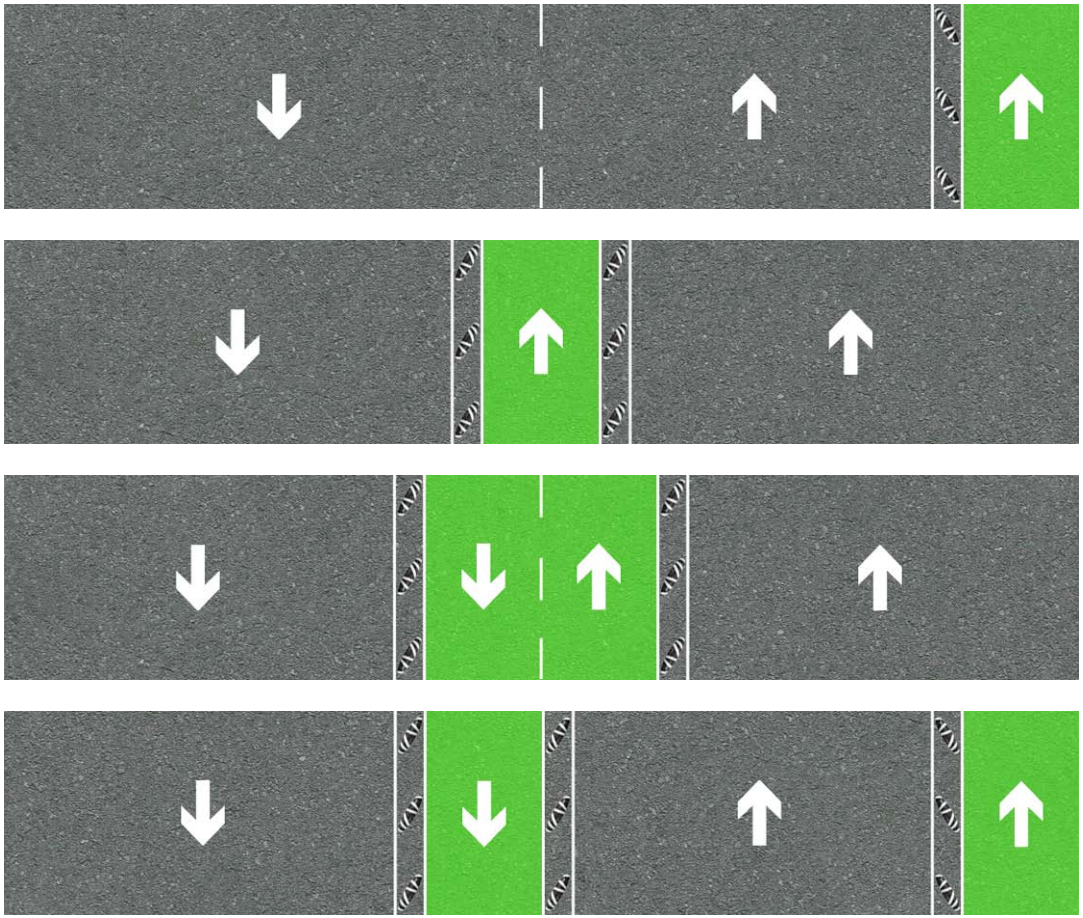
4.2. Generic case study: Two-way road

A One option is to install a one-way cycle lane on the right side of the road, in the same direction as the adjacent traffic flow.

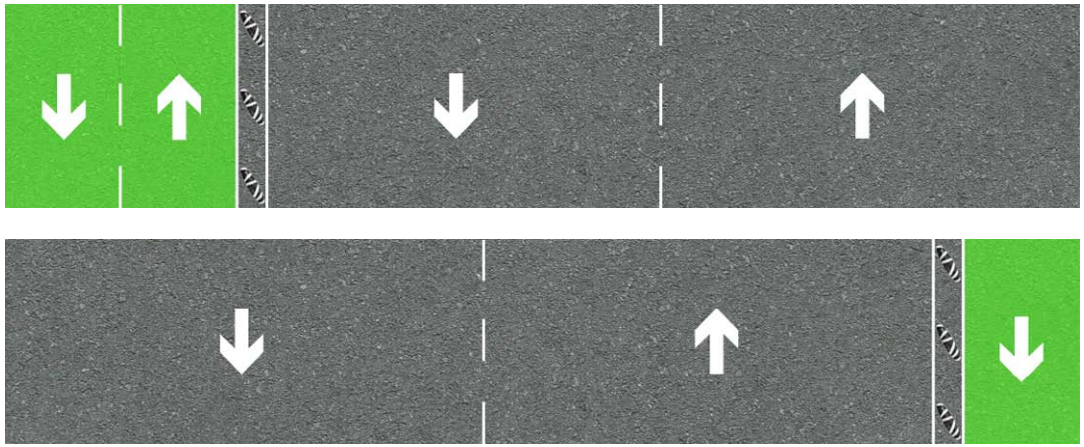
B There is also the option of installing a cycle lane in the same direction as motorized traffic, but to the left of the traffic lane, so bicycles will be travelling in the center of the carriageway. This method requires a median strip or island, or light segregation using separators on either side of the cycle lane.

C This same option can be installed for two-way cycle traffic, with a two-way cycle lane in the center of the carriageway. This method requires a median strip or island, or light segregation on either side of the cycle lane.

D A further option is to combine the first and second options, resulting in one cycle lane adjacent to a traffic lane at the side of the road, and another in the centre of the carriageway



E The use of the following two solutions should be limited, as they break with the traditional flow of traffic. They can, however, be useful for certain justified cases. It is strongly recommended both by this manual and by NACTO the use of segregation using separators.

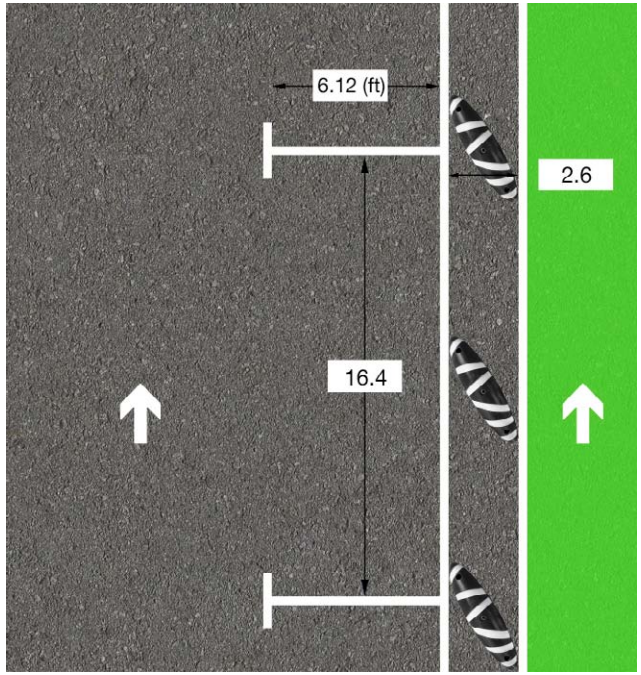


4.3. Segregation of cycle lane and car parking

Another interesting design option for segregating a cycle lane is to situate it adjacent to a parking lane.

In this case a safety strip must exist to avoid collisions with car doors as they are opened.

Section 6.4.1. (pg. 27) discusses the possibility of combining separators with bollards to avoid cars invading the cycle lane, while at the same time acting as a guide for drivers as they are parking their vehicle.



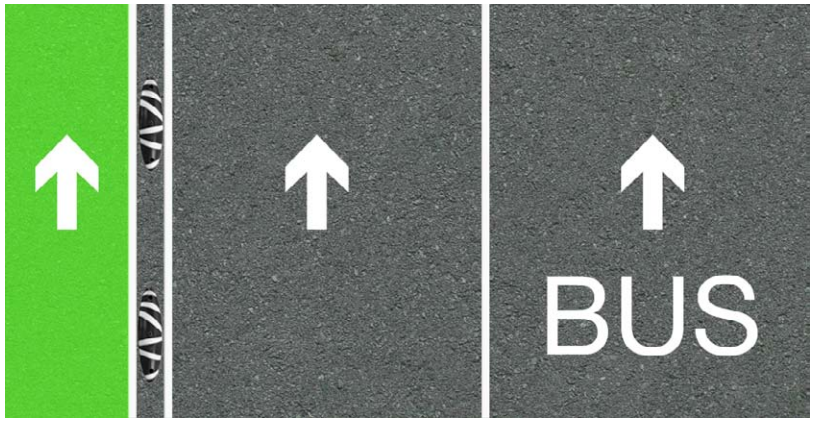
4.4. Segregated bus lane and cycle lane

In areas where both a cycle lane and a bus lane share the road, it is recommended to install the cycle lane on the side of the road opposite the bus lane.

Bicycles should travel in the right lane wherever possible and be able to leave the road and access the shoulder or the pavement if necessary. If the bus lane is situated on the left, shared used may be an option.

If an enhanced-feature bus lane is desired, this lane may be installed in the center of the carriageway (for two-way roads), or on the left for one-way roads.

For two-way roads where there is a bus lane on either side, one serving each direction, the ideal configuration would be to install cycle lanes in the center of the carriageway.



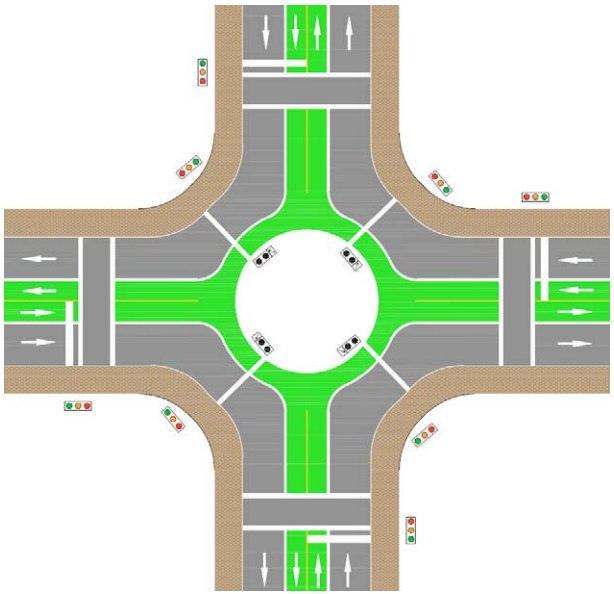
4.5. Roundabouts

At roundabouts, there are three suggested cycle lane design models.

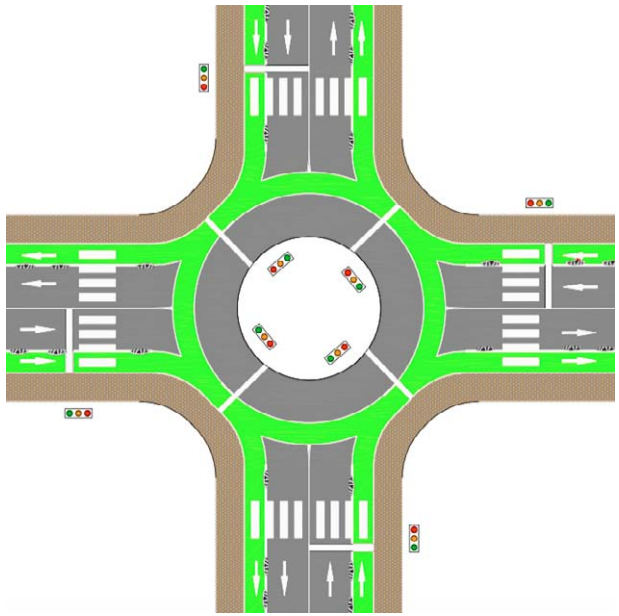
In the first case, when access to the roundabout comes from both directions, the cycle lane should be installed around the inner ring, wherever possible (Image **A**). Traffic signals must be installed at the roundabout junction, and the cycle lane must be segregated from vehicular traffic lanes using bollards (see section 6.3.1. pg. 24).

Another option is to incorporate the cycle lane into the outer rim of the roundabout, although it is considered that this type of design carries a greater safety risk (Image **B**).

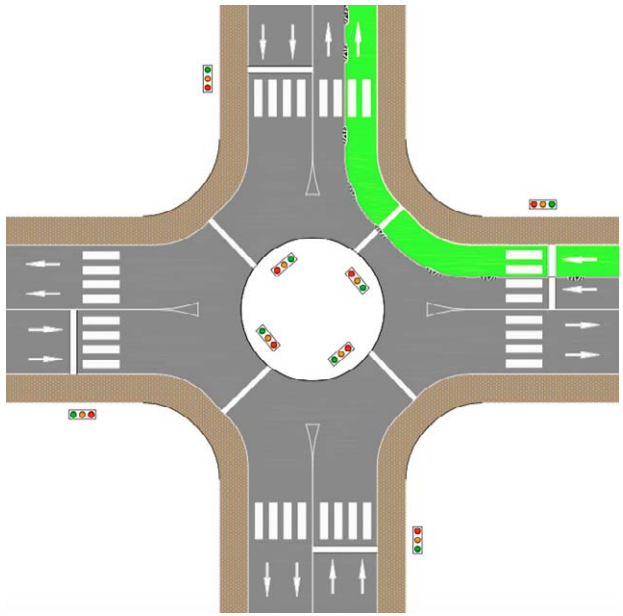
Finally, in cases where cyclists will not cross the roundabout, no special signage or signalling is required (Image **C**).



A



B



C

4.6. 20mph Zones

In areas where the typology of a series of lanes permits, a 20 mph zone can be implemented. Roads with this speed limit must be one-lane roads.

It is recommended that roads with one lane in each direction, except those acting as main roadways or those with lateral areas (i.e. pavement), generally be designated as 20 mph zones.

The ZEBRA separator recommended for these cases is the ZEBRA 5 model.

5. Decision factors

5.1. Choosing the right ZEBRA separator

To decide which is the most suitable separator for a specific road, various criteria related to the type of traffic must be considered, like: various criteria related to the type of traffic, such as:

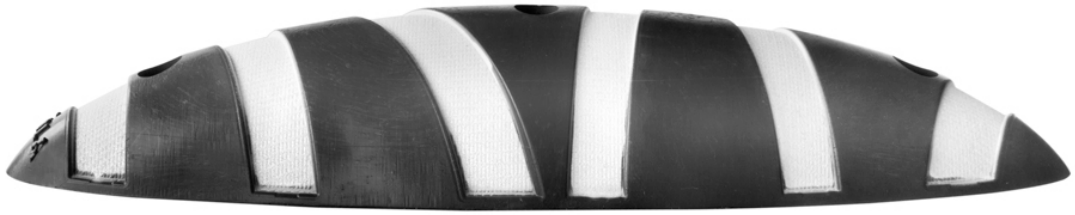
- **A** Lane direction
- **B** Number of lanes in each direction
- **C** Average traffic intensity for light and heavy vehicles
- **D** Social values
- **E** Location of cycle lane (pavement, carriageway)

The type of separation required between a cycle lane and a traffic lane is not the same for adjacent same-way traffic as for contraflow traffic. So, if a contraflow cycle lane is installed, a minimum of 10 mph should be added to the “average vehicle speed” or “maximum speed” variables.

It must also be considered whether they are roads in 20 mph zones or wide avenues with several lanes in each direction

ZEBRA 5

ZEBRA 9



ZEBRA 13

Cycle lane culture varies widely from city to city, and depends on the number of users who use their bicycle as their daily means of transport. Parking style is another relevant factor.

Three road usage levels can be established, which will facilitate the selection of separator types I, II or III.

There is always a transition zone where the project director may choose the type of ZEBRA element to use, although it is always advisable to use the larger of the two options.

In segregated areas shared by non-motorised users, it is suggested to use more appropriate elements of urban furniture such as three-feet-high planters or other elements to create a barrier, such as a line of trees.

Road usage levels	I	II	III
ADI of automobiles (thousands)	< 8	8 - 15	>10
ADI of automobiles at peak hour	< 350	200 - 600	> 500
ADI of heavy vehicles	< 100	50 - 250	> 150
Average speed of buses (mph)	< 10	5 - 20	> 15
Maximum speed (mph)	< 15	20	> 30
Width of carriageway (ft - in)	< 22’ 10”	Between 16’ 4” and 49’ 3”	> 32’ 9”
Recommendation:	**ZEBRA 5**	**ZEBRA 9**	**ZEBRA 13**

5.2. Contradictions for use: physical space

It is best not to use separation elements in the following areas:

A Street markets and fairs: Arrangement of market stalls must be considered and avoid any obstruction for set-up and placement

B High pedestrian traffic areas: In the event of an emergency, buildings such as theatres, cinemas, clubs, supermarkets, stadiums, etc. may need to be evacuated, so building exit areas (especially emergency exits) must be kept free and clear of segregation elements.

5.3. Contradictions for use: Climate, physical and environmental factors

When installing separators in areas of low visibility due to scarce natural light during the day or artificial lighting at night, ZEBRA separators with fluorescent bands may be used, providing even greater visibility than reflective bands.

In order to better identify cycle lane separation in heavy snow areas, bollards may be used to avoid snowploughs from damaging separation elements when ploughing the road (see section 6.3.1, pg. 24).

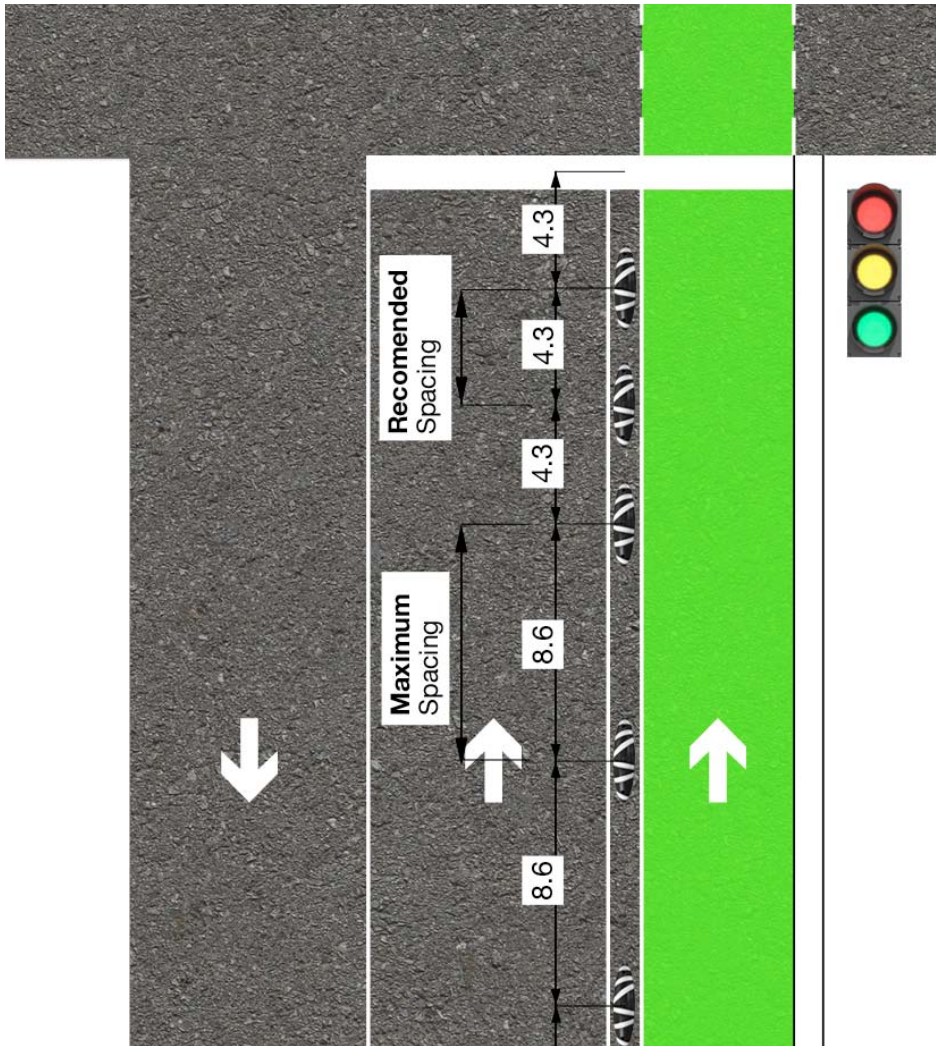
6. Design factors inherent to any typology

6.1. Spacing between the elements

The recommended distance between Zebra separators - which is measured from the centre of one piece to the centre of the next one - is 4.3 feet for both parallel and oblique installation styles. This optimum spacing allows bikes to exit quickly from the cycle lane in case of an emergency.

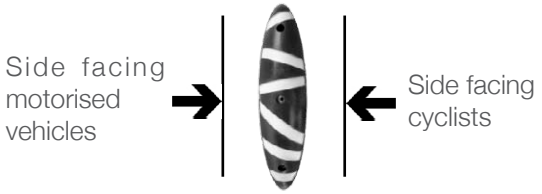
Spacing greater than 4.3 feet increases the risk of invasion by motor vehicles which are attempting to park or overtake.

Finally, gaps between the ZEBRA separators that are over 8.6 feet pose a great risk for both cyclists and other road users. This is because a wide spacing arrangement could result in the separators being overlooked and seriously increases the probability of vehicles colliding with them or pedestrians tripping up.



6.2.1. Positioning of ZEBRA elements

The natural positioning of a ZEBRA element is with the main axis parallel to the carriageway; however, there are other aspects to be considered if enough space is available.



As ZEBRA elements are not symmetrical, it is recommended for the side that has the greater density of reflective bands in the centre of the separator to face the motorised vehicle lane. If this creates a problem, the separators may also be installed with alternating faces.

On roads where vehicles and bicycles are travelling in the same direction, ZEBRA elements may be installed at a maximum angle of 30º. This angle allows:

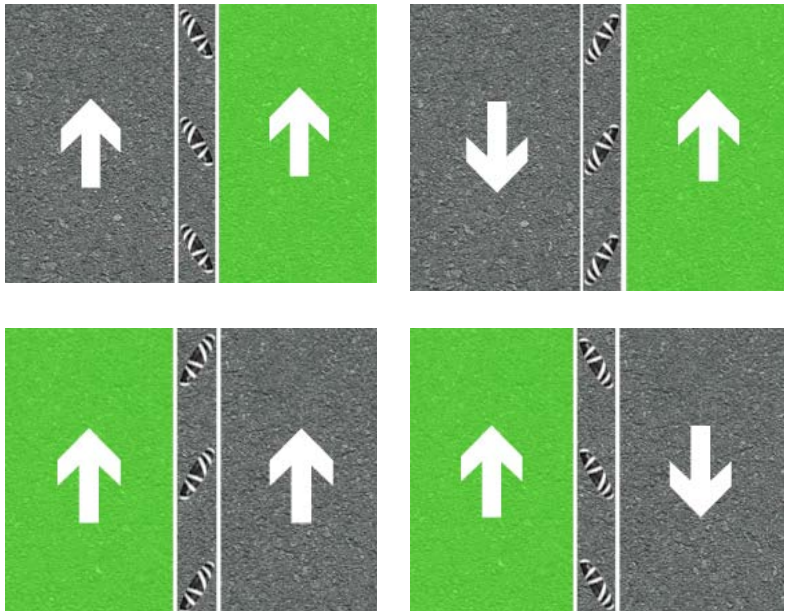
A Cyclists to leave the cycle lane in case of blockage or emergency

B Motorised vehicles to see a greater surface area of the ZEBRA elements, generating a stronger barrier effect for both cars and motorcycles

An angle of greater than 30º would require an excessive use of space, so more than 30º is not recommended.

If contraflow vehicular traffic is present, ZEBRA elements may also be installed at a maximum angle of 30º. This angle gives both cyclists and vehicles a more effective barrier, hindering invasion of the other lane.

ZEBRA elements should be angled as follows:



6.2.2. Cycle lane widht and separation from road markings

This section discusses cycle lane width and separation from road markings.

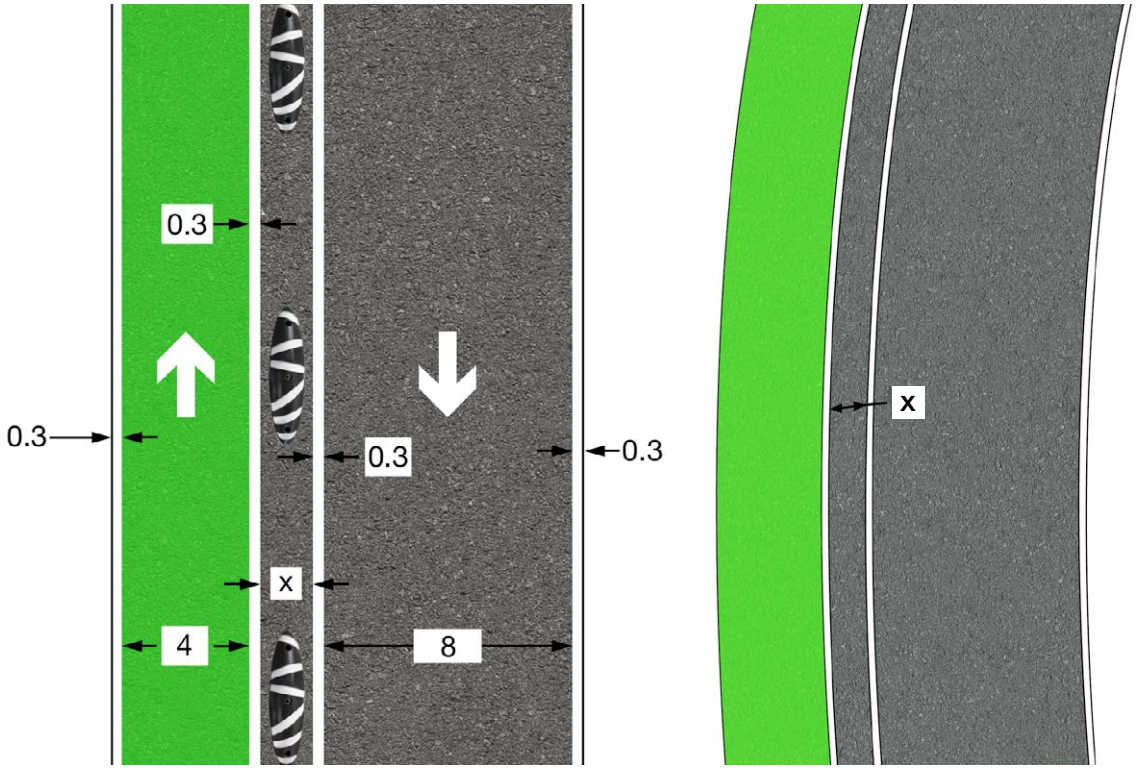
According to general practices, it is suggested to set a minimum width for different lane purposes as follows:

- **A** One-way cycle lanes: 4 ft.
- **B** Motorised vehicle lanes: 8 ft.
- **C** Bus lanes: 10 ft.

Under no circumstances is it recommended to install a lane wider than 11.5 feet in urban centres, as this encourages high speeds.

Road markings must have a minimum width of 0.3 ft.

On curves, the “X” separation value between road markings depends on the radius (of the inner marking) of the curve, as shown in the tables on the following page. All other values may be the same as for straight sections, bearing in mind the type of project to be carried out.



Here you can see the minimum and maximum distances of separation between road markings for X, shown on the previous page.

Separation between road markings depends on the following variables:

A Traffic conditions (explained in section 5.1, p. 16), expressed in the table as Minimum I, Minimum II and Minimum III

B Selected positioning of ZEBRA elements (section 6.2.1, p. 20)

C Selected ZEBRA element: ZEBRA 5, ZEBRA 9, ZEBRA 13

D Radius of the curve where ZEBRA elements are to be installed, as the geometry of a curve with a smaller radius requires greater separation between elements

The figures shown in the tables refer to the separation from road markings in accordance with the parameters described above. An N/R value means that the use of the ZEBRA separator is not recommended.

Zebra 13

(ft)	Minimum I	Minimum II	Minimum III	Maximum
0º angle of ZEBRA separator				
On straight roads				
	N/R	0.82	0.99	1.15
On curved roads (inner radius)				
984	N/R	0.82	0.99	1.15
656	N/R	0.83	0.99	1.15
328	N/R	0.83	1.00	1.16
131	N/R	0.85	1.01	1.18
66	N/R	0.87	1.04	1.20
49	N/R	0.89	1.06	1.22
33	N/R	0.93	1.09	1.26
16	N/R	1.03	1.19	1.36
30º angle of ZEBRA separator				
On straight roads				
	N/R	2.08	2.24	2.40
On curved roads (inner radius)				
984	N/R	2.08	2.24	2.40
656	N/R	2.08	2.24	2.40
328	N/R	2.08	2.24	2.41
131	N/R	2.09	2.25	2.42
66	N/R	2.10	2.27	2.43
49	N/R	2.11	2.28	2.44
33	N/R	2.13	2.29	2.46
16	N/R	2.18	2.34	2.51

Zebra 9

(ft)	Minimum I	Minimum II	Minimum III	Maximum
0º angle of ZEBRA separator				
On straight roads				
	0.54	0.64	0.80	0.96
On curved roads (inner radius)				
984	0.54	0.64	0.80	0.97
656	0.54	0.64	0.81	0.97
328	0.55	0.65	0.81	0.97
131	0.56	0.66	0.83	0.99
66	0.59	0.69	0.85	1.01
49	0.60	0.70	0.87	1.03
33	0.63	0.73	0.90	1.06
16	0.73	0.83	0.99	1.15
30º angle of ZEBRA separator				
On straight roads				
	1.74	1.84	2.00	2.40
On curved roads (inner radius)				
984	1,74	1.84	2.00	2.17
656	1.74	1.84	2.00	2.17
328	1.74	1.84	2.01	2.17
131	1.75	1.85	2.01	2.18
66	1.77	1.86	2.03	2.19
49	1.77	1.87	2.04	2.20
33	1.79	1.89	2.05	2.22
16	1.84	1.94	2.10	2.27

Zebra 5

(ft)	Minimum I	Minimum II	Minimum III	Maximum
0º angle of ZEBRA separator				
On straight roads				
	0.40	0.50	N/R	0.59
On curved roads (inner radius)				
984	0.40	0.50	N/R	0.59
656	0.40	0.50	N/R	0.60
328	0.40	0.50	N/R	0.60
131	0.42	0.52	N/R	0.61
66	0.44	0.54	N/R	0.64
49	0.45	0.55	N/R	0.65
33	0.48	0.58	N/R	0.68
16	0.57	0.67	N/R	0.77
30º angle of ZEBRA separator				
On straight roads				
	1.57	1.67	N/R	1.83
On curved roads (inner radius)				
984	1.57	1.67	N/R	1.83
656	1.57	1.67	N/R	1.83
328	1.57	1.67	N/R	1.84
131	1.58	1.68	N/R	1.84
66	1.60	1.69	N/R	1.86
49	1.60	1.70	N/R	1.87
33	1.62	1.72	N/R	1.88
16	1.67	1.77	N/R	1.93

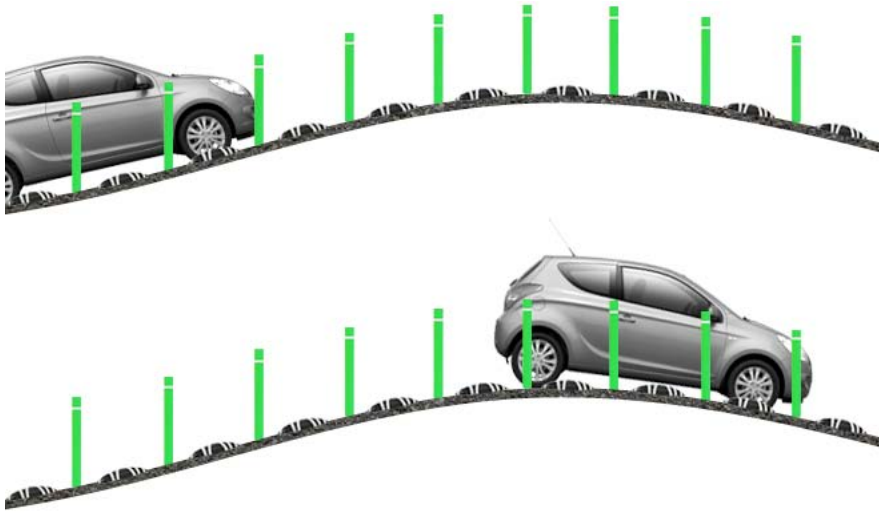
6.3.1 Bollards at roundabouts

It is suggested that in areas where additional segregation may be beneficial, such as roundabouts, bollards can be placed between the ZEBRA separators.

It is not necessary to install a bollard between each ZEBRA separator; one bollard for every two or three ZEBRA separators should be sufficient.

6.3.2. Bollards for changes in gradient

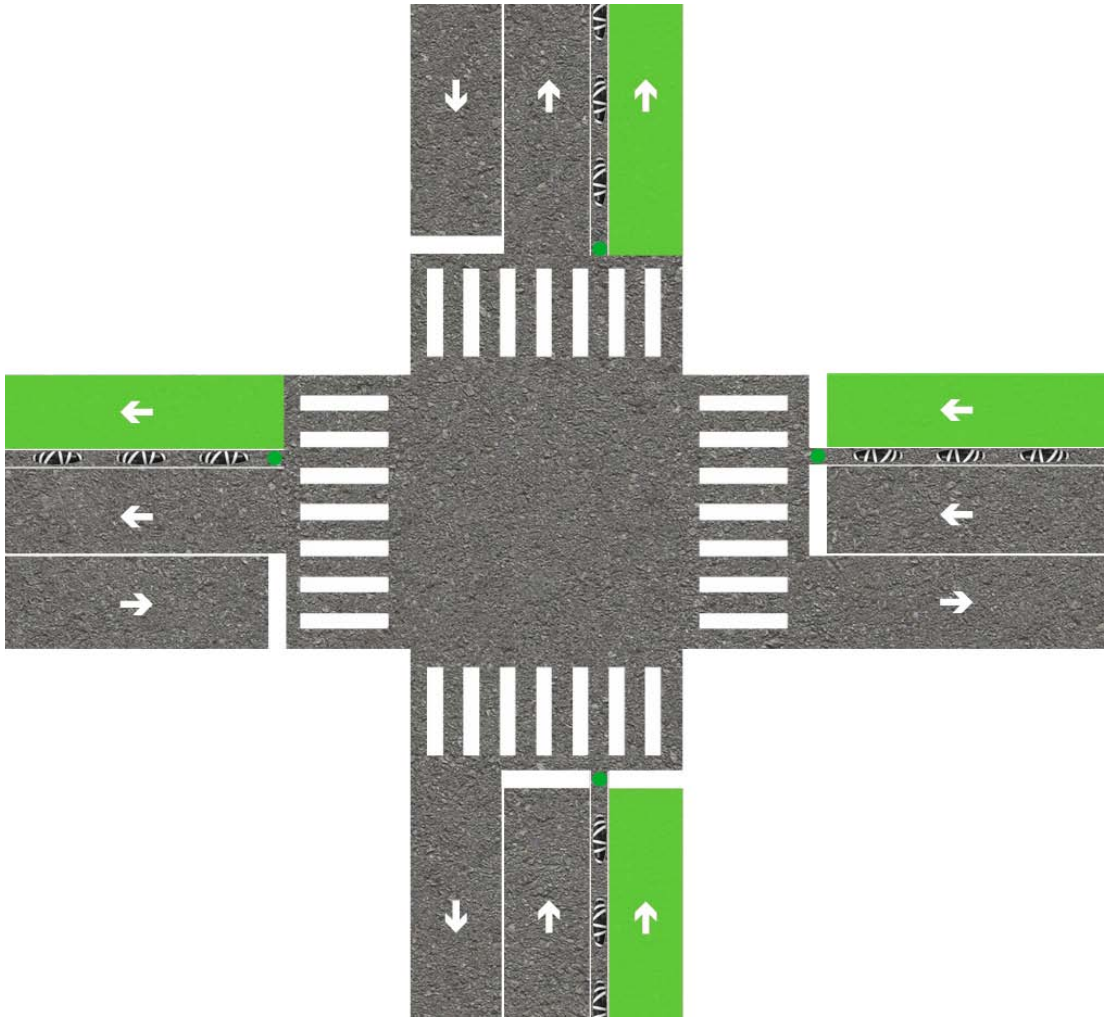
On hills with limited visibility, it is recommended to install bollards to overcome this obstacle. The ZEBRA elements on the other side of the vertical transition are not visible to the car in the diagram. The placement of bollards is essential to maintain the proper level of safety in the cycle lane.



6.3.3. Bollards at beginning of cycle lane

Bollards should also be installed at junctions where turns are allowed and there is little space for the merging of the cycle lane in order to warn drivers and avoid accidental invasion of the cycle lane.

It is important that bollards placed at junctions do not interfere with the flow of traffic, as a ZEBRA separation element or the bollard itself would be overly exposed.



6.4.1. Parallel parking

To enhance the safety of cyclists using cycle lanes separated from the traffic lane by a line of parallel parking, it is recommended to:

A Install a line of ZEBRA separators between the chosen separation element and the line of parked vehicles. These elements should not be placed as an angle, as they are used as a parking guide.

B Install bollards at the edge of the cycle lane to avoid car doors invading the lane.

The ZEBRA separators should be installed parallel to the wheels of the parked vehicles, and bollards should be placed in such a way as to permit the opening of car doors.

It is possible in these cases to increase the separation between road markings, although it may not exceed the following upper and lower limits:

A The lower limit is as shown in section 6.2.2, using the lower category of traffic conditions plus the diameter of the bollard.

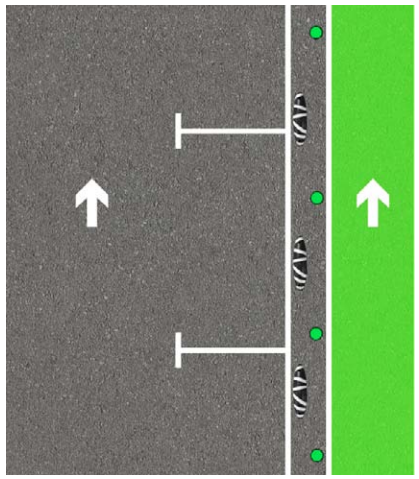
B The upper limit is established at 3.3 feet.

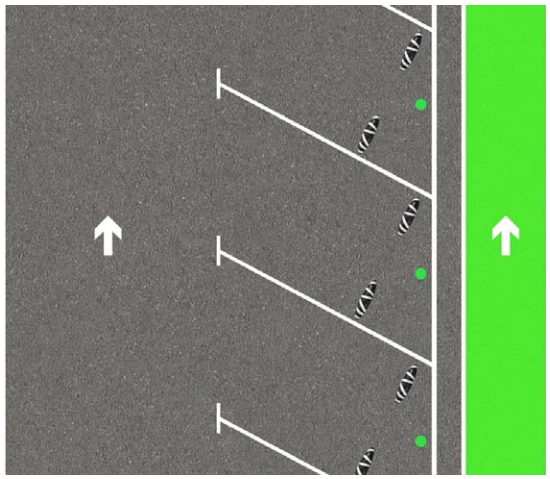
6.4.2. Angled parking

In angled parking areas, ZEBRA separators can be used as wedges to avoid vehicles invading the cycle lane (recommended: ZEBRA 13).

An additional precautionary measure is to install a bollard at the end of each parking space to avoid that cars entering the parking space too quickly can lose sight of the far edge.

It is also recommend positioning angled parking spaces in such a way that the driver is required to back into the space, providing greater visibility when pulling out.

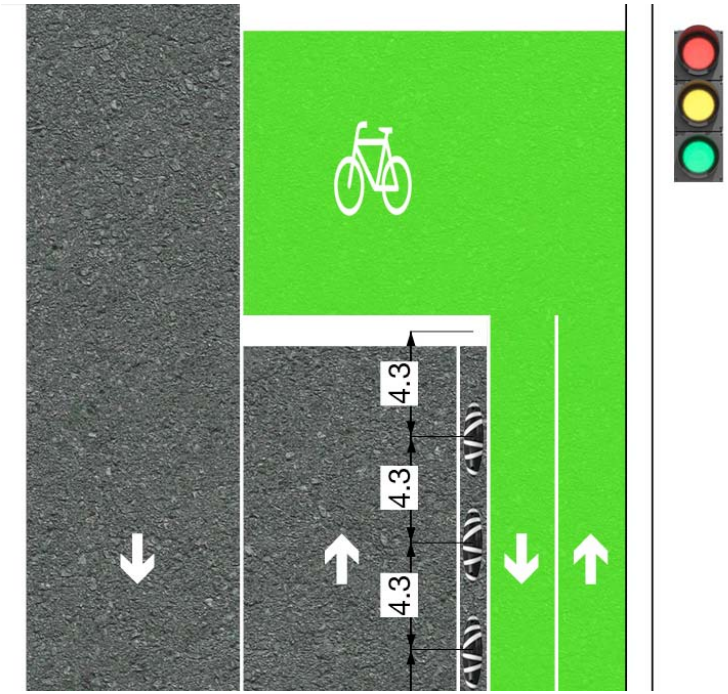




6.5.1. Advanced stop lines (ASL)

Another safety element is the installation of advanced stop lines (or ASL boxes) for bicycles so motorised vehicle drivers can easily detect their presence. It also allows bicycles to make a left turn without crossing paths with motor vehicles.

For optimum safety, two separate ASL boxes may be installed: the first one for bicycles and a second one behind it for motorcycles and mopeds.

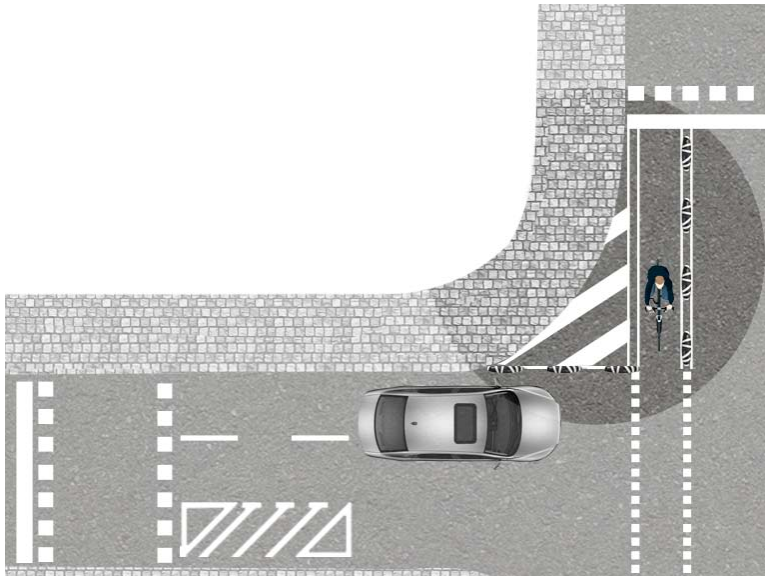


6.5.2. Shelters

A shelter is a stopping point for bicycles on the road which, in its original configuration, would remain exposed to vehicular road traffic that is going to turn.

In areas where bicycles are at risk of being intercepted by motor vehicles, it is suggested to create a shelter through the installation of ZEBRA separators, as shown in the figure.

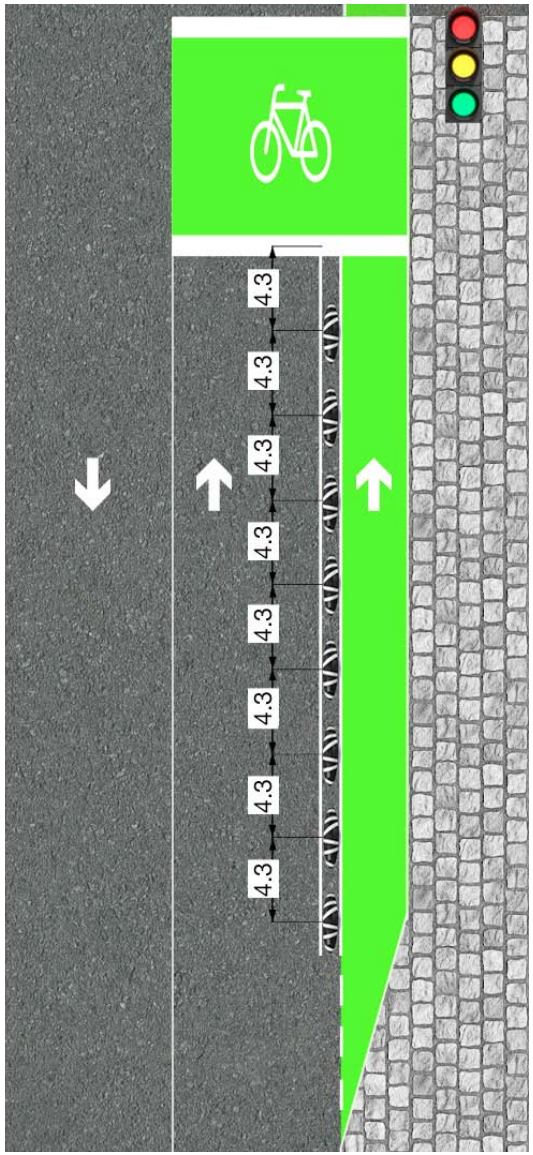
Areas of risk where stopped bicycles could potentially be intercepted by other vehicles should be identified at each junction.



6.5.3. ASL Feeder lane

For road designs that are unable to accommodate a continuous cycle lane, feeder lanes may be added as an additional safety measure to facilitate the flow of cyclists.

Feeder lanes are short access lanes located at junctions regulated by traffic signals at the verge of the road. They provide access to the ASL box and avoid cycles having to negotiate through vehicle traffic.



6.6 Bus stops

At and near bus stops it is recommended to install a raised pedestrian crossing area which creates an area of conflict between pedestrians and cyclists, where cyclists do not have the right of way.

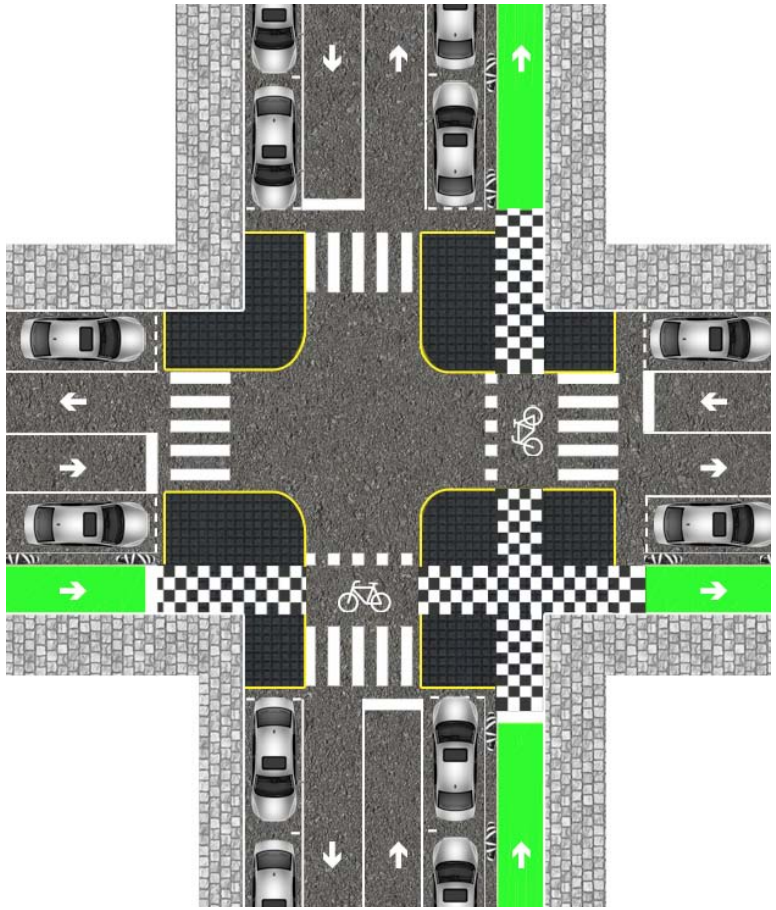
This crossing area should be reserved exclusively for bus access purposes, leaving the existing bus shelter on the pavement. Other solutions may be possible for placement of the bus shelter.

Ramps should be installed to resolve the conflict in the shared pedestrian-cyclist area, and road markings should indicate that cyclists must give way.

Checkerboard markings may be painted on the road to advise cyclists that they must give way to pedestrians. Give way signs for cyclists may also be painted on the road as an additional precaution (see 6.8).

6.7. Waiting areas

Waiting areas are an element of road safety. They serve a dual purpose, which is to protect pedestrian crossings or crosswalks from the invasion of parked vehicles and to increase visibility of both crosswalk users and oncoming vehicles.

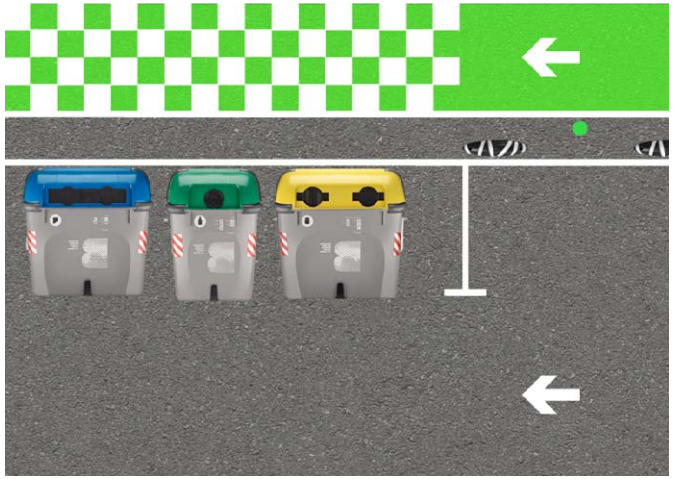


6.8. Pedestrian access to services

ZEBRA separators should also not be installed in service access areas in order to facilitate pedestrian accessibility and avoid unnecessary costs for the client.

Checkerboard markings may be painted on the road to advise cyclists that they must give way in areas of service access. Give way signs for cyclists may also be painted in the cycle lane as an additional precaution.

This road mark is originated in Barcelona and is used in zones where the yield zone is not continued to other (such as from cars to pedestrians). This kind of road mark may be really useful where in specific narrow bike lanes both crossroad with zebra crossing or transversal delimitation might be not enough due to the narrow and long of the whole yield zone.



6.9. “Keep Clear” markings

Lateral vehicular access areas or driveways have similar issues as junctions. As an access where vehicles may be turning, we should first identify the type of vehicle that will normally be using the driveway, whether passenger vehicles or heavy vehicles such as lorries. This will help us to determine the space that should be kept clear. This point is of particular importance when the vehicular access point is located in an industrial park or area of heavy vehicle transit: lorries, road trains, etc.

Typically, an area equal to the width of the cycle lane (cross-section), as a minimum, should be left free on either side of the vehicle access point, with no ZEBRA elements which might impede the access of vehicles.

6.10. Segregation of cycle lanes on pavement

ZEBRA separators should also not be installed in service access areas in order to facilitate pedestrian accessibility and avoid unnecessary costs for the client.

Checkerboard markings may be painted on the road to advise cyclists that they must give way in areas of service access. Give way signs for cyclists may also be painted in the cycle lane as an additional precaution.

This road mark is originated in Barcelona and is used in zones where the yield zone is not continued to other (such as from cars to pedestrians). This kind of road mark may be really useful where in specific narrow bike lanes both crossroad with zebra crossing or transversal delimitation might be not enough due to the narrow and long of the whole yield zone.

7. Installation process

7.1. Anchor system

Proper installation of ZEBRA separators is essential for guaranteeing durability and fulfilment of the element's function, so it is therefore important to select the proper anchors and resin for installation.

A series of mechanical criteria must be considered before selecting the proper anchor. Separation elements must withstand the impact and friction of vehicles. As the separators are anchored to the pavement, load weight is transferred to the ground through these bolts, making it essential for both the fasteners and the road surface to be able to absorb these strains.

ZICLA's experience, after having installed more than 50,000 ZEBRA cycle lane separator elements between 2008 and 2014, has shown that chemical anchors offer better results, regardless of the type of pavement or road surface and the conditions it is in. Expanding metal anchor bolts, on the other hand, are only suitable for concrete surfaces.

Plastic mechanical anchors offered poor results in nearly all instances.

Anchor technology has reached a sufficient point of development to provide a solution to any anchoring need under any conditions. Anchor bolts are available in a wide variety of models and prices.

7.1.1. Mechanical anchors

Mechanical anchor bolts are not recommended for bituminous pavements, as this type of surface is more easily deformed by temperature fluctuation, which can lead to a loss of friction on the outer surface of the anchor assembly and a subsequent loss of efficiency.

Top results have been observed from multiple expansion anchor assemblies made of galvanised steel. The condition of the pavement and the degree of cracking must be considered when making the final choice of anchor assembly.

The threaded rod must measure at least 12 mm in diameter in order to withstand the ordinary dynamic weight of an average vehicle. However, if the road has a high level of heavy vehicle traffic, or if the accident rate on urban roads is high, it is recommended to increase the diameter of the rod to 14, or even 16 mm. The ZEBRA separator can accommodate various anchor rod diameters.

Rods must be at least 4 inches in length, with 2 inches inside the separator and the remaining 2 inches below the pavement. If the road surface is in less-than- optimum conditions, it is recommendable to use longer bolts. This is also the case if the road surface is not reinforced.

7.1.2. Chemical anchors

Chemical anchor design consists of a minimum 12 mm threaded bolt with an M12 hex nut, and is installed using an epoxy, polyester or styrene-free resin. These types of resin have been shown to perform well in all weather conditions. It is suggested to use a styrene-free resin because styrene emits a strong odour and may be toxic if inhaled deeply.

Chemical anchor bolts require special attention in two areas. (1) Both the bolts and the holes where they are to be inserted must be clean and free of debris; and (2) Resin curing time varies according to meteorological conditions. The resin manufacturer's instruction manual should provide information on this point, and it is always recommended to consult the manufacturer's technical safety data sheet before use.

Anchor rod assemblies should be grade 5.8 steel or higher, with a minimum 5 µm galvanized plating. Rods must be at least 6 in. in length, with 2 in. inside the separator and the remaining 4 in. below the pavement. For concrete surfaces, the anchor may be shorter, but not less than 2 in.

The threaded rod must measure at least 12 mm in diameter in order to withstand the ordinary dynamic weight of an average vehicle. However, if the road has a high level of heavy vehicle traffic, or if the accident rate on urban roads is high, it is recommended to increase the diameter of the rod to 14, or even 16 mm. The ZEBRA separator can accommodate various anchor rod diameters.

For further information, it is recommended consulting the following anchor system manufacturers:

www.hilti.com
www.indexfix.com/en
www.spit.com

7.2. Roadwork signage and execution

The roadwork required for installation requires special signage.

Signage should be put in place at least one week in advance to indicate the amount of time the roadway will be occupied and to prohibit parking (and stopping) during this period. Where possible, traffic in the work area should be stopped entirely as a safety measure for workers. If this is not possible, the work area should be blocked off with the largest separation elements possible.

Also where possible, a traffic officer should direct traffic that has not been diverted in order to avoid accidents. Users should not be overwhelmed by excessive signage, but basic signage and protection must be provided.

Manual with examples of fixed roadwork signage:

http://www.fomento.gob.es/AZ.BBMF.Web/documentacion/pdf/RE2037.pdf

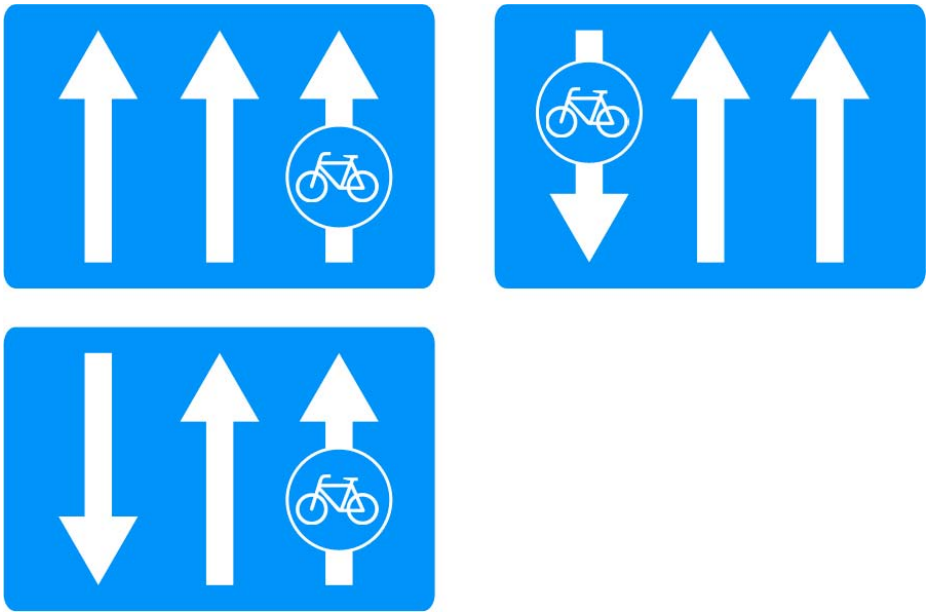
A question that often arises is when separation elements should be installed: before or after road markings.

Experience has shown that road markings should be painted prior to installing separation elements. This will provide an initial idea of the final distribution of lane widths, and the end result will be cleaner (i.e. road painting equipment will not have to negotiate obstacles, and separation elements will not accidentally get painted).

7.3. Acclimatisation period

In areas where ZEBRA elements are a new presence as lane separators on carriageways, it may be necessary to apply special measures to get users used to their presence.

This should be taken into consideration particularly in areas of swift driving, non-laminar traffic flow and, in particular, where bicycle presence is a minority.



8. Maintenance

8.1 Introduction to maintenance. Effective life

Preventive maintenance should begin during the cycle lane design stage, with the aim of extending the effective life of ZEBRA separators. The basic points to bear in mind are:

A Reduce overexposure of separation elements, allowing for user routes, speed, traffic intensity, etc. Chapter 5 discusses areas where ZEBRA sepa- rators should ideally not be installed

B Select the most appropriate model of the ZEBRA separation element for each case

Highly exposed areas tend to be those at the beginning of segregated areas and in areas near turns. In these areas, damage to elements may be more evident and/ or frequent.

The need to replace an element more than once a year may indicate a defective design in the layout of the lane or in the placement and installation of the ZEBRA element.

Heavy vehicles (in general, > 3.5 ton MAM) behave quite differently from other vehicles. When manoeuvring the vehicle, the driver may not notice a collision with ZEBRA separators, even the largest ones.

In these areas it will be necessary to provide for:

A A higher level and frequency of maintenance for ZEBRA separators, e.g. repaint reflective strips

B Reduced separation between ZEBRA separators C More frequent substitution of elements

C More frequent substitution of elements

The effective life of ZEBRA separators under normal conditions, is more than 6 years. The first installation of zebra was in 2008. At present time, this installation still working good.

8.2 Replacement following temporary removal

At times it may be necessary to temporarily remove ZEBRA separators. Some of the most frequent reasons are:

A Special events being held on public roadways B Repainting of road markings.

B Repainting of road markings.

C Repair of adjacent road surfaces.

D Thorough cleaning of the public roadway.

The removal of elements requires the same precautions as for installation, as regards pre- cautionary signage for road users that roadwork is taking place.

Warning signs should take account of both motorised traffic and users of the separated lane.

Removal and re-installation may require repositioning of some elements, such as anchor bolts, caps, and occasionally a separator that may have become damaged.

8.3 Road resurfacing

Road resurfacing requires a careful study of the situation.

ZEBRA separators must be removed, along with anchor bolts and fixtures. If the road is to be repaved without removing the ZEBRA separators, the elements should be covered prior to paving.

If ZEBRA separators are not removed and the height of the pavement or tarmac is to remain even throughout, the pavement must be milled prior to resurfacing. For this we will need equipment which does not exceed the width of the cycle lane.

If the entire roadway is going to be milled and resurfaced, it is advisable to remove anchor systems to avoid damage to road milling equipment, as well as for possible reuse.

8.4 Breakage and striations. Removal of ZEBRA separators

Breakage is a normal wear-and-tear process of ZEBRA separators. Wear and tear of these elements can reveal two factors:

A The element does not separate from the road surface, nor does it wobble (i.e. it is properly anchored), it remains in place (it does not need to be replaced immediately), and it does not break or crack (meaning it can continue to absorb energy from subsequent impacts)

B This shows that the element is fulfilling its function

This type of wear and tear avoids exposure of anchor elements.

The piece continues to fulfil its function as long as the reflective strips continue to be visible in low light and the anchor system is not exposed. If either of these conditions is not fulfilled, the element should be repainted or replaced.

If a ZEBRA element has been completely pulled out, it must be considered:

A The way in which the anchor bolts have been pulled out

B If there are bits of pavement lodged in the anchor system

If an element has been fully pulled out, anchor bolts and all, the element has not been properly anchored to the ground. This may be due to the use of an improper bolt size or type of anchor.

9. Glossary

20 mph zones: Road or group of roads for which, due to their typology, the local government (or other competent authority) has decided to apply a series of traffic rules for users such as a speed limit of 20 mph, right of way for pedestrians or cyclists, parking limitations or restrictions, etc.

ADI: Average daily intensity. Estimated number of vehicles that goes through a section of a street in a day.

Advanced stop box: In areas near junctions, and just before arriving at one, two stop lines may be painted on the pavement, separated by a free area designated for the use of bicycles, mopeds and/or motorcycles. All other motorised vehicles must remain behind the second stop line. This area is referred to as an advanced stop box. Ideally, three stop lines can be painted such that the first two create an advanced stop box for the exclusive use of bicycles, and the second for mopeds and motorcycles.

Advanced stop line (ASL) feeder lane: Small access points located at the side of the road when approaching junctions regulated by traffic signals which allow cycles, mopeds and/or motorcycles to access the advanced stop line, thus reducing the hazards involved when negotiating vehicles.

AHI: Average hourly intensity. Estimated number of vehicles that goes through a section of a street at the hour being studied.

Average length of queue: Weighted average distance derived from the maximum length of all vehicle queues at junctions, whether regulated by traffic lights or fixed vertical signage.

Bollard: Vertical signage element. Cylindrical column, general painted red or green, with two white reflective bands near the top. They act as light segregation from adjacent traffic flow.

Chemical anchors: Element fasteners that rely on a structural chemical bond based generally on a single or dual component resin.

Conflict area: Area on the road where the paths of various groups of users, though not necessarily of different types, meet and intersect, thus requiring a reduction in speed or slight change in direction to continue travelling safely.

Cycle lane: Lane for bicycle (cycle) users, segregated to a large degree from motorised vehicle traffic, except at junctions, access to service bays, etc., and normally installed in the carriageway.

Cycle lane separator: Element of urban furniture, whether continuous such as a kerb, or discontinuous such as ZEBRA separators, which creates greater segregation of the cycle lane from motorised vehicle lanes.

“Keep Clear” area: Area marked off by the local government (or other competent authority) where parking is not allowed; this is generally an access to a garage or similar.

Mechanical anchors: Element fasteners that utilize friction to obtain holding values.

Mechanical resistance: Resistance to crushing, tearing and bending.

Raised crossing area: Structure installed on the roadway as an extension of the pavement to facilitate pedestrian crossing, normally used to access buses that stop away from the pavement in city centres.

Reflective material: Material which reflects part or all of incidental light.

Roadway markings: Horizontal signage element. Painted indications on the pavement, generally white to contrast with the dark asphalt, or yellow in areas where roadwork is being performed. Painted indications on the pavement alert users to the limits of traffic and cycle lanes, entry and no entry areas, speed limits, give way, etc.

Segregated escape lane: Area of the road which allows cyclists to leave the road, and where vehicle traffic cannot enter.

Shelter: Stopping point for bicycles on the road which, in its original configuration, would remain exposed to vehicular road traffic that is going to turn.

Vertical transition: Transition curve on a roadway so that changes in gradient are protected and safe. They are generally in the form of a parabola.

Waiting area: Elevated platform installed in the roadway to enhance road safety. It serves a dual purpose, which is to protect pedestrian crossings or crosswalks from the invasion of vehicles that are going to park, and increase visibility of both crosswalk users and oncoming vehicles.