पुणे सायकल प्लान
Pune Cycle Plan

(पुणे महानगरपालिका)

DECEMBER, 2017

URBAN CYCLING DESIGN GUIDELINES (UCDG)

iTrans

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1. Introduction

The CBP (Comprehensive Bicycle Plan for Pune) is a masterplan that provides information about the kind of cycling infrastructure that is needed at each road of the road network, but does not provide detailed designs for roads. These design guidelines are not a complete cycling design manual, but provide concise guidance for a proper design of cycling infrastructure in Pune. Existing cycling infrastructure in Pune, is of such quality that the majority of cycle tracks is barely used by cyclists. These guidelines, therefore, include a focus on some of the typical challenges for the design of cycle tracks (and lanes) in Pune with the objective to increase cycling-infrastructure usage and cycling in the city.

These guidelines should be seen as a more detailed specification of the Urban Street Design Guidelines. Regarding cycle track design, the USDG is very short and without a lot of specific guidance on dimensions or design details. These design guidelines aim to fill those gaps. On the other hand, the USDG provides many cross-sections for different roads with different right of way. These design guidelines, however, provide design principles that can then be applied at different roads.

Above all, these design guidelines are meant to be a tool to assist consultants in the design of good quality cycling infrastructure. Like any manual or guidelines, they are not a replacement for expertise and should, in time, be accompanied by proper capacity building to consultants who will use these guidelines.

This document has been prepared and complied by JB Mobility and PDA in close cooperation with CEE and iTrans.

2. Cycling-inclusive planning and design

2.1 Introduction

To make cycling safer and more attractive, much more needs to be done than providing cycle tracks and cycle lanes. In the case of Pune and other Indian cities, there are many aspects of road planning and design that discourage cycling and make it less safe. Cycling-inclusive planning and design makes cycling more attractive and safer. Underneath a number of key cycling-inclusive planning and design measures are explained together with references to the less cycling-inclusive practices today. Cycling-inclusive planning and design is essential to enable Pune to reach its ambitious targets for cycling (25% of journeys) which have only been met in (European) cities that have implemented all of the following cycling-inclusive planning and design measures.

2.2 Demotorization of the core city

Car-free city-centres

One of the factors that has contributed enormously in making cycling a success in the world's most cycling-friendly cities (for instance in the Netherlands or Denmark) is the development of car-free city-centres. By closing off, or severely limiting access to these areas a situation is created where cycling (and public transport) becomes a more attractive mode of transport to reach the city-centre than the car. Experience in many European cities show that the creation of bicycle and pedestrian-friendly city-centres with limited access for motorised vehicles has many advantages:

- The quality of life improves and real-estate prices go up.
- Tourism flourishes. This leads to more spending in hotels, restaurants and shops in the city-centre.
- Air quality improves and accident rates drop drastically.

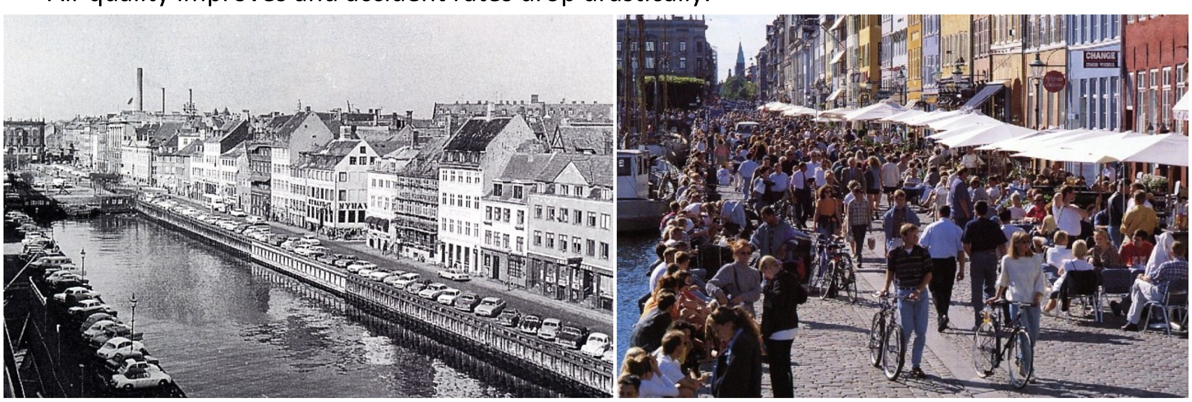

Fig. 2.1 De-motorization of 'Nyhavn' in Copenhagen has led to a flourishing local economy and increased spending by tourists and visitors of the city (Left: 1970, Right: present situation)

Decongestion

Experiences in countless cities in Europe and elsewhere show that the most successful measures in reducing congestion in a city are to make it impossible to cross the city-centre by making certain streets and areas in the city-centre car-free. The figure below explains this clearly:

1. Picture on the left: While streets in the city-centre are often narrow, they attract the greatest amount of traffic (see picture on the left) and thus are subject to serious congestion. Also in Pune, the combination of a lot of through traffic and many people that want to access the many destinations in the core city, leads to serious congestion in the core city.
2. Picture on the right: By taking out through traffic and make city-centre streets pedestrian and cycling-only streets (as has been done in cities in The Netherlands, Denmark, Germany , France and many other countries since the 1970's) traffic volumes reduce significantly and congestion improves.

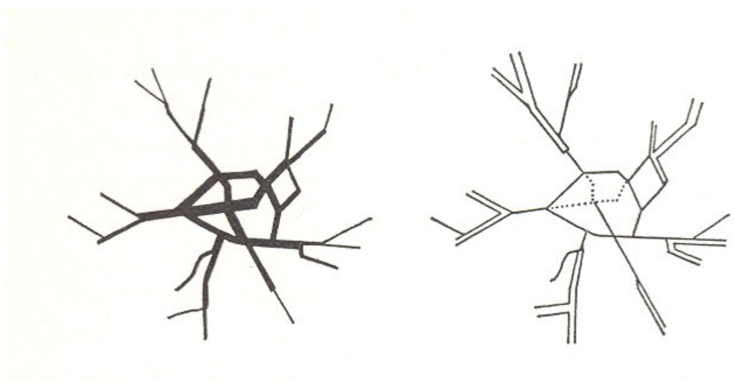

Fig. 2.2 Congested city with city-centre open for motorised traffic (left) and decongested car-free city-centre

De-motorization of the core city of Pune

The only way to resolve the congestion in and improve the livability of the core city is to make, at least certain streets in the core city, car and motor cycle free to remove through traffic from the core city. Countless cities in Europe and the United States saw the economies of their inner cities dying because of congestion and pollution and discovered that only de-motorization helped to bring back businesses, residents and clients.

For a successful de-motorization of the core city the following needs to be done:

- Create an inner ring road around the core city.
- Make it impossible to cross the core city by car or motorcycle by creating streets that are only open to non-motorized transport in such a way that cars and motorcycles cannot cross the core city, but instead go around it by using the inner ring road (see figure below).
- Create a parking plan and policy that requires all visitors with motor vehicles to pay for parking (see section 2.3).

The figure below shows the de-motorization of the city-centre of the city of Groningen.

Fig. 2.3 The yellow streets in the Dutch city of Groningen are car- (and motorcycle) free.

Inside Groningen more than 50% of all journeys is done by bicycle

Challenges for Pune Core city

A challenge for Pune is the high motorcycle use. It is probably neither possible nor necessary to ban these in the majority of the core city. However, creating a limited amount of streets where only non-motorised traffic can pass and which can also not be crossed by cars and auto-rickshaws is recommended. One of these streets, as proposed in the Comprehensive Mobility Plan (CMP) could be Lakshmi Road, which is an excellent choice to start the de-motorization of the core city.

Auto-rickshaws can easily be kept out of certain de-motorized areas or streets with bollards. Where to allow auto-rickshaws, should be the outcome of a detailed study since auto-rickshaws can play an important role in keeping a de-motorized core city accessible. The same is true for public transport. Clean buses, trams or metros should be able to still cross the core city to allow for maximum accessibility without the use of private motorised vehicles.

2.3 Restrictive parking policies

Between 1990 and 2010 Amsterdam saw cycle trips to the city-centre increase from 15 to 25% of all journeys, mostly at the expense of the car[1].In this period, a relatively lesser number of new cycle tracks to the city-centre were constructed, instead it was particularly an increase of the price of paid parking in the city-centre, that made that more and more visitors came to the city-centre by bicycle instead of by car. Currently (2016), parking a car in the city-centre of Amsterdam costs 5 Euros (Rs. 375) per hour.

Paid parking reduces the demand for motorised trips and makes alternative modes of transport more attractive. In the case of Pune it is essential that both cars and motorcycles pay for parking.

[1] Source: The Netherlands mobility survey and Periodical travel survey Amsterdam

For car-free city-centres - such as shown below, with all streets within the yellow lines being NMT-only streets - parking garages or parking lots with paid parking at the periphery of the demotorized area allow access to the area.

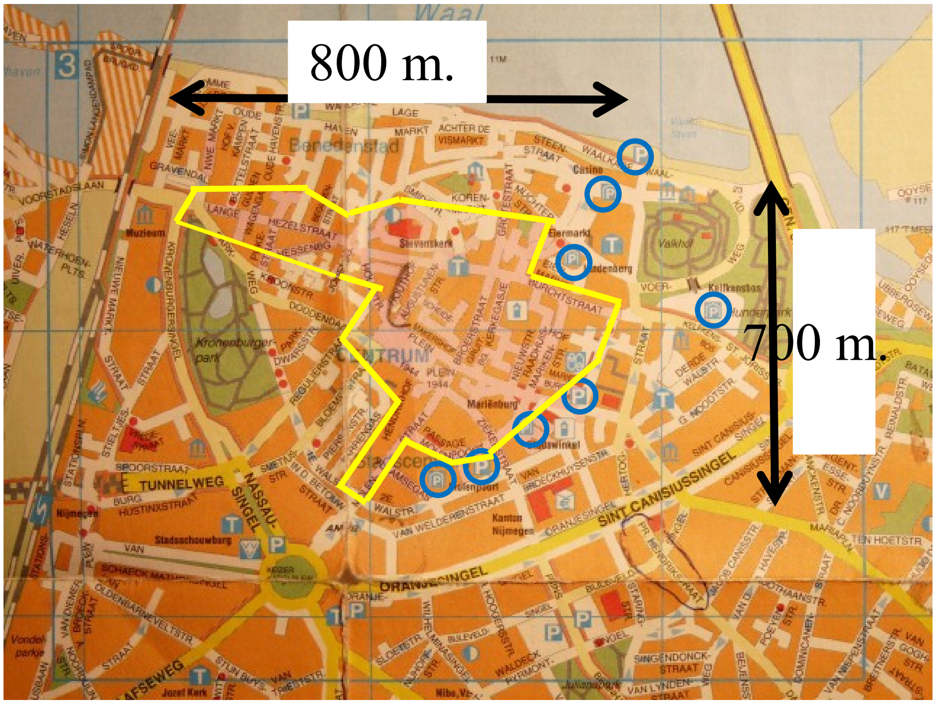

Fig. 2.4 Demotorized city-centre with car parking at the periphery (Nijmegen, The Netherlands)

2.4 Dismantling multi-lane one-way roads

One-way roads with more than one traffic lane per direction (multi-lane one-way roads) are negative for cycling and road safety and should therefore be avoided. Particularly in centrally located areas (such as FC Road and JM Road), a one-way traffic system is not appropriate because of the following reasons:

- **Road safety:**The (maximum) speeds of motorised traffic at one-way roads with more than one lane of traffic increase. This leads to a worsening of the road safety (one of the main problems mentioned in the CMP) particularly for pedestrians and cyclists crossing the road. This means that in highly commercial areas with many pedestrians, one-way roads should be removed.[2]
- **Road safety and directness:**Cyclists still will move (and want to move) in two directions. Even when this is provided for in the designs, cyclists moving against traffic on one-ways creates serious problems at intersections - where motorised traffic has free turns, and where traffic does not stop. This leads to problems for road safety and directness for cyclists. Therefore multi-lane one-way roads should be avoided.

[2] Note that because of road safety problems with cyclists and pedestrians multi-lane one-way roads have been removed everywhere in cities in The Netherlands in the 1970's.

- **Road safety:** For pedestrians and cyclists crossing the road, on one-way roads, traffic does not always come from the same direction like on two ways (where you always look right first). This leads to more accidents with cyclists and pedestrians crossing the street.
- **Road safety and directness:** Right-turns on multi-lane one-way roads are almost impossible to negotiate for cyclists because they need to cross several lanes of fast moving traffic (see photo below).
- **Road safety:** On multi-lane one-way roads application of central traffic islands to make it easier and safer for pedestrians and cyclists to cross cannot (safely) be applied.
- **Directness:** One-way roads lead to detours for motorised traffic and thus more kilometres travelled on urban roads. This also leads to higher traffic volumes at intersections where vehicles would not need to come if they could reach their destination without having to make a loop.

Fig. 2.5 JM Road in Pune: Cyclists that want to turn right here must weave across 4 lanes of traffic

To conclude: One-way roads are an American invention that was meant to 'improve the flow of motorised traffic'. In car-country, the US, with very limited numbers of pedestrians and cyclists, this seemed to work relatively well. However, since the 2000's, because of the negative effects for cycling, walking and road safety, many cities in the US are also changing their one-way streets back to two-way streets.[3]

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[3]See the article ***One Way? Wrong Way?*** here: http://articles.courant.com/2009-12-27/news/hc-plc-condon-one-way-streets.artdec27_1_two-way-streets-downtown-traffic. Quote: *"Will it be time to remove some or all of the one-ways? That seems to be the trend across the country."*

Recommendations:

As mentioned above, multi-lane one-way roads should be avoided in urban areas. This leads to the following recommendations for design on existing one-way roads:

- At one-way roads with more than 2 traffic lanes, such as in figure 2.5, it is recommended to convert the road into a two-way road with - depending on connectivity needs for cyclists - in most cases one-way cycle tracks (or in some cases lanes) on either side of the carriageway.
- On one-way roads with two traffic lanes (5.00-8.00 m. carriageway width), there are two options:
    1. Remove one lane and provide cycling infrastructure using the available extra space, as is done in fig. 2.6.
    2. Keep both lanes and make the road two-way. This allows for shared use of the road in two directions. Of course, in some cases, enough space is available to still provide cycle tracks or cycle lanes at either side of the carriageway.

Fig. 2.6 One-way, one lane road with two-way cycle track (this road used to have two traffic lanes)

It is, of course, possible to provide cycle tracks even on multi-lane one-way roads. In this case one-way cycle tracks on either side, or a one-way cycle track on one side of the road is possible. However, such a solution creates serious road safety and traffic flow problems at intersections and should therefore be avoided at all costs. The construction of cycle tracks is a great opportunity to replace an outdated one-way traffic system with a cycling- and pedestrian-inclusive two-way alternative.

Of course, new roads should not be designed as one-way roads. With one exception: In those cases where the one-way road only has one traffic lane as shown in figure 2.6, there is no problem to make the road one-way. On the contrary, this can be a great way to provide space for cycling infrastructure, where otherwise no space would be available.

2.5 Flyovers

2.5.1 Why not to apply flyovers

When promoting cycling, flyovers should not be implemented for the following reasons:

- Flyovers are a short-term measure that in the long-term leads to more traffic and more serious congestion at locations where flyovers are not constructed.
- Flyovers typically start in the centre of the road and thus lead to dangerous weaving manoeuvres for cyclists at busy times when trying to access the flyover. This is because cyclists need to cross lanes of fast moving traffic where traffic lights cannot be placed.
- Cyclists using the flyover would need to ascend which means significant additional effort.
- Speeds on flyovers can be high, therefore flyovers should have cycle tracks. This significantly increases the costs of the flyover and in practice is often not done creating an environment hostile to cycling.
- Cyclists that avoid the climb

Fig. 2.7 A cyclists is accessing a flyover in Pune (Karve Road) when traffic is relatively light.
The application of flyovers is a short-term solution for traffic problems that should be avoided

And finally:

- Flyovers take a lot of space. This leads to situations where it becomes difficult or impossible to create cycle tracks. Fig. 2.8 (with BRT) shows this. On the left side of the road 12.75 m. is available for motorised traffic. This is more than sufficient for three traffic lanes + a cycle track. However, with a lane needed to access the intersecting road, on the left side, there is no space left to create a cycle track here.

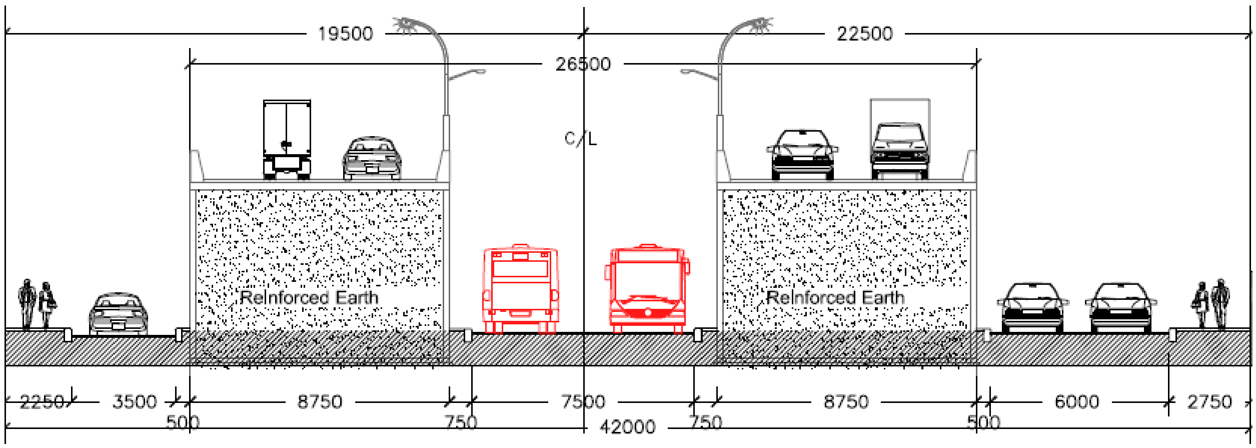


Fig. 2.8 Space taken by flyovers limits the possibilities to provide cycling infrastructure

2.5.2 Approach at existing flyovers

In the case of existing flyovers, something needs to be done to provide at least some cycling infrastructure. Taking fig. 2.8 as an example the following could be done:

- **On the flyover.** Here about 8.00 m. road space is available in each direction. While many cyclists prefer to stay at road level, some cyclists might want to mount the flyover to avoid having to wait for traffic on the cross-road below. Possible design:
  A 2.00 m. raised adjacent cycle track (section 4.2.2) at the left side of the road and two traffic lanes of 3.00 m. each. If available space is less, a 1.75 m. cycle lane (red asphalt with continuous white line) could be applied.
- **Left side.** Here only 5.75 m. in total is available for all modes. This is a pinch point where providing proper cycling infrastructure is not possible. If additional space cannot be created there are some options:
  1. With lesser number of pedestrians: 1.50 m. footpath, 1.50 m. cycle lane (red asphalt), 2.75 m. traffic lane. This entails a widening of the carriageway width to 4.25 m.
  2. With lesser number of pedestrians: Widen the footpath to 2.75 m. and convert this into a shared cycle track / pedestrian footpath.
  3. With many pedestrians: Leave road as is and lead cyclists onto the carriageway, sharing with motorised traffic.
- **Right side.** Here 6.00 m. of carriageway is available. Because this is only used by vehicles accessing the main road from the crossroad, the carriageway can be reduced to one traffic lane only - like at the left side of the flyovers. The design could then look as follows:
  3.25 m. carriageway, 0.75 m. dividing verge (see table 4.2, option 5, section 4.2.5), 2.00 m. one-way cycle track. This, unlike the proposed designs above, is appropriate cycling infrastructure.

Fig. 2.9 on the next page show how this looks likes. Cyclist will weave across one MV lane from the left cycle lane to the central cycle lane that leads onto the flyover. This weaving area should be at least 30 m. long.

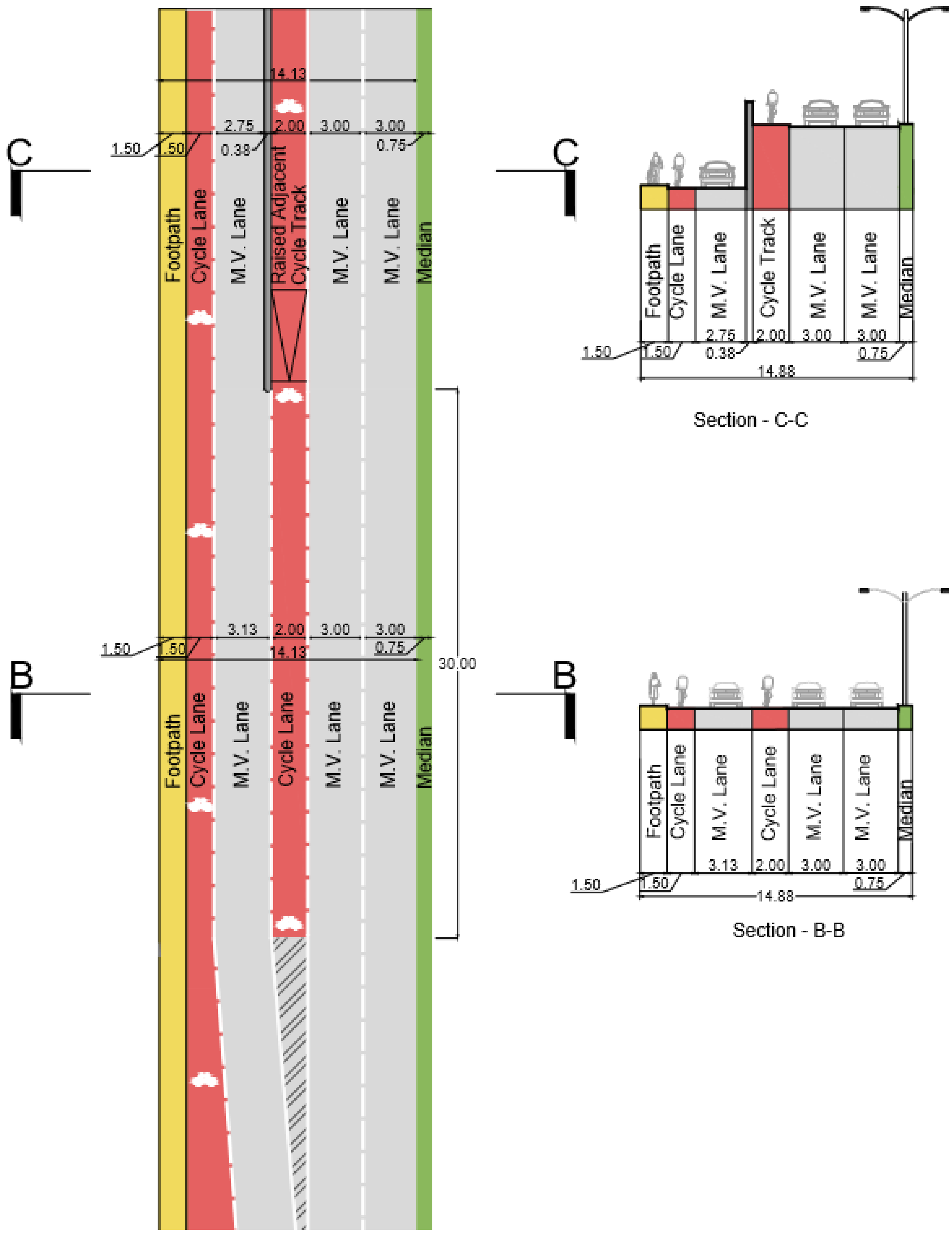


Fig. 2.9 Possible approach to the existing flyover of fig. 2.8. (Note that a wider cycle lane of 1.80 m. is preferred (see section 4.3). A 1.50 m. cycle lane is proposed because of a lack of space.)

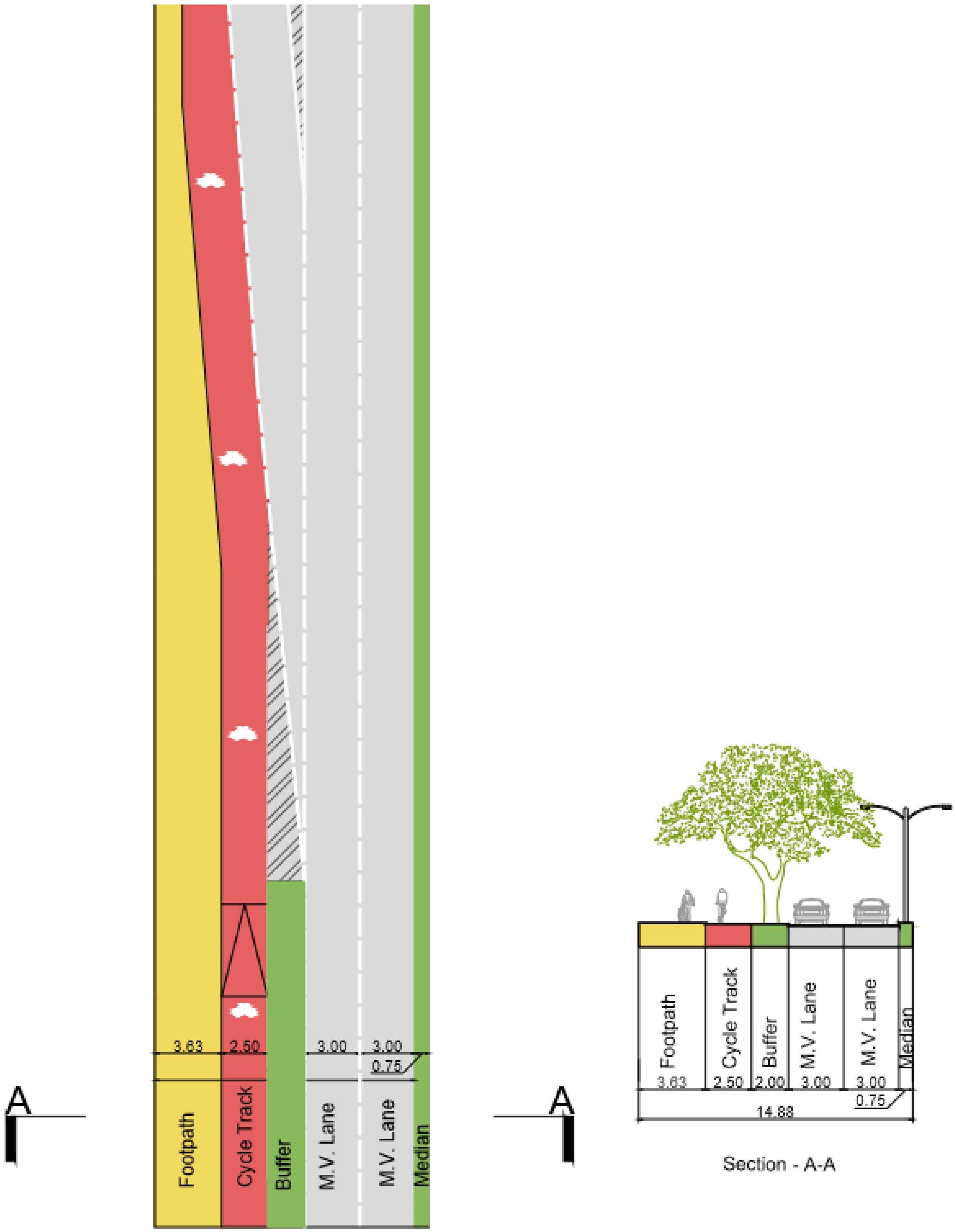


Fig. 2.10 MV lane exiting the main carriageway. The cycle track converts into a cycle lane which allows cyclists to leave the cycling facility and enter onto the flyover (see fig. 2.9).

2.5.3 Approach at new flyovers

As mentioned above, the construction of new flyovers should be avoided. However, if projects are underway or cannot be stopped anymore, it is important to include proper cycling infrastructure as described below.

Traffic lanes entering and leaving the main road

- Typically: One lane of MV traffic only (since most traffic will go over the flyover)
- Apply segregated cycle track with verge as per section 4.2.
- When there is only 1 traffic lane adjacent to the cycle track it is acceptable, even on an arterial road, to apply a 2.00 m. width for a one-way cycle track with a verge of 1.00 m.

Crossing the road under the flyover

A question here is how easy it is to cross the cross-road under the flyover. In many cases, because motorised traffic is generally not crossing here (they'll use the flyover), crossing the road for cyclists is very difficult. It is therefore recommended to provide a traffic island in the crossroad to provide a safe refuge for cyclists. In case there are traffic lights, adapting them in such a way that cyclists can use them to safely cross the road is also recommended.

On the flyover

It depends how easy it is to cross the crossroad and how steep and how high the climb over the flyover is, whether cyclists will prefer to cycle over the flyover. However, on flyovers at 1 level height (up to 5 or 6 metres), at least some cycling infrastructure is recommended. In case it is very difficult or impossible (e.g. the flyover crosses a rail track) it is recommended to also apply a footpath. Because low volumes of cyclists and pedestrians can be expected a 1.50 m. footpath and a 2.00 - 2.20 m. wide one-way cycle track on each side with a verge of 0.50 m. is sufficient. If needed the verge can be narrowed further because no pedestrians will cross here, and no vehicles will stop. But the cycle tracks should not be narrowed further. This is because of the speed differences uphill that should allow for overtaking - slow and faster cyclists - and the high speeds downhill that also require sufficient width.

Note that accessing a flyover by bicycle, see fig. 2.7, can be difficult because a continuous flow of traffic needs to be negotiated. However, if only one lane is passing the flyover on the left, it is much easier to access the flyover.

3. Main requirements for cycling-infrastructure planning and design

3.1 Introduction and characteristics of cyclists

Cyclists, like other road users, have certain requirements. Five main requirements can be distinguished to guarantee cycle-friendly infrastructure. These requirements should be met as good as possible and can be used to:

- Properly design cycling infrastructure.
- Evaluate cycling infrastructure designs before implementation.
- Evaluate cycling infrastructure after implementation.

Each of the five requirements need to be met at network level, road section level, intersection level and road surface level. Below each of the five requirements are explained one by one.

3.2 Coherence

Coherence: Cycling infrastructure forms a coherent and recognizable whole.
Criteria: Ease of finding; freedom of route choice; continuity of routes; consistency of quality; completeness of the network.

3.2.1 Coherence at network level

Coherence is important at network level. A coherent network allows cyclists to make their whole journey on cycle-friendly infrastructure. Missing links - locations where cycling infrastructure does not connect or is not provided - lead to a less complete and coherent network.

3.2.3 Coherence at road section level

Coherent cycling infrastructure provides continuity along the whole road section without disturbance by trees, lamp posts, bus stops or other obstacles.

Fig. 3.1 No continuity of cycle track at bus stop (Ganeshkind Road)

3.2.4 Coherence at intersection level

Consistency of quality: Cycle tracks should be clearly marked across intersections. At side roads along main roads this can be emphasized with a different colour road surface as shown below:

Fig. 3.2 Coherence at intersection level: cycle track is clearly marked across the intersection

3.3 Directness

Directness: Cycling infrastructure offers direct routes with minimal delays and detours. *Criteria:* Detour distance; cycling speed; delay (time).

Because cycling is a relatively slow mode of transport and cycling takes significant effort, cyclists - more even than motor cyclists - want to stop as little as possible and try to avoid any possible detours or delays. In Pune the following can be done to improve the directness for cycling:

- Provide a smooth **road surface** on cycle tracks (preferably asphalt) rather than interlocking pavement blocks (cycling speed) and ensure proper maintenance of cycle tracks.
- Avoid or dismantle multilane **one-way streets**. These streets force cyclists to make detours. Even if contraflow cycle tracks are provided one-way systems make it difficult for cyclists to cross (continuous flow of traffic) and lead to longer waiting times.

Other measures to improve directness:

- Make **intersections** as compact as possible and reduce signal cycle times (preferably not more than 90 seconds)
- Make cycle tracks **wide enough** and without obstacles that affect the continuity and flow of cycle traffic.

3.4 Road Safety

Road safety: Cycling infrastructure guarantees the safety of cyclists and other road users. *Criteria:* Chance of encounter with motorized traffic; complexity of riding; subjective road safety.

Road safety is one of the most important and complex requirements for cycling. Therefore we pay extra attention to this requirement. Good road safety should be created at network level, road section level, intersection level and road surface level as explained below.

3.4.1 Road safety at network level:

Chance of encounter with motorised traffic

The number of conflict points with motorised traffic should be as small as possible.

- Avoid encounters with heavy flows of fast moving traffic. This can be done for instance by leading motorised through-traffic around city-centres and residential areas, rather than through these areas.
- Limit the number of side roads and crossings with motorised traffic.

Figure 3.3, below, illustrates one way how the number of encounters with motorised traffic can be minimised. Figure 3.3a shows the current situation in Pune with through-traffic going through the heart of the core city, thus leading to the necessity for cyclists (and other road users) to cross busy roads in the central area of the city.

This leads to higher rates of traffic accidents. Figure 3.3b is the solution at network level to lead traffic around the city-centre and thus significantly improve road-safety inside of the city-centre.

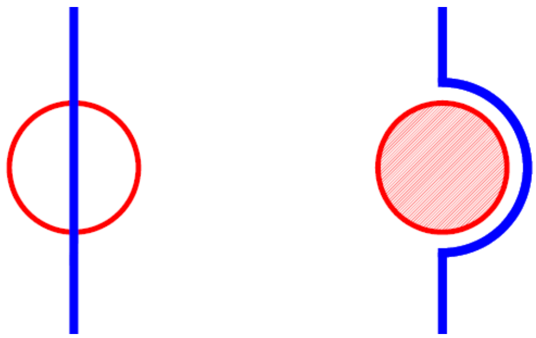


Fig. 3.3 Road safety problems resulting from traffic going through the city centre (left) are resolved by leading all through-traffic around the city-centre (right).

3.4.2 Road safety at road section level

At road section level the following criteria are important:

Time and length of encounter with motorised traffic

- Limit the part of the trip where conflicts with motorised traffic are possible. This can be done, for instance, by applying segregated cycle tracks.

Visibility for cyclists

- The road surface, kerbs, road markings, etc. should be well visible and well lit.

Visibility by other traffic

- Where conflicts between cyclists and other traffic are possible, the cyclists should be well visible and eye-contact should be possible.

Complexity of riding

Potentialproblems on encounters between cyclists and other traffic should be minimised.

- The higher the flows and volumes of motorised traffic, the more segregation is needed.
- Facilities should be wide enough to enable safe encounters, overtaking and evasive movements.
- Cycle lanes and raised adjacent cycle tracks should never be two-way to avoid that cyclists will end up on the carriageway in the case of conflicts between approaching cyclists.


Fig. 3.4 Lack of road safety at road section level. This cycle track is too narrow.

Figure 3.4 shows an example of a very narrow cycle track. The limited width here has a negative impact on the requirements road safety and comfort. On top of this, raised adjacent cycle tracks should never be two-way to avoid conflicts and the risk that cyclists end up on the carriageway.

3.4.3 Road safety at intersections level

Many accidents happen at intersections. Hence this is a location where much can be done to improve road safety for cyclists. In many cases changing the geometry of the intersection is necessary after which cycle facilities can be added to allow for safe crossing.

Complexity of riding

The chance of conflicts and (severe) accidents with cyclists is minimised by:

- Reducing the crossing distance (keep intersection compact).
- Enabling eye-contact between road users.
- Reducing waiting times (in order to discourage cyclists to jump the red light).
- Reducing speed differences between motorised modes and cyclists by slowing down motorised traffic at the intersection.
- Providing space for overtaking and deviating manoeuvres.
- Changing one-way roads for general traffic into two-way roads in order to avoid confusion from which direction vehicles are coming, to reduce the need for cyclists to weave between cars and to avoid that cyclists will use the road in contra-flow direction.
- Removing slip roads (free left-turn at intersections).

Chance of blinding

Cyclists are not blinded by motorised vehicles' headlights.

Figure 3.5, below, shows an example of a left-turn slip road. For cyclists (and other vehicles) going straight and passing the slip road, there is a potential conflict with vehicles leaving the slip road with relatively high speeds. These designs are made with the speed and flow of motor vehicles in mind, but this has a very negative effect on the road safety for cyclists. In cycle-friendly countries like the Netherlands slip roads are no longer applied in urban areas. Closing the free slip and leading vehicles via the heart of the junction is the solution here.

Fig. 3.5 Lack of Road safety. Left-turn slip roads allow vehicles to keep their speed when turning left.

3.4.4 Road safety at road surface level

Chance of encounter with motorised traffic

The state of the road surface does not induce cyclists to abstain from using provided cycle facilities.

- The road surface of a cycle lane or cycle track should be at least as smooth as that of the carriageway.

Complexity of riding

The road surface makes it easy to cycle and keep course.

- The state of the road surface does not distract the cyclist from traffic or force the cyclist into dangerous manoeuvres.
- The road surface is rough enough (also when wet) to enable safe cycling.

3.5 Comfort

Comfort: Cycling infrastructure enables quick and comfortable cycling.

*Criteria:*Hindrance from traffic; smoothness of road surface; chance of stopping; hindrance from weather.

Most important to ensure comfortable cycling are:

- A smooth road surface (see picture below).
- Limited hindrance from traffic by creating a wide enough verge (separation) between cycle track and carriageway.
- Limited hindrance from the weather (sun, heat, rain) by providing trees along the cycle track.
- No hindrance from obstacles on the cycle tracks.

Fig. 3.6 A smooth road surface, also at intersections, leads to better comfort.

In Pune, many cycle tracks are not comfortable because of a bad uneven road surface (block pavement), obstacles such as trees, lamp posts and bollards.

3.6 Attractiveness

Attractiveness: Cycling infrastructure provides an attractive cycling experience for cyclists. *Criteria:* Experience of surroundings; sense of social safety; chance of blinding.

Attractiveness is probably the most subjective of the five requirements with each individual having their own personal opinion on what is attractive. In general, we can say that attractive cycling conditions at least have to do with 'social safety' and an attractive environment. Social insecurity can be minimised by leading cycle routes through areas where there are people and by providing sufficient lighting. An attractive cycling environment, on the other hand, has much to do with aesthetics of the built environment (architecture) and a pleasant natural environment (green space).

3.6.1 Attractiveness at network level

Environmental quality

Select a routing that is attractive for cyclists.

- Routes lead through green areas.
- Routes lead through lively urban areas
- The routes are quiet and with clean air.

Social safety

Select a routing that doesn't lead through deserted areas and which avoids areas known for delinquency.

Fig. 3.7   Attractive cycle route along a park in the Turkish city of Antalya

Figure 3.7 shows an example of attractive routing. At road section level this cycle track could have been made even more attractive by providing a greater separation with the carriageway.

3.6.2 Attractiveness at road section level

Environmental quality

The direct surroundings of the cycle facility are (made) attractive for cyclists.

- Well-designed and lively
- Provide trees and attractive street furniture.

Social safety

Cycle facilities are visible for other road users and well lit.

- No walls or bushes that could provide a shelter for potential offenders.

3.6.3 Attractiveness at road surface level

Aesthetic quality

The appearance of the road surface fits with the character of the surroundings.

Note that the requirement attractiveness does not apply at intersection level.

4. Principles of cycling infrastructure at road sections

4.1 Three types of cycling infrastructure

There are three main types of cycling route infrastructure: Cycle tracks, cycle lanes and shared use. Below the different types of cycling infrastructure are shown with mention of the types of streets where they should be applied.

Cycle Track	**Cycle Lane**	**Shared use**
		
Physical segregation	Visual segregation	No Segregation
High speeds and volumes of motorised traffic	Medium speeds and volumes of motorised traffic. To be applied in specific situations only (see section 4.3).	Low speeds and volumes of motorised traffic

Table 4.1 Three types of cycling infrastructure

In the paragraphs below, the design and application of cycle tracks, cycle lanes and shared use are explained.

4.2 Cycle Tracks

4.2.1 Raised cycle tracks

Cycle tracks need to be applied along the main roads to protect cyclists from high volumes of fast moving traffic. There are different types of cycle tracks. For Pune the design as shown below is recommended:

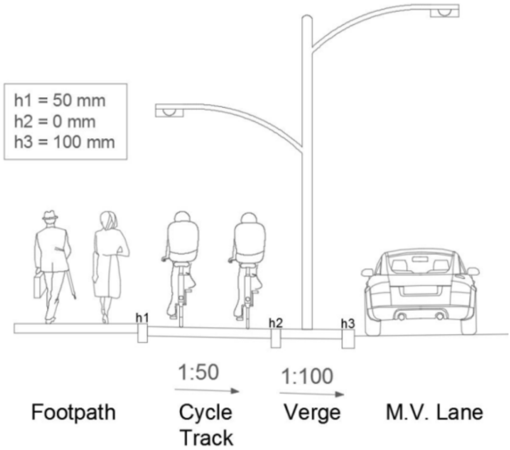


Fig. 4.1   Raisedcycle track

This design is the so-called **raised segregated cycle track** design. Essential for this design is the following:

- Water runs off from the footpath to the cycle track to the buffer zone, to the carriageway.
- The buffer zone protects cyclists from vehicles with a full curb (hr = +120 mm) at the road side.
- The footpath is located at +50 mm. above the cycle track to separate pedestrians and cyclists.
- In this example, if the buffer is 1.00 m. wide and the cycle track 2.00 m. wide, the footpath would be located at +200 mm (100+10+40+50) above the carriageway[4].
- If the buffer is permeable (e.g. grass verge, see below) there is of course no need for a 1% slope.

The photo below shows a few more important details:

Fig. 4.2   Raised cycle track

- The cycle track should be constructed in, preferably coloured, **asphalt** (with concrete being a second best option).

[4] Note that at intersections, the footpath and cycle track need to slowly slope down, over a distance of 5 m. In such a way that the footpath ends up at +150 mm at the road side and the cycle track at +000 mm (carriageway level)

- The footpath and buffer zone should be constructed in **pavement blocks** or other permeable material.
- There should be a **material and colour difference** between cycle track and footpath, and between cycle track and buffer zone.

4.2.2 Raised adjacent cycle tracks

A raised adjacent cycle track is a raised segregated cycle track without a verge. While the design is similar the cycleable road surface is continued till the curb of the road. With this design cyclists cycle closer to the carriageway than with a segregated cycle tracks (see drawing below), and thus safety and comfort are not as good as in the case of segregated cycle tracks.

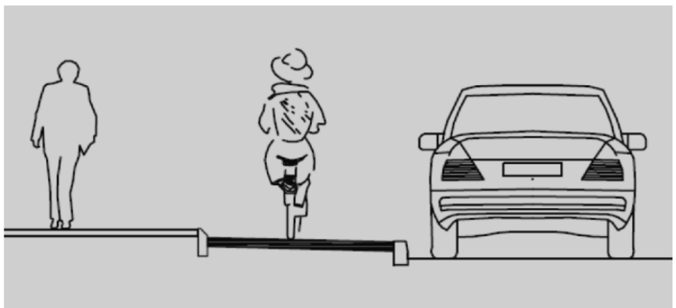


Fig. 4.3 Raised adjacent cycle track

Raised adjacent cycle tracks should only be used in very specific situations where not sufficient space is available to apply a segregated cycle track.

Raised adjacent cycle tracks should **not be applied** in the following situations:

- **Along car parking**. When car drivers open the left car door, there is no safety buffer between the parking and the cycle track. Where there is car parking a segregated cycle track is needed.
- For **two-way cycle tracks** or where there two-way cycle tracks is expected.
- Anywhere where sufficient space is available for a segregated cycle track.

Note that lamp posts can only be placed between the carriageway and the cycle track in the case of segregated cycle tracks (on the verge). In the case of raised adjacent cycle tracks the lamp post should be placed on the footpath.

Fig. 4.4 Raised adjacent cycle track in Pune

4.2.3 Road level cycle tracks

Cycle tracks at road level are generally not recommended in Pune because it is much harder to provide proper water drainage then with the design shown above:

Fig. 4.5a *Road level cycle track without proper drainage*

Fig. 4.5b. *Road level cycle track with proper drainage*

However, when well constructed with proper drainage, road level cycle tracks can be an easy and efficient way to create cycle tracks by replacing a part of the carriageway with a cycle track.

Road level cycle tracks can be applied under the following conditions:

- When using the existing road surface: Only where existing road surface is of very good quality.
- Separate drainage is provided on the cycle track (see photo above).

4.2.4 Cyclists and pedestrians

Separation of cyclists and pedestrians

Pedestrians move at much lower speeds than cyclists and behave very different than cyclists. Therefore it is very important that the footpath and cycle track are physically segregated. This can be done in two ways:

1. By vertical segregation with a height difference (+50 mm) as shown before.
2. By horizontal segregation with a zone with trees and/or lamp posts (see below). In this case it is important that the buffer zone has a different material and colour than footpath and the cycle track.

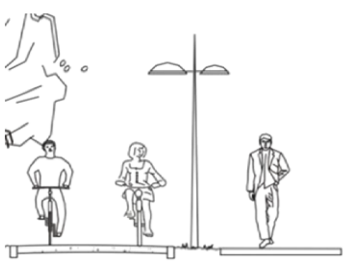


Fig. 4.6 Horizontal segregation

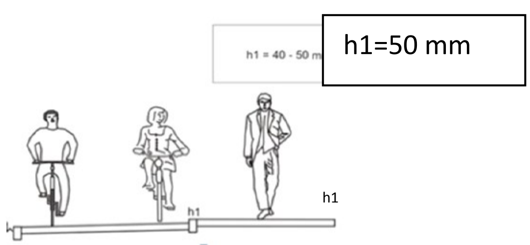


Fig. 4.7 Vertical segregation

Shared paths for pedestrians and cyclists are not recommended on urban roads because this create conflicts between cyclists and pedestrians.

For Pune, it is also not recommended to apply cycle tracks and footpaths only segregated by a line and/or material difference because this will lead to even more pedestrians encroaching on the cycle track than is happening already today.

4.2.5 Verge / Multi Utility Zone

The verge is what makes a cycle track, a cycle track. This zone can have different forms and sizes. When it is at least 2.00 m. wide it is called a Multi Utility Zone (MUZ).

Segregating verges can have the following characteristics:

Verge	**1. Green / non paved (without parking)**	**2. Paved with trees (with or without parking)**
		
Width on photo	2.00 m. (on photo)	2.00 m.
Recommended width:	1.50 - 5.00 m.	1.50 - 2.00 m.
Minimum width:	1.50 m.	1.00 m. (small trees)

Verge:	**3. Paved with parking**	**4. Paved without parking**	**5. Paved with lamp posts (no parking)**
			
Width on photo	0.70 m.	0.50 m.	0.70 m.
Recommended width:	1.00 m.-2.00m.	0.70 -2.00 m.	1.00 m.-2.00 m.
Minimum width:	0.70 m. (safe distance for door opening)	0.50 m.	1.00 m. (to allow for safe distance to lamp post)

Table 4.2 Different types and widths of verges and multi utility zones

A good example of a cycle track with a green verge is shown below:

Fig. 4.8 Two-way cycle track with raised footpath and green verge at Solapur Road (Pune)

It is important to understand that the minimum width of the verges depends on what is placed here. With car parking 0.70 m. is a safe width that allows door opening without cyclists hitting the doors. 1.00 m. is the minimum width needed for car drivers to safely exit their vehicles before crossing the cycle track.

Lamp posts and trees need to be placed at least 0.35 m. away from the edge of the cycle track to not reduce the effective width of the cycle track and avoid cyclists hitting the obstacle. Hence for the verge to be wide enough for a narrow tree (less than 0.30 m. wide) or lamp post to be place on it in the centre, it needs to be 1.00 m. wide.

The figure below shows how this works in practice:

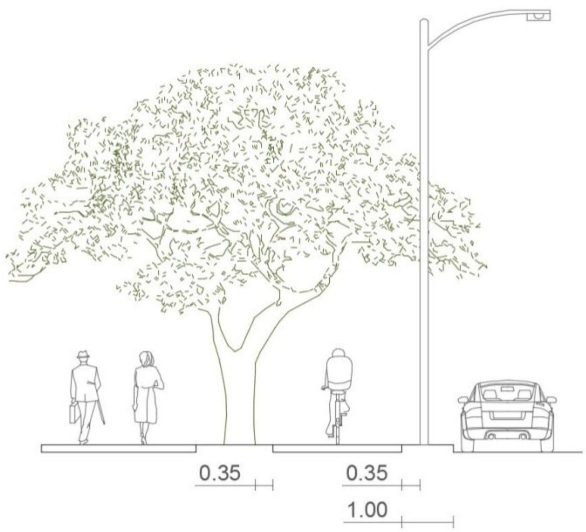


Fig. 4.9 Minimum obstacle distance from edge of cycle track

Obstacle	Minimum Clearance distance from edge of cycle track
Lamp post or tree	0.35 m.
A row of bollards	0.35 m.
Wall bus stop or closed fence	0.50 m.

Table 4.3 Obstacle distance

Finally, a wider verge creates safer side road crossings without a need to bend out the cycle track (see section 6.2). Therefore a verge of 2.00 m. (where there is no parking) is recommended at arterial roads where there is space. Where space is limited, a 1.00 m. verge is also acceptable.

Summarised the following verge widths are recommended:

	Recommended verge width	Minimum verge	
Verge with lamp post (with or without parking)	**1.00 m.**	0.70 m.	
Verge with trees (with or without parking)	**1.50 - 2.00 m.**	1.00 m.	
Narrow verge without trees, lamp posts and parking	**0.70 m.**	0.50 m.	
Arterial road	**2.00 m.** 1.00 m. + 2.00 m. parking (preferred without parking)	1.00 m.	Preferably with trees
Sub-arterial road	**1.00 m. + 2.00 m.** parking	1.00 m.	Trees between parking
Collector road	**1.00 m. + 2.00 m.** parking **1.00 m.** (no parking, with lamp posts) 0.70 m. (without lamp posts)	0.70 m. 0.70 m. 0.50 m.	Trees between parking Without lamp posts

Table 4.4 Width of verge for cycle tracks

4.2.6 Two-way cycle tracks

When applying cycle tracks, one of the main questions to be asked is whether to apply one-way or two-way cycle tracks. There are basically three ways to apply cycle tracks as shown below:

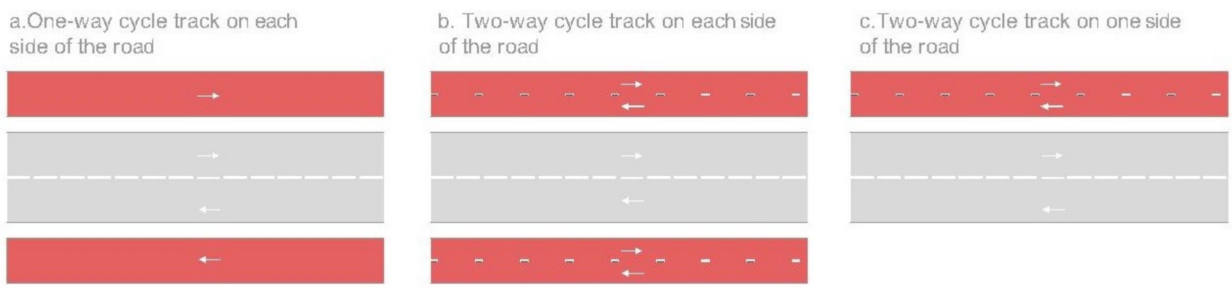


Fig. 4.10 Three ways to apply cycle tracks

When deciding between one-way or two-way cycle tracks, the following needs to be taken into account:

- One-way cycle tracks are safer at intersections (requirement: safety).
- Two-way cycle tracks provide better connectivity (requirement: directness, coherence)

a. Application of one-way cycle tracks	
The safest option at intersections	
Preferred at *collector roads*	
Preferred*sub-collector roads.* Sufficient crossing possibilities for cyclists should be provided (at least every 500 m.)	
Possible at *arterial roads.*	
b. Application of two-way cycle tracks (both sides)	
Accident risk at intersections twice as high as with one-way cycle track	
Can be applied where contraflow use of one-way cycle tracks is likely (where there is less than one crossing per 500 m. and many destinations along that side of the road)	
Possible at *arterial roads with ROW of 55 m and over* (at both sides of the road!) where frequent contraflow cycle use is expected (or observed)	
c. Application of two-way cycle track (on one sides)	
Note: This is not a standard design and should only be provided at specific situations after study of the connectivity for cyclists.	
For through cycle routes along canals or rail-lines (at the side of the canal or railway). Condition: The main road needs to have cycle crossings at every side road on the opposite site of the main road.	
Possible on *collector roads*in very specific situations where this leads to better accessibility for cyclists.	

Table 4.5 Application of one-way and two-way cycle tracks

Because **arterial roads** have lesser numbers of possibilities for crossing than roads of lower hierarchy, contraflow use of one-way cycle tracks is more likely on these roads. Therefore *at arterial road*2.50 m. wide one-way cycle tracks are proposed (these are also wide enough for two-way use). *Two-way cycle tracks can be applied at extra wide arterial roads (> 3 lanes per direction and ROW > 55 m.).* Because two-way cycle tracks are less safe at intersections it is essential to create a safe design at major intersections as well as minor side road. This is explainedin chapter 6.

At **sub-arterial roads**and **collector roads**, crossing the street is easier and (ideally) possible at many locations. Therefore here, one-way cycle tracksare the default option. On collector roads, also cycle lanes can be applied.

4.2.7 Width of cycle tracks

The figure 4.11 shows that, for a cyclists to comfortably overtake another cyclists, 2.00 m. is the minimum width *for one-way cycle tracks* derived by adding up the width of the cyclists and the distance they keep to edges and obstacles. With a low edge (h2 = 0), theoretically a width of even 1.80 m. is possible, but this makes overtaking difficult and is not recommended for Pune[5]. On routes with higher volumes of cycle traffic the cycle track width should be greater. On such routes 2.50 m. is preferred.
Two-way cycle tracks should be wider.

[5] The USDG advises a minimum width of 2.00 m. for one-way and a minimim of 2.50 m. for two-way cycle tracks.

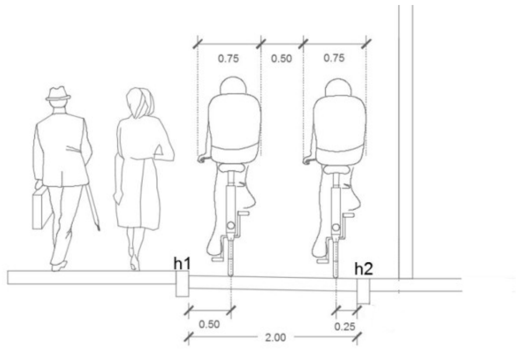


Fig. 4.11 Minimum width for one-way cycle track

Below recommendations for segregated cycle track widths in Pune are given[6]:

	Cyclists in peak hour in one direction	**Width**
One-way cycle tracks	0 - 150	2.00 m.
	> 150	2.50 m.
	At collector roads	2.00 m.[7]
	At sub-arterial roads	2.20 m.[8]
	At arterial roads	2.50 m.
	Cyclist in peak hour (sum of two directions)	**Width**
Two-way cycle tracks	0 - 50	2.50 m.
	50 - 150	3.00 m.
	> 150	3.50 m.
	At arterial roads	3.00 m.

Table 4.6. Recommendations for cycle track widths in Pune

Because at **arterial roads** there are fewer locations where cyclists can cross, some contraflow use of one-way cycle tracks is likely. Therefore, here one-way cycle tracks should preferably be 2.50 m. wide independent of the amount of cyclists.
On **sub-arterial** roads there are more locations where crossing is possible, hence here a smaller width can be applied. 2.20 m. is appropriate, but where space is available or volumes of cyclists are high, 2.50 m. can also be applied.

In Pune the busiest cycle routes - according to our counts - have about 150 cyclists in the busiest peak hour in two directions (Bhajirao Road, FC Road) or 75 cyclist per hour per direction (on each side of the road). Hence, for these roads, currently 2.00 m. wide one-way cycle tracks are still possible, but when applied along sub-arterial or arterial roads wider widths, as per table 4.6, are recommended.

Note that all these cycle tracks are segregated by a dividing verge or MUZ of 1.00 till 5.00 m. with an absolute minimum (collector road verge without lamp posts or trees) of 0.50 m.

[6] In the USDG one-way cycle tracks are either 2.00 or 2.50 m. wide.
[7] Depending on available space and amount of cyclists.
[8] Depending on available space and amount of cyclists.

Raised adjacent cycle tracks

However, in the case of raised adjacent cycle tracks, there is no dividing verge. The most obvious location to apply such cycle tracks is on collector roads with limited space or at pinch points. In this case the following is recommended:

	Recommended width	Minimum width
Raised adjacent cycle track (one-way)	2.20 m.	2.00 m.

Table 4.7 Recommended widths for raised adjacent cycle tracks on Collector roads

Where more space is available a 2.00 m. wide segregated cycle track with 0.50 m. wide verge can be applied.

4.3 Cycle lanes

In Pune, segregated cycle tracks are proposed as the default option because they are the most effective way to provide a safe and dedicated space for cyclists. However, in some situations, cycle lanes can be applied, but they should be seen as pilot projects. Hence they should only be applied in exceptional situations where the risk of encroachment is relatively low. The conditions for application are mentioned at the end of this section.

The photo below shows a well-designed cycle lane on a collector road in the Netherlands.

Fig. 4.12 Cycle lanes (1.80 m.) on a collector road in The Netherlands

Cycle lanes are cycling infrastructure with the following characteristics:

- Visual segregation from the carriageway.
- Cycle lanes are always one-way!
- Cyclists can, and are allowed to, overtake other cyclists by using the carriageway.
- Motorised vehicles cross the cycle lane to access parking, but are not allowed to stop or park on the cycle lane.
- Where there is car (or autorickshaw) parking, cars are parked behind the cycle lane, hence, cars or autorickshaws need to cross the cycle lane to access the parking. This is not needed in the case of cycle tracks (see figure below).

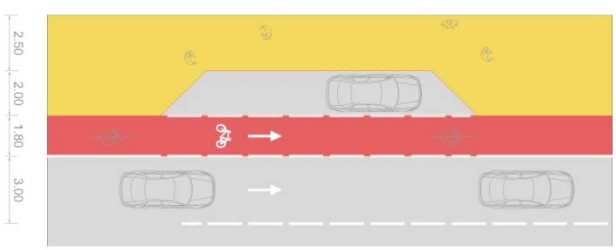
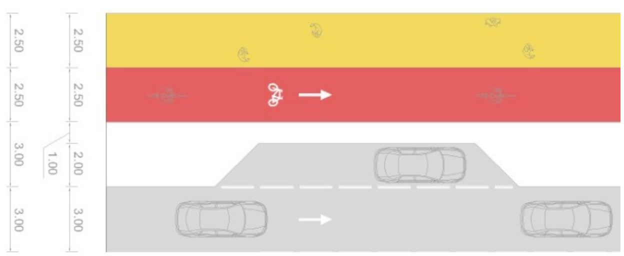
Cycle lane with parking (Blue circle shows the conflict location)	**Cycle track with parking** (Blue circle shows the conflict location)
Conflict 1: Car-door of car-driver **Solution:** buffer zone (see photo below)	**Conflict 1:** Car-door of passenger **Solution:** wide enough verge (0.70 m +)
Conflict 2: Car crossing cycle lane **Solution:** Apply only where very few parking movements	**Conflict 2:** Car-passenger crossing cycle track **Solution:** Wide enough verge (0.70 m +)
	
	

Table 4.8 Cycle lanes (left) and cycle tracks (right) with car parking

To reduce conflicts with car door opening (conflict 1), a buffer zone can be applied as shown below:

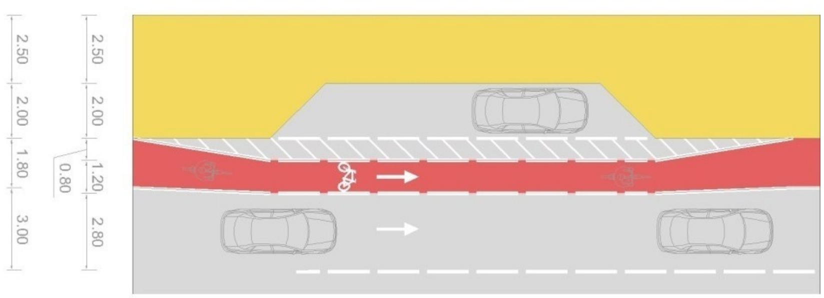


Fig. 4.13 Cycle lane with buffer zone at car parking

A buffer zone of 0.80 m. is a safe protection against drivers opening their doors. This is recommended because Indian drivers are not used to cycle lanes and will probably easily forget to think about them when opening the door of their vehicles.

Where to apply?

Until today, cycle lanes have not yet been applied in Pune. Because they do not provide physical segregation, their use should be limited and initially only be applied as a pilot project. Invasion by motorcycles, and possibly also cars is very likely. Below, the conditions for the application of cycle lanes in Pune are given.

Application of cycle lanes is possible when the following conditions are met:

- The cycle lane is a pilot project.
- Application on collector roads with one MV lane per direction where insufficient space is available to provide a segregated cycle track.
- Only where there is no car or M2W parking or where there are very few parking movements (e.g. residential parking only).
- Only when after implementation, a period of education and enforcement is applied to avoid illegal parking on the cycle lane.

Note: The first cycle lane project in Pune should be a pilot project accompanied by a proper before and after study to learn from the experience. Only when this experience turns out to be mostly successful, can this be replicated on other roads.

Specifications

While other widths are sometimes applied, cycle lanes of at least 1.80 m. have proven to be the safest. Wider cycle lanes are not recommended because they increase the chance of misuse for illegal car parking.

	Recommended
Width of cycle lanes	1.80 m.

4.4 Shared use

On local streets (access streets) cyclists can share the street with motorised traffic. Important here are the following things:

- 30 km/h speed limit and observed speed
- Limited width of carriageway (4.00 - 7.00 m.), no traffic lanes marked.
- Parallel parking bays can be applied (see figure 4.14a).
- Particularly at inner city Access Street, a different pavement is recommended. For instance brick pavement.
- Traffic calming measures, such as speed humps, need to be applied.

See Urban Street Design Guidelines for further details.

Fig. 4.14a Access Street with shared use and parallel parkingbays

Fig. 4.14b Access Street with shared use andwithout dedicated parking bays

5. Cycling infrastructure in relation to street typology

5.1 Introduction

Different types of roads require different types of cycling infrastructure. In chapter 4the different types of infrastructure are explained in detail. Simply put, the type of infrastructure required is as follows:

	Motor vehicle speeds	**Motor vehicle volumes**
Segregated cycle tracks	High (50 km/h or more)	High
Cycle lanes (painted)	Medium (20-50 km/h)	Medium
Shared use	Low (20 km/h or less)	Low

Table 5.1 Application of cycle tracks, cycle lanes and shared use

In order to know which cycling infrastructure is needed for which type of roads, the different types of roads described in section 4.2 are linked with different types of cycling infrastructure.

5.2 Pune Street typology

The Pune road network consists of four different types of roads in line with the Comprehensive Mobility Plan. Because in the Urban Street Design Guidelines there is no clear relation between carriageway width (and hence capacity of the road) and road type, here the CMP hierarchy is used. The table below also gives recommendations for the cycling infrastructure to be applied at each type of road:

	Road type (CMP)	**USDG**	**Traffic lanes (typical)**	**Typical cycling infrastructure**	**Examples**	**Typical ROW**
1.	Arterial road	Mobility corridor	2 x 2 + 2 x 1 BRT 2 x 3[9] 2 x 2	One-way cycle tracks (or Two-way cycle tracks on both sides of the road)	Nagar Road, Solapur Road Baner Road	> 34 m.
2.	Sub-arterial road	Feeder road	2 x 2 2 x 1 + 2 x 1 BRT	One-way cycle tracks	Bund Garden Road	24 - 32 m.
3.	Collector road	Feeder road or busy local street	2 x 1 (possible 2x2 at intersections)	Cycle tracks or, under very specific conditions, cycle lanes	ITI road	16 - 24 m.
4.	Local street	Local street	No lanes defined (4-7 m. carriageway width)	Shared use		< 16 m.

Table 5.2 Main characteristics of the 4 types of roads

[9] Road with two directions and 3 MV lanes per direction (6 lanes in total).

At arterial roads, 2.50 m. wide one-way cycle tracks are recommended, as default. However, at very wide arterial roads two-way cycle tracks (each 3.00 m. wide) **on both sides of the road** can be applied to better facilitate two-way cycling along these roads that are very difficult to cross.

To further distinguish between the four road types, underneath additional information is provided for the typical characteristics of the different types of roads:

	Arterial	**Sub-arterial**	**Collector road**	**Local street**
Median?	Yes	Yes, low median	No	No
Average distance between cycle crossings	> 500 m.	200 - 500 m.	at each side road	everywhere
Car Parking?	No	Limited possible	Possible	Yes
BRT	Possible	Limited possible	No	No
Typical amount of traffic lanes (incl. BRT)	2 x 3 MV (2 x 2 MV possible)	2 x 2	2 x1 (2x2 at intersections possible)	No lanes defined

Table 5.3 Additional characteristics of the four types of roads

5.3 Traffic lane widths

When creating cycling infrastructure along a road, it is recommended to use the opportunity to redesign the whole carriageway. This is important, because a properly designed road will be safer for cyclists at intersections and have a more smooth traffic flow.

Traffic lane width

Traffic lane widths should be constant throughout the design. Too wide traffic lanes, 3.50 m[10]. or more, should be avoided because of the following reasons:

- Wide traffic lanes allow two cars or autorickshaws to drive side by side and lead to poor lane discipline. The result is a disturbed traffic flow and a lower capacity of the road.
- Wide traffic lanes lead to higher speeds which leads to worse road safety.
- Application of wide lanes takes road space which can better be used for cycle tracks or footpaths.

[10] 3.50 m. wide MV lanes are acceptable only if there is a significant volume of heavy vehicles.

The following lane widths are recommended:

Traffic lane width		Standard width	Minimum width
Arterial roads and sub-arterial roads[11] (2x2 or 2x3)	Regular traffic lane	3.00 m.	2.75 m.
	Bus or BRT lane or lane with high volume of busses or trucks (>10%)	3.50 m.	3.00 m. (bus) 3.50 m. (BRT)

Table 5.4 Recommended traffic lane widths on arterial and sub-arterial roads

See for traffic lane widths on collector roads, section 5.6.

Local roads where cyclists share the road have no delineated traffic lanes. Here the total width of the road can vary between 4.00 and 7.00 m. depending on traffic volumes and the presence of parking.

5.4 Cycle tracks at road sections of arterial roads

At arterial roads cycle tracks are needed with 2.50 m. wide one-way cycle tracks to allow for two-way use on midblock sections. See section 4.2.6.

Typically there should be no parking on arterial roads, because arterial roads are flow roads. To create safe side road crossings (particularly with collector and access roads), a 2.00 m. wide verge is preferred. Such a verge also allows for trees to be placed. Because of the width of arterial roads separate lighting between footpath and cycle tracks is needed although it is also possible to place lighting on the verge between cycle track and carriageway.

Typical cross-sections of arterial roads have the following characteristics:

	Standard	Min.
One-way cycle track	2.50 m.	2.00 m.
Verge	2.00 m.	1.00 m.
Footpath	> 3.00 m.	2.00 m.

Table 5.5 Width of cycle track, verge and footpath at arterial roads

Table 5.6 below shows the typical characteristics of arterial roads:

[11] In the USDG, traffic lane widths on roads with 2 or 3 lanes per direction vary between 2.75 m. and 3.00 m.

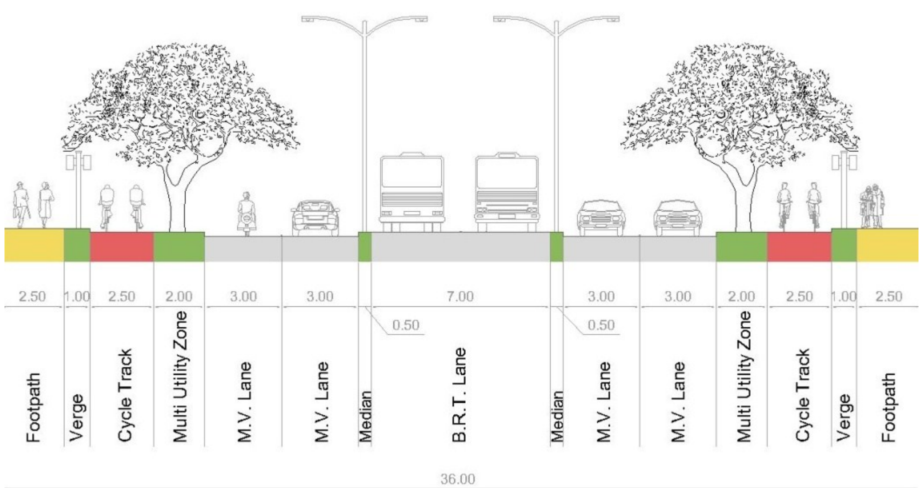
Characteristics of arterial roads:

		Typical	Possible
MV-lanes:		2 x 2 + BRT (2x1)	2 x 1 + BRT (2 x 1) 2 x 2 + parallel roads (2 x 1) + BRT (2 x 1) 2 x 3 + BRT (2 x 1)
Carriageway width:		6.00 m. (2 lanes) 9.00 m. (3 lanes)	5.50 m. (only at pinch points)
Maximum speed:	50 km/h		
Traffic volumes:	> 3000 PCU/hr. in two directions		
ROW:		> 34 m.	28 - 34 m. (2 x 1 + BRT)
Cycling infrastructure:		Segregated one-way cycle tracks. 2.50 m wide	Segregated two-way cycle tracks. 3.00 m. wide
Verge:		2.00 m. with trees	1.00 m. where lack of space
Car parking:		No	
Median:		1.00 m at both sides of BRT	0.50 m. where there is lack of space

Table 5.6 Characteristics of arterial roads

In the next pages different cross-sections are shown for each road type. For each cross section different alternatives of the same design are shown for smaller or larger ROWs.

The cross-section below shows an arterial road with two lanes for traffic per direction and a centrally located BRT. Typical ROW is 35 m. (with 2.75 m. footpaths) till 40 m (with 5.25 m. footpaths).



Alternative widths	
ROW	
32.00 m.	*- MUZ: 1.00 m.* *- Footpaths: 2.50 m. (no separate footpath verge)*
40.00 m.	*- Footpaths: 4.00 m.*

Fig. 5.1 Arterial road (35-40 ROW) with one-way cycle tracks and without parking

Footpath verge

Note that a separate 1.00 m. verge between footpath and cycle track is proposed. This is recommended to create greater segregation between cyclists and pedestrians but is not a requirement. This verge should have a different road surface than both footpath and cycle track and can be used to place lighting poles and small trees. The same material can be used as used for the cycle track verge.

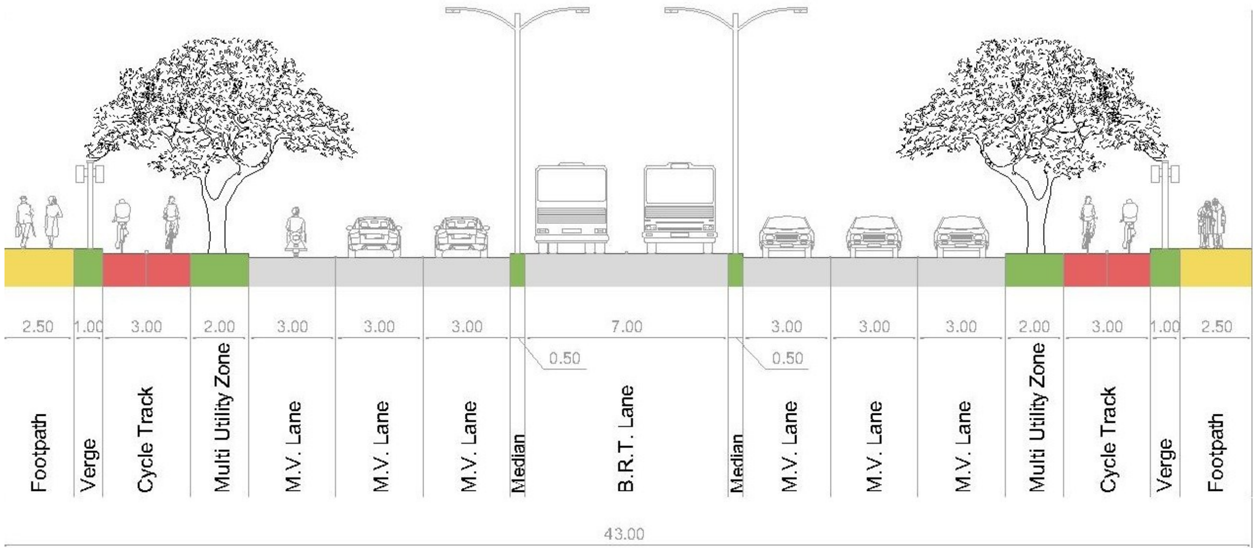


Fig. 5.2 Wide Arterial road (40-48 ROW) with two-way cycle tracks and without parking

Alternative widths are shown below. Note that an MUZ of 1.00 m. is not recommended where two-way cycle tracks are applied. See chapter 6 for details.

Alternative widths	
ROW	
40.00 m.	- MUZ 1.00 m. - Cycle track 2.50 m. (one-way)
45.00 m.	- Medians: 1.00 m. - Footpaths: 3.00 m.
48.00 m.	- Medians: 1.00 m. - Footpaths: 4.50 m.

Arterial roads with a width of 45 m. or over can also be designed as 2x2 lanes + BRT + parallel roads.

5.5 Cycle tracks at road sections of sub-arterial roads

Typically, sub-arterial roads are the connectors between arterial roads and collector roads. In some cases however, sub-arterial roads also connect directly to local access roads.

Typical cross-sections of arterial roads have the following characteristics:

	Standard	Min.
One-way Cycle track	2.20 m.	2.00 m.
Verge	3.00 m. between parking, 1.00 m. + parking	0.80 m.
Footpath	> 2.50 m.	2.00 m.

Table 5.5 Width of cycle track, verge and footpath at sub-arterial roads

Characteristics of sub-arterial roads:

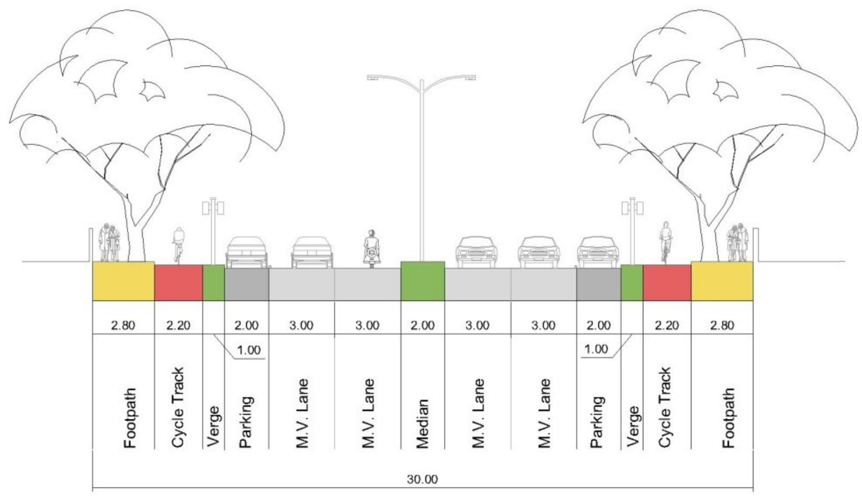
		Typical	**Possible**
MV-lanes:		2 x 2	2 x 3 at intersections
Carriageway width:		6.00 m. or 6.50 m. (with busses)	5.50 m. (only at pinch points)
Maximum speed:	50 km/h		
Traffic volumes:	2000-4000 PCU/hr. in two directions (peak hour)		
ROW:		24-32 m.	
Cycling infrastructure:		Segregated cycle tracks. 2.20 m. wide	
Verge:		1.00 m. where there is parking 3.00 m. at locations without parking	
Car parking:	Often present	2.00 m.	
Median:		2.00 m. low median	1.00 m. low median

Table 5.6 Characteristics of sub-arterial roads

The design of sub-arterial roads is very similar to that of arterial roads. With three main differences:

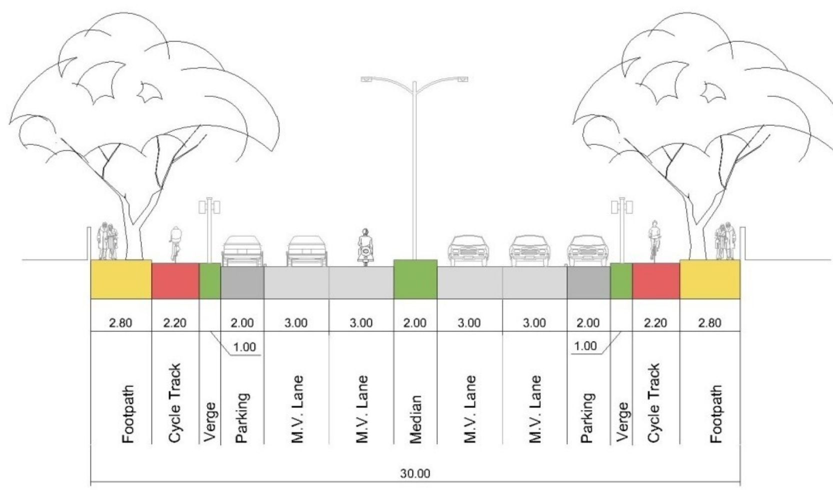
- Parallel parking can be applied at specific locations.
- Wide and low median (2.00 m.) to be provided to allow for simple creation of safe crossings for pedestrians and cyclists[12]. Also at certain side roads where MV-traffic is not allowed to cross.
- Slightly narrower cycle tracks because of less contraflow use because more cycle crossing possibilities per kilometre.

[12] In cases where space is limited a narrower median (1.00 m.) is possible. In that case the median needs to be widened to at least 2.00 m. at cycle crossings.



Alternative widths	
ROW	
24.00 m.	*- No car parking* *- MUZ: 1.00 m.* *- Median: 1.00 m.* *- Footpaths: 2.30 m.*
26.00 m.	*- No car parking* *- MUZ: 2.00 m.* *- Median: 1.00 m.* *- Footpaths: 2.30 m.*

Fig. 5.4 Sub-arterial road at locations without parking (ROW 24-32 m.)



Alternative widths	
ROW	
24.00 m.	*- No car parking* *- MUZ: 1.00 m.* *- Median: 1.00 m.* *- Footpaths: 2.30 m.*
26.00 m.	*- No car parking* *- MUZ: 2.00 m.* *- Median: 1.00 m.* *- Footpaths: 2.30 m.*
32.00 m.	*- Footpaths: 3.80 m.*

Fig. 5.5 Sub-arterial road at locations at locations with parking (ROW 28 - 32 m.)

Note that at sub-arterial roads with high volumes of busses, the left traffic lane should be 3.50 m. wide, while the right one remains 3.00 m, thus making the carriageway 6.50 m. wide.

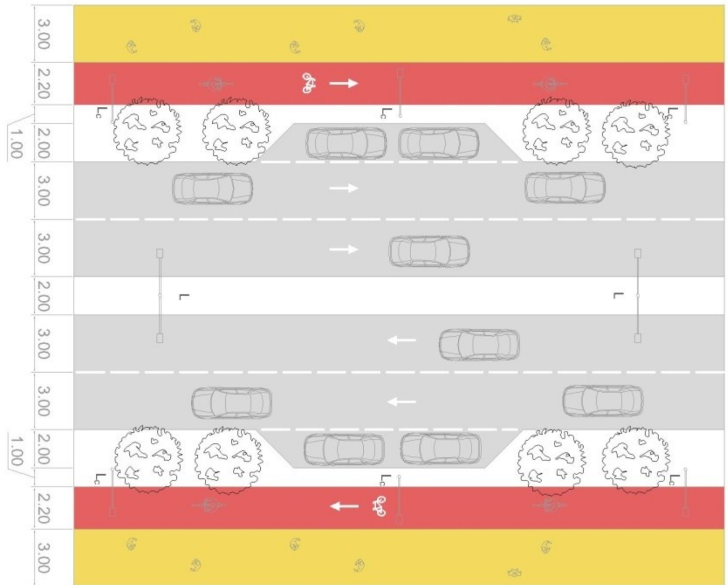


Fig. 5.6 Sub-arterial roads with locations with parking (Fig. 5.5) and locations without parking Fig. 5.4)

5.6 Cycling infrastructure at road sections of collector roads

Collector roads are roads that collect neighbourhood traffic from local roads and then connect to sub-arterial or arterial roads. While local roads have low volumes of traffic and low speeds (< 30 km/h), collector roads can be quite busy (up to 1500 - 2000 PCU in two directions) with a maximum speed of 50 km/h. Collector roads have one MV lane per direction and can have parking. For collector roads there is a wide variety of designs possible.

Typical cross-sections of collector roads have the following characteristics:

	Standard	**Min.**
Cycle track	2.00 m. (segregated or raised adjacent)	2.00 m.
Verge	1.00 m. with trees	0.50 m. without trees or lighting poles
Footpath	> 2.00 m.	1.80 m.

Table 5.5 Width of cycle track, verge and footpath at sub-arterial roads

Characteristicsof collector roads:

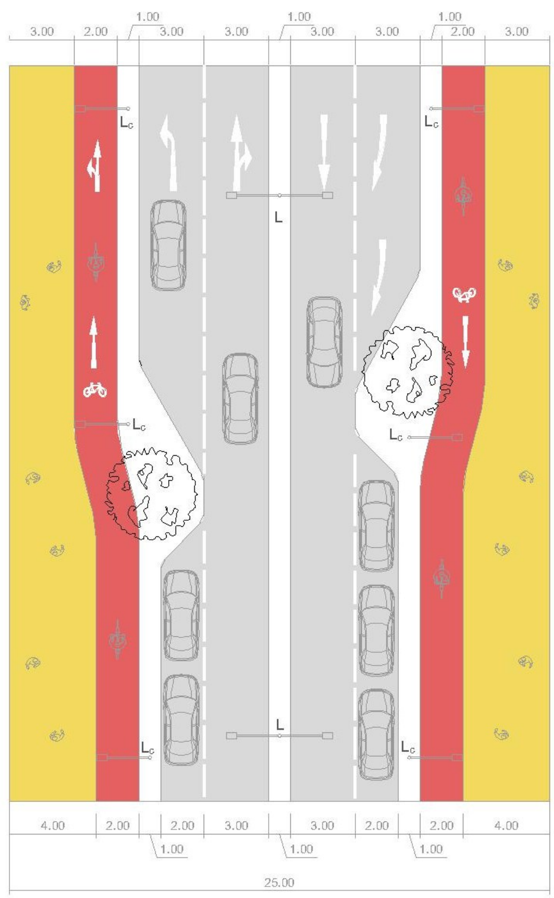
		Typical	**Possible**
MV-lanes:		2 x 1	2 x 2 at intersections
Carriageway width:		- 6.00 m. (2 x 3.00 m.) without median - 6.50 m. (2 x 3.25 m.) where many busses or trucks	5.50 m. (2 x 2.75 m.)
Maximum speed:	50 km/h		
Traffic volumes:	500-2000 PCU/hr. in two directions		
ROW:		18-24 m.	14-18 m.
Cycling infrastructure:		Segregated cycle tracks	Raised adjacent cycle tracks Cycle lanes
Verge:		1.00 m. with trees	0.70 m. with lamp posts, parking, no trees 0.50 m. without parking or lamp posts or trees
Car parking:	Often present	2.00 m.	1.80 m.
Median:		Not present	1.00-2.00 m. low median

Table 5.7 Characteristics of collector roads

In the following sections, we show different types of designs for collector roads. Types are not just defined by the right of way, but also by the amount of lanes at intersections, whether or not car parking is provided and the type of cycling infrastructure. While the design of arterial and sub-arterial roads is rather straightforward, for collector roads there are many different options that can be applied.

5.6.1 Wide collector roads: 21-25 m. right of way

The widest collector roads can be up to 24 m. ROW or even wider. In this case the typical design is a 2x1 lanes carriageway with a median and widening to 2x2 at the intersections (top of figure 5.7.1) to increase capacity. Away from the intersection the additional available space can be used for car parking or, if car parking is not needed, a wider MUZ and/or wider footpath. And of course, where needed, for the provision of bus stops. Because the capacity of a road is mostly determined by the capacity of the intersection, the capacity of this design is only a little lower than the capacity of a full 2x2 lane road. Fig. 5.7.1 and 5.7.2 show this design.

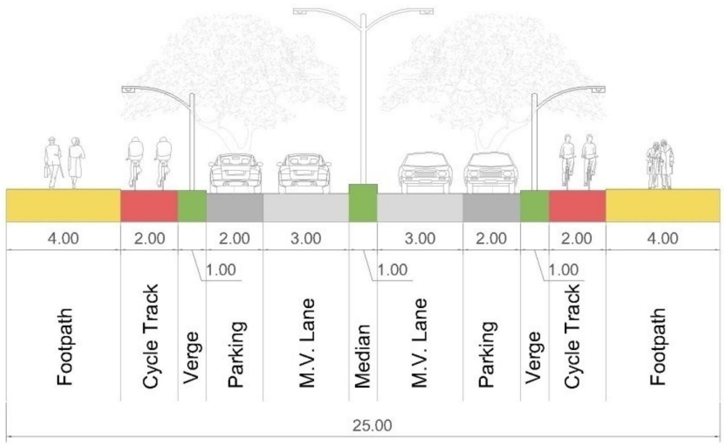


L = Lighting for carriage way

L_c = Lighting for cycle tracks and footpaths

Alternative widths and designs	
ROW	
25.00 m.	- 3.50 m. MV-lane widths away from intersection (where many busses) - 3.50 m. footpaths
23.00 m	- 3.00 m. footpaths (2.00 at intersections)
21.50 m.	At intersection: - 2.00 m. footpaths - 2.75 m. traffic lanes - 0.75 m. verges

Fig. 5.7.1 Wide collector road (21.50-25.00 m) with additional capacity at intersections

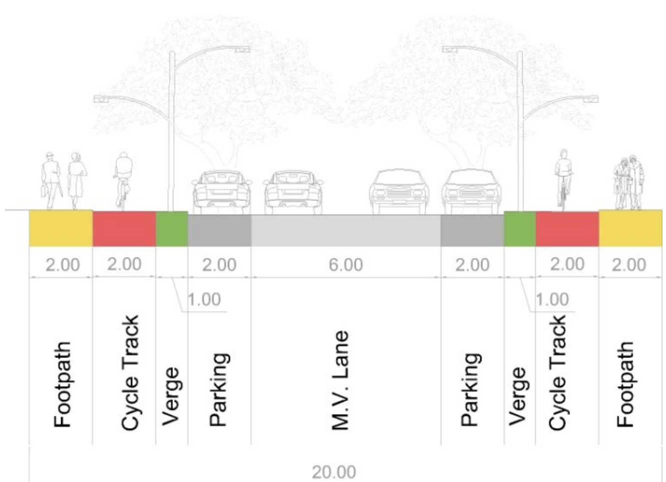


Alternative widths	
ROW	
18.50 m.	- 2.00 m. footpaths - 2.00 m. cycle tracks - 0.70 m verge with lamp posts - 1.80 m. parking - 5.50 m. carriageway
19.00 m.	- 2.00 m. footpaths - 2.00 m. cycle tracks - 0.70 m verge with lamp posts - 1.80 m. parking - 6.00 m. carriageway
22.00 m.	- 3.00 m. footpath

Fig. 5.7.2 Wide collector road (21.50-25.00 m) at road sections (away from the intersection)

5.6.2 Collector road 18 - 22 m. with parking

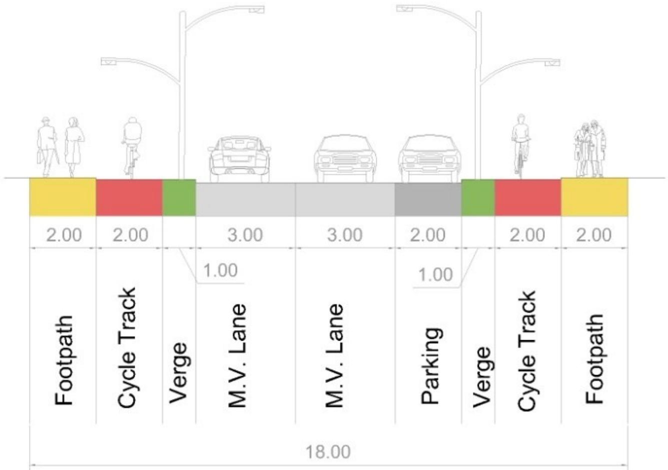
Typically, collector roads do have parallel parking. While this can be on one side of the road or on both sides of the road. Below, a standard design (with ROW 20 m.) is shown with parking on both sides of the road.



ROW	
17.50 m.	- 0.75 m. verges

Fig. 5.8 Collector road (18.50 - 22.00 m.) with parking on both sides

Figure 5.8 shows that 20.00 m. is the minimum ROW needed to comfortably apply cycle tracks and parking on both sides of the road. With smaller ROWs, particularly below 19.00 m, preferably parking is only applied on one side of the road as is shown below in Fig. 5.9. However, as shown in the table above, parking on both sides of the road can still be accommodated up to a width of 18.50 m.



Alternative widths and designs	
ROW	
18.00 m.	- Footpaths: 2.75 m. - MV-lanes: 3.25 m. (roads with many trucks and busses)

Fig. 5.9 Collector road (18 m) with segregated cycle tracks and parking on one side

5.6.3 Collector road with segregated cycle tracks (15-18 m.) without parking

On collector roads where no parking needs to be provided, proper cycling infrastructure can easily be provided up to a ROW of 15.00 m.

Fig. 5.10below shows a design for a collector road with a ROW of 18 m. with 1.00 m. verges and the lamp posts in the verge. Fig. 5.11 is the same design with a 16 m. ROW and 2.00 m. footpaths. Fig. 5.12 shows a design with maximum footpath width and the lamp posts on the footpath. Because lamp posts are nor placed in the verge, the verge can be as narrow as 0.50 m. on collector roads.

Fig. 5.10 Collector road (18 m) with segregated cycle tracks and without parking.

Below the same design is shown for a 16 m. wide road with 2.00 m. wide footpaths.

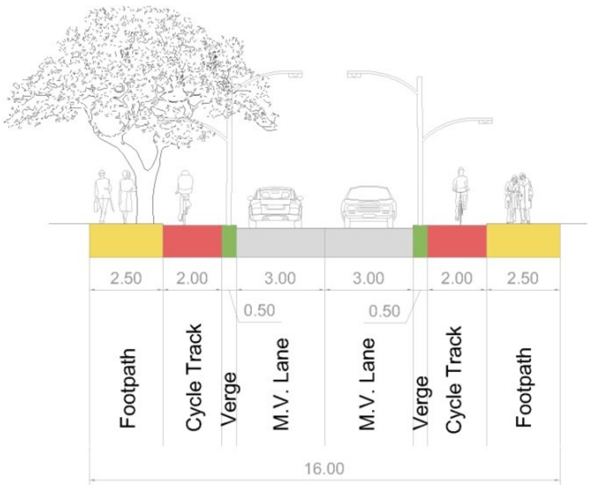
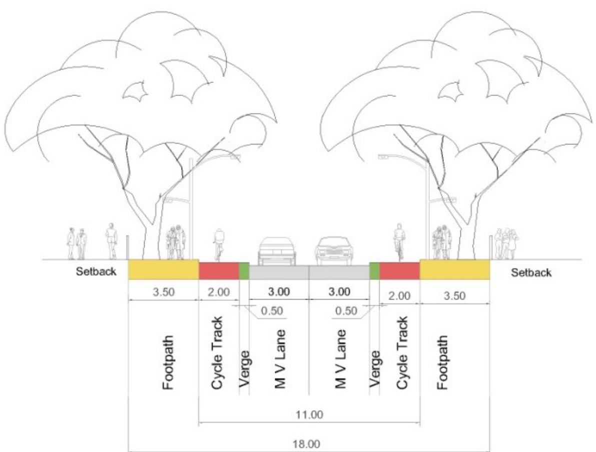


Fig. 5.11 Collector road (16 m) with segregated cycle tracks and without parking.

It is possible to apply segregated cycle tracks at collector roads with even narrower ROWs by moving the lamp posts onto the footpath. In that case the verges can be narrowed to 0.50 m. as shown in fig. 5.12 below.

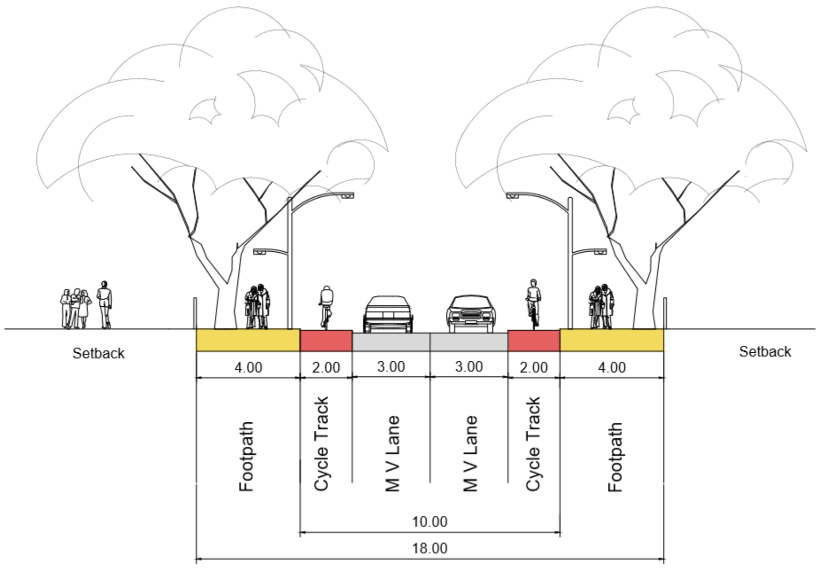


Alternative widths	
ROW	
16.00 m.	*- Footpaths: 2.50 m.*
15.00 m.	*- Footpaths: 2.00 m.*

Fig. 5.12 Collector road (18 m) with segregated cycle tracks, without parking and with lamp posts on the footpath

5.6.4 Collector road with raised adjacent cycle tracks (14-18 m.) without parking

In order to create more pedestrian space, or apply cycle tracks at roads with even an even smaller ROW, it is also possible to apply raised adjacent cycle tracks. This is possible at locations where there is no parking. However, in most cases the designs shown above (fig. 5.11 and 5.12) are preferred because they provide better segregation between cyclists and motorised traffic.



Alternative widths	
ROW	
16.00 m	- Footpaths: 3.00 m.
15.00 m.	- Footpaths: 2.50 m.
14.00 m.	- Footpaths: 2.00 m.

Fig. 5.13 Collector road with raised adjacent cycle tracks, without parking

Figure 5.14 shows the same designs on a road with a 15.00 m. ROW.

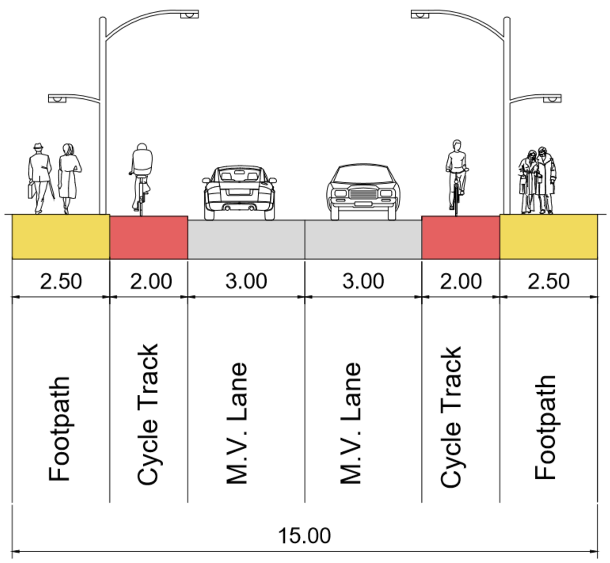


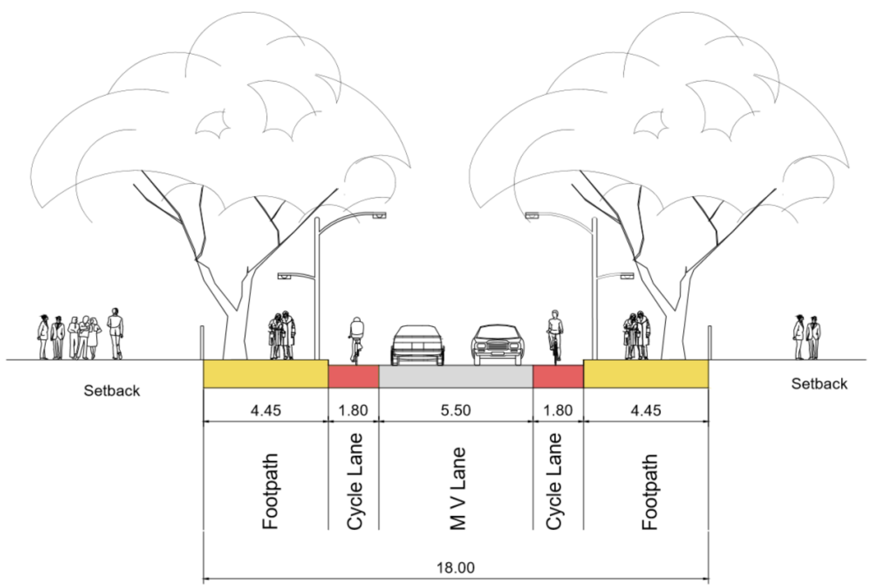
Fig. 5.14 Collector road with raised adjacent cycle tracks, without parking

5.6.5 Collector road with cycle lanes (13-18 m.) without parking

Cycle lanes are an appropriate option at collector roads:

- where there is no car parking.
- where there are very few trucks or busses.

The typical and preferred width for cycle lanes here is 1.80 m. According to research in the Netherlands, narrower cycle lanes lead to a worsening of the road safety. Wider cycle lanes are not recommended for the Indian situation because of an increased risk that cars park on the cycle lane.



Alternative widths	
ROW	
16.00 m.	- Footpaths: 3.45 m.
14.00 m.	- Footpaths: 2.45 m.
13.00 m.	- Footpaths: 1.95 m.

Fig. 5.15 Collector road with cycle lanes

Critical is the width of the carriageway. When the MV-lanes are too wide, the speeds increase, when the MV-lanes are too narrow there is too much encroachment of the cycle lanes. For the Indian situation 5.50 m. is considered appropriate. Only on routes with many trucks or busses a wider MV-lane needs to be applied, however in this case segregated cycle tracks or raised adjacent cycle tracks are preferred. Note that cycle lanes are always one-way!

5.7 Cycling infrastructure at road sections of local access roads

Neighbourhood streets or access roads are roads with low traffic volumes. The most important measures here to allow safe cycling are:

- Making the street a 30 km/h street with speed humps or other speed reducing measures.
- Reducing the volumes of motorised traffic by disabling through traffic or creating a one-way street.

Characteristics of local access roads:

	Typical	**Possible**
MV-lanes:	No traffic lanes marked	No traffic lanes marked
Carriageway width:	5.00 - 7.00 m. incl. on-street parking	4.00 - 4.75 m. (one-way traffic with or without parking)
Maximum speed:	30 km/h	
Traffic volumes:	< 500 PCU/hr. in two directions (peak hour)	
ROW:	10.00 -16.00 m.	8.00 - 10.00 m.
Cycling infrastructure:	Shared use	Cycle lanes Two-way cycle track (at main cycle routes)
Verge:	n.a.	1.00 m. in case of two-way cycle track
Car parking:	On-street not marked Preferably parallel	Marked with parking bays Preferably parallel parking but perpendicular parking is also possible
Median / lane marking	No median No lane marking	

Table 5.8 Characteristics of access roads

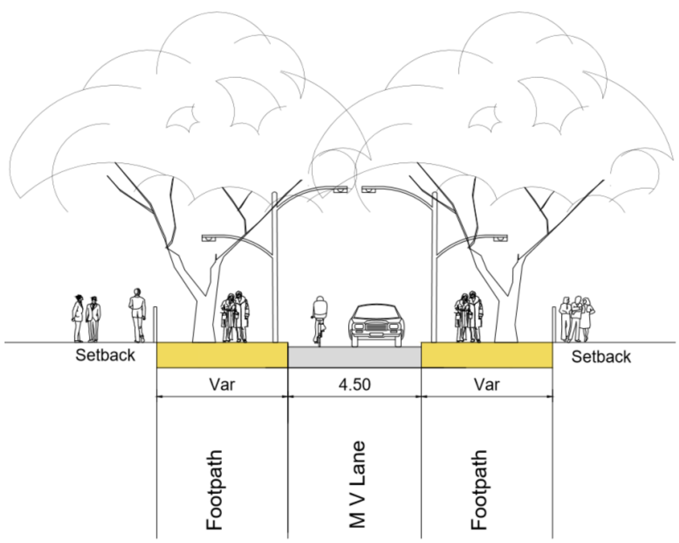
The appropriate width of an access road depends on the most common use. Table 5.9 shows how the appropriate width can be calculated by adding up measuring segments for vehicles and obstacle distances.[13]

[13] The obstacle distances (distances between vehicles and between vehicles and immoveable obstacles) come from research in The Netherlands. In India vehicles pass each other at a much closer distance. However, for safe cycling (and general traffic), larger passing distances are preferred.

Measuring width of 30 km/h access roads	
Measuring segment	**Width needed**
cyclists	0.75 m.
autorickshaw	1.20 m.
passenger car	1.85 m.
goods vehicle or bus	2.60 m.
bicycle - edge (curb)	0.25 m.
bicycle - parked vehicle	0.50 m.
bicycle - bicycle (in same direction)	0.25 m.
bicycle - moving vehicle	0.85 m.
vehicle - vehicle (both moving)	0.30 m.
moving vehicle - curb	0.25 m.

Table 5.9 Measuring segments for 30 km/h access roads

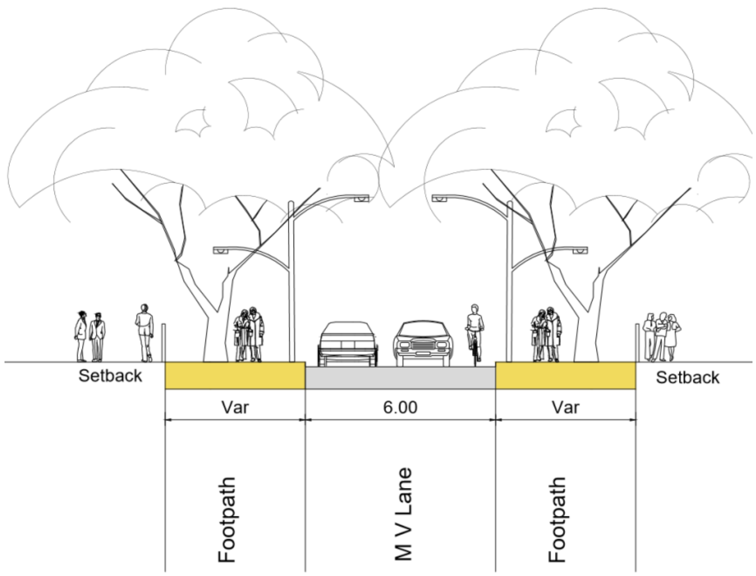
Typical access roads have no traffic lanes marked. Using the dimensions of table 5.9 different widths for access roads can be determined. For instance, on busier access roads where it is possible that two cars meet each other together with one cyclists, a width of 6.00 m. (0.25 + 1.85 + 1.85 + 0.85 + 0.75 + 0.25 = 5.80 m.) isappropriate as shown in figure 5.16.



Typical use:
car-car-bicycle

Fig. 5.16 Two-way access road with shared use and space for on-street parking

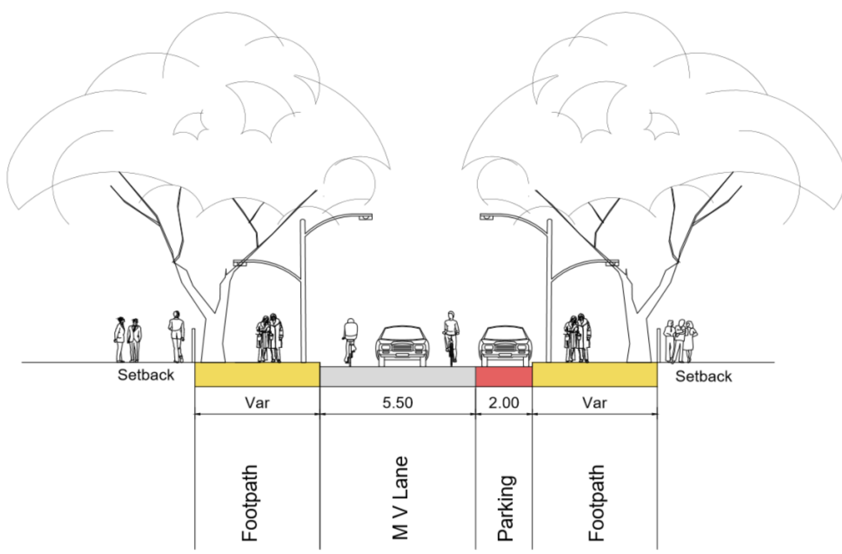
The same design can also be used on a road with less traffic and on-street parking on one side of the road. With 4.20 m. left for traffic, two cars can pass each other at a low speed at locations where cars are parked. Elsewhere, 2 cars and a bicycle can pass each other at the same time.



Typical use:
car-car
or:
car-bicycle
or:

Fig. 5.17 *Narrow two-way access road with shared use*

The design of fig. 5.17 is appropriate for access roads with low volumes of traffic. Here two cars can comfortably pass each other (a Mercedes Benz E class car is 2.00 m. wide including mirrors) at a low speed or a car and one or two bicycles in the opposite direction can pass each other.



Typical use:
bicycle - car - bicycle
car -car
car - bus

Fig. 5.18 *Access road with shared use and parking bays*

The design of figure 5.18 is appropriate where a lot of car parking is expected (planned for on one side) and where the typical use is: (motor)bike - car - (motor)bike. In other words: fewer cars than bicycles or motorcycles. In that situation a carriageway width of 5.50 m. is appropriate.

5.8 Pinch point design

In the previous sections many possible cross-sections have been introduced with different alternatives. However, in Pune, most roads have a right of way that varies from location to location. When a road has a continuous width (e.g. between 30 and 32 m.) but short stretch that is significantly narrower (e.g. 26 m.) we call that a pinch point. The previous sections show a variety of possibilities to reduce the space needed for a certain design.

Pinch points should be dealt with as follows:

- In principle, the narrowest cross-section is normative for the road design. At the wider sections it is than possible to add for instance parking, a wider verge or even additional traffic lanes if that makes sense.
- Where a continuous design (at the wider sections) need to be narrowed at a pinch point, where different elements of the design have already been minimised (e.g. verges for cycle tracks of 1.00 m. wide and footpaths of 2.00 m. wide) the following approach should be applied in the order as shown:

	Measure to reduce the space needed	**Absolute minimum width to be applied**
1.	Remove car-parking on one or both sides of the carriageway	
2.	Reduce the width of traffic lanes	2.75 m.
3.	Reduce the amount of traffic lanes	e.g. from 3 per direction to 2 per direction or from 2 to 1 per direction
4.	Reduce the footpath to absolute minimum	1.75 m.
5.	Reduce cycle track verge with lamp post to absolute minimum	0.50 m.
6.	Reduce cycle track to absolute minimum	1.75 m. (for one-way) without presence of obstacles such as trees or lamp posts
7.	Apply shared cycle track/footpath	Below 3.50 m. a shared cycle track/footpath is generally preferred over a separate footpath and cycle track of less than 1.75 m. each.

Note that these are conditional. This means that an absolute minimum width footpath (4.) should only be applied after parking has been removed (1.) and traffic lanes widths have been reduced (2.) and a study has been done to see if the amount of traffic lanes can be reduced (3.).
Hence, shared cycle tracks/footpaths should only be applied after all the measures 1 till 6 have been applied or at least seriously studied before. Shared footpath/cycle tracks should never be a first option or easy way out to maintain MV-space.

6. Cycling infrastructure at intersections

6.1 Introduction

Intersections are generally the locations where most accidents happen with cyclists and where the most severe accidents happen. Therefore proper intersection design is important. Because the vast majority of cycling infrastructure in Pune will be cycle tracks, this chapter focuses on the design of cycle tracks at side roads and intersections, with a few references to cycle lanes at intersections.

In order to create a safe intersection for cycling, first the geometry of the intersection needs to be adapted, after that cycle tracks can be added.
Safe intersection designs will:

- Reduce speeds
- Reduce crossing distance
- Reduce amount of locations with encounters
- Make intersection comprehensible
- Provide good previsibility
- Assure good visibility: car ↔ car, car ↔ bicycle
- Provide exclusive space for cyclists (and pedestrians)

Key design measures that lead to those goals are:

1. Make the intersection as compact as possible.

Wide intersections as shown below, lead to:
- more chaos
- higher speeds
- more accidents

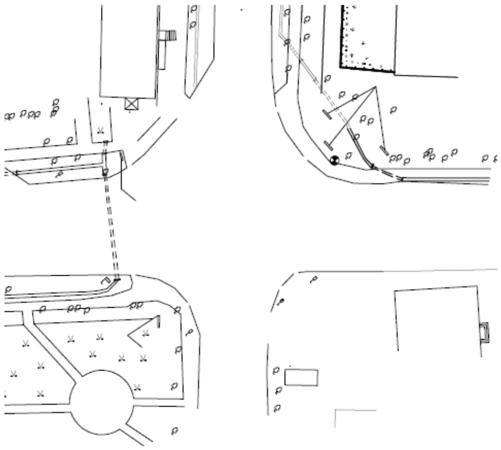


Fig. 6.1 Wide and inappropriate intersection geometry

2. Use narrow radii. For large intersections curb radii of 10.00 m. or less are recommended.[14]
3. Provide proper road marking leading into and on the intersection.

6.2 Design of side roads and property entrances

Before focusing on large intersections we take a look at the design at side roads. Side roads are access roads that connect to a road of higher hierarchy as follows:

- Access road x Collector road
- Access road x Sub-arterial road
- Access road x arterial road (this combination should be avoided but is still quite common in Pune).

Priority rules
Cyclists cycling on a cycle track along the main carriageway should have priority over vehicles turning into the side road. While in India cyclists are generally expected to yield for turning motor vehicles, the infrastructure design should support a change in this behaviour. To reduce conflicts between cyclists on the cycle track and vehicles leaving or entering side roads, it is important to reduce the speeds of motorised vehicles that cross the cycle track. In the next section is explained how to do this.

6.2.1 Elevated crossings at side roads with cycle tracks

Wherever cycle tracks on main roads (arterial, sub-arterial) or collector roads pass side roads (local street) or property entrances, the cycle track and footpath should continue at level while motor vehicles entering the side road or property entrances have to drive up a ramp. In this case, ideally, the cycle track is located at some distance from the main carriageway in order to give drivers some time to see and stop for cycling. According to research in The Netherlands a distance of between 2.00 and 5.00 m. is the

[14] In the Urban Street Design Guidelines radii as small as 4.00 m. are recommended for sub-arterial roads.

safest. With 5.00 m. cars can wait for passing cyclists at a distance from the main road, while 2.00 m. allows for a safe buffer.

	Option 1	**Option 2**	**Minimum** (to be avoided if possible)
Width verge at side roads	5.00 m.	2.00 m.	1.00 m.

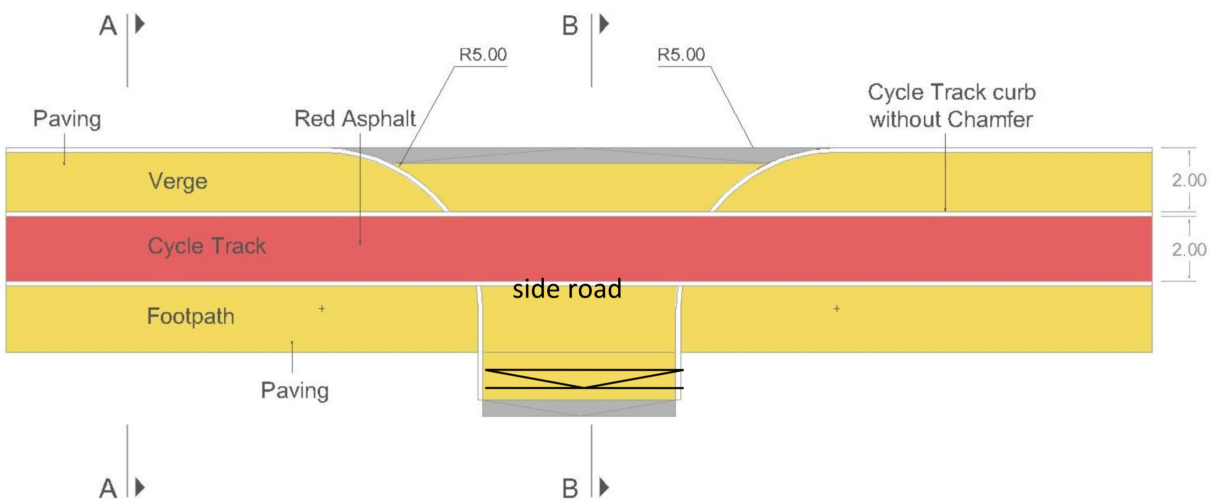


Fig. 6.2 Raised crossing at side road (verge width of 2.00 m.)

Figure 6.3 below shows how this elevated side road crossing can be designed. Note that at road sections (between intersections) the footpath should be separated by a 50 mm curb from the cycle track. However at elevated crossings there is no curb between the cycle track and the footpath. In cases where illegal use of cycle tracks by two-wheelers is expected, bollards can be placed at the entrance of the cycle track. See section 7.4 for further information.

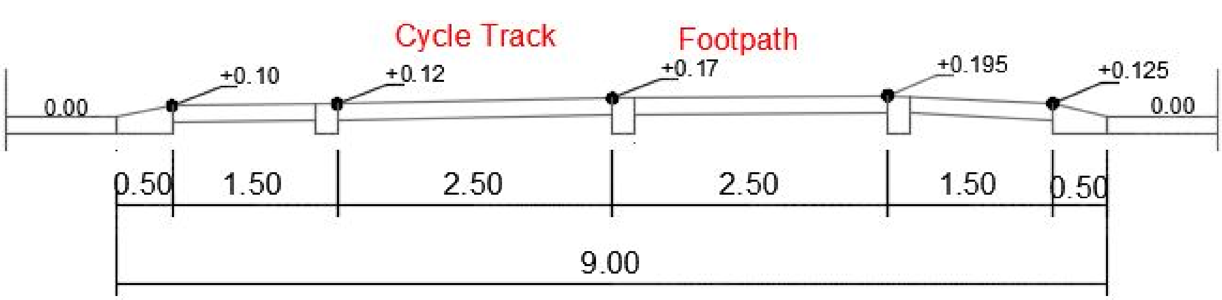


Fig. 6.3 Cross-section B-B at elevated crossing

6.2.2 Bending out of cycle tracks at side roads

Where the cycle track is located closer to the carriageway, for instance with a verge of 1.00 m., it is possible and recommended to bend the cycle track away from the carriageway at side roads till 2.00 m. or 5.00 m. This allows cars and motorcycles to first leave the carriageway and break, if needed before the cycle track in case there are cyclists passing. On the other hand cyclist have bit more time to react to drivers that do not stop when crossing the cycle track because they are further away from the carriageway, thus increasing the road safety. Bending out 2.00 m. is also possible where space is limited.

Note: Motor vehicles that turn left or right and cross the cycle track should yield to cyclists as well as pedestrians moving along the main road.

The drawing below shows how to bend out a cycle track at a side road (or intersection):

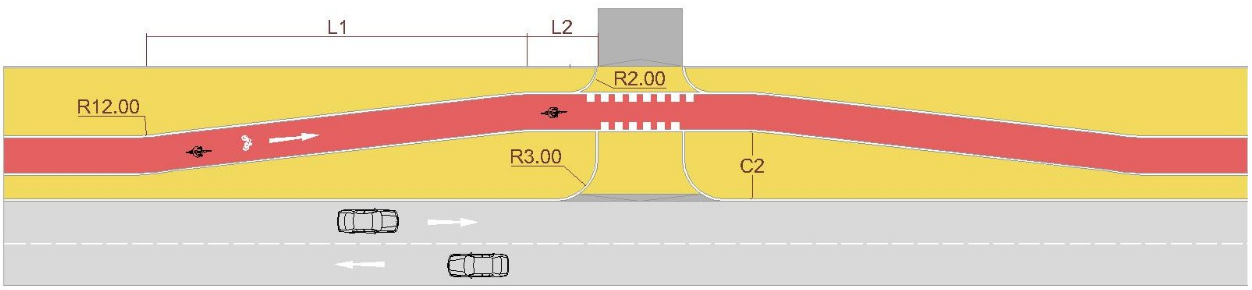


Fig. 6.4 Bending out of a cycle track at side road

The dimensions in this design are as follows:

- C2 = 5.00 m.
- L1 = 30.00 m.
- L2 = 5.00 m.

The dimensions of the ramps can be as in fig. 6.3: 0.50 m. x 0.125 m for maximum reduction of speed at entrances or 0.50 m. x 0.100 m. or 0.70 m. x 0.125 m. for a regular speed hump on side streets. The 2.00 m. radius for cyclists to turn into the side road is not always applied (see fig. 6.2). This depend on the demand for cyclists to turn into or leave this side road.

Fig. 6.5 Bending out of an elevated cycle track at side road

For the Indian situation, the bending out of cycle tracks is something new and thus has to be tried out. For the road types discussed in chapter 5, the following guidelines can be applied:

	Standard verge width at road sections	**Recommended verge width at side road**	**Possible verge width at side road**
Arterial road with one-way cycle tracks	2.00 m.	2.00 m.	
Arterial road with two-way cycle tracks	2.00 m.	5.00 m.	2.00 m.
Sub-arterial road	3.00 m. (with parking)	3.00 m.	5.00 m.
Collector road with cycle tracks	1.00 m.	2.00 m.	1.00 m.

Table 6.1 Verge width at side roads

Table 6.1 shows that the cross-section designs are already taking a safe verge width at side roads into account and thus in most cases bending out further is not needed. However, it is recommended for collector roads and for arterial roads with two-way cycle tracks to bend out to 2.00 and 5.00 m. respectively. Particularly for two-way cycle tracks, bending out to 5.00 m. is recommended. See section 6.2.3.

6.2.3 Side roads with two-way cycle tracks

In principle the design for elevated one-way and two-way cycle tracks at side roads is the same. However, because the risk of accidents (at side roads and intersections) with two-way cycle track is 90% higher than with one-way cycle tracks, a sufficiently wide verge between the two-way cycle track and the carriageway is recommended at the side road. For two-way cycle tracks bending out 5.00 m. is ideal because it gives motorists the possibility to come at an almost 90 degree angle in relation to the cycle track and have a good view on cyclists from either side. A 2.00 m.distance from the carriageway is also possible as shown below. Accident risk rises when the verge is less than 2.00 m.

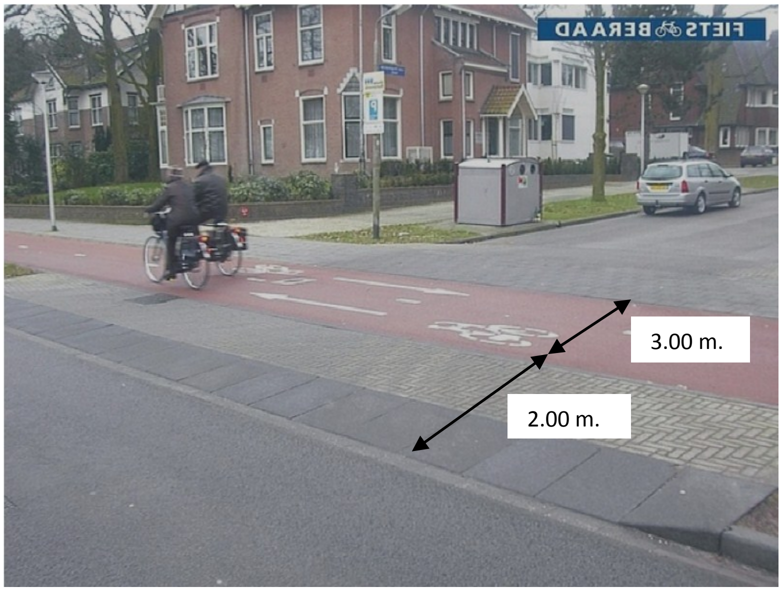


Fig. 6.6 Two-way cycle track at 2.00 m. from the carriageway.

6.3 Intersections with cycle tracks

Cycle tracks have to be applied at arterial and sub-arterial roads and can be applied at collector roads. While the design at the road sections, in principle, determines the design at the intersection, there are different ways to design the intersection. The two basic designs are:

1. Segregated design at intersections
   This is the standard design. The cycle track is continued at the intersection, thus providing maximum protection and continuity for cyclists.
2. Unsegregated design at intersections
   Here the cycle track is converted into a cycle lane prior to the intersection and bike boxes are created to enable cyclists to turn right. This is the design proposed in the Urban Street Design Guidelines.

These two solutions are fundamentally different. In section 6.3.1 the segregated intersection design is shown and explained. In section 6.3.2 the unsegregated intersection design is shown. Section 6.3.3 explains the advantages and disadvantages of both options.

6.3.1 Intersections with one-way cycle tracks and segregated design

An example of the so-called segregated design[15] is shown below.

Basically, this is a design where, typically, at all arms the cycle track is bend out to 5.00 m. from the carriageway. This design has the following particularities:

1. At each corner, oval islands (A), protect the cyclists against motorised traffic.
2. Cyclists do not mix with motorised traffic and thus need their own traffic lights. This also alows for a separate phasing for cyclists which makes the crossing even safer.
3. Cyclist turning right, see blue arrows, will cross in two stages. In most cases, this means that cyclists will cross one arm, then wait, and then cross the other arm. Signal phasing can be set in such a way that delays for cyclists are limited as much as possible.
4. Central traffic islands (B) are not a necessity, but make the crossing safer, particularly when traffic lights are not working.

Fig. 6.7 Segregated design at intersection with one-way cycle tracks

[15] This design is used in the Netherlands at all locations where roads with cycle tracks intersect and has proven to be very safe and comfortable for cyclists.

Fig. 6.8 Segregated design at intersection with one-way cycle tracks

Below a design is shown of an intersection between an arterial road and a sub-arterial road as recommended in chapter 5:

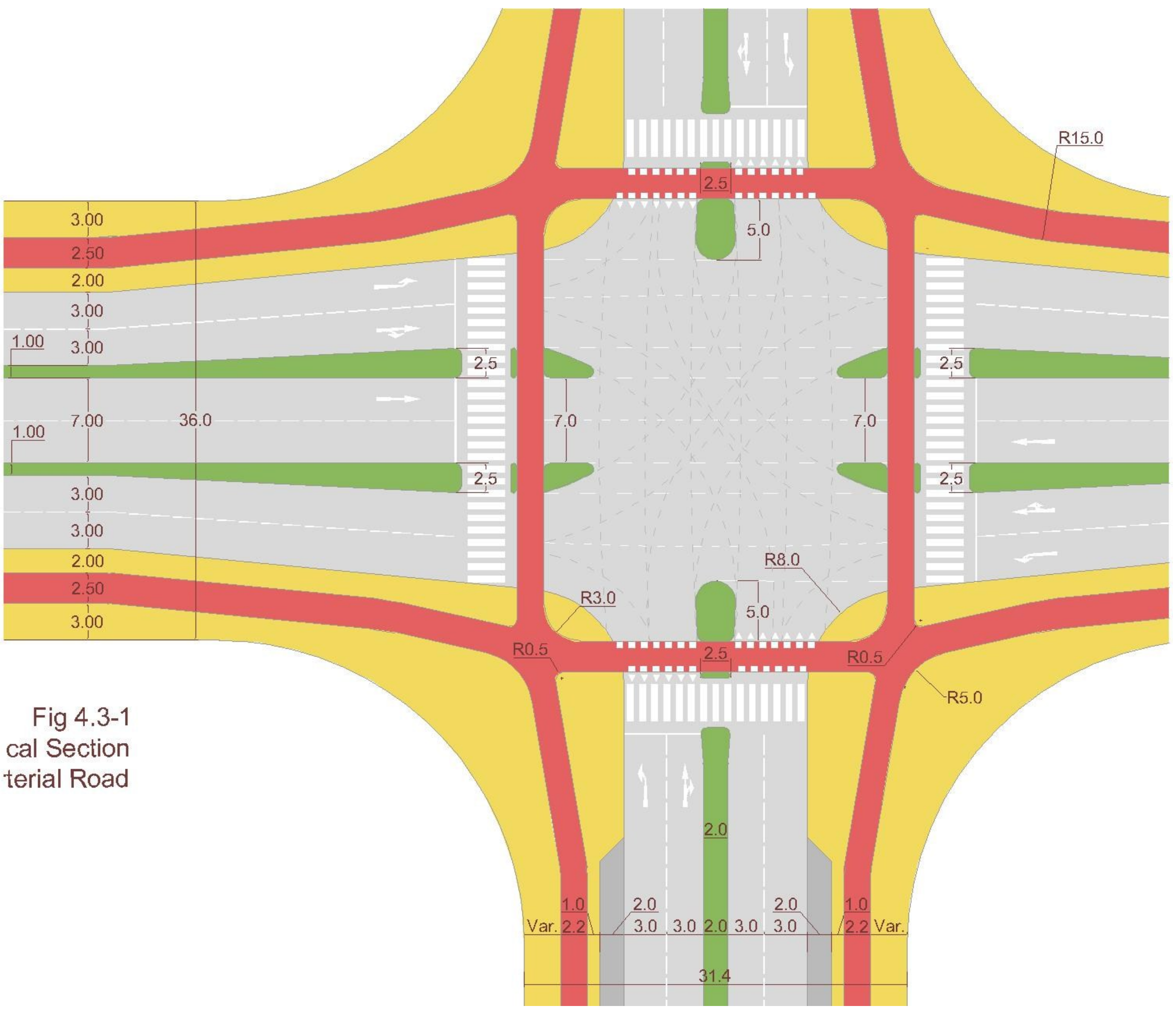


Fig. 6.9 Intersection of a typical arterial road with central BRT-lanes and a typical sub-arterial road with parking

Fig. 6.9 shows a number of things:

- The arterial road is the main road. This mean that left-turning traffic has to yield for cyclists going straight along the arterial road unless traffic lights indicate otherwise (conflict free traffic light settings).
- Cyclists have a 2.50 m. wide central median (two in the arterial road) as a safe refuge halfway the crossing.
- All cycle tracks are bend out till 5.00 m. distance from the carriageway.

6.3.2 Intersections with two-way cycle tracks with segregated design

A segregated intersection design with two-way cycle tracks is very similar to that with one-way cycle tracks. The most important difference is the turning radii in the cycle track, which needs to allow cyclist to cycle in two directions.

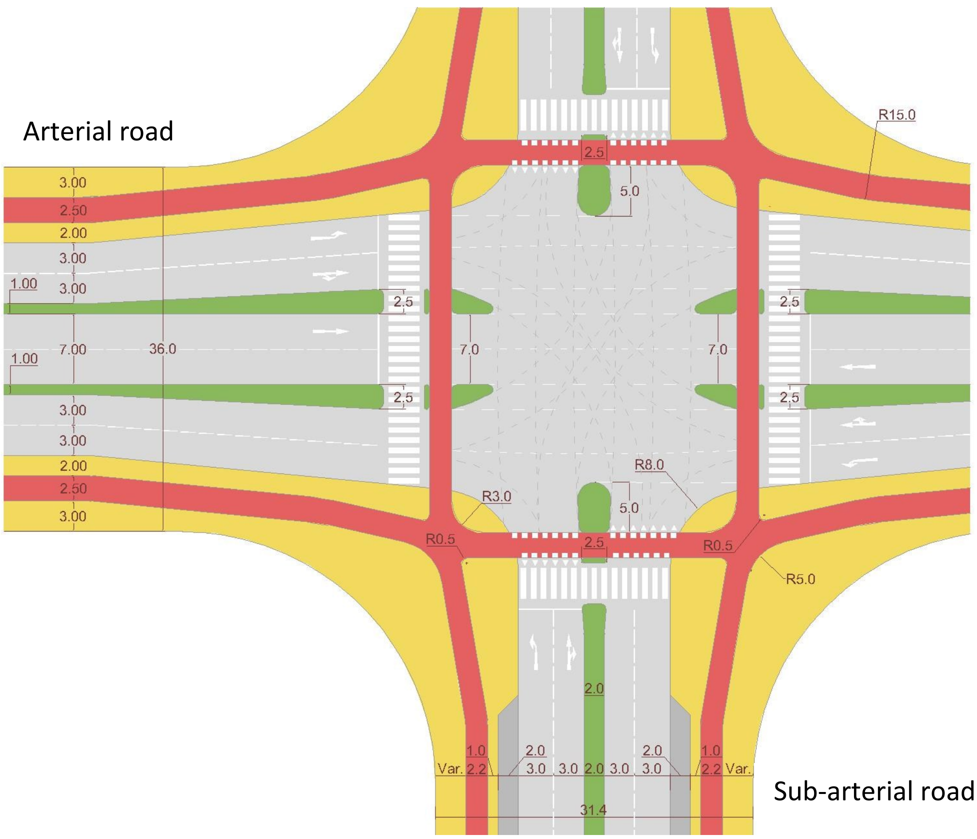


Fig. 6.10 Intersection with two-way cycle tracks along the arterial road and one-way cycle tracks along the sub-arterial road

Of course, a large intersection like the one in figure 6.10 does need traffic lights. However, whenever traffic lights fail the arterial road gets priority over the subarterial road. This holds also true for the cycle tracks along the arterial road as is shown with road marking and by continuing these cycle tracks in red accross the intersection. Below this is shown in detail:

1. The two-way cycle track crossing the sub-artieral road and along the arterial road is marked through the intersection in red. This is because this direction gets priority here.
2. The one-way cycle track crossing the arterial road and crossing the sub-arterial road is only marked with a broken line because this direction doesn't get priority (when traffic lights are not functioning).
3. The priority is emphasized by road marking. The triangles, or 'shark teeth' show who has priority.

6.3.3 Cycle tracks with unsegregated design at intersections

It seems obvious to continue cycle tracks at the intersection as shown in section 6.3.1 and 6.3.2. There is however another design possibility as proposed in the Urban Street Design Guidelines where cyclists are mixed with motorised traffic at intersections. This can be done by using bicycle boxes. The bicycle box is a Dutch invention used to allow cyclists to turn right (in the Indian situation) by moving ahead of motorised traffic. In The Netherlands this solution is only used in combination with cycle lanes at the arms of the intersection, not in combination with cycle tracks. In section 6.3.4. the segregated (cycle track) and unsegregated (cycle lanes + bicycle boxes) designs are compared.

In the USDG this design is proposed for all intersections, including those with segregated cycle tracks. With some adaptation this is possible. Figure 6.11 shows how bicycle boxes can be applied before the zebra. This is the standard approach.

Bicycle boxes before zebra crossing
The figure below shows how bicycle boxes can be applied before the zebra crossing. For a successful and safe application of bicycle boxes, lane discipline by drivers and separate lanes for separate directions is important. The figure below shows that, at green, cyclists first weave across one lane of traffic to get to the cycle lane and the cycle box to turn right. After that cyclists can turn right without there being a conflict with motorised traffic that goes straight or turns right.

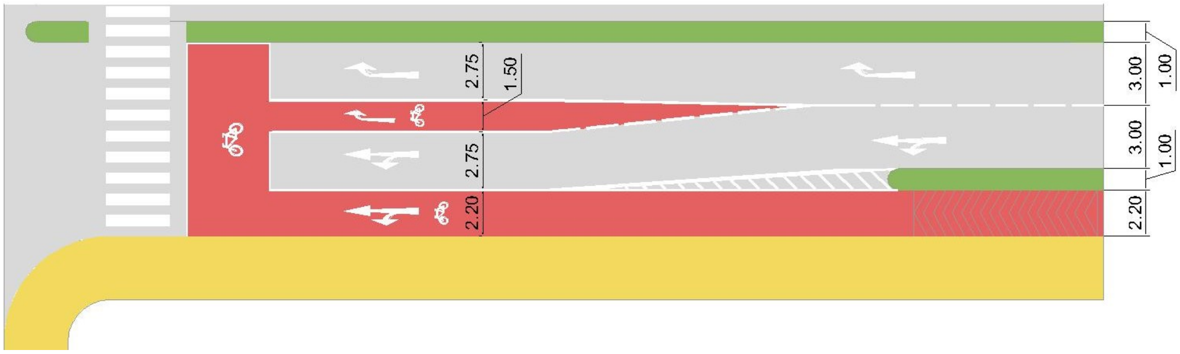


Fig. 6.11 Bicycle box before zebra crossing (at sub-arterial road)

The main advantage of this design is that when the traffic light (for traffic on this road) is red cyclists can position themselves in the bicycle box without conflicts with pedestrians crossing the road. A full intersection with this design is shown in fig. 6.12.

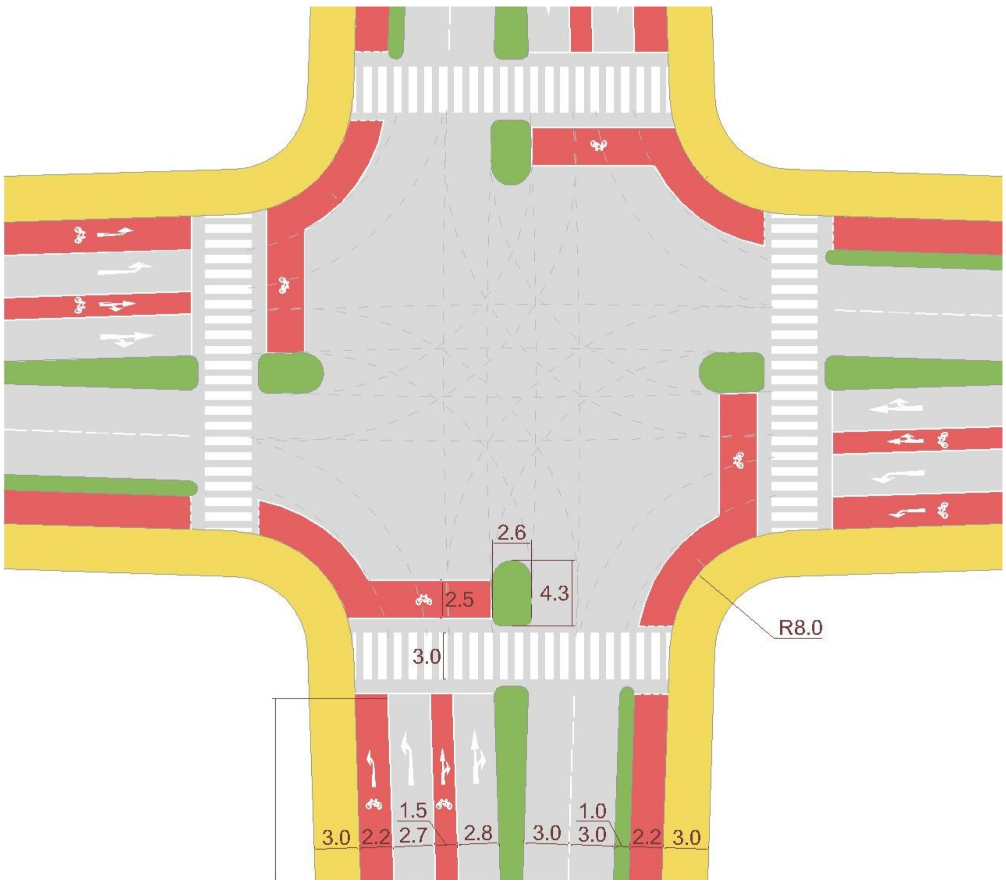


Fig. 6.12 Intersection with bicycle boxes before the zebra (two sub-arterial roads)

A possible disadvantage of this design is that motorists encroach the bicycle box. A possible solution for this is shown in figure 6.12.

Bicycle boxes after zebra crossing

An uncommon alternative is to apply the bicycle boxes after the zebra crossing. This has the following advantages and disadvantages:

+ Drivers of motor vehicles will be less inclined to enter the bicycle box at red. The zebra crossing here functions as a buffer.
+ At red, cyclists will have to cross the zebra crossing, while pedestrians have a green light to cross. This creates conflicts that do not occur in the design of Fig. 6.11.

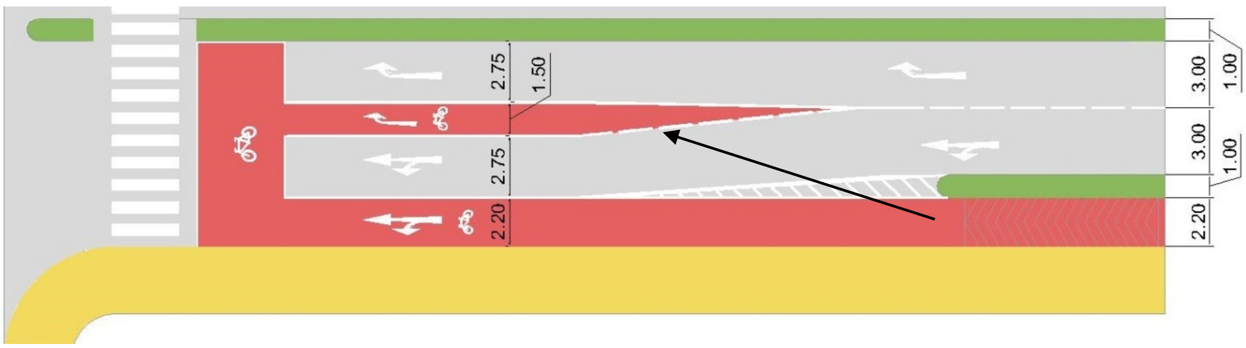


Fig. 6.13 Bicycle box after zebra crossing (at sub-arterial road)

Figure 6.11 shows how an intersection with bicycle boxes looks like. One thing that is important to realise - see blue arrows - is that cyclists that turn left do not have segregation and can thus be hindered by cars and motorcycles turning left. This is not the case in the segregated design shown in figure 6.7 till 6.10.

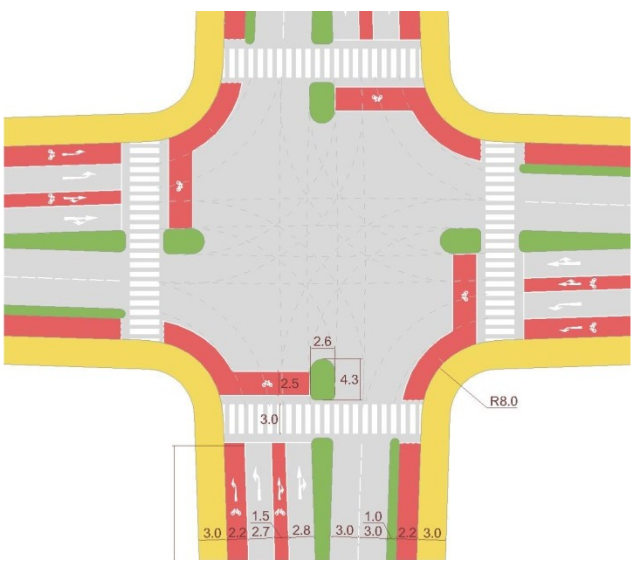


Fig. 6.14 Intersection with bicycle boxes after the zebra

Traffic signals

In order to give cyclists a head start, when applying bicycle boxes, cyclists should be given green 5 seconds before MV traffic so they can get ahead of motorised traffic.

Because both the segregated and the unsegregated design have advantages and disadvantages, they are compared in the next section.

6.3.4 Comparing segregated and unsegregated designs at intersections

The segregated and the unsegregated design, both have their advantages and disadvantages. The basic difference is that the segregated design has better road safety and the unsegregated design better directness (less delay) for cyclists turning right.

An overview of advantages of both designs is given in table below:

Segregated design **(cycle tracks)**	**Unsegregated design** **(cycle lanes and bike boxes)**
+ Better road safety + Better subjective road safety + Attract new, inexperienced cyclists	
+ Only option with two-way cycle tracks	− Not possible with two-way cycle tracks
− Less direct for cyclists turning right (cross intersection in two stages)	+ Better directness for cyclists turning right (in one move with motorised traffic)
− More difficult to design and construct	
− Motorists and cyclists have to learn how to use this design	+ Design is in line with current use where cyclists mix with motorised traffic at intersections

Table 6.2 Advantages and disadvantages of segregated and unsegregated designs

It is important to emphasize that the segregated design has benefits when properly designed and integrated in the traffic light control of the intersection, the unsegregated design is easier to apply.

For instance, to make the segregated design work well, it is important to have separate traffic lights for cyclists at the intersection as shown in figure 6.6.

Pilot segregated design
Therefore it is recommended to consider applying segregated designs at large intersections as pilot projects that will get extra attention in the form of information to users as well as studies to observe the behaviour of cyclists and motorists.

At side roads the segregated designs as explained in section 6.2 can be applied as the standard design.

7. Special topics and design details

7.1 Vertical design details and ramps

As shown in chapter 6, cycle tracks at side roads with a lower hierarchy (access roads) should preferably continue at the same level while MV will ramp up and down. However, at roads with similar hierarchy or when crossing a road with an important traffic function, the cycle track should ramp down to carriageway level. For a height difference of 10 to 15 cm. the ramp should go down over a distance of 3 to 5 metres to allow for a smooth transition. Lips of any kind should be avoided.

Fig. 7.1 A smooth transition between a raised cycle track and the carriageway

7.2 Bus stops

When a cycle lane or cycle track passes a bus stop, a special design is needed that minimizes the conflict between cyclists and bus passengers and between cyclists and busses. While one way to deal with bus stops is to apply bus bays, they are not shown here as standard solutions because of the risk that these will be used for car or autorickshaw parking.

There are in principle three ways to deal with bus stops. Table 7.1 shows the options and the implications for the conflict between bus passengers and cyclists and between busses and cyclists.

	Options	**With cycle track or cycle lane?**	**Passengers <--> Cyclists**	**Busses <--> Cyclists**
1.	Cycle track behind the bus stop	Cycle track or cycle lane	No conflict	No conflict
2.	Cycle track in front of the bus stop	Cycle track or cycle lane	Conflict	No conflict
3.	Bus stops on cycle track, cycle lane or shared road	Cycle track, cycle lane or shared use	No conflict	Conflict

Table 7.1 Different ways to apply bus stops

Recommendation:
Wherever there is space option 1, with the cycle track leading behind the bus stop should be applied. Where space is more limited one of the other options can be applied. The different options are explained below.

1a. The cycle track leads behind the bus stop

This is the typical cycle track design. Typically, the bus stops at a bus bay so that other traffic can pass while the bus is halting. Fig. 7.2 shows how this can look.

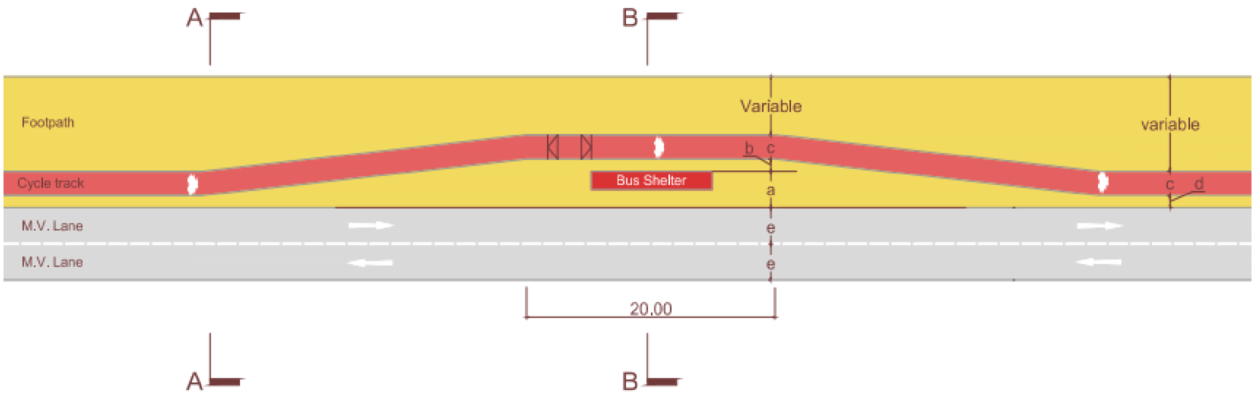


Fig. 7.2 Bus stop with cycle track behind the bus shelter

The dimensions for this design are as follows:

- a + b = 2.00 m. (minimum with narrow bus shelter) - 3.00 m. (preferred)
- b = 0.50 m. or greater
- c = 2.00 - 2.50 m. (one-way). Where space is limited it is possible to locally narrow the cycle track behind the bus shelter to 1.80 or even 1.50 m.
- d = 0.50 - 5.00 m. (dividing verge width is independent of bus island width 'b')

Fig. 7.3 shows the cross-section of the design shown in figure 7.2.

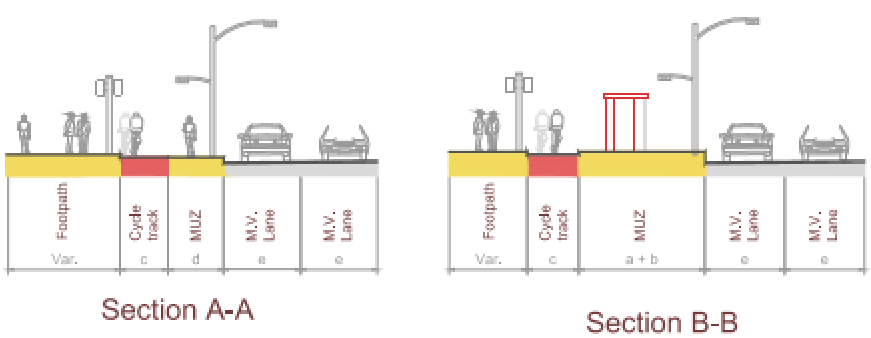


Fig. 7.3 Cross-sections of cycle track leading behind the bus shelter

Note that before the bus shelter, the cycle track is brought to the same level as the footpath and the bus island (MUZ) to allow bus passengers to cross the cycle track at level.

Dimensions at the location of the bus shelter (section A-A) and bus bay are as follows:

	Preferred	Minimum
Footpath	> 3.00 m.	1.50 m.
Cycle track (c)	2.00 m.	1.50 m.
Bus island - width (b)	3.00 m.	2.00 m.
Bus bay - depth (a)	3.00 m.	2.80 m.
Bus island - length	20.00 m.	18.00 m.
Total bay length	15.00 + 20.00 + 15.00 = 50.00 m.	14.40 + 18.00 + 14.40 = 46.40 m.

Table 7.2 Dimensions of bus stop with cycle track behind the bus shelter

Below is an example of Cycle Track behind a Bus Stop:

Fig. 7.4 Example of a Cycle Track behind a Bus Stop

1b. Cycle lane converts into cycle track behind the bus stop

However as shown in figure 7.5, leading the cycle track behind the bus stop is also possible in a situation with cycle lanes. In this case the cycle lane is locally converted into a cycle track. In figure 7.5 the cycle track behind the bus stop is locally raised to the level of the MUZ (Section B-B) and goes down to the level of the MV lanes afterwards (Section C-C). Here the example is shown without a bus bay. Thus, traffic must wait on the MV lane till the bus has departed. Of course, it is also possible to create a bus bay. In that case the length needed between the end of the cycle lane and the beginning of the bus island is between 15 and 20 m.

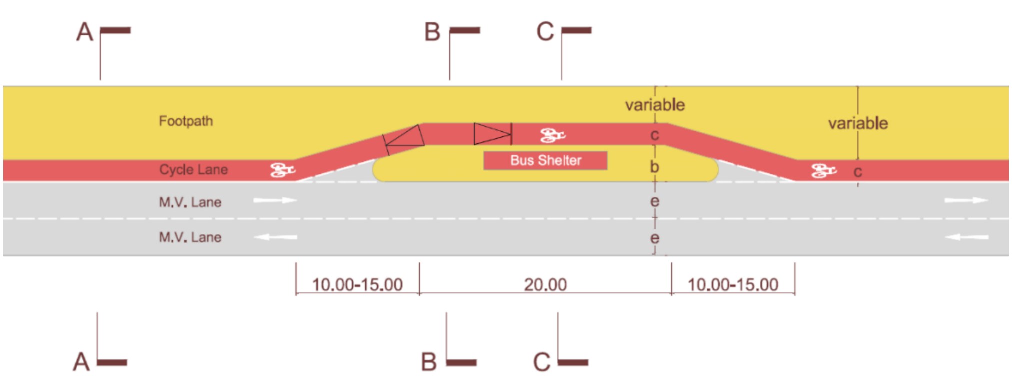


Fig. 7.5 Cycle lane converted into a cycle track behind the bus stop (Collector road)

The cross sections are shown in fig. 7.6.

variable	recommended	minimum
b	3.00 m.	2.00 m.
c1	1.80 m.	
c2	2.00 m.	1.80 - 1.50 m.

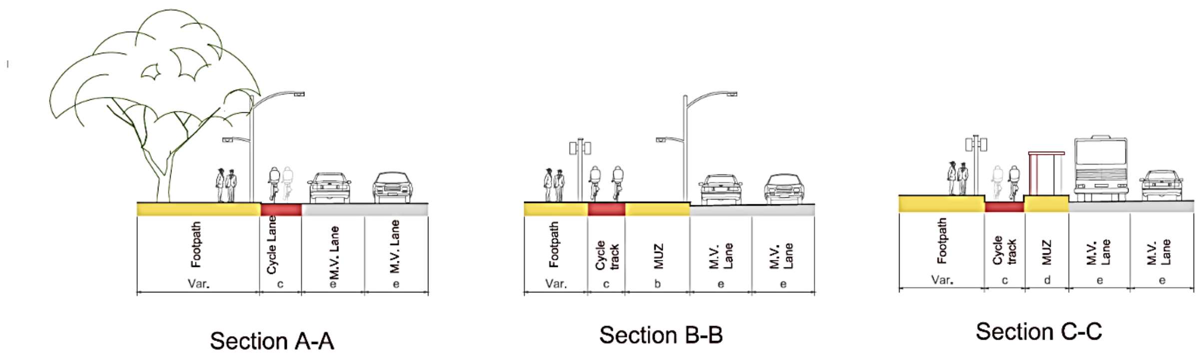


Fig. 7.6 Cross-sections of cycle lane being led behind bus stop

Fig. 7.7 Cycle lane converts into cycle track behind bus stop / bus shelter.

2. Cycle track in front of the bus shelter - no bus bay

When there is limited space between the carriageway and the cycle track, the total ROW is limited or when a bus stop creates problems with visibility, it is also possible to place the bus shelter on the footpath behind the cycle track as shown in figure 7.8, 7.9 and 7.10.

In this example the cycle track is brought to footpath level in front of the bus stop to allow for an easier access for bus passengers, across the cycle track, to the bus. However, it is also possible to maintain the height difference between footpath cycle track. This is recommended when the bus stop is used by many bus passengers at the same time to discourage that waiting bus passenger stand on the cycle track.

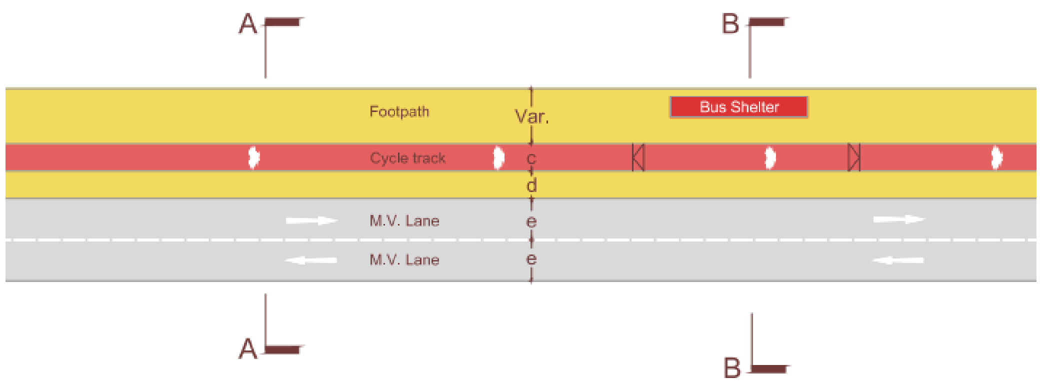


Fig. 7.8 Bus stop on the footpath behind the cycle track with bus halting on the MV lane

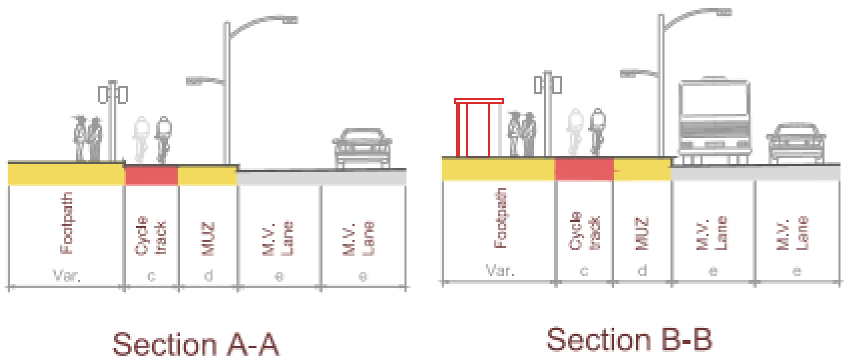


Fig. 7.9 Cross-sections of bus stop on the footpath behind the cycle track

variable	recommended	minimum
c	2.00 - 2.50 m. (one-way cycle track)	
d	1.50 - 5.00 m.	1.00 m.

This last design should not be applied at bus stops with large numbers of passengers mounting and dismounting since waiting passengers are likely to stand on the cycle track. Make sure that the verge (d) is wide enough for passengers to stand on.

Fig. 7.10 Bus shelter behind the cycle track and Island for bus stop

3. Bus stop on a raised adjacent, cycle track, cycle lane or shared road

On roads with cycle lanes or shared use where space is very limited, the bus can simply stop on the cycle lane or carriageway. In this case, cyclists and all other traffic must wait till the bus leaves. On roads with raised adjacent cycle tracks (+ 0.10 m.) it is possible to lower the cycle track to road level at the bus stop as shown in figure 7.11 below.

This option - the bus stopping on the cycle lane of shared road - is acceptable in cases where there are very few busses (less than 6 per hour) or on roads with very low volumes of motorised traffic and cyclists.

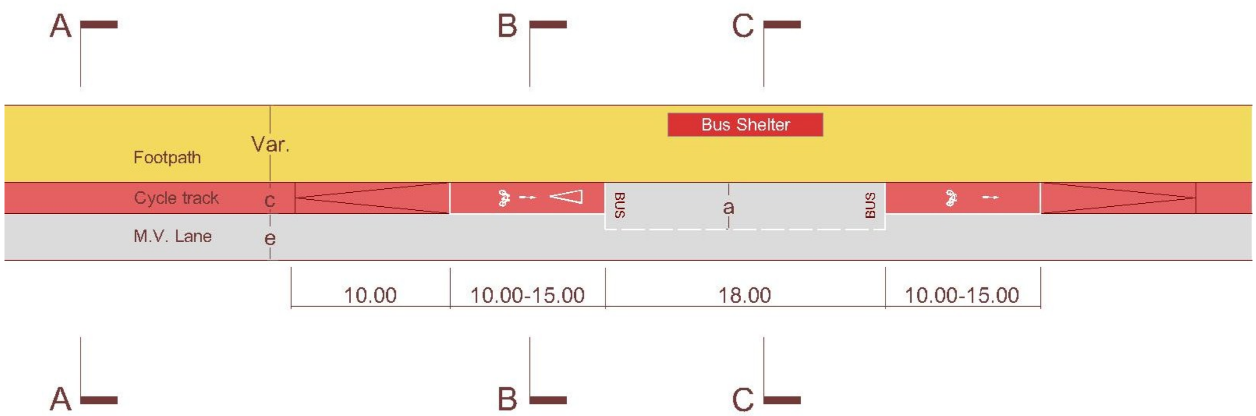


Fig. 7.11 Bus stop with raised adjacent cycle track converted into bus lane and shared use bus stop

In this design, with a raised adjacent cycle track, the dimensions are as follows:

variable	recommended	minimum
a	3.20 - 3.50 m.	3.00 m.
c	2.20 m.	2.00 m.

With a cycle lane, a width of 1.80 m. can be applied.

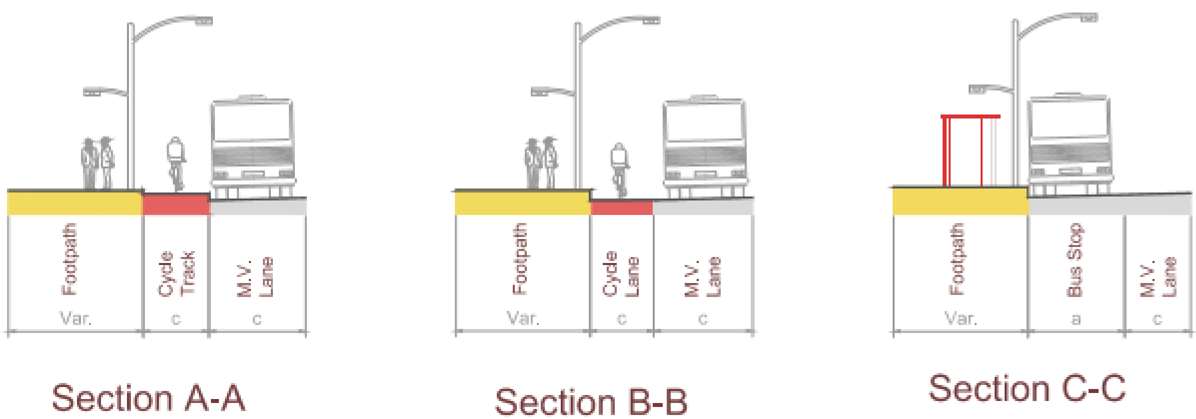


Fig. 7.12 Cross-sections of raised adjacent cycle track converted into shared use bus stop

7.3 Material use, road surface and colour

These guidelines focus on design and planning. Implementation is not the main focus. However, it is important to say a few things about material use and colour.

Material use and road surface

Comfort is important to ensure that cyclists do use the cycle track. Therefore, the following should be taken into account:

- *Asphalt* is the preferred material because it smooth and can deal with deformations due to movements in the underground or roots. For the best result an asphalt cycle lane or cycle track should be laid with a narrow asphalt machine, not manually.
- Second best is *concrete*. In this case doing it mechanically is also preferred, but highly skilled craftsman can also create good quality concrete laid manually.
- Interlocking *pavement blocks* are generally not preferred because they are generally less smooth and over time they can settle. Without proper maintenance cycle tracks made of pavement blocks deteriorate and end up not being used by cyclists.

Colour

It is very useful to use a special color for cycle tracks and cycle lanes. This makes cycling infrastructure easily recognizable and can help to emphasize the presence of cyclists at intersections. It can even improve road safety. Different colours are used.

- Blue is used, for instance, in Denmark. This is very visible, but esthetically not that attractive.
- Green is used in the United States and some other countries. While this is a pleasant colour with the emphasis on the sustainable nature of cycling, it is not as visible as blue and red.
- Red is used in the Netherlands, Belgium and some other countries. It is a pleasant colour that is still visible enough. For Pune red is recommended.

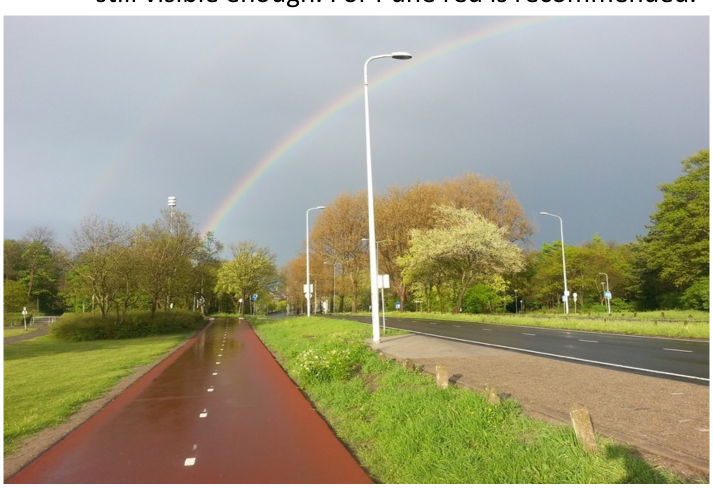


Fig. 7.9 A red two-way cycle track in The Netherlands

7.4 Bollards

Bollards on cycle tracks are potentially dangerous obstacles for cyclists. In the Netherlands, accidents with cyclists crashing into bollards amount to some of the worst cycling accidents with injuries. These accidents have led to research and studies about the application of bollards on cycle tracks and most Dutch cities have developed and implemented plans to reduce the number of bollards on cycle tracks. Therefore, bollards should only be applied where they are absolutely necessary to keep motorised vehicles out.

To reduce the chances of accidents the following can be done:

- Apply bollards of between 0.75 m. and 0.85 m. high so that they are well visible. A height of 0.85 m. is sufficiently low for mountainbikes and bicycles of older children (14+) to pass. Where younger children pass a height of 0.75 or even lower is recommended.
- Apply a distance between bollards of 1.20 m. to keep auto-rickshaws out.
- Place the bollards on a little traffic island with a rumble line marking that lead cyclists away from the bollard (see fig. 7.9)

Fig. 7.9 A narrow two-way cycle track with a bollard

However, on some cycle tracks in Pune, bollards are placed to keep motorcycles out. This leads to bollards placed very close together. While this is far from ideal, this might sometimes be unavoidable. IN this case the distance between the bollards should be as large as possible while still keeping motorcycles out while allowing cycles to pass.

8. Key success factors for cycling infrastructure design and implementation

Until today, cycle projects in Pune have generally not been successful. Many cycle tracks are not meeting the five requirements - particularly coherence and comfort are a problem - with the result that most cycle tracks are not used by cyclists.

Fig. 8.1 Cyclists use the carriageway while pedestrians use the cycle track

A good parameter to measure the quality of cycle tracks is to measure the percentage of cyclists using the cycle track. On a good quality cycle track more than 95% of cyclists will us the track. A significantly lower percentage is a sign that the cycle track does not meet the requirements for cycling-friendly infrastructure.

There are a number of key success factors that need to be applied to increase the success of cycling infrastructure in Pune.

1. **Continuity:** Detailed designs need to include dealing with trees, lamp posts, bus stops and pinch points. It is quite common in Pune that one single cross-section design is applied throughout the length of the road without taking trees, lamp posts, bus stops and pinch points into account.
2. **Footpath width:** Not only cycle tracks need to be wide enough, footpaths need to be designed for the existing actual use and flow of pedestrians to avoid that cyclists walk on the cycle track. If footpaths are full of obstacles pedestrians will walk on the cycle track (see figure 8.1). As mentioned in chapter 5 the minimum width of footpaths on collector roads should be 1.80 and 2.00 m. on sub-arterial roads and arterial roads. But in many cases land use and pedestrian flow require a larger width.
3. **Road surface:** Cycle tracks should preferably be made of asphalt so that an irregular road surface is not a reason for cyclists to cycle on the carriageway instead of the cycle track. Another option is concrete, but pavement blocks should not be applied as they are generally not smooth enough.

4. **Maintenance:** Many cycle tracks in Pune have not been maintained. It is essential that the PMC reserve an annual budget for the maintenance of cycling infrastructure in the city. This budget should increase when the total length of cycling infrastructure increases.

5. **Distinction from footpath:** Cycle tracks should be clearly distinguishable from footpaths by using both a different colour and a different material. For instance a red asphalt surface for the cycle track and block pavement or concrete for footpaths.

Finally, it is important to emphasize that good cycling infrastructure planning and design is not easy. It needs to be done integrally with the whole road design, as shown in these guidelines, and significant time and expertise is needed to develop good quality detailed designs as well as to properly implement these designs. Cyclists more than motor cyclists or car drivers are very sensitive to details. A small lip or edge or poor maintenance that would not be felt by a car driver can be enough to create a cycling accident. Hence: never underestimate the difficulty to create good quality cycling infrastructure and do use the guidance in these guidelines.