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Contents

Summary

This design manual describes the steps required to create a bicycle-friendly infrastructure. Chapter 1 contains a brief description of the role of the bicycle, the importance of integral thinking and the process surrounding cycling policy. Actual design backgrounds are discussed in chapter 2, which looks at the bicycle/cyclist system, the characteristics of cyclists and the resulting design requirements. The chapter concludes with the five widely known main requirements for a bicycle-friendly infrastructure, which can briefly be expressed as cohesion, directness, safety, comfort and attractiveness. These aspects still form the main theme in this revised design manual.

Chapter 3 looks at a number of basic details that form the basic tools that enable every designer to create a bicycle-friendly infrastructure. Chapter 4 deals with the establishment of a network and the possibility of distinguishing specific main and other cycling routes within it. It also looks at recreational networks, because recreational cycling is becoming an increasingly important way of spending leisure time.

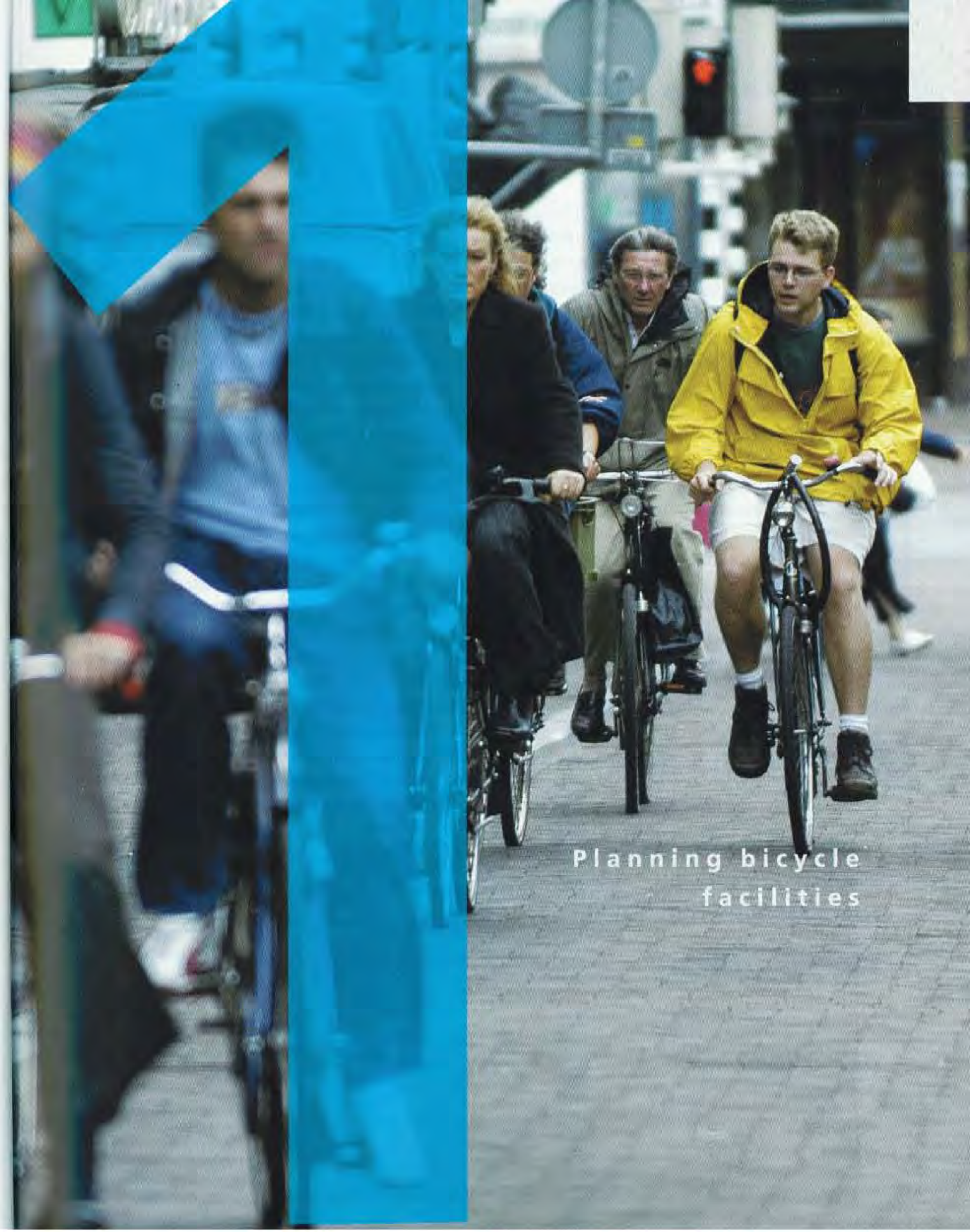
Chapters 5 and 6 focus on road sections and intersections, respectively. A description of the main requirements in each chapter is followed by a look at the infrastructural options. In the case of road sections, there is an explicit examination of the combination of the bicycle with other forms of transport. The chapter about intersections categorises them according to functional types of intersections. It goes without saying that both chapters focus particularly on the elements that affect the position of the cyclist.

Chapter 7 discusses various more technical aspects that play a role in any design. These include the road surface and pavement, lighting, social safety, green areas and signposting.

Chapter 8 addresses the subject of bicycle parking. A bicycle-friendly infrastructure is not complete if no attention is paid to bicycle parking. The design manual looks specifically at the design choices at analysis level. Parking facilities themselves are dealt with in a functional sense. Concrete facilities are not discussed. Designers can consult the catalogues published by manufacturers and suppliers of bicycle parking facilities for more information.

Chapter 9 concludes the manual and discusses the inspection, maintenance and management of bicycle facilities. It looks at inspection methods, ice and snow prevention and clearing, and temporary measures.

V 8, 12 From chapter 5 on, a number of facility pages have been included at the end of each chapter. This symbol in the text refers to the relevant facility page.



1 Planning bicycle facilities

1 Planning bicycle facilities

1.1 The role of the bicycle

When the bicycle was introduced in the late nineteenth century, planning bicycle facilities posed no problem at all. The infrastructure for bicycles was already in place in the form of main roads, cart tracks, dikes and routes for slow traffic, and its structure may have been better than it is today: a route usually followed the shortest line from steeple to steeple. The main barriers were waterways, but the numerous pedestrian ferries offered a solution. The only technical problem was the pavement. There was a good reason why Dunlop developed pneumatic tyres for bicycles first. The first cycle tracks – often the result of private initiative – were also primarily designed to improve the cyclist's comfort.

The invention of the car drastically changed the situation. Although, in absolute terms, the number of cars was negligible in the early years (in 1930, there were 67,000 cars and 2.5 million bicycles on the Dutch roads), the car heralded an enormous change for the road network. Speed and mass of the different kinds of road users suddenly began to vary considerably, which resulted in a dramatic rise in the number of accidents. In order to improve road safety, cyclists and cars were separated more and more often. At the same time, cycle tracks were built to ensure an uninterrupted flow of motorised traffic. Far from comprehensive, the approach to bicycle traffic was focused primarily on the traffic engineering aspect of prevention of conflicts with the car.

A second development was the construction of cycle tracks for recreational use from the fifties onwards. These were separate cycle tracks in attractive recreational areas, which were built with the aid of specific grants. Cohesion with the 'utilitarian' cycle tracks was not a goal in itself and was even excluded from the grant system.

The energy crisis of the seventies and the environmental awareness greatly encouraged the interest in bicycle traffic. Demonstration projects in Den Haag and Tilburg, which showed the importance of directness, comfort and short stops at traffic lights, proved that good bicycle facilities served more purposes than road safety alone. The demonstration project in Delft also revealed that a network approach could significantly improve the competitive position of the bicycle compared to other means of transport. It also appeared that in situations of high bicycle usage, neglect of this competitive position led to a loss of the bicycle's share in the modal split. In other words, continuous attention to policy for the bicycle is vital.

When the first design manual [1] was introduced in 1993, it proposed an integral approach in order to achieve the best possible design of the bicycle infrastructure. This design manual was an important product of the 'Bicycle Master Plan', which was in turn an elaboration of the second 'Structure Plan for Traffic and Transport' (SVV2). One of the goals of the Master Plan was that use of the bicycle would increase partly because people would leave the car at home more often. The more businesslike approach in the 'Policy Document on Mobility' [2] shows that although the goals lack the ideology of the SVV2, use of the bicycle will continue to be of great importance in the Netherlands.

In this policy paper, the national government stipulates that all provincial and municipal authorities are to encourage the bicycle as the principal means of transport, particularly for journeys of less than 7.5 kilometres. Municipal councils, water boards and regional and provincial authorities do so, for example, by building cycle networks that meet the main traffic engineering requirements. These authorities are also responsible for providing bicycle parking facilities. The paper also requires newly built residential estates to have good cycle connections to the centre of the municipality in question and to the outlying area.

Table 1. Development of the proportion of motorists and cyclists on all journeys, 1991 - 2003 (in %)

	All journeys	
	proportion of motorists	proportion of cyclists
1991	28.9	25.4
1992	29.4	25.8
1993	29.9	25.2
1994	28.8	25.4
1995	29.7	25.8
1996	30.6	25.1
1997	30.2	26.0
1998	31.3	25.0
1999	31.9	25.5
2000	32.1	25.7
2001	32.2	25.6
2002	32.8	25.4
2003	32.4	26.4
2004	32.8	26.0

Table 1 shows the importance of the bicycle. This shows that for many years, about 25 per cent of all journeys in the Netherlands have been made by bicycle. After the car, the bicycle is the most popular means of transport for daily mobility. In spite of the shortness of bicycle journeys, the annual number of kilometres ridden by cyclists is almost the same as that travelled by train passengers (13.9 billion kilometres by bicycle compared to 14.5 billion kilometres by train in 2004).

Table 2. Development of the proportion of cyclists in all journeys according to distance class, 1996 - 2003 (in %)

	0 to 2.5 km	2.5 to 5 km	5 to 7.5 km	over 7.5 km
1996	35.0%	36.0%	20.0%	5.6%
1997	36.0%	38.0%	22.9%	6.4%
1998	35.0%	34.7%	20.0%	5.4%
1999	36.2%	34.0%	22.2%	6.7%
2000	35.3%	34.7%	20.6%	5.6%
2001	35.8%	33.3%	21.2%	5.6%
2002	35.3%	34.7%	21.2%	5.6%
2003	36.7%	35.4%	24.2%	7.8%

It is the shorter journeys in particular where the bicycle plays an important role. In the total number of journeys of a distance of up to 2.5 km and between 2.5 and 5.0 km, the proportion of bicycles is consistently around 35 per cent (see table 2).

Cycling: for all ages and reasons
Cycling is a phenomenon that occurs at all ages, in all places, among all income groups and for all kinds of reasons. To illustrate the last point: at 46.4%, the proportion of cyclists is exceptionally high for the 'education' reason. This is, of course, primarily attributable to the fact that this includes children, who simply have no alternative. The education motive only covers a small part (7.6%) of all journeys in the Netherlands (see figure 1). In the case of the reasons to travel that determine the total amount of traffic to a far larger extent, the proportion of cyclists remains around the general average of 22% for 'other reasons' to 29.2% for shopping.

Recreational cycling
Apart from its use for the daily, functional journeys, the bicycle also plays a major role in recreational activities. There are about 11 million recreational cyclists in the Netherlands, who make some 28 million day trips lasting more than two hours [3]. Recreational cycling is primarily for fun, but often also for health reasons. Bicycle facilities and attractive surroundings are essential for people on cycling trips. If these facilities are close to home, they improve the liveability and hence the quality of the living environment.

1.2 Bicycle-friendly infrastructure

A bicycle-friendly infrastructure is a necessary prerequisite if the bicycle is to retain and possibly strengthen its full status in the traffic system. The infrastructure should enable the cyclist to make direct, comfortable bicycle journeys in attractive, safe traffic surroundings. Only then is it possible to compete with the car. Various studies have shown that a good-quality cycling infrastructure actually

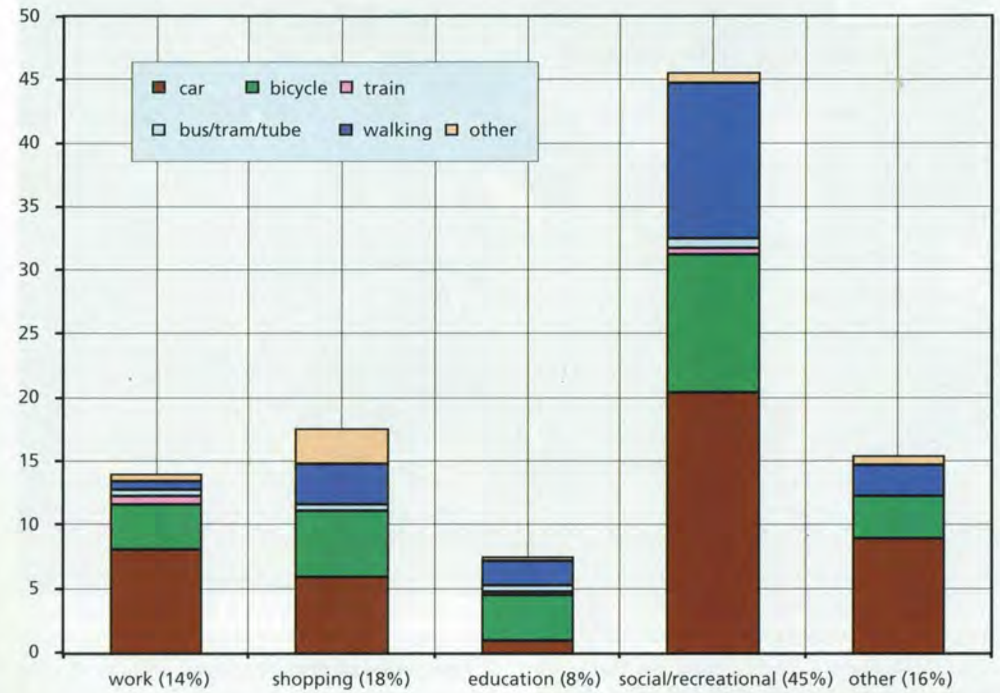


Figure 1. Relative ratios of reasons to travel and the role of the bicycle in each reason, 2003 (source: National Travel Survey OVG)

leads to a higher proportion of bicycles in the modal split. One of the most recent studies in this area is 'Fietsbalans' (Bicycle Balance). This showed that towns and cities that scored high in the Bicycle Balance project have more active cyclists than towns and cities that scored low (see figure 2 [4]).

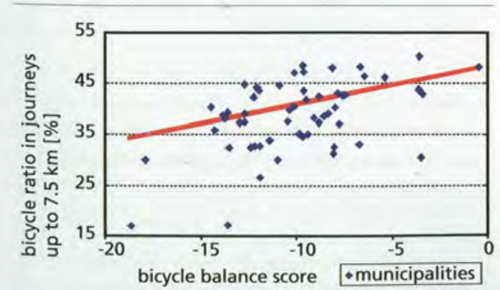


Figure 2. Relationship between Bicycle Balance score and bicycle proportion (source: Dutch Cyclists' Union, 2000)

Generating large-scale bicycle use by means of a high-quality network requires patience and continuous attention in policy. This is shown in an analysis of the towns and cities with the highest levels of bicycle use in the Netherlands [5] and in studies of examples abroad.

This design manual describes all steps required for the creation of a bicycle-friendly infrastructure, from the policy proposal for promoting use of the bicycle to the actual construction of a bicycle-friendly infrastructure. Bicycle infrastructure refers to all technical facilities intended for cyclists. Traffic engineering handbooks have the following drawbacks, however:

- they provide examples and/or templates that tempt planners to apply them without thinking;

- they attempt to achieve integration with the requirements set by other means of transport, which leads to compromise at an early stage of the design.

To avoid these drawbacks, this design manual contains a continuous theme that compels designers to:
- study the cyclist as the future user of the design;
- define their goals;
- balance function, form and use.

This is a creative challenge that requires more than the use of templates. The method forces designers to think and to formulate the consequences of the choices in their design.

1.3 Integral design

It is impossible to design for the bicycle solely on the drawing table or computer. Present-day traffic problems can only be solved using an integral approach, and this applies to various spatial levels of scale. In existing situations, it is always advisable to have a look at the actual situation, because the cyclist is so flexible that

Templates down the years

A well-known template in the 1970s was the cycle track as a mould to achieve more and safer cycling. But there are other ways to provide cyclists with a safe and comfortable infrastructure than merely separating the various types of traffic. Speed reduction and the introduction of streets with restricted motorised traffic produce the same results in terms of goals.

In the 1980s, traffic lights became the primary weapon in the struggle to improve safety, even though traffic lights have only limited use when it comes to protecting cyclists crossing the road.

A template from the 1990s is the roundabout, which has unmistakeable major advantages in certain traffic situations. But in this case again, more is required than just application of a simple template. If traffic intensity becomes so high that it is deemed necessary to revoke the cyclists' right of way, then something is wrong with the design. Safety may be ensured, but the other chief requirements for bicycle friendliness are disregarded.

there is a good chance of cyclists using a design in different ways than the designer intended. Actual behaviour on the street is important input for a design, and designers should not simply ignore it.

Integral thinking at network level

Integral thinking starts in the spatial planning phase. The power of the bicycle is primarily evident in short journeys and in its use as a means of transport before and after using public transport. The evaluation in the Bicycle Master Plan [6] shows that the main threat to bicycle use in the Netherlands is posed by continuing increases of scale caused by urban sprawl. People who live within three kilometres of a centre or sub-centre make more frequent short journeys than people who live farther away or people who live in smaller municipalities [7]. This is why new residential areas should not be built farther than three kilometres from a town or city centre. In this respect, it can be said that the best chance for cycling policy to succeed is to some extent the responsibility of spatial planners.

By analysing the mobility pattern in a town or region, the traffic planner can ascertain which locations merit the time and energy required to improve the position of the bicycle. But they can also work with urban planners to cut distances, reduce the number of barriers and deal with spatial densification. In terms of cost effectiveness, it is hardly worth investing in high-quality public transport systems if journeys in a particular area are primarily short. This kind of investment is more appropriate if there is an alternative for the car in an area of low bicycle use.

Integral thinking at connection level
Many cyclists choose how they travel. They often opt for a different means of transport, particularly when directness, safety and comfort of cycling are not ideal. As far as safety is concerned, cyclists are the most vulnerable group in encounters with fast-moving traffic, and this fact requires special attention. Avoiding conflicts by separating traffic types completely is an extreme yet often essential measure. However, possible solutions are also reduction of the speed of motorised traffic or limiting the amount of motorised traffic on major cycle routes.

Integral thinking at facility level
Bicycle-friendly design means that the cyclist is not saddled with the remaining space in the road design or the remaining time in the traffic light sequencing. The quality offered to cyclists should be assessed with the same criteria as the quality offered to other road users. In this regard, integral thinking means that traffic is seen as an interaction between parties that are theoretically prepared to comply with the rules. The conditions for conflict avoidance are present if a cyclist can establish eye contact with a motorist, for example. Conversely, an encounter between two road users in which eye contact is not possible is almost by definition unsafe. The design of the infrastructure has an enormous effect on the possibility of road users being able to see one another.

1.4 A plan as the basis

Creating a bicycle-friendly infrastructure requires technical design skills, but these alone are often not enough. The long road from policy to implementation runs through an environment in which countless interests vie for the

limited resources. Working according to a plan gives the best chance of protecting the interests of the bicycle.

In spite of the benefits of a planned approach, cycling policy is often an ad hoc process. This is largely due to the fact that the bicycle itself causes few problems, only cropping up when problems caused by other road users have to be solved. Furthermore, cycling policy is in itself hardly controversial. Another factor is that people opt for the bicycle for a great many – mostly positive – reasons [8]. They enjoy cycling: it is healthy, good for the environment, fast, fun, normal and tried and tested, so permanent attention to policy is only logical.

Generally speaking, local traffic and transport policy is embedded in the traffic and transport policy of a regional or provincial authority. The same applies to cycling policy. But in addition to this administrative and policy-based co-ordination, co-ordination 'on the street' is also vital. Cycle links are usually local links and have to be established on a local scale. They often cross municipal borders as well, so policy co-ordination is inevitable.

To set up an integral approach, a plan for a bicycle-friendly infrastructure should form part of an integral traffic and transport plan. Only then is it possible to weigh up the interests of

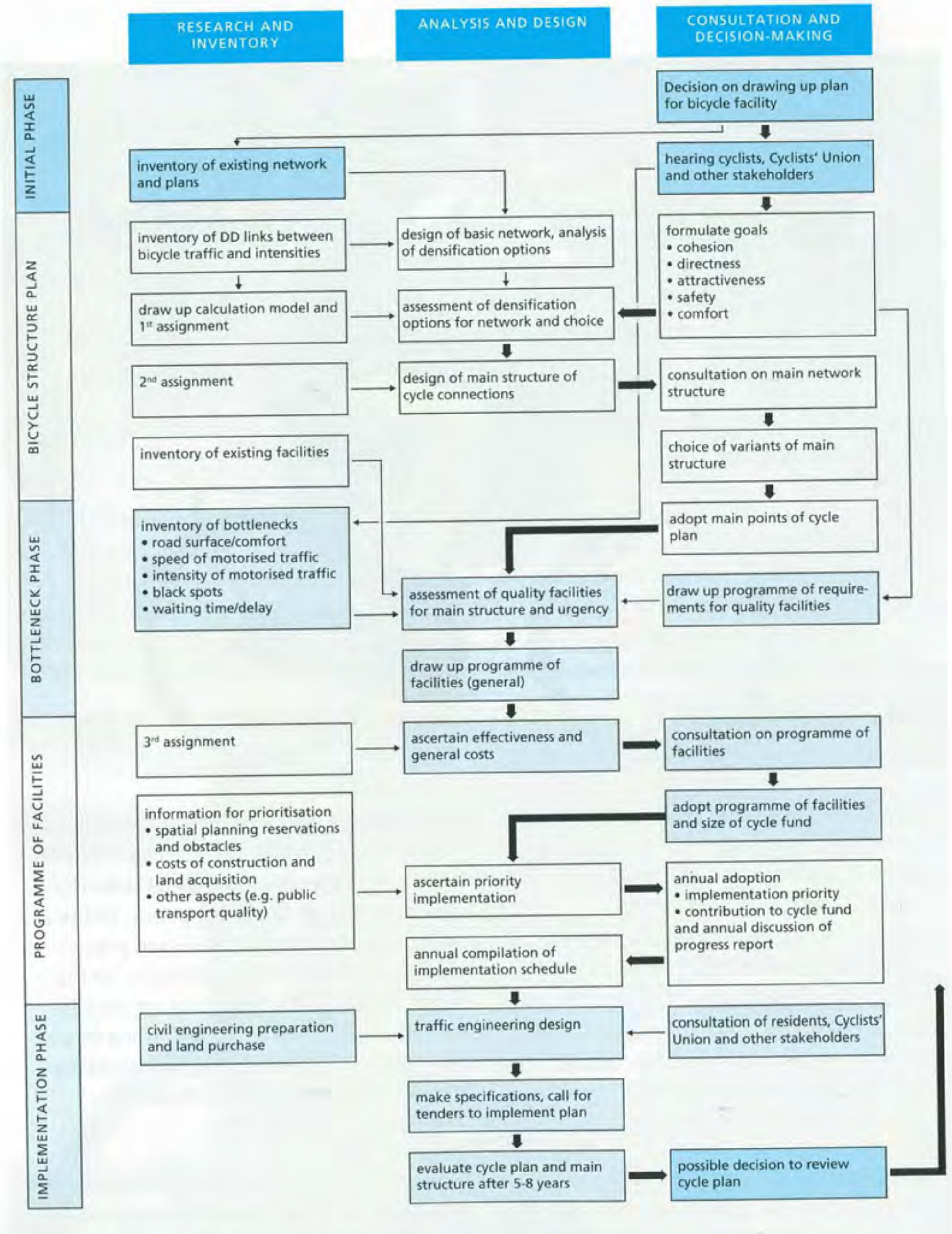


Figure 3. Steps in the plan formulation and their interrelationships

the various road users and assign the different means of transport to where they can function most effectively.

Figure 3 is a diagram of the possible steps in the formulation of a plan and their interrelationships. If a plan forms part of a more extensive traffic plan, the planning process should also be related to that larger plan. To ensure clarity, these relationships have not been included in the diagram.

Although it is not possible to provide a blueprint for the plan formulation, generally speaking, five phases can be distinguished. It should be borne in mind that the steps described represent a simplification of the actual state of affairs. In practice, the design procedure is of a highly cyclical nature. Procedures are run through repeatedly, particularly within the individual plan phases. It may also be necessary to return to a previous planning phase. This way of working is inherent to the assignment to balance the aspects form, function and use.

Quantifiable criteria

The 2005-2020 Municipal Traffic and Transport Plan drawn up by the Utrecht municipal council is an example of a plan with quantifiable criteria. The plan sets the average speed along the main cycle network for distances of 4 to 7 km at a preferable minimum of 16 km/h for at least 85% of journeys made. The travelling time (including stops) by bicycle to the nearest lockable bicycle parking facility at a public transport stop from a location in a regional or supraregional core area is preferably no more than 5 minutes, and a maximum of 10 minutes from the home.

1. Initial phase

This is the phase in which goals are formulated and a project organisation is set up. Goals are quantified where possible. If at all possible, abstract goals are expressed in verifiable standards.

2. Bicycle structure plan

The transport links for existing and potential cyclists are analysed and the most popular routes in the network determined. This requires an understanding of the pattern of places of departure and destinations of the cyclists. On the basis of a network analysis, new connections are selected to keep detours to a minimum, reduce the number of encounters with motorised traffic and create a cohesive network structure. It may be an idea to use a traffic model. Although this seldom happens when drawing up cycle plans, use of a traffic model can certainly be useful in a number of situations, particularly at the network analysis level (see chapter 4).

'Cycling culture'

Drawing up a plan does not guarantee a good cycling climate in a municipality. However, experience in the Netherlands and abroad has shown that paying permanent, systematic attention to the cyclists in the traffic planning does bear fruit in the long term. The development of a broad 'cycling culture' within a government organisation is sometimes more important than the financial resources.

3. Bottleneck phase

In the bottleneck phase, the quality of the roads and cycle tracks included in the bicycle structure plan is assessed against the programme of requirements. The more important the connection in the main structure, the higher the quality of the form of implementation becomes. Once all the bottlenecks have been inventoried, they are ordered in sequence of urgency, so that the worst bottlenecks can be solved first.

It is possible to look for alternative routes in this phase of the design process, for example, when the shortest connection is of such poor quality that improving it would require a disproportionately high investment. It is hardly worthwhile to improve a short cut if a slightly longer parallel route is of a far higher quality, because of the absence of traffic lights, for example. Issues such as planning routes through shopping streets and car-free shopping areas are also discussed in this phase of the planning process. This is fed back to the bicycle structure plan, which may lead to a full or partial review of the plan.

4. Programme of facilities

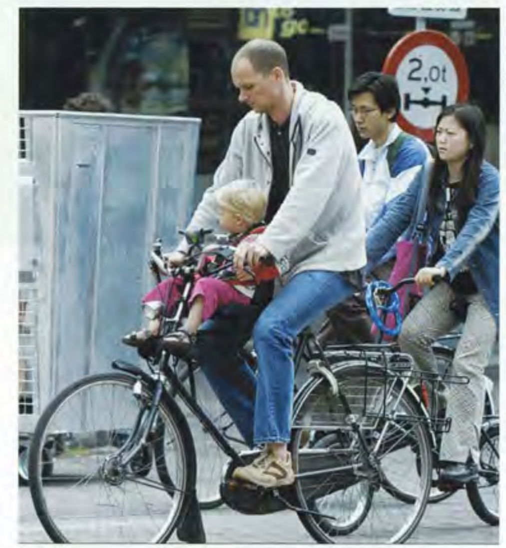
The next step is to determine what improvements are necessary to achieve the level of quality laid down in the programme of requirements. Facilities are proposed for the improvement of the weak or poor elements in the network (road section, intersection, bridge, et cetera). These may involve the construction of cycle tracks, but there are many other options, such as:

- adjustment of traffic light regulation;
- reduction of the amount of motorised traffic on a route;
- construction of a flyover;
- reduction of the speed of motorised traffic;
- construction of cycle lanes;
- reprofiling;
- modification of the intersection (for example conversion to a roundabout);
- improvement of the crossing;
- improvement of the road surface;
- construction of bicycle parking facilities.

It is quite clear that a 'cycle track plan' is not sufficient to meet the criteria of a bicycle structure plan with a programme of facilities. After all, there are far more options other than simply constructing or resurfacing cycle tracks to improve the comfort and safety of the cyclist. Chapters 4 to 8 look at these facilities in detail.

5. Implementation phase

The required facilities are put in place according to a priority sequence in which costs and benefits (effectiveness) play a role. Once the programme of facilities is complete, a general budget is drawn up of the total costs of implementing the plan. The individual measures can be paid for from different funds. Some of the measures may be included under 'regular maintenance', while infrastructure to and in new residential areas can be financed with the operating funds for that area. Other measures will probably be included as new policy in the periodic budgeting cycles conducted by every road authority. It is at this point that the value of 'a plan as a basis' becomes evident.



6. Evaluation of the design

A bicycle structure plan is regularly assessed to ensure it is up to date. The plan should preferably be updated every five to eight years. The quality of the bicycle infrastructure is represented by the total number of objecti-

fied value judgements on the five main requirements. If it turns out that none of the criteria exceed the limit values, it goes without saying that the quality is fine. It gets more complicated if the limit values for some of the main requirements are met and those for others are not. The Cyclists' Union's 'Bicycle Balance' is a good tool for assessing quality.

The designer will have to be able to recognise situations that are not in balance. Concentrations of accidents clearly show that function, form and use are not in balance. But the designer can see from other indications that something is wrong with the balance. Depending on the level of scale (network level, connection level or facility level), stress in traffic is expressed in a number of ways. Road users then behave differently to what the designer had in mind (see box).

Stress-avoidance behaviour

Network level

Discomfort can play a role when someone is deciding to make a journey or choosing the means of transport. Among the elderly, for example, many people are prone to diminished mobility. They stay at home because they are no longer able to cope with the speed of the traffic these days or find it too dangerous. Children are driven to school for safety reasons. And many women are reluctant to cycle in the evenings because they do not feel safe.

Connection level

People who do participate in traffic can also demonstrate stress-avoidance behaviour, making detours to avoid unsafe situations, traffic lights or 'scary places'.

Facility level

A traffic situation that acts as a stress factor causes abnormal traffic behaviour. This means that cyclists act differently to what the designer had in mind. The signs include:

- Cyclists dismount, even if they have right of way. This category also includes other forms of informal behaviour in the case of right of way.
- Cyclists shoot the lights en masse because they regard waiting in that situation a waste of time.
- Separate cycle tracks are not used because another route is quicker, easier or more attractive.

Finally, there is a situation in which discomfort approximates a real accident: a near accident. These conflicts can be registered by means of conflict observation techniques. Studies have shown that near accidents that are registered using this technique can provide an accurate prediction of actual accidents [9].

Comfort and discomfort are difficult to gauge objectively, although stress-avoidance behaviour and near accidents provide a good indication. Road users themselves are best equipped to tell us where 'things are not what they should be', indicating the limits of their physical and mental capacities. For designers of bicycle facilities, user complaints are a valuable source of information on the perception of comfort.

2 Functional design

2 Functional design

2.1 The cyclist as a design parameter

Cycling calls on both the physical and mental capacities of the cyclist. The physical capacity is required to get the vehicle underway and to keep it moving. Mental capacity is required to ride the bicycle safely in traffic. In the Sustainable Safety concept, safe road design is based on the road user. Presented in 1992, the report on Sustainable Safety states that the sustainably safe traffic system has an infrastructure in which the design is adapted to the limitations of human capacities [10].

Cyclists have no standard traits. On the contrary, the Dutch cycling population is characterised by a broad composition in terms of age, gender, physical capacities and reasons for cycling. In certain conditions, the fast commuter cyclist is indicative for the design (in terms of design speed, for example). More often than not, however, the group of older

cyclists with limited physical capacity will determine the limits (in terms of gradients and crossing times, for example). In still other cases, the design will be geared to young, inexperienced, sometimes careless cyclists (in terms of eye level, red light discipline and the complexity of intersections, for example).

Physical capacity
It is not straightforward to express physical capacity in figures. The following definition is generally used: physical capacity is the limit of dynamic muscular work per unit of time. The absolute capacity is used as the reference quantity. This is the maximum effort that can be kept up for a period of four minutes. It is clear that the maximum load and hence the absolute capacity differ from person to person. The physical capacity depends on the duration of the exertion and the activity (sport, factory work, recreation). A measure for comfort is the ratio between the physical capacity and the absolute capacity. Chapter 3 contains a number of core figures that provide an indication for design elements as far as physical capacity is concerned.

Mental capacity
Cyclists are not only subjected to physical load, but also to mental load, whether consciously or not. Steering the bicycle, keeping balance and riding in a straight line require considerable mental effort. At the same time, the interaction with other traffic places a strain on the concentration capacity. Studies of the cycle route network in Delft have shown that the improvement of comfort is an important condition for the encouragement of bicycle use. Task simplification also makes a significant contribution to a sustainably safe traffic system. In complex traffic situations, a lot of

information has to be processed in the blink of an eye in order to make the right decision [11]. Mistakes can be made when answering each of the following questions:

- Who has right of way?
- What rule applies?
- Have they seen me?
- What speed are the other road users doing?
- Can I get past?
- What will the other person do?

Limiting the risk of errors and increasing the 'willingness to forgive' if mistakes are made improve traffic safety considerably and also make cycling more comfortable. To a large extent, the idea behind the categorisation of roads is based on these principles [12].

Discomfort, or the extent of the lack of comfort, is closely related to 'perception' and 'subjective danger'. These are feelings of unease that occur in traffic situations that are complicated, unclear, threatening or tiring. Complaints about traffic situations arise when a critical stress level is reached between the requirements posed by the situation, on the one hand (the stress factor), and the personal ability to meet the requirements, on the other [13]. The critical level is reached sooner when the road user finds it more difficult to meet the requirements due to lack of experience (youngsters) or a diminished ability to function (the elderly). There is a relationship between comfort and traffic safety. When

stress levels rise, there is more chance of making mistakes. Accident statistics also show that youngsters and the elderly not only experience a variety of comfort problems, they also run more of a risk in traffic.

Bicycle-cyclist system

Designers of a bicycle-friendly infrastructure naturally have to be well-versed in the technical possibilities and limitations of cyclist and bicycle. They are aware that cycling entails a number of more or less conflicting characteristics. An example is muscle power, which serves as a natural speed limiter, although a certain speed is required to ensure stability. On the one hand, the bicycle is vulnerable, while on the other hand, it is highly manoeuvrable and flexible in traffic. Furthermore, bicycles are designated and counted as slow traffic, even though they are one of the fastest means of transport in the urban environment. Table 3 shows a number of typical characteristics of the bicycle, cyclists and cycling.

Table 3. Characteristics of bicycle, cyclist and cycling

1 The bicycle is powered by muscle power.
That is why a bicycle-friendly road design keeps energy loss to a minimum.

2 The bicycle is unstable.
Crosswinds, the slipstream and turbulence caused by lorries, bumps and holes in the road surface and involuntary low speeds determine the stability and hence the room required to manoeuvre.

3 The bicycle has no crumple zone.
Accident statistics are a clear indication of the cyclist's vulnerability. However, the road authorities are in a position to exert a great deal of influence on this situation. They can give cyclists a 'spatial crumple zone' to allow them enough room for evasive manoeuvres . Cyclists can balance on a strip of ground 0.20 m wide, but this amount of space is totally inadequate to be able to cycle comfortably. When a car door opens, additional space on the bicycle lane can save lives. Their vulnerability also means that cyclists cannot mix with fast-moving cars and intensive lorry traffic.

4 The bicycle has hardly any suspension.
A smooth road surface is a minimum condition when it comes to meeting the requirements of bicycle friendliness.

5 The cyclist rides in the open air.
This has both advantages and disadvantages. Shelter against wind and rain removes a number of disadvantages. The advantages must be retained in the design, so designers should take note of the attractiveness of the surroundings in which the cyclist rides.

6 Cycling is a social activity.
That is why two cyclists should be able to ride side by side. This applies particularly if a lot of recreational cyclists can be expected. Furthermore, the option of riding next to each other gives parents the opportunity to escort their children safely.

7 People as the key factor.
The number of tasks a traffic participant can perform and their complexity are bound by limitations. Designers should respect these limitations, taking less experienced and less able-bodied road users into account.

The cyclist as a customer in the traffic and transport system

The properties and limitations of the vehicle and its driver are recognised parameters for the design of roads for motorised traffic. Comfort and safety go hand in hand. A similar approach is required for the design of facilities for bicycle traffic. The cyclist can be regarded as one of the customers within the traffic and transport system as a whole. This customer has preferences that can be seen as the quality requirements to be set for the infrastructure. It is the designer's responsibility to ensure that these preferences or quality requirements are expressed in the infrastructure as completely as possible. Bearing in mind the bicycle-cyclist system and the technical and physical properties of bicycle and cyclist, the following requirements are essential to achieving a bicycle-friendly infrastructure:

- ensure the required section of free space;
- make it possible for two cyclists to ride side by side;
- minimise the resistance cyclists experience when riding;
- take the limits of physical and mental capacity into account (optimise the mental capacity);
- take the vulnerability of cyclists into account;
- take cyclists' perception into account;
- ensure a complete and comprehensible infrastructure.

2.2 Main requirements for a bicycle-friendly infrastructure

The quality preferences described in section 2.1 can be translated into five main requirements which a bicycle-friendly infrastructure has to meet.

- perception and being able to ride side by side create requirements in the area of *attractiveness* and *comfort*;
- the minimisation of resistance creates requirements in the area of *comfort* and *directness;*
- the optimisation of mental capacity and the section of free space create requirements in the area of *comfort* and *safety*;
- the vulnerability of cyclists creates requirements in the area of *safety*;
- the need for a complete, comprehensible bicycle infrastructure creates requirements in the area of *cohesion*.

Generally speaking, if the minimum level of one or more of the five main requirements cannot be met, the infrastructure should be modified. The main requirements are explained generically in this chapter. Chapters 4, 5, and 6 address the requirements in detail for networks, road sections and intersections, respectively.

Main requirement - cohesion

As the word suggests, cohesion means that the bicycle infrastructure forms a cohesive whole. Furthermore, the network has to provide connections that link up with cyclists' points of departure and destinations. So cohesion is about giving people the opportunity of going somewhere by bicycle, with integration with other means of transport (chain journeys) being important at the same time. Elements that play a role in this regard include ease of finding the way, consistency of quality and the freedom to choose a route.

Main requirement - directness

Directness means that the cyclist is always offered as direct a route as possible, thus keeping detours to a minimum. If the travelling time by bicycle is longer than by car, this is a major reason for people to use the car and leave the bicycle at home. On the other hand, many motorists are willing to use the bicycle for short trips if it is quicker and more convenient. All factors that influence the travelling time have been included in this main requirement. Possible criteria in this case are traffic flow speed, delays and detour distances.

Main requirement - attractiveness

Attractiveness means that the bicycle infrastructure is designed and fits into the surroundings in such a way that cycling is attractive. Cycling behaviour, however, is determined by a wide range of factors; for each individual, these can be of variable importance when it comes to deciding whether to go by bicycle or not and what route to take. Certain aspects of cycling are considered positive by one person and negative by another.

The main requirement attractiveness includes a summary of the psychological factors that can generally be expressed in terms of 'perception'. This was examined in the 1978 ITS study of the use of the bicycle in the Netherlands [14]. The preliminary and follow-up research conducted in Delft also provides insight into the extent of the cycling potential created when certain obstacles that prevent people from going cycling are removed [15]. The nature of the subject matter entails that attractiveness is difficult to work out in concrete terms. To reiterate, this is due to the fact that perception is highly personalised. However, this does not mean that complaints made by cyclists should not receive serious attention, even if they are hard to verify objectively.

Attractiveness also includes the criterion 'social safety'. A comparative study between the Dutch cities of Zwolle and Breda showed that social safety and how it is perceived is a major determinant in the decision to use the bicycle, particularly in the evening and at night. Chapter 7 deals with this in more detail.

Main requirement - safety

The main requirement safety entails the bicycle infrastructure guaranteeing the safety of cyclists and other road users in traffic. Cyclists are vulnerable because they are in the same space as motorised traffic, with the consequent major differences in mass and speed. The cyclist does not have the benefit of external technical provisions such as a cage construction and a crumple zone.

Designers are unable to exert any influence on this inherent vulnerability, but they are able to influence the conditions in which cyclists travel. One of the key points of this aspect is that encounters with fast motorised traffic should be avoided as much as possible by means of a separation in time or space. The importance of this requirement is confirmed by the accident figures. In towns and cities with a large number of busy intersections, there are relatively more serious accidents involving bicycles than in urban environments with fewer busy intersections [16] (see also section 2.4).

Safety is relevant at many different levels and can be influenced in a variety of ways. The requirements formulated as part of a sustainably safe traffic system can play a leading role in this process. This concerns the following options [17]:

- construction of as extensive tracts of uninterrupted residential area as possible;
- a minimum part of the journey on relatively dangerous roads;
- make journeys as short as possible;
- combine the shortest and safest route;
- avoid situations in which cyclists have to search to find their way;
- make road categories identifiable;
- limit the number of traffic solutions and give them an unambiguous design;
- avoid conflicts with oncoming traffic;
- avoid conflicts with crossing traffic;
- separate different types of vehicles;
- reduce speed at potential conflict locations;
- avoid obstacles at the side of the road.

Cyclists are extra vulnerable in the dark or in rainy weather. In those conditions, visibility of both the cyclist and other road users is not at its best. Designers can alleviate this problem by

creating the best possible conditions for good visibility.

Main requirement - comfort

The main requirement comfort comprises factors that concern nuisance and delay caused by bottlenecks and/or shortcomings in the bicycle infrastructure, which require additional physical effort on the part of the cyclist. Discomfort resulting from excessive mental exertion is particularly related to safety and has, therefore, been included as part of that main requirement under the criterion 'complexity of the cycling task'.

The main requirement comfort is a result of the knowledge that not only extreme exertion but also irregularity of the exertion (repeatedly stopping and starting) make cycling less enjoyable, as does nuisance caused by vibrations. Criteria that play a role in the comfort

aspect include the smoothness of the pavement, hilliness, the chance of stopping and nuisance caused by weather and traffic.

2.3 Function, form and use

The design of bicycle infrastructure involves three spatial levels, namely network, connections and facilities, and specific design problems occur at each level. The designer's task is to keep finding the right balance between the function (functional requirements), form and use. Before beginning on a design, the designer has to carefully check the functional requirements and the expected use of the planned design. Initially, the designer will opt for a form that is most suited to the function and the current or expected use. The planned function comes from the programme of requirements, which tells the designer what conditions the design has to meet. The current or expected use can be studied. Depending on the phase in the planning process (preparation or evaluation), this study will be based on calculation (future situation) or observation (existing situation).

The quality of a design is determined by the extent to which the five main requirements are met, so the main requirements form the evaluation criteria for the design. It will be clear that this balance can only be found by means of an

interactive process. The three 'adjustment screws' have to be turned repeatedly to 'level' the design. If form, functional requirements and use are out of balance, there are three ways of restoring the equilibrium:

- change the design;
- influence use/behaviour;
- modify the functional requirements (and hence the quality).

Form
The most obvious start to the design process is to look for an appropriate form that matches the functional requirements and use. In practice, however, external factors also influence the required balance between function, form and use. The form required to match the function and use can sometimes not be implemented due to spatial claims by third parties. Cycling interests then compete with other interests. This dilemma occurs, for example, in spatial conflicts between networks for different means of transport. In this kind of situation, the importance of the other interests must first be established. A realistic solution is to consult the designer of facilities for public transport or motorised traffic to ascertain the functionality of aspects such as the occupation of space, the right-of-way rules, or priority at a set of traffic lights for the other means of transport.

Use
If the external factor is important enough for the bicycle infrastructure to be designed in another way than proposed in the guidelines in this design manual, it should be established whether the use of the facility can be influenced. It goes without saying that the use of facilities for other means of transport can also be influenced. If the intensity and speed of motorised traffic make it advisable to construct cycle tracks, for example, but there is no room for them, the most obvious alternative is to reduce the amount of motorised traffic and/or the speed at which it travels. In addition, the cyclical nature of the design process makes it possible to return to the design of connections in the event of problems arising at facility level. Developing a high-quality alternative connection will minimise the use of the 'problematic connection'.

Function
Finally, it may be necessary to adjust the goals. In practice, this means that the facility is implemented at a lower level of ambition than prescribed on the basis of the programme of requirements. A compromise is made with regard to the bicycle friendliness of the facility. Designers and policymakers will (have to) realise that far from all of the facilities can fulfil the functions that are required. Changing the function is the last resort, only to be used when all other alternatives have been examined and there are good reasons for the change of function.

2.4 The bicycle and Sustainable Safety

A sustainably safe road network is based on the following principles [18]:

1. Functionality of roads: monofunctionality of roads in a hierarchically structured road network.
2. Homogeneity of mass and/or direction and speed: equality in speed, direction and mass at moderate to high speeds.
3. Willingness to forgive of the surroundings and road users among themselves: limitation of injury due to a willingness to forgive of the surroundings and road users' anticipation of the behaviour of others.
4. Recognisability of the design of the road and predictability of how the road continues and the behaviour of road users: surroundings and the behaviour of other road users who satisfy the expectations of road users by means of consistency and continuity of the road design.
5. Status acknowledgement by the traffic participant: the ability to estimate task proficiency.

There is now general agreement on dividing the road network into three road categories for motorised traffic, namely:

1. Distributor roads. These are designed to ensure a continuous, uninterrupted flow of traffic at a relatively high speed. This means that the road has separate directions of flow, there is no crossing traffic and a relatively homogeneous group of road users. Cyclists are not permitted on distributor roads, they cross them by means of overpasses or tunnels.

2. District access roads. These roads are used for flow and exchange. However, these functions are separated spatially: the flow takes place on the road sections, the exchange on the intersections. On road sections, as much as possible is done to meet the requirements of a distributor road: separate directions of flow, no crossing traffic and a relatively homogeneous group of road users. At the exchange points (intersections and crossings), speeds should be low enough to avoid serious conflicts.

3 Estate access roads. These roads are intended to provide access to housing estates, which means that all groups of road users must be able to use them. It must be possible to make manoeuvres such as parking, getting in and out, turning and crossing safely, so the speed of motorised traffic must be kept low.

Layout requirements
The design principles and road categories together determine the layout requirements for the three kinds of roads. These layout requirements can be summarised as follows:

- Distributor roads: uncrossable carriageway separation, overpasses, access to or from the road by means of slip roads only.
  As yet, distributor roads are only built for motorised traffic. Plans to have distributor roads built for cyclists have never made it past the drawing board.
- Estate access roads: crossable carriageway separation, mostly single-level intersections with right-of-way rules or a roundabout, no parking on the carriageway.
- Estate access roads: no carriageway layout, no separation of traffic types apart from pedestrians from other traffic.

The following also applies to cyclists:

- minimisation of (longitudinal and lateral) encounters (or separation from motorised traffic) when speeds differ considerably;
- minimisation of speed differences if separation is not possible or advisable.

The Sustainable Safety concept is designed to prevent accidents. To be able to anticipate problem areas, designers must have a good understanding of the safety problems associated with cycle traffic. Statistics show that most serious accidents occur at intersections (see table 4 [19]). This applies to a greater degree inside the built-up area than outside it, and that is of tremendous importance. People are naturally inclined to assess traffic safety from the perspective of collisions on road sections, thus wrongfully overlooking most of the accidents that occur.

Table 4. Number of dead and seriously injured cyclists in 2002 resulting from accidents between cyclists and motorised vehicles

	50 km/h limit		80 km/h limit	
	road section	intersection	road section	intersection
deaths	15	56	19	31
hospitalised injuries	303	842	104	179
total	318	898	123	210

In the most serious accidents, cars and lorries are the primary collision partners. About half of the serious accidents between bicycles and cars are caused by the manoeuvre 'crossing combined with/without turning off'. The most common manoeuvre that preceded intersection accidents was the one in which both the cyclist and the motorist went straight on and crossed each other without turning off. Road section accidents often only involve a single vehicle or vehicles travelling in the same direction. The latter category includes accidents involving parked and parking vehicles.

Most fatal victims are cyclists aged sixty and over, with diminished balance and increased susceptibility playing an important role. Youngsters aged between 12 and 17 are also over-represented.

Points for attention
So we see that safety on intersections and crossings is vital to ensuring the safety of cyclists. Minimising speed differences plays a particularly important role. Motor vehicles should not approach a sustainably safe pedestrian crossing at speeds in excess of 30 km/h [20]. The same requirement could be applied at bicycle crossings. Other measures to benefit the safety of the cyclist are the reduction of the number of busy intersections and the conversion of full intersections into roundabouts or bayonet intersections.

A low speed is not only important for intersections, but also for road sections used by both cars and bicycles. A low speed and calm driving behaviour help prevent accidents because road users have more time to react and the stopping distance is shorter. If an accident does occur, the result will be less serious than at high speed. This means that bicycle safety would benefit if the number of 30 and 60 km/h zones was increased.

The other functional safety requirements as formulated in section 2.3 are also important, of course. These requirements are discussed again in chapters 4, 5 and 6, which look at networks, road sections and intersections, respectively.

3 Basic information

the bicycle and the width of the handlebars. To be able to park a bicycle properly in a parking system, the available width should be a little more than the width of the handlebars. In the case of bicycle racks with two height levels ('high-low' racks) however, the handlebars of two bicycles parked next to each other may overlap. In that case, the centre-to-centre distance (between two adjacent spaces) may be less than the width of the handlebars.

The length of a bicycle parking space is at least the length of the bicycle, possibly with the addition of the space required for the parking facility itself. A length of 2.00 m can be applied as a rule of thumb, with 1.80 m being the minimum.

Special circumstances
For bicycle parking as well, designers should ask themselves whether the 95 percentile value is appropriate in the situation in question. Specific situations may require that other widths be taken into account. Outside supermarkets, for example, it is advisable to increase the width (0.80 m) to make it easier for customers to load their shopping onto the bicycle. More width is also preferable in places where a lot of bicycles with children's seats can be expected (outside a nursery school or day-care centre, for example) to give parents enough room to place their child in the seat.

The rule of thumb for parking bicycles at a single level is a width of 0.65 m and a length of 2.00 m for each bicycle. In special cases (such as the supermarket or day-care centre), a greater width is recommended.

Width of paths
Apart from the parked bicycle, space is also needed for actually parking the bicycle in the facility. The access path should at least make it easy to do so, that is at the same angle as the facility. The recommended minimum width for a path is therefore 1.80 m, assuming that bicycles are parked at right angles to the facility. For large parking facilities (at schools, offices, stations, et cetera), the main paths should be wider, so that people can walk past one another while wheeling their bicycles. In these cases, the width should be 3.00 to 3.50 m.

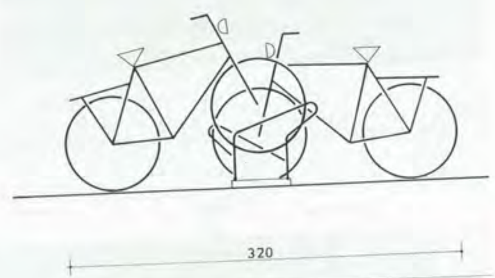


Figure 5. Double-sided bicycle rack

Aisles in guarded and neighbourhood parking facilities require a width of at least 2.00 m, particularly when bicycles are parked in dual-level racks. Aisles outside private sheds should be at least 1.20 m wide. Because this width does not allow people to pass one another while wheeling their bicycles, it should only be applied in situations with only a limited number of sheds in the passage.

Use of space
The space taken up by parked bicycles largely depends on the type of parking facility and the width of the paths. Outside supermarkets, for example, it is advisable to position the parking facilities a little farther away from one another to allow cyclists to hang bags on the handlebars or load shopping into the panniers. More width is also required outside day-care centres. It is, therefore, impossible to provide an indication of an average surface area for a parking facility. The minimum (at a centre-to-centre distance of 0.375 m) should be 1.05 m^2 per bicycle. In normal situations, each bicycle should be allocated 1.8 m^2. If parking facilities are spaced farther away from one another (> 0.80 m) and the paths are a little wider, the user surface area should be about 3.00 m^2 for each bicycle.

3.3 Speed, design speed, accelerating and braking

In physical terms, cyclists have to overcome two forces: rolling resistance and air resistance. Rolling resistance is largely determined by the tyres and the road surface. The air resistance depends on the design (streamlining) of the bicycle and the wind speed.

Resistance
The bicycle is driven by the rider's muscle power. The capacity a cyclist can generate is limited. Extra resistance has to be compensated for with extra physical effort. If this is not done, the bicycle will slow down. A bicycle-friendly road design, therefore, causes

as little energy loss as possible. The main components that cause energy loss are:
- friction losses in bearings and the chain;
- rolling resistance between the tyre and road surface;
- air resistance;
- vibration losses in the frame, saddle and tyres;
- braking and accelerating;
- gravity when riding uphill.

If a bicycle is well looked after, the first component causes only a fraction (1 to 1.5%) of the total resistance. Obviously, the road designer has no influence on this component whatsoever. The extent to which the other five components occur does, however, depend wholly or in part on the road design, which means that the designer has a major influence on the effort required of the cyclist.

Figure 6 shows the various forms of resistance in relation to speed. The gravity resistance only occurs on inclines, of course. The energy consumed when cycling uphill is partially recovered when the cyclist goes down the other side.

The rolling resistance and vibration losses are caused primarily by the quality of the road surface and the bumps and holes in it. With a hard tyre on a smooth surface, the rolling resistance is 0.06 N/kg; on a poor road surface, this can be a multiple of that figure. The limited amount of literature on this subject tells us that smoothness and joints are important factors and that roughness and texture have less of an effect on the rolling resistance. The last two properties are important for the stability and thus the safety of the cyclist.

Air resistance depends chiefly on the riding speed and only plays a role at relatively high speeds (over 20 km/h). Headwind (head-on or at an angle), on the other hand, is an important resistance factor at low speed; the higher the air speed, the greater the resistance, which increases the faster a cyclist travels. Unlike sailors, cyclists cannot benefit from crosswind. Crosswind causes a lot of friction for cyclists, who perceive it as resistance, due in part to their unfavourable aerodynamic form. In the case of major turbulence, between buildings, for example, the changing wind speed places an additional burden on cyclists because they are intermittently slowed down and have to accelerate again. The subjective perception of the wind also plays a role. In a trial with a windbreak, cyclists made a negative assessment because they still felt the wind and perceived it negatively, even though the wind nuisance was reduced considerably [21].

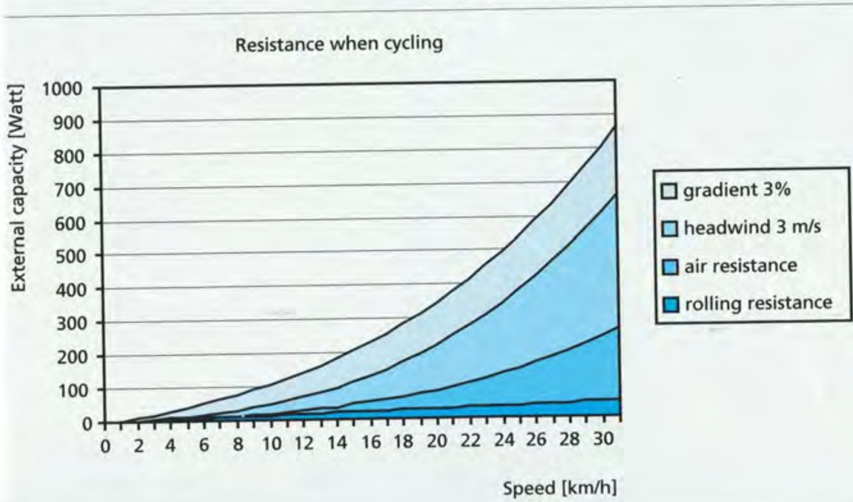


Figure 6. Resistance when cycling

Cycling speeds

The pedalling frequency of about 70 revolutions a minute produces a 'normal' cycling speed of 15 to 20 km/h, depending on the personal traits of the cyclist, the properties of the bicycle and the specific ambient conditions. In the study conducted in the 'Bicycle Balance' project, a bicycle travelled at a cruising speed of 18 km/h. The 5-percentile speed proved to be 13 km/h and the 95 percentile speed almost 16 km/h, so for normal situations, a design speed of 20 km/h is recommended. On through cycle routes where a road authority wishes to offer additional quality, people must be able to cycle at high speed. It is, therefore, advisable to incorporate a design speed of 30 km/h. A point requiring particular attention is the speed on inclines, where speeds of up to about 35 km/h can occur.

The options open to the designer
Road designers and road authorities can have a significant effect on the energy lost by cyclists. Every stop because of a red traffic light or other traffic occurrence destroys the energy built up by physical labour, and the resistance caused by friction and low speed has to be overcome again as the cyclist pulls away. The basic premise regarding this aspect of design is that cyclists should have to stop as little as possible.

Speed
The speed at which a cyclist opts to travel depends on the duration of the exertion, the amount of resistance that has to be overcome and the reason for the bike ride. In the case of headwind on a commuter trip, a higher load level will be more acceptable (the cyclist wants to get to work on time) than on a recreational ride, for example. For planning purposes, cyclists in the age group of 50 to 60 can be used as indicative.

Accelerating and braking
A value of 0.8 to 1.2 m/s^2 can be used for accelerating from a standstill. Slowing down depends on a number of factors, but a braking value of about 1.5 m/s^2 (comfortable) to about 2.6 m/s^2 (emergency stop) can be assumed.

The design assignment: prevention of unnecessary energy loss

The fact that the driving force is produced by muscle power means that in a bicycle-friendly design, energy loss should be kept to a minimum. Not all of the causes of energy loss that occur while cycling are important to the designer, but the rolling resistance is, because it is determined primarily by the road surface and how smooth it is. To keep energy loss as low as possible, the surface should preferably be covered with a smooth, non-porous pavement such as asphalt or concrete. But apart from ensuring a smooth road surface, there are other things a designer can do to minimise unnecessary loss of effort for cyclists. These include:

- preventing or minimising height variations;
- preventing unnecessary stopping and starting;
- providing shelter against the wind.

3.4 Stability, zig-zagging and the section of free space

Bicycles are unstable vehicles. Crosswinds, lorry slipstreams, powerful gusts of wind (caused by the presence of high buildings, for example), bumps and holes in the road surface and involuntary low speeds determine the stability and hence the room required to manoeuvre. To remain stable on the bicycle, it is necessary to cycle at a speed of at least 12 km/h. If the speed is lower than this, instability increases and the bicycle begins to wobble. This occurs when cyclists pull away from a stationary position, in tight bends and when riding uphill.

At a speed of around 20 km/h, it is easy to maintain stability with slight handlebar and body movements. It also requires little effort to keep bicycles in balance at speeds of over 20 km/h. Apart from the speed, stability also depends on external factors such as wind and the smoothness of the road surface. This means that designers have to protect cyclists against lorries that pass close by, provide shelter against gusts of wind and ensure a smooth road surface.

Zig-zagging

When trying to retain their balance (the constant correction of the loss or impending loss of balance), cyclists move from side to side slightly, even when they are riding fast. This is called zig-zagging. Apart from speed, zig-zagging also depends on age, experience, physical capacity, disruptions in the road surface (potholes and transitions from one kind of surface to another) and crosswinds. Crosswinds exacerbate a bicycle's instability, particularly in the event of extreme variations in wind speed (near large buildings, for example) and the slipstream caused by lorries that pass close to cyclists.

In the case of zig-zagging, designers can take the characteristics of the user into account. At normal cycling speeds in normal conditions, the zig-zag movement is about 0.20 m. However, different figures may apply to specific groups. Young, inexperienced cyclists and older people, for example, often have a more pronounced steering deviation than average. In situations where cyclists are forced to travel at less than 12 km/h, more free space is required to keep their balance. This is the case at traffic lights, for example, where cyclists have to pull away from a stationary position, and when cycling uphill. In those kinds of situations, zig-zagging may require a track width of up to 0.80 m. A relatively wide track is also necessary for stopping and dismounting.

Although zig-zagging is generally minor and the space required to compensate for it could theoretically be taken away from the traffic path, that is not the preferable option in prac-

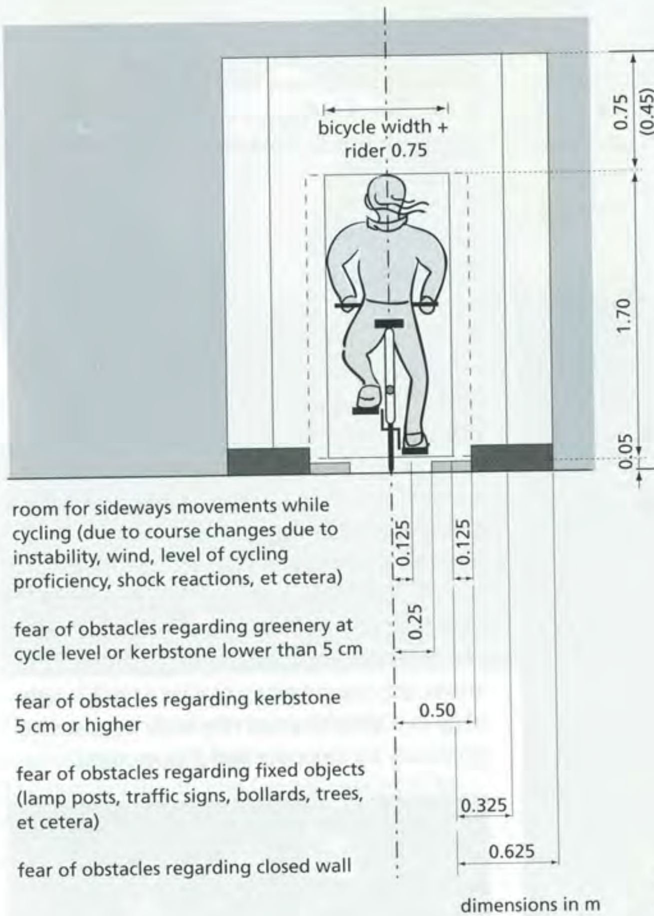


Figure 7. Section of free space for the bicycle

tice, since riding on a narrow track requires a great deal of mental effort. In busy traffic, this distracts cyclists from the task in hand of actually riding the bicycle, detracting from the attention they pay to other road users. In recreational cycling, the effort required to ride along a narrow track reduces the enjoyment of cycling.

Apart from zig-zagging, designers also have to take the fear of obstacles into account. For green verges and low kerbstones, the obstacle distance is 0.25 m (0.50 m for higher kerbstones). The combination of the obstacle distance and zig-zagging results in a minimum pavement width of 0.75 m.

Section of free space

The track width of the zig-zagging movement is continued into the section of free space, which is the space or width that designers have to take into account in their designs. The section of free space is determined by the actual width required by the bicycle and its rider and

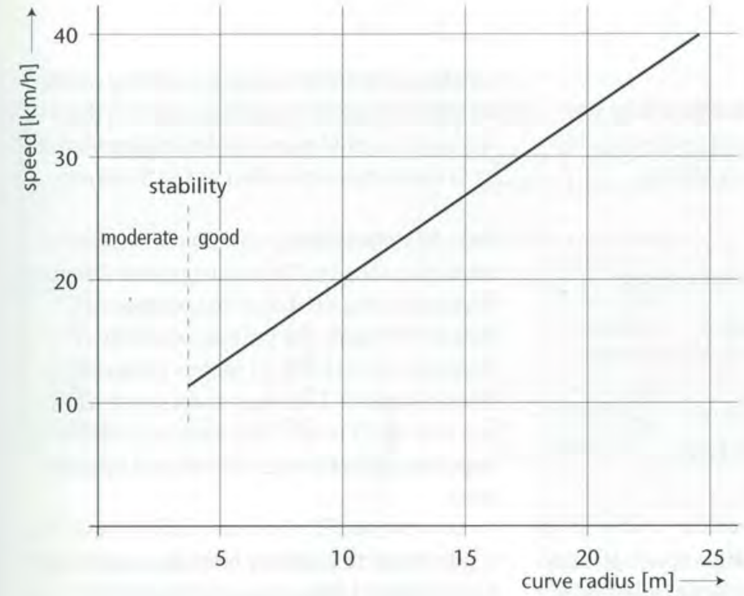


Figure 8. Relationship between curve radius and bicycle speed

by necessary margins, particularly those intended for zig-zagging and the fear of obstacles. The margins can overlap to a certain extent. A large enough obstacle distance can, therefore, provide the margin required for zig-zagging (see figure 7).

It goes without saying that the various margins for each situation (road section, intersection, incline) have to be co-ordinated. Designers also have to bear in mind that the section of free space is larger in curves than in straight lines, particularly at high speeds. Although no research data is available on this point, it is advisable to take account of additional space of about 0.50 m, depending on the speed.

Since cycling is not only a mobility activity with a certain destination in mind, but can also be a form of relaxation and social interaction, the basic design premise is that cyclists should be able to ride side by side.

3.5 Curves and visibility

Horizontal curves

Curves are necessary for the smooth interconnection of road sections. The radius of a curve affects the speed at which cyclists can travel where the curve occurs. The minimum curve radius is 5.00 m; below this value, cycling speed drops below 12 km/h and the cyclist has to work hard to remain upright. As the design speed increases, the radius of the curve will have to increase accordingly. Studies show the relationship between curve radius and cycling speed as presented in figure 8. On the basis of this figure, we can say that:

- cycle connections that form part of the basic network should have a radius of ≥ 10 m, geared to a design speed of 20 km/h;
- cycle routes and main cycle routes should have a radius of ≥ 20 m, geared to a design speed of 30 km/h.

Visibility
To be able to participate in traffic safely, cyclists must have a sufficient level of visibility. There are three kinds of visibility.

Table 6. Riding visibility for cyclists

Minimum riding visibility required	(main) cycle routes	other routes
design speed	30 km/h	20 km/h
riding visibility for cyclists	35 - 42 m	22 - 30 m

Firstly, there is riding visibility. Cyclists must have a good view of enough of the road, cycle track or intersection in front of them in order to carry out the task of cycling safely and comfortably. Comfortable riding visibility can be determined as the distance travelled in 8 to 10 seconds; the minimum required riding visibility is the distance travelled in 4 to 5 seconds.

Secondly, the braking visibility has to be taken into account. This concerns the distance covered during a braking manoeuvre. At a speed of 30 km/h, the braking visibility is 40 metres, at 20 km/h 21 metres (assuming a reaction time of 2 seconds and a speed reduction rate of 1.5 m/s^2). This form of visibility is important on both road sections and intersections.

A third form of visibility is the approach visibility (table 7). This form of visibility is important at intersections and junctions. To cross a carriageway safely, cyclists must have sufficient visibility of the traffic on the road they wish to cross and be able to estimate the speed of this traffic. The required approach visibility is calculated from 1 metre from the side of the main carriageway, that is from where the cyclist is waiting to cross. Approach visibility is determined by:
- the closing speed of crossing traffic;
- the time the cyclist needs to cross safely (crossing distance);
- the delay time (safety margin, depending on the closing speed of crossing traffic).

The time cyclists need to cross the carriageway from a standstill depends on the physical qualities of the cyclist in question. Older people and young children need more time than 'vital cyclists'. Table 7 provides a number of guideline values for the approach visibility for cyclists. These are based on an acceleration rate of no more than 0.8 m/s^2, a reaction time of approximately 1 s and a maximum speed on the crossing of about 10 km/h (= 2.8 m/s). Because approach visibility concerns cyclists who want to cross the carriageway from a standstill or almost a standstill, the distance does not depend on the functional level of the cycle connection. The delay time depends on the closing speed of the crossing traffic and varies from 1 second at 30 km/h to 5 seconds at 80 km/h.

Table 7. Approach visibility required for various road widths and riding speeds

		approach visibility required (m) for various closing speeds of motorised traffic (V_{85})			
crossing distance (m)	crossing time (s)	30 km/h	50 km/h	70 km/h	80 km/h
4.00	4.2	45	100	180	205
5.00	4.5	45	105	185	210
6.00	4.9	50	110	190	220
7.00	5.1	50	115	200	225
8.00	5.5	55	120	205	235

3.6 Inclines

Upward inclines
Upward inclines require cyclists to make an extra effort and should be avoided where possible in the design of a bicyclefriendly infrastructure. That is not always possible, however. Inclines in the Netherlands are usually artificial in the form of bridges or tunnels. In that case, there is a clear relationship between the height to be overcome and the gradient. The steeper the incline, the more effort cyclists have to make to overcome the force of gravity. Per unit of time, the human body can produce more power over a short period than over a prolonged period, which means that if an incline is steep but short, the difference in height can be overcome with a little extra effort but without much trouble. If the effort has to be maintained for a longer period, the same gradient can be far more tiring.

Tunnels and bridges

In the case of a tunnel, a steeper gradient can be applied than for a bridge. The reason for this is that cyclists passing through a tunnel first have to cycle downhill. The speed accumulated on the descent can be exploited on the ascent out of the tunnel.

This is why an uphill, artificial incline should not be too long. If a height of over 5.00 m has to be climbed, it is advisable to incorporate a 'resting place' in the form of a horizontal section about 25 m in length before cyclists have to climb the next part of the incline. The same applies to gentler inclines in open country where the prevailing wind is a headwind. Once again, the higher the climb, the lower the gradient should be.

It is inadvisable to keep the gradient constant all the way up the incline. Since the cycling speed diminishes somewhat when climbing an incline, for relatively short inclines (h < 10 m), it is better to design the lowest section according to the higher percentage on the graph and the highest section according to a lower percentage. This enables cyclists to maintain an almost steady speed on the uphill climb.

In addition to the height to be overcome and the cyclist's physical fitness, the wind is another determinant for the convenience or inconvenience to a cyclist riding uphill. It goes without saying that the stronger the wind, the more energy the cyclist has to use up. See figure 9 for the recommended gradients in various wind conditions.

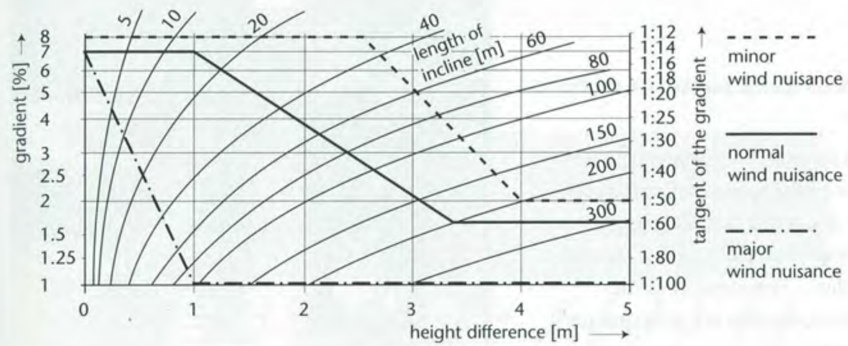


Figure 9. Ratio of height difference to gradient for bicycle traffic

Explanatory note: in the case of low wind nuisance, designers should opt for the 15 percentile point (1.4 m/s), for the normal situation the average (4.3 m/s) and for high wind nuisance, the 95 percentile point (8.8 m/s). It is a good idea when designing an incline to take local prevailing wind speeds into account, because these vary in each situation.

Downward inclines
In the case of downward inclines, attention should focus on the speed of the descending cyclist. On long inclines, this speed can be relatively high (35 to 40 km/h), which is why there should be plenty of free deceleration space at the bottom of the incline, with no intersections, sharp bends or other obstacles in the way.

3.7 Weekly and daily patterns of bicycle use

Figures A and B represent the use of the bicycle on the days of the week and during the hours of the day, respectively. Figure A shows the intensity progression throughout the week. Of the working days, Wednesday is the quietest day. The weekends are also quieter than working days.

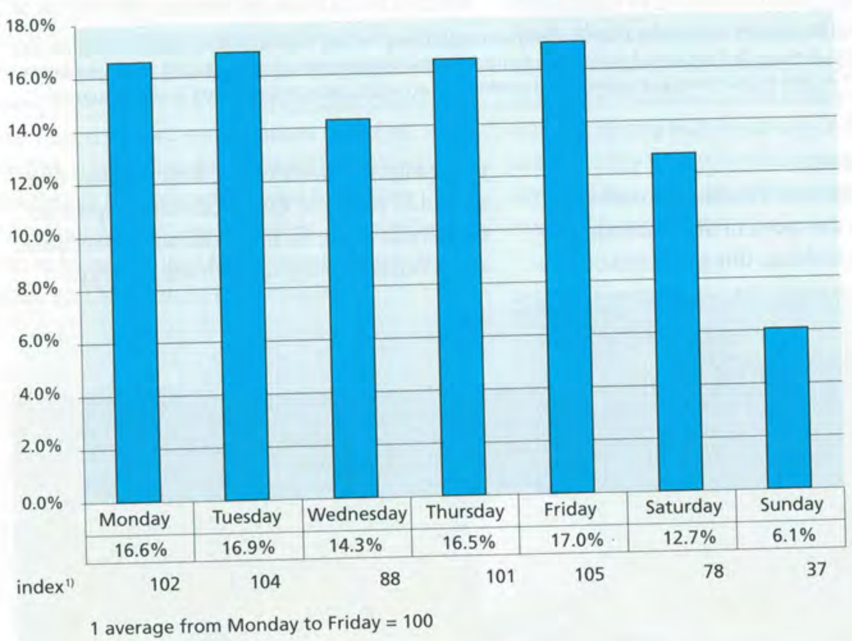


Figure A. Weekly pattern of cycling intensity in the built-up area

Looking at the pattern during the day (figure B), there is a notable morning rush hour: school-going traffic is particularly diffuse, with a much more level evening rush hour as a result.

The most reliable means of ascertaining cycling intensities is to count bicycles on several days. On busy routes, this is recommended in order to gain a complete picture. To be able to make reliable statements about cycling intensities, random checks are an alternative. These should take account of the substantial variations in traffic intensity during the day.

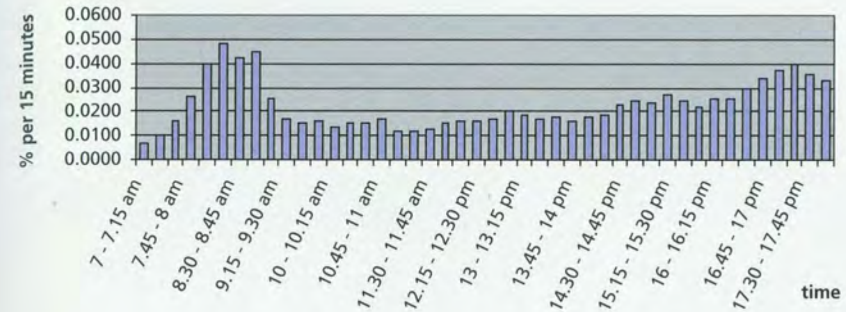


Figure B. 15-minute periods of cycle traffic

A survey conducted at 20 counting sites determined the cycling intensity for a period of 11 hours. The hourly share was determined on the basis of the total number of bicycles, including an incremental factor, to produce figures showing the intensity for a 24-hour period. The basic premise here is that 85% of the bicycle traffic takes place between 7 am and 6 pm.

Period	Share	Incremental factor
7-8 am	0.050	20.0
8-9 am	0.148	6.7
9-10 am	0.063	15.9
10-11 am	0.052	19.3
11-12 am	0.044	22.6
12-13 pm	0.059	17.0
13-14 pm	0.060	16.7
14-15 pm	0.071	14.1
15-16 pm	0.083	12.1
16-17 pm	0.097	10.3
17-18 pm	0.123	8.1
Total	0.85	1.18

4 Networks and routes

4 Networks and routes

4.1 The basis of any design

The most abstract yet extremely important activity when designing a bicycle-friendly infrastructure is the development of a cycle network, since the quality of the network is an essential element in determining the quality of an area's 'cycling climate'. It is also true that an effective design for an intersection or road section is only possible if the designer is aware of the function of a particular road section or intersection within the total cycling network. In that context, the network forms the basis for any design.

There may be a number of reasons for updating a cycle network. New policy may give rise to a new policy document on bicycle traffic. The results of benchmarking cycling policy (for example a comparison with other municipalities) may be another reason. And of course, complaints from the population may result in close scrutiny of the cycle network. However, if the network has to be renewed, the designer does not have to start from scratch. Existing areas already have a great many routes in place, and measures taken in the past have ensured a highly or less highly cohesive network.

4.2 Requirements for a network

Three requirements are key factors in the development of a cycle network – cohesion, directness and safety. There are also other requirements in the area of comfort and attractiveness, but these are less relevant at the network development level, playing more of a role at the concrete design level of routes and road sections.

4.2.1 Cohesion

The main requirement cohesion is the most elementary network requirement and concerns the extent to which cyclists can reach their destination. At network level, this means that connections have to link up with a cyclist's point of departure and destination. Cohesion is hard to make concrete. It involves the construction of a complete system of connections, providing access to all points of departure and destinations: every home, company and amenity must be accessible by bicycle.

The most fundamental indicator is the physical presence of infrastructure that is accessible by bicycle. A simplified network indicator for the extent of cohesion inside built-up areas is the mesh width of the network, where a value of no more than 250 metres applies as a guide value. If a network is designed properly, it will link up with cyclists' travelling patterns. An indicator of this is how much the network is used. If about 70% of bicycle journeys is made via the network of cycle routes, it can be concluded that the network is in line with the travelling demand.

It is also important that cyclists can choose from various routes. If, for example, the most direct route is not safe in the evenings, an alternative route should be available. If the mesh width requirement is met, an alternative route will always be available within 250 metres, thus meeting the freedom of route choice requirement. If the mesh width requirement is not met, it will be necessary to make an explicit assessment of the presence of alternative routes. This applies in particular to connections of a utilitarian nature.

Mesh width is only relevant inside the built-up area (see also section 4.3.2 under cohesion and mesh width). Outside the built-up area, it is only important for bicycle connections to be present between villages, centres and amenities that attract cyclists.

Cohesion with other networks

Apart from the internal cohesion of a cycle network, the cohesion with other networks also plays a role. This concerns primarily the connection to networks for cars, public transport and pedestrians. As for the car network, it is important that park and ride facilities and car pooling sites are accessible by bicycle. Gearing the cycle network to the public transport network (stations, transfer points and bus stops) is relevant because the bicycle plays a vital role as pre-transport for journeys or main journeys by public transport. A good link to pedestrian networks is primarily relevant for city centres and pedestrian precincts. It must be possible for the bicycle to use these areas and to get the bicycle as close to them as possible (see also section 5.7).

4.2.2 Directness

As far as the directness requirement is concerned, two components are important at network level, namely directness in terms of distance and directness in terms of time.

Directness in terms of distance

Directness in terms of distance concerns the extent to which a network – resulting from a collection of routes and connections – provides the opportunity to cycle between points of departure and destinations via as direct a route as possible. In terms of policy, the bicycle should be a good alternative for the car, particularly inside the built-up area. If cycling is quicker than taking the car, motorists will be more willing to use the bicycle for short trips. Factors that influence travelling times have been bundled under the main requirement directness.

The directness of a network can be determined using the detour factors (see text box). Generally speaking, a detour factor concerns a specific link. A network value can be achieved if the detour factor of a large number of randomly selected links (for example between the most important points of departure and destinations in a network) is determined and these values are then plotted against the straight-line distance along these links. The resulting scatter plot can then be used to draw a regression line that can be regarded as a network characteristic. Incidentally, the average detour factor (determined for all links) is also a characteristic of the quality of the network.

Detour factor

The detour factor is the relationship between the shortest distance over the road and the distance as the crow flies. By itself, the detour factor does not tell us much. It has to be related to the distance. At long distances, a high detour factor is far less favourable that at short distances, because the absolute detour factor is then considerable.

Signals from the field indicate that detour factors of no more than 1.2 for cycle routes and main cycle routes and 1.3 to 1.4 for other routes are applied, but there are no studies in which these values are substantiated. Of course, the designer or policy-maker is free to work towards a higher ambition (a lower detour factor). Data from the Bicycle Balance project shows that the 5 and 95 percentile values for the detour factor are 1.24 and 1.50, respectively. In practice, therefore, it is not easy to meet the target of 1.2.

Directness in terms of time

Directness in terms of time concerns the provision of connections that optimise the flow of traffic. In a network, it will theoretically always be possible to achieve an uninterrupted flow via the connections as a whole. However, the question is whether the connections in question are the most direct in terms of time. Again, the detour factor plays an important role here. It means that the directness in terms of distance at network level is more favourable than directness in time. Another important aspect is the possibility at route level to carry on cycling unimpeded. The number of intersections per kilometre at which a cyclist does not have right of way applies as a criterion. For main cycle routes, that number should be zero or as close to zero as possible. For the other routes as well, the target should be as few intersections per kilometre as possible where the cyclist does not have right of way, although this will prove difficult in practice. For example, in the towns and cities that took part in the Bicycle Balance project, it turned out that the 5 and 95 percentile values for the number of intersections where cyclists do not have right of way were 2.18 and 5.5 per kilometre, respectively.

The stopping frequency could also serve as a parameter. The standard could be the number of stops per kilometre; the 5 and 95 percentile values from the Bicycle Balance project are 0.40 and 1.56, respectively.

4.2.3 Safety

At network level, the following requirements are important to ensuring safety:

- *Avoiding conflicts with crossing traffic*
  Every encounter with a passing flow of traffic is a potential conflict. The more the number of encounters grows, the higher the inherent danger of a network becomes, so the number of intersections should be kept to a minimum. A measure that takes account of both the number of intersections and the traffic load is the sum of the intensity of crossing cyclists times the intensity of the flow of traffic to be crossed, weighted for speed. Totalled for all road sections, the amount could be: the density of the motorised traffic times the density of the bicycle traffic times the speed difference squared times the length of the road section; the density here is equal to the intensity divided by the speed. The network variant with the lowest risk of encounter best meets the main requirement safety.

- *Separating vehicle types*
  Cyclists and motor vehicles have different characteristics and traits. The safety of cyclists is improved when they are separated from motor vehicles travelling at high speed and bicycles are guided via their 'own' network of connections. Apart from the safety aspect, separating vehicle types can also be considered for comfort reasons.

- *Reducing speed at points of conflict*
  At places where the cycle network crosses networks of other types of vehicles, the speed differences between the two are minimised. The speed of the slowest means of transport (usually the bicycle) is used as the basis.

- *Ensuring recognisable road categories*
  Recognisability at network level primarily plays a role in the application of specific traffic provisions and in that sense, it is more a road section and intersection requirement than a network requirement. Every provision should be recognisable as such to road users.

- *Ensuring uniform traffic situations*
  Uniformity in traffic situations at network level primarily plays a role in the application of certain solutions. Bicycle facilities and intersection solutions are related to functions of roads for car and bicycle traffic. It is preferable not to use solutions that are characteristic of a certain type of road on other types of road.

4.2.4 Other main requirements

Apart from the cohesion, directness and safety requirements, a network also has to meet the requirements of comfort and attractiveness. With regard to the network level, however, these two are less important, because any negative aspects can be improved in the design at network and intersection level.

Comfort

At network level, comfort concerns the extent to which cyclists can use the connections as a whole comfortably. Nuisance, the ease of finding the way and comprehensibility are three important elements.

- *Prevention of traffic nuisance*
  Preventing traffic nuisance is an important condition for comfortable use of the infrastructure, and includes the health aspect, which also plays a role. Fumes emitted by motorised traffic can cause health problems, both in the short and long term. This means that when designing a cycle network, longitudinal or lateral combinations of cycle connections with busy flows of motorised traffic should be avoided where possible.

- *Optimisation of the ease of finding the way*
  Cyclists must be able to find their way. At network level, it is relevant that towns and cities, villages, districts, amenities and public functions are included in a system of bicycle signposts.
- *Comprehensibility*
  In this context, the comprehensibility of a network is important. A network should be geared to the logic of the user, and that is the case when 'natural' points of recognition are used. In the past, routes between villages ran from church steeple to church steeple, since steeples were a natural signpost. If cyclists have these kinds of orientation points at their disposal and can use them to make a mental map of the vicinity, it improves the comfort and attractiveness of the network. Of course, designers are unable to influence the surroundings, but they can try – with due regard for the other main requirements – to plot a route in such a way that it passes recognisable, notable and attractive urban design and landscape elements.

Attractiveness
Everyone has their own ideas on what an attractive cycling climate is. Generally speaking, however, enjoyable cycling will always depend on public safety and the attractiveness of the vicinity. At network level, this means that utilitarian connections should run through built-up areas in varied surroundings with well-maintained public space and that the connections should be lit where possible. See section 4.5 for the requirements that apply to recreational connections.

For existing networks, the pattern of complaints provides designers with indications regarding the locations where social safety should be improved by means of spatial construction, reconstruction and design. If there are no complaints, that does not mean that the situation is acceptable. There may be few or no complaints because people do not use a particular connection (due to the lack of social safety). This subject is discussed in more detail in section 7.5.

Results achieved in the past still count

When considering networks in an existing situation, policymakers or designers never have to start from scratch, because it is unnecessary to build a totally new cycle network from time to time. Only in areas of new construction are completely new networks needed. The further expansion, detailing and updating of existing cycle networks does not have to be a complex activity which can only be done with GIS and other, relatively labour-intensive model techniques and others. This has proved to be the case in practice. An analysis of 94 municipal traffic and transport plans showed that cycling models were only used in five cases. A survey commissioned by the Dutch Bicycle Council also showed that government staff and private consultants are pragmatic when they design cycle networks: a thorough knowledge of the local situation, a series of observations and plain old common sense are enough. To a certain extent, these results are confirmed by a study of local cycling policy [72]. Municipal councils are generally satisfied with the development and implementation of cycling policy. A more solid basis for the policy is considered to be unnecessary or inadvisable. Cycling models are hardly used for designing provincial cycle networks either.

Table 8. A summary of the main requirements for a cycle network

Main requirement	Important aspects	Explanation
Cohesion	• Network completeness (inside built-up area) • Route completeness (outside built-up area) • Match with need to travel	The mesh width of the network is no more than approx. 250 m. Centres and important amenities are interconnected. At least about 70% of all bicycle journeys is made via the cycle network.
Directness	• Directness in terms of distance • Directness in terms of time	The average detour time is optimised. • Minimisation of the number of intersections where cyclists have no right of way. • Minimise the stopping frequency.
Safety	• Avoid conflicts with crossing traffic	Summed up for all intersections, the number of crossing movements made by cyclists times the intensity of the passing flow of motorised traffic, weighed according to speed is minimised. Summed up for all road sections, the density of motorised traffic times the density of bicycle traffic times the speed difference squared times the length of the road section is minimised.
	• Separate vehicle types	In the case of major speed differences, cyclists are separated from motorised vehicles.
	• Reduce speed at conflict points	Where the cycle network crosses networks carrying other vehicle types, speed differences between both are reduced.
	• Recognisable road categories	Every amenity should be recognisable as such to all road users.

Table 8. A summary of the main requirements for a cycle network (continued)

Main requirement	Important aspects	Explanation
	• Uniform traffic situations	Cycle amenities and intersection solutions are related to functions of tracks and roads for bicycle and motorised traffic. Solutions that are characteristic of a certain type of road should not be used on other types of road.
Comfort	• Prevent traffic nuisance	Encounters between bicycles and cars are minimised by combining busy cycle connections (in longitudinal and lateral direction) as little as possible with busy car connections.
	• Ease of finding destination	Towns, cities, villages, districts and amenities that attract the public are signposted.
	• Comprehensibility	The network makes the best possible use of spatial and landscape features so that users can form a mental map.
Attractiveness	• Social safety	Networks, and particularly the main routes within them, meet the requirements of social safety (see chapter 7). At network level, this means that busy routes are plotted in areas where there is sufficient social control in the community.

4.3 Utilitarian cycle network

The utilitarian cycle network comprises the connections required for functional reasons. This concerns reasons to travel such as shopping, living, working, education, socio-cultural visits, et cetera. There are a number of different methods that can be applied when designing a utilitarian cycle network. This design manual looks at two of them, namely the one that uses a traffic model (section 4.3.1) and the adapted grid method (section 4.3.2).

4.3.1 Traffic models

A traffic model is used to calculate the traffic flow (in terms if the amount of traffic and the route forming) of one or more means of transport. A variety of models is used in the Netherlands. Although unimodal cycling models are relatively simple, model calculations are performed more and more often with a multimodal car/bicycle/public transport model, in which interaction between the means of transport is possible.

The results of applying a model are determined to a large extent by the basic premises and calculating techniques that form the basis for the model. This is where the danger of using models lies: results are too easily regarded as 'absolute values', while basic premises that form the input for the models are not discussed enough. Once a model works, it is too often treated as a black box, so that policymakers or designers have no idea whatsoever of the contextual points of departure and calculation models.

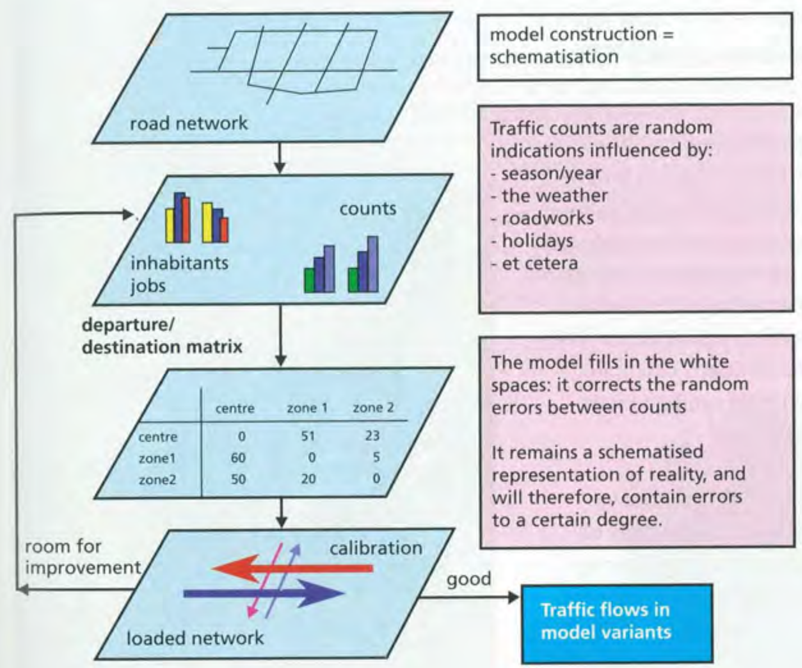


Figure 10. Cohesion of model stages [23]

Model theory

Traditional traffic models often comprise three steps:

- journey generation;
- distribution/modal split;
- assignment and calibration.

The journey generation step comprises the collection of the socio-economic characteristics of individual districts/neighbourhoods: the number of residents, jobs according to category, pupil places, et cetera. Journey generation coefficients are used to calculate arrivals and departures for each reason to travel. The result is a general picture of how many journeys begin or end in a district or neighbourhood.

In the distribution step, distance functions are used to calculate how many journeys will or may be made between the districts/neighbourhoods. Many models calculate the modal split at the same time, but this calculation may also be performed as a separate step. The result is one or more departure/destination tables (DD table), in which the theoretically calculated journeys (also referred to as synthetic journeys) have been worked out.

For existing situations, a DD table can be determined synthetically or on the basis of research data. The results of a house survey supplemented with those of road surveys are ideal input data for a cycling model, enabling the creation of a first-rate DD matrix for bicycle traffic. However, this method is far more labour intensive than a calculated matrix.

Cyclists know the quickest routes

Studies of route choice behaviour [22] show that 50% of the cyclists use a route that is less than 6% longer than the shortest route. Travelling time is more important to the route choice than distance. Half the time, cyclists are able to choose a route that differs by less than 5% from the fastest route in the network.

In the assignment and calibration step, network characteristics (speeds, intersection types, one-way traffic or not, et cetera) are used as a basis for calculating the routes between all zones and the journeys from the DD table are assigned to them. Assignment can be based on the shortest route in terms of time or distance or a combination of the two. Once this theoretical calculation process has been completed, the model is calibrated. By relating all available statistics to the calculated values, the model can be calibrated according

Ample selection of models

In the 1990s, the use of cycling models was encouraged via the 'Bicycle Master Plan'. A great many model packages are now available, most of which are used to make calculations from a multimodal point of view. Apart from traffic engineering software packages, a GIS package can also be a useful tool for drafting cycling plans. GIS is often applied in combination with a traffic model, thus again creating added value due to the possibility of using GIS to make spatial calculations. In addition to the numerous local and provincial models, there is the New Regional Model (NRM) used by the Directorate-General of Public Works and Water Management. This model includes the bicycle as a means of transport. An NRM model makes it possible to conduct analyses at a strategic level of shifts in the modal split and can be used to draw up policy scenarios. An NRM cannot be applied for the local network and route level because it is not detailed enough.

Model zones and the network

Zones
When ascertaining the points of departure and destinations, the question is what scale level has to be distinguished. In theory, every home is a point of departure and every shop, amenity and activity a destination. For reasons of practicability, however, this data has to be clustered. The scale level at which it is clustered depends on the size of the area in question and the density of the socio-economic activities. An area can be divided up on the basis of natural and artificial barriers, such as water connections, areas of vegetation, main roads or public transport axes. Because bicycle journeys are normally shorter than car journeys, a finer area division is applied than for motorised traffic. To determine a cyclist's point of departure, in 1979, Ploeger [73] established an area size of 250 x 250 m as a measure for an urban area, and this is still practicable today. It is also essential for important cyclist destinations, such as schools, shop and work concentrations and stations to be included as separate zones. A minimum number of visitors can be used as a parameter for destination areas and locations.

It is up to the planner to choose a suitable division; there are many possible variants, as long as they are clear and consistent. As an illustration, see figure 11, which only shows work locations where more than 100 people are employed and neighbourhood shopping centres with over 1,000 m^2 of sales area. The more points of departure and destinations are indicated, the less clear the establishment of DD links becomes. If too few points of departure and destinations are indicated, however, there is a danger of locations ultimately being situated too far from the cycle network.

A provincial or regional plan requires a less detailed area classification than a local plan. After all, journeys made at provincial or regional level usually entail greater distances.

Figure 11

The measure to be used depends in part on the spread and density of the population. The greater the spread and the lower the density, the less detailed the area classification becomes. In its cycle plan, the Dutch province of Friesland opted for about 750 residents per area of departure; the province of Zuid-Holland, on the other hand, with a greater level of density, opted for 1,500 residents. In the large residential centres, a division into smaller areas is advisable. A good tool that can be used for this division is the four-digit postcode.

At the provincial or regional level, business parks with a supralocal service level can be indicated as destinations; at the local level in a smaller centre, a business park can be indicated as a collection of individual companies. A minimum annual number of visitors can be used as a criterion for recreational facilities.

Network
The structure of a network has a tremendous impact on the results. For a municipality with about 50,000 inhabitants, it is advisable to draw up a list of all connections on which cycling is permitted. This should also include unofficial cycle tracks formed by cyclists themselves on unused land, for example, as well as separate footpaths that are used by cyclists. Taken together, these connections form the basic network for cyclists. For the large municipalities, the network will have to be simplified. This simplification may comprise the omission of residential streets and home zones that can never play a role in the network (the '0 link'). This all coincides with the choice of the zone size and the location of the supply points. Simplification can also be found in the omission of neighbouring parallel routes. The densification analysis may reveal that some connections should still be included in the basic network.

For a large area (that may cover more than one municipality), the existing interlocal network forms a good basic principle. Bottlenecks in this network may be the residential centres and important attraction points outside the built-up area. They are interconnected by corridors. Initially, it is only important that one or more connections are actually available. A noticeable aspect will be how many of the historically shortest routes are crossed by main roads, motorways, railway lines and canals.

Generally speaking, the quality of the connections and the nature of the amenity only become important in the bottleneck phase. However, certain properties of the connection can be coded in so far as they are important for the assessment of the planned targets (such as safety). This could be a code for the connection type (mixed traffic, cycle track, illegal connection, et cetera). In any case, when compiling the basic network, designers have to watch out for one-way streets and other physical obstacles that influence the choice of a route in the network. This also includes delays at traffic lights. Central reservations on roads with vegetation, et cetera, can form a barrier to people crossing over. The cycle tracks that run parallel to this kind of road should be included in the model as two one-way tracks.

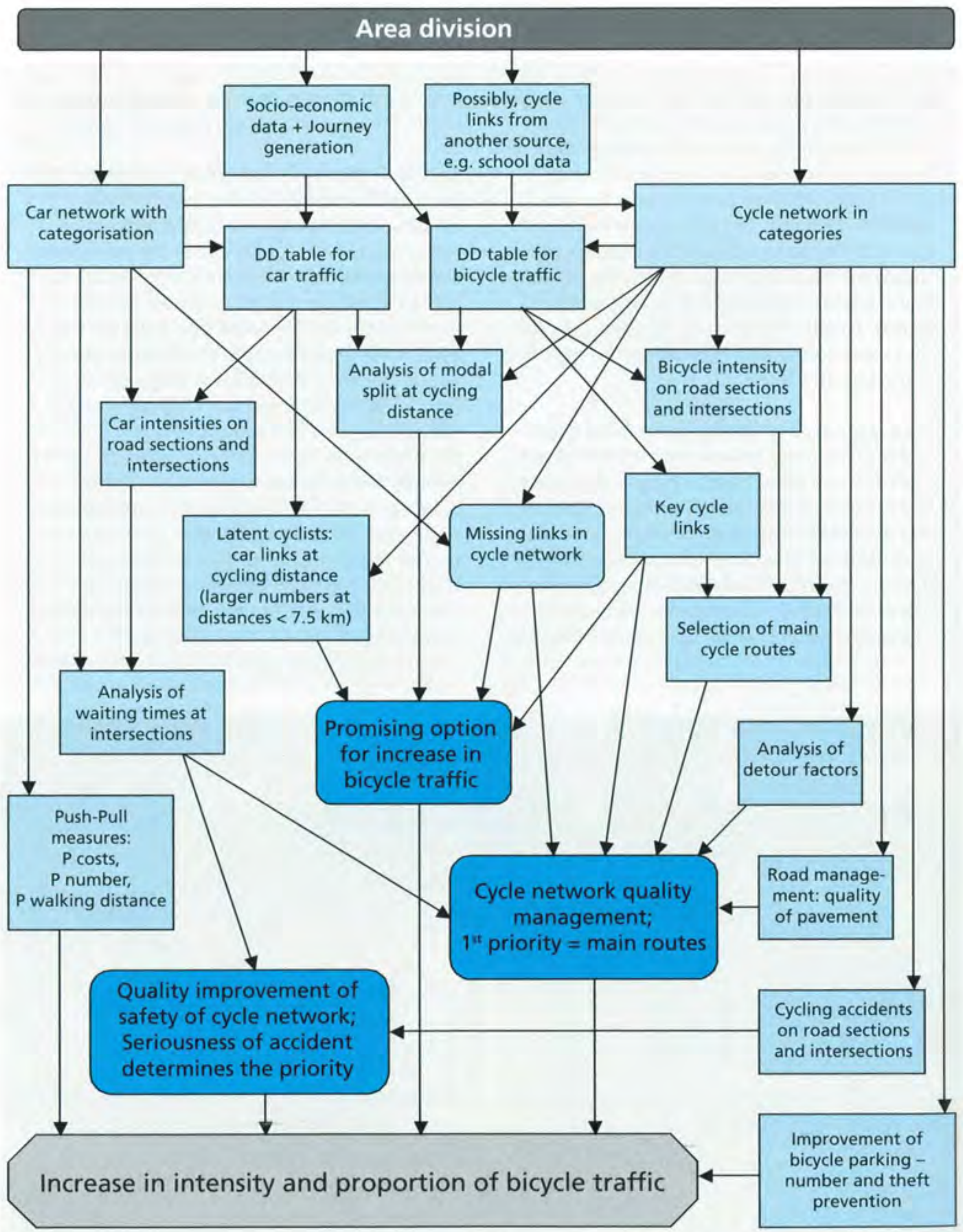


Figure 12. Diagram of model use in practice

to the actual situation in the base year. The results consist of a corrected DD table and a 'loaded' network that is as close to the real situation as possible.

Analysis options
Figure 12 shows a large number of analysis options. A few of the most important ones are dealt with briefly in this section. These summaries are far from exhaustive; depending on the model and the associated applications, other uses are also possible.

DD data
In large-scale extension locations, a model can be used to visualise problem areas, analyses and considerations, in terms of both quantity and quality. It can also be used to calculate a departure-destination table (DD table) for the reasons for travelling from home to work, from home to the shops and from home to other destinations. If no model is available, a DD model can also be calculated on the basis of the results of a survey, for example. When working out the DD table for travelling from home to school, an analysis of each school's pupil address list is a useful method.

Route forming
A model can calculate the choice of route on the basis of speeds, capacities, intersection types, et cetera Intensities of car and bicycle traffic can then be calculated by assigning DD tables to the routes. By combining neighbourhoods into districts (recoding), important bicycle links can be visualised. A model can be used to put this information on the map in the form of a link diagram. Main cycle routes and other routes can be distinguished on the basis of the most important bicycle links, the cycling intensities and the available network.

Densification options
The basic network consists of all connections that are available to cyclists in the current situation. In practice, a network is not always complete; it may contain 'holes'. New, shorter connections encourage use of the bicycle and also provide cyclists with the opportunity to choose a low-traffic route, thus avoiding busy and potentially dangerous locations.

The detour factor method can be used to trace shortcomings in the basic network. If the detour factor is calculated for all links between two zones, the holes in the network can quickly be found. When looking for new routes, designers and planners should also bear in the mind the possibility of the construction of new cycle amenities 'piggybacking' on other infrastructural work, either in the new construction phase or in the event of mainte-

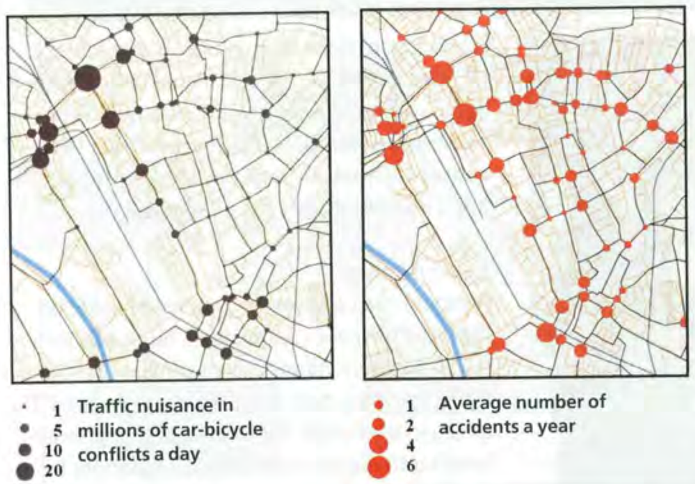


Figure 13. Evaluation with cycling model

The Utrecht Cycle Plan had a combined evaluation performed with a cycling model: traffic nuisance – expressed in the number of crossings made by cars and bicycles a day – was compared to the average number of accidents a year. The locations with a relatively low level of nuisance but a high level of accidents merit extra attention.

nance work. There are often surprising possibilities for building cycle routes parallel to existing or new transections (railway lines, main roads, motorways and canals).

Delays
A model for motorised traffic can be used to gain insight into the measure of delay that cyclists encounter at intersections.

Latent demand
When DD tables are available for both car and bicycle traffic, the division of means of transport can be calculated on links, and particularly those at cycling distance. This is relatively simple to do with a model by combining the calculated distances on the shortest routes. A significant proportion of journeys shorter than 7.5 km is made by car. A model can be used to visualise these car links, which can be regarded as latent cycle links. A combination of latent demand and missing cycle links can be used to visualise promising options for additional bicycle traffic.

Other analysis options
The traffic model provides an opportunity to evaluate the extent to which the existing or newly designed network achieves the required goals. The total reduction in bicycle kilometres on a densified network can be calculated by re-assigning the DD matrix. The most effective location can be determined for a connection (for example a tunnel under a railway line) by assessing it against the minimisation of the detour. Road safety goals can also be assessed by calculating the number of encounters between motorised and bicycle traffic, for example.

4.3.2 Adapted grid method

It is not necessary or productive to build a cycling model for every situation. If there is no base model (car or bicycle), building it requires a lot of time and money. In such cases, designers will have to weigh up the benefit and need against the costs. To illustrate the point: an experienced model builder requires a month to build a cycling model for a town with a population of about 50,000.

If no model is available, a network can be created or checked on the basis of the adapted grid method. This method is based on the original grid method, which assumes that cyclists benefit from as full and complete a network of connections as possible. Depending on the grid size (mesh width), if a grid of connections is laid out over an area (neighbourhood, district, village, town or city), it will produce a complete infrastructure. If necessary, various quality levels can be distinguished, with the basic network having a smaller mesh width than the quality level above it.

The drawback of the grid method is that no account is taken of the spatial and traffic structure of the area, including the actual cycle links. If these cycle links transect the grid of connections radially, cyclists on the link will not benefit from a smooth, direct connection. This is an undesirable effect, especially when traffic flows are heavy.

The adapted grid method responds to this objection by looking not only at the grid, but also at the main cycle links. Two steps can be distinguished:

- charting the main departure and destination areas and links (step 1);
- converting preference lines into routes (step 2).

Network map of Veenendaal

Step 1: determining the main departure and destination areas and links

This step charts the main departure and destination areas, and the size of the study area plays a decisive role. At provincial level, a centre can be regarded as a single departure area, while for the network inside the centre, the various neighbourhoods and districts will be regarded as individual departures.

Departure areas are usually cohesive residential areas and campsites of all sizes. The scale level for which the cycle network is designed is indicative of whether a particular departure or destination is included.

Destination areas are all those functions, buildings, activities and amenities that attract a lot of cyclists, such as:

- shopping areas and city, district and village centres;
- government and other buildings with a major public function;
- schools and universities;
- sports amenities: swimming pools, sports fields, recreational areas and activity centres;
- concentrations of employment, such as large companies or business parks;
- main public transport hubs (railway, bus, tram and underground terminals);
- links to the surrounding regional or provincial cycle network and the recreational cycle network;
- activities that do not occur every day but that may attract a lot of cyclists such as markets, theatres, cinemas, churches and catering facilities.

Differences in mesh width

A scan of 94 municipal traffic and transport plans has revealed that municipal councils generally pay little attention to the mesh width aspect. The mesh widths used for the various quality levels within a cycle network differ (see below), but the plans hardly show what mesh width belongs to what quality level, because the details of the quality levels are already different.

Nijmegen
The 1992 Structural Vision proposes a mesh width of 400-600 metres for the cycle network. However, at certain points, the present network has a mesh width of 800-1,000 metres. A mesh width of about 500 metres ensures that cyclists always have a route nearby.

Valkenswaard
The primary cycle network consists of main routes for bicycle traffic. It is a coarse mesh network that provides fast, direct connections over great distances. Inside the built-up area, the primary cycle network has a mesh width of about 500 to 600 metres. The mesh width of the secondary cycle network is about 200 to 300 metres. Most of the secondary cycle routes cross the residential areas and form short cuts between the routes in the primary network.

Wijk bij Duurstede
For the utilitarian bicycle traffic, a number of important links have to be added to the regional network. The plan assumes a maximum mesh width of about 300 to 400 metres.

A cycle network is usually available. In that case, it is important to check whether major changes have taken place in the area of living, working, education or recreation since the formulation of the last bicycle traffic plan. It is also important to check whether any such developments are planned for a period of five to ten years. If that is the case, the new departure and destination areas will have to be added to the cycle network. If there are no plans for change, step one in the step plan can be skipped.

Once departures and destinations have been determined at the right scale level, the links are plotted between them. Preference lines are used to mark the ideal links between departure and destination areas. Preference lines form an

Cohesion and mesh width

A mesh is the smallest, closed element in a network. The mesh width is the distance between parallel amenities in a network. The larger the mesh width, the lower the network density (the total link length per surface unit) and the lower the level of cohesion. If it turns out that the mesh width is becoming too large, it has to be made smaller, but that is only necessary if there is a latent or active demand. That means that the mesh width is only relevant for networks inside an uninterrupted built-up area. Outside the built-up area, where there is hardly any latent or active demand outside the centres, the mesh width plays no role whatsoever.

The size of the mesh width depends on the quality requirements set in a particular area. For the basic network, a size of 200 to 250 m seems realistic, because it will then serve most residential neighbourhoods. For functional routes at a higher level, the mesh width is less relevant. It is better to have two busy main routes located close to each other than to have one of them at a greater distance on the basis of the mesh width, but not connected to the DD links.

abstract representation of the journey pattern, without taking the spatial structure or the existing network into account. Because of the number of links (particularly in an urban environment), it is possible to combine preference lines situated together.

For a large city, the preference lines can initially be plotted at a high scale level (the whole city), with the centres, subcentres and destinations important for the area connected, after which details can be added at a lower scale level (district/neighbourhood). Important aspects include the cross-linking of the various levels of scale (such as neighbouring municipalities).

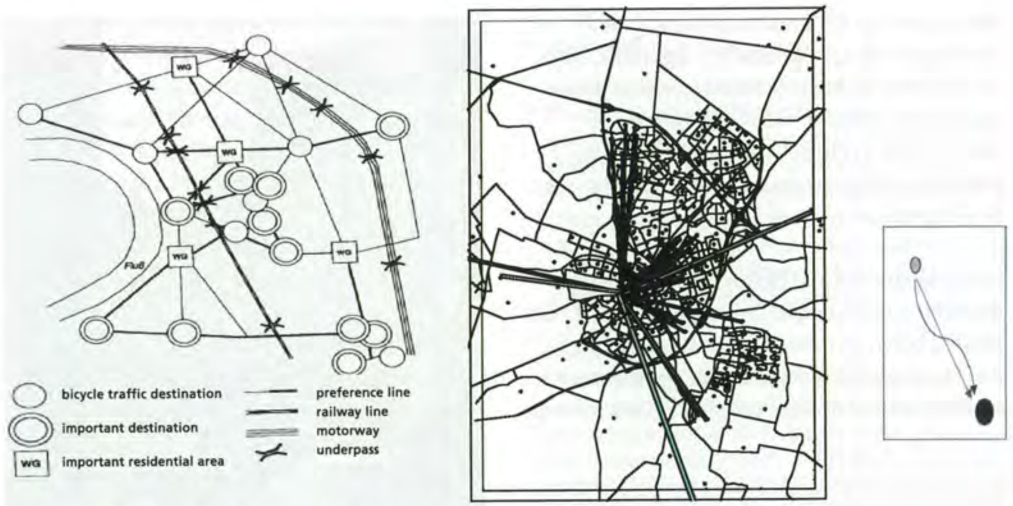


Figure 14. Examples of preference lines between destinations

It may be advisable to distinguish quality levels within the cycle network, to make more focused improvements to the network, for example. This creates a hierarchy in the network (see also section 4.4). If this distinction is deemed necessary, step 1 is repeated to ascertain what specific links it involves.

Step 2: converting preference lines into routes

In this step, the DD links converted into preference lines are converted into possible routes. This entails making as much use of the existing infrastructure as possible, but it is not really necessary to adhere to the grid. There are often several routes between departure and destination, in which case the most direct route in terms of distance is preferable. The shortest route is then checked on the basis of the set route criteria. If the route does not meet the criteria but it can be improved, it is included in the network and the confrontation with the network of other means of transport can take place in the next step. If a route does not meet the criteria and there is no room for improvement, designers will look for the next best route. However, the second choice must not be much longer in terms of distance than the first one.

It is sometimes impossible to project a preference line between a departure and a destination onto an existing connection in the network or only possible via a connection with a high detour factor. In that case, a new connection will have to be considered for the link in question, particularly if it has a function for a large group of cyclists.

4.4 Cycle routes and main cycle routes

4.4.1 Levels of quality

The power of the bicycle is its flexibility, speed and convenience. These advantages can only be exploited if as many roads, streets and tracks as possible are suitable for cycling. That means that the network should theoretically be as extensive and finely meshed as possible. Within this finely meshed network of basic amenities, it may be advisable to distinguish various quality levels in order to offer extra quality on top of a general level of basic quality. Higher levels require higher quality standards because of the function in the network as a whole. In that context, a parallel can be drawn with the categorisation of the road network for motorised traffic, where three functions are distinguished on the basis of network quality, with more flow quality the higher the function.

Recognisable main routes

Cyclists have only a limited awareness of the route choice options available in a network. One of the aspects that influence their choice is the spatial image they have of the surroundings (the mental map). That is why clearly recognisable main routes attract more cyclists, even if they are not the fastest. In Delft, 63% of the bicycle kilometres on the city network was covered, while these through connections only form 19% of the network length.

Traditionally, manuals for bicycle amenities within the built-up area have always distinguished the following three levels of cycle connections: connecting (city level), dividing (district level) and access (neighbourhood level). Together, these three levels of connections form the network; each level is not expected to form a full or cohesive network by itself. After all, the access connections complement the connections 'above' them, forming a great many 'separate' connections rather than a network.

In actual practice, road authorities sometimes use three levels, but far more often two levels of cycle connections. The two levels have a variety of names. They may be referred to as the primary and secondary levels, main and branch routes or subroutes, a quick or star network and basic network. The difference between three levels and two levels seems (regardless of the terminology) considerable at first glance, but is actually minor in practice. What it comes down to is that in networks with two levels, the lowest level (third, access or neighbourhood level) is not taken into consideration. This is not because it has no relevance, but because it is far too detailed; it is sometimes assigned to 'district management' rather than local cycling policy. Furthermore, at the lowest level of 'connections between homes

and district routes', the required quality is often already in place.

At that level, the main priority is the physical presence of connections via regular streets and tracks. These access connections form a sort of underlying level that should have as small a mesh width as possible, to a maximum of 200 to 250 m. The optimisation of this network level comprises the improvement and construction of short cuts and the pavement of tracks worn in the grass, et cetera. In other words, measures that can hardly be planned by the planners.

This design manual distinguishes two basic levels, with the following neutral terms:

- *Basic network*
  Inside the built-up area, this concerns the access connections at neighbourhood level, corresponding in practice with almost every track and every street that can be used by cyclists (a mesh width of no more than 250 m). Outside the builtup area, it concerns the network of roads and tracks that provide access to the outlying area.
- *Cycle routes*
  Inside the built-up area, this concerns the connections at district level that provide access to districts and neighbourhoods ('district access tracks'). Outside the built-up area, it concerns the connections between centres, villages, towns and cities.

Figure 15. Preference structure of a cycle route

In a number of cases, it may be advisable to distinguish a third level. That is the case when there are cycle routes that are used by a great many cyclists. These routes, which can be referred to as main cycle routes, should offer cyclists the highest level of quality.

Table 9. Additional main requirements for main and other cycle routes

Main requirement	Important aspects	Explanation
Cohesion	Match with need to travel	The main cycle routes link up with the most important departures and destinations and are used a lot as a result: a minimum of 1,000 (village) or 2,000 (town) cyclists a day.
	Recognisability	The route is recognisable as such. That means that guidance may be required when cyclists have to choose (on the pavement or with signposts).
Directness	Directness in terms of distance	This concerns the detour factor per link. For main and other cycle routes, this is no more than 1.2.
	Directness in terms of time	Directness in terms of time concerns the average speed and the rate of flow. Indicators for this aspect are the speed on a route and the delay. For main and other cycle routes, the design speed is 30 km/h. The number of intersections without right of way and the stopping frequency are minimised. At intersections with traffic lights, the lights are set to give priority to the cycle route. The width of main and cycle routes is sufficient to allow an unimpeded flow of traffic in normal conditions.
Safety	Avoid conflicts with crossing traffic	The risk of conflicts with crossing traffic is reduced if the product of the intensity of crossing cyclists and motorised vehicles is minimised on all intersections and connections.
	Separate vehicle types	Main cycle routes are preferably not combined with motorised traffic. If this cannot be helped, the intensity of the motorised traffic is restricted to a maximum of 2,000 motorised vehicles (pcu) a day and the speed is reduced to 30 km/h.

Table 9. Additional main requirements for main and other cycle routes (continued)

Main requirement	Important aspects	Explanation
	Recognisable road categories	Main cycle routes are recognisable as such from their design.
	Avoid one-sided conflicts	Collisions with bollards are a common form of (onesided) accident among cyclists. Bollards should not be placed on main and other cycle routes. Collisions with and as a result of parked vehicles (swerving) are another common form of accident. Parking on main cycle routes is prevented as far as possible and in the case of mixed traffic, is only permitted off the carriageway.
	Lighting	The course a route follows is clearly visible, even when it is dark. Main and other cycle routes are sufficiently lit. The level of lighting should be appropriate to the surroundings.
Comfort	Flow	Main cycle tracks benefit from an unimpeded flow. In this context, right of way, stopping frequency and nuisance caused by other traffic (requiring speed reduction) are important factors. Curves are designed for 30 km/h.
	Smoothness	Main cycle routes have pavements that best suit cyclists (asphalt). Cycle routes are covered with a non-porous pavement of asphalt or concrete.
Attractiveness	Social safety	(Main) and other cycle routes meet the requirements of social safety: they are lit, they are visible to the vicinity, the surroundings are visible and the public space is well maintained (see section 7.5 for more information).

Requirements for main and other cycle routes
Due to the intensive use, additional requirements may be set for main and other cycle routes. These requirements apply in addition to the requirements for a cycle network listed in table 8. The additional requirements are listed in table 9.

4.4.2 Criteria for designating main and other cycle routes

A connection can be designated a main or other cycle route on the basis of two criteria (in both cases, this is a translation of the term 'function'), namely:

- the location of the network;
- the actual or forecasted cycling intensities.

A combination of the two factors is the ideal option. Deciding theoretically that a route merits the title of main cycle route (on the basis of its location in the network) is risky, because it is uncertain whether the cyclists themselves see this on the street; it is possible that more cyclists use other, parallel routes than the 'designated route', in which case the extra investments in the higher quality level of the main cycle route are of little use.

After a practical study [24] commissioned by the Dutch Bicycle Council, a categorisation as a main cycle route based on more theoretical and more empirical data has been clustered into three criteria which a main cycle route is required to meet. These are:

- *Distance*
  In order to provide a connection through or between districts or villages, the route has to be long enough. The length of the main cycling route should be at least 1 km.
- *Combination*
  The directness, passage of barriers and/or attractiveness of the route should make a large proportion of the cyclists use it on the link that it serves.
- *Use*
  In absolute terms, the route should be used by large numbers of cyclists.

Application of these criteria leads to a situation in which inside the built-up area, predominantly radial routes between the centre and a district on the outskirts or an important function outside the centre act as genuine main cycle routes. In large cities as well, the centre, with its surrounding amenities, still forms the most important destination and is also the transfer area for the different routes.

Added value due to combination
In existing urban areas, there are often various cycle connections available between city boroughs and districts, without one of them being designated a main route. It is only when a barrier has to be crossed that a clear combination occurs (out of sheer necessity), thus creating added value for a main cycle route at city level. When the combination occurs at the site of a barrier, as well, there are often various routes available on either side that can all serve as a cross-district urban main route. It should be noted that providing a safe, attractive, comfortable cycle connection on one of the alternatives does not always guarantee a full combination of bicycle traffic on this particular route. Conversely, a route that could be a main cycle route due to its location and directness will not function as such if the amenities are uncomfortable and the waiting time too long.

Criteria for intensity

A study of main cycle routes commissioned by the Dutch Bicycle Council showed that in the major cities that were examined, over 2,000 cyclists used main cycle routes a day, to a maximum of 10,000. To take it a step further, the following intensity values for the various categories on the cycle network could be applied for these cities (actual or expected use):

- main cycle routes: > 2,000 cyclists/day
- cycle routes: 500 – 2,500 cyclists/day
- other connections (basic network): < 750 cyclists/day

In villages and small centres, it will be more difficult to achieve these values for main cycle routes. There may, however, be cycle routes that stand out because of their function and/or use, which is why it is a good idea to apply an intensity criterion of 1,000 cyclists a day.

Main cycle routes outside the built-up area
Main cycle routes can also be found outside the built-up area.. The functional requirements set for these routes are the same as the requirements for main cycle routes inside the built-up area. This was evidenced by the ambitions formulated in a number of initiatives designed to take specific measures to encourage cycling over longer distances:

- availability of a long stretch of separate cycle track (full cycle track), meaning no bicycle lanes or roads with restricted motorised traffic;
- right of way for cyclists on the route and minimum waiting times at traffic lights;
- no ambiguity in terms of perception and recognisability of the route.

The use of routes outside the built-up area will never be as high as on busy routes inside the built-up area, simply because the number of points of departure and destinations are considerably lower in outlying areas than in the urban area. However, it is still important for main and other cycle routes outside the built-up area to be used significantly more intensively than other routes in the area. What intensity values are relevant depends on the local/regional situation; there are no national limit values.

Initiatives for cycle motorways

Apart from the ambitions for interlocal connections referred to above, there have been a number of initiatives that went a step further. These concerned the target group of fast cyclists (racing cyclists, recumbent cyclists, et cetera, who ride at speeds of over 25 km/h). The proposed connections would have wide lanes and were to be virtually free of intersections for long distances. Two of these innovative initiatives were the two-lane bicycle motorway called 'From Dom to Dam' (over 30 km between Utrecht and Amsterdam) and the VLITS project (Innovative Light Individual Transport System) between Helmond and Eindhoven, including a heated surface, windbreaks and shelters, and even ideas to develop a special, possibly multiperson, bicycle-like vehicle. As yet, not much has come of these kinds of initiatives.

4.5 Recreational cycle network

4.5.1 Cycling as a form of recreation

Recreational cycling is a collective term for various forms of cycling. In recreational cycling, a distinction can be made between touring (longer trips from home), racing and ATB cycling (cycling on paths and through the countryside on an All Terrain Bike, mountain bike or similar). Where this design manual talks about recreational cyclists, it refers primarily to touring cyclists.

4.5.2 Route types

There are all kinds of recreational routes. The main types of signposted and unmarked routes and their properties are shown in table 10. There are also a lot of theme cycle routes, with or without signposts.

Characteristics of the recreational cyclist

Studies have revealed the following characteristics for the recreational cyclist. He or she cycles for an average of 45 minutes, usually covers a distance of 15 km and does not like to travel for more than 5 km to get out of the town or city. Another preference is a different route back than the outward journey [74].

National cycle routes

There are a number of national long-distance routes that are the responsibility of the Dutch National Cycling Platform, which implements government policy and co-ordinates projects. The local road authority plays no role in the development of this network, which is why this design manual pays no further attention to the national long-distance routes. It should be said, however, that the ownership and hence the management and maintenance of the infrastructure these routes use are often the responsibility of the local and regional road authorities. Agreement with the inclusion of a road section or route in a national network gives the road authority a kind of moral obligation to perform at least a certain amount of maintenance.

Local routes (round trips)

The development of networks of local routes is primarily the responsibility of the local and regional government. Outside the built-up area, most cyclists go to the woods and heathlands, in spite of the fact that these are relatively scarce in the Netherlands. There are also a lot of people who like to cycle through the countryside.

Figure 16. Network of national cycle routes

Studies [74] have shown that to get out of the built-up area, cyclists usually take the shortest route from home (through the town or city). This demonstrates the need for building and maintaining direct cycle connections between residential districts and the outlying area (short cuts, farm roads, bridges, et cetera). In that respect, the policy currently being pursued by ProRail, the Dutch railway maintenance division, to close as many minor level crossings as possible to all traffic, poses a serious threat to recreational cyclists (as well as to utilitarian cyclists, who also make regular use of these crossings). There should, therefore, be more frequent, detailed studies to see whether these kinds of crossings could be kept open.

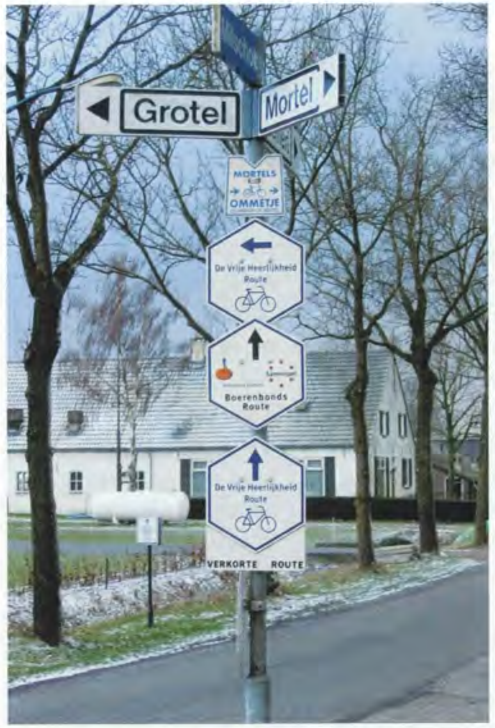
Most recreational cyclists vary the trip out and back. Over three quarters of them work out the route to the country in their heads. The most important factors that determine the route through the town or city to the country are:

- the maintenance level of the connections;
- the chance of delays on the route, in which traffic lights play a particular role;
- road safety: separate cycle tracks and quiet roads are preferable.

For inhabitants of urban agglomerations, it is not always possible or desirable to get to the

Table 10. Overview of types of recreational cycle routes

	National cycle routes (NC routes)	Round trips	Regional networks and junction networks
Properties	A national network of through routes; allows long round trips. Main route structure for recreational cycling, high quality standard. 6,500 km, throughout the country, 4,500 km of which signposted in two directions	Circular, mainly local/ regional routes. All shapes and sizes, including long theme routes (Zuiderzeeroute). Many hundreds of routes, throughout the country, 400 of which (almost 15,000 km) are signposted in one direction. Also eight long, signposted round trips (almost 3,000 km)	Fine-meshed regional network, allows an endless number of round trips in the region. Relatively new and growing fast. Over 3,700 km signposted in two directions. Situated in Limburg, part of Noord-Brabant and Friesland, Hoekse Waard, Zeeland and Almere.
Use	Flexible use, trips can be planned by individual cyclists. Suitable for day trips and longer.	Less flexible use, necessary to finish the route to get back. Suitable for day trips (only long cycling round trips, also for longer than a day).	Flexible use, local or regional trips can be planned by individual cyclists. Suitable for touring trips.
Responsible organisations	National Cycling Platform (implements government policy, co-ordinates projects).	Municipal, regional or provincial council. Private initiatives as well.	Municipal, regional or provincial council. Private initiatives as well. National Cycling Platform advises.



countryside directly from their residential neighbourhood. If the country is not within 5 km, 'links' are needed to bridge the distance, as recreational cyclists are apparently reluctant to 'bridge' a distance of over 5 km [75].

In terms of perception value, the links between urban and rural areas must form attractive routes so that cycling in the city can be regarded as recreational. 'Stad en Ommeland' (City and surrounding countryside) [75] contains guidelines on how to achieve this on the basis of four themes (see table 11). The themes 'Blue lines' and 'Green lines: old land in and around the city' focus particularly on situations in which use is made of existing countryside elements. The themes 'Infrastructure as a connection and a barrier' and 'Plan and practice' centre on human intervention in the countryside.

In the country, the recreational network or touring network consists of a combination of cycle tracks, farm roads, parallel roads and paved or semi-paved forest tracks. There is no blueprint available for the structure of the network. Signposted routes are laid out in consultation with local tourist boards, community centres, village associations, nature associations, the recreation trade, historical guilds, estate managers, the Dutch automobile association ANWB, the Dutch Forestry Commission and other parties that play a role in the area. These kinds of organisations are familiar with the local features and know the nicest, most attractive spots and routes. In consultation between the road authorities and these organisations, an attractive, safe network of recreational routes can be developed. Given the quality requirements set by recreational cyclists, signposted routes should always be on quiet roads where motorised traffic assumes a subordinate position.

Regional networks
Regional networks are signposted in two directions and offer a wide range of route choices. When regional routes meet, they create junction networks, which can form an ideal addition to the network of national cycle routes (NC routes). Theoretically, the regional

Table 11. City and surrounding countryside connected

Blue lines	Green lines: old land in and around the city
Blue lines stretching between city and countryside, such as rivers, streams, canals and other watercourses form an important guideline for recreational connections in this country of water. Many routes run alongside these watercourses, which are popular among ramblers and cyclists because of the babble of the water, panoramic views and the rich birdlife. The attractiveness of these exit and approach tracks is boosted by the return to nature and wilderness of the washlands and banks: by making them more sloped, wetter and greener with pools and boggy banks, strips of marshland, ponds, reed banks and clumps of alder. Opening these zones up completely or in part would significantly expand the possibilities for new routes.	Existing green lines in the countryside on the edge of the city can be used as stepping stones in cycle routes: old farmland, estates and woods. Sometimes, these old green areas were spared for this purpose by urban planners, sometimes they have to be fought for against the urban sprawl. In any case, they are an ideal opportunity to lay out attractive routes.
Infrastructure as a connection and a barrier	**Plan and practice**
Old railway lines, fortification lines and canal dikes are often inconvenient barriers for ramblers and cyclists. However, they can be reused for recreational purposes and form an effective guide for trips to the country. Where the city has too few options for safe, attractive connections to the rural area, public transport can be the answer, with stations on the edge of the city as a 'base of operations' – an alternative to bicycle carrier tourism (on the back of the car).	Urban design and spatial planning are not only for the major infrastructure, but also for the small-scale networks for ramblers and cyclists. The green zones are nothing new. They were designed by planners in the beginning and middle of the 20th century. More recent are the ideas about combinations of red and green, in which the lines of urban construction are continued into the greenery outside the city. There is also the concept of the recreational area as a green buffer against the advancing concrete, interesting to ramblers and cyclists as stepping stones in the route network.

and national networks are complementary. It is easy for NC cyclists to leave the main route. Where junction networks are in place, they are supposed to replace existing, signposted local routes. Directions on these routes are then given by junction signposting.

4.5.3 Additional network requirements

The infrastructure for recreational cyclists is not subject to any real requirements other than those set for the other cycle infrastructure. However, the importance of the main requirements is assessed in another manner. A variety of studies investigated what quality aspects are important to cyclists, and recreational cyclists in particular. In 1997, Goossen et al. conducted a study of the quality indicators for a number of forms of recreation in the country, including cycling. This resulted in a ranking of indicators (table 12) [71].

Table 12. Relative importance of the quality indicators for cycling in the country

Quality indicator	Ranking (%)	Relationship to main requirement
extent of quiet	15.33	attractiveness
land use	10.11	attractiveness
accessibility	8.89	cohesion
traffic intensity	7.95	attractiveness, safety
maintenance of cycle track or road	7.20	comfort, safety
cycling options	6.30	cohesion
cycle traffic intensity	5.53	comfort
picturesque road	4.31	attractiveness
resting places	4.29	comfort
banks	3.98	attractiveness
width of cycle track or road	3.61	comfort
signposting for tourists	3.43	comfort
pavement of cycle track or road	3.31	comfort
places of interest	3.00	attractiveness
intersections	2.81	cohesion, safety
lay of the land	2.70	attractiveness
reachability	2.59	cohesion
safety	2.43	safety
marked cycle routes	2.18	comfort

Studies have shown that during recreational cycling trips, cyclists value quiet above all, with the quality of the surroundings playing an important role at the same time. Translated into the context of the main requirements, attractiveness and comfort are of primary importance, as well as road safety of course. This distinguishes the routes for recreational use from the routes designed for utilitarian use, on which cohesion and directness are the main network requirements.

Quiet as an element of attractiveness applies as cyclists get further into the countryside, away from the built-up area. Near towns and villages, recreational routes can be combined effectively with utilitarian routes, even if they are only designed to enable recreational cyclists to reach the country quickly and safely. Incidentally, cycling to a swimming pool or recreational complex located outside the built-up area should not be misconstrued as recreational cycling. Connections to important recreational amenities must definitely meet the requirements of directness!

Attractiveness

Recreational cyclists set great store by peace and quiet, which is why recreational networks make as much use as possible of roads that are closed to motorised traffic or that carry only a limited amount of motorised traffic (no more than about 1,000 pcu/day).

Recreational cyclists also enjoy cycling on idyllic country roads, which is why as little use as possible is made of roads with markings and signposting, et cetera; outside the built-up area, 60 km/h roads laid out in harmony with the landscape are most suited to recreational cyclists, as are roads and tracks that are closed to motorised traffic.

Comfort
The smoothness of the pavement is an important requirement, as it is for utilitarian cycle connections. Because recreational routes are not used as much as utilitarian routes, the level of maintenance is sometimes lower. This is unacceptable if it impacts the smoothness of the pavement.

Unlike utilitarian cyclists, recreational cyclists need to stop regularly, one reason being that they cycle greater distances, so the recreational cycle network has a series of resting places built in. A logical spot to situate these resting places in the network is at the option points or branches. But there is also a need for resting places elsewhere. The rule of thumb is a distance of 5 km between them. It is advisable to locate these resting places where the surroundings are attractive and quiet. When designing a network, it is also a good idea to have a route run past a catering facility from time to time.

People often wrongly think that recreational cycle tracks can be narrower than utilitarian tracks. Pairs of recreational cyclists often cycle next to each other and whole families often go cycling together. A bicycle-friendly cycling policy should envisage an infrastructure that enables recreational cyclists to cycle next to each other. This requirement should only be disregarded on routes where the surroundings call for it. If the route runs through an area of significant natural value, it may be an idea to keep the width of the pavement to a minimum, but no less than 1.00 m.

Many recreational touring cyclists make their trips 'off the cuff'. However, the action radius is greatly increased if there are plenty of signposts. Places of special interest (estates, wooded areas, recreational areas, et cetera) can be signposted, offering cyclists the most direct route at the same time. It is also possible that signposts allow people to 'discover' routes they would never have cycled without the signposting.

Safety
With regard to safety, recreational cycle tracks are subject to the same requirements as other cycle tracks (road sections and intersections). A point meriting particular attention is the control of speed at locations where recreational cyclists come into contact with motorised traffic.

4.6 Integration of networks

Once a utilitarian or recreational network has been developed, it will have to be assessed with regard to its cohesion with other networks, both for the bicycle and for other means of transport. Special attention should also be paid to the barrier effect in the ordinary network or the cross-linked network.

Figure 17. Cohesive structure of recreational networks

4.6.1 Cross-linking cycle networks

When networks are cross-linked, the first thing to do is to look at the integration of the utilitarian network with the recreational network. To a certain extent, utilitarian and recreational cyclists have the same needs and it would hardly be efficient not to allow both groups to benefit from each other's routes. At the same time, it is particularly important to check whether new connections can strengthen the cohesion between both networks. This creates more freedom of choice for the cyclist. An example of cross-linking networks is the scenario 'Stad en land verbonden' (Town and countryside connected) compiled by the province of Zuid-Holland (see figure 17) [71]. In this project, a scenario was used to cross-link networks in four stages:

- The basic premise is the current location of routes and networks, looking at whether they can be perfected by means of local alterations and additions.
- The networks for the national and regional routes are regarded as individual networks

that should be able to function on their own. However, efforts are made to link up junctions or support points or by developing network links.
- For each network of regional routes, every effort is made to ensure good connections with the urban area in the form of town links.
- The networks for the various activities (rambling, cycling, and canoeing) are interconnected via the 'junctions'.

4.6.2 Confrontation with other means of transport

Once utilitarian and recreational routes have been laid out and cross-linked, they are confronted with the networks for other means of transport, and particularly with the network of district access roads and distributor roads for motorised traffic and the network of public transport, whether connective or otherwise. Criteria that play a role in the assessment of these kinds of conflict points are:
- the function or planned function on the cycle connection;
- the extent to which the proposed amenity solves a bottleneck and thus forms a quality improvement for the cycle network;
- an overview of the criteria that are not met if the desired amenity is not built at all or if the quality is insufficient.

In practice, it appears that relatively little attention is paid to the confrontation between the cycle network and networks for other means of transport. However, as this confrontation determines the quality of the cycle network to a certain extent, it should not be forgotten. Statistics show that in municipalities where cyclists often have to cross busy main roads, the risk of them being involved in an accident is on average higher than in municipalities where this is not the case. Figure 18 shows that in towns and cities with relatively few busy intersections, relatively few cyclists

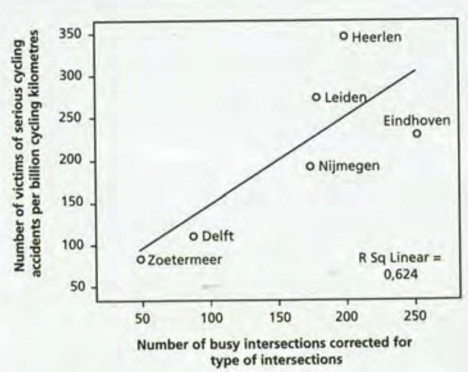


Figure 18. Ratio between cycling victims to the number of busy intersections (inside the built-up area)

are involved in accidents compared to towns and cities with a lot of busy intersections [16]. Co-ordinating the car and cycle networks effectively is, therefore, an important tool for improving cyclist safety.

At network level, the situation for the bicycle can be optimised if large-scale residential areas are constructed with a limited number of main roads, preferably situated on the periphery, with cycle routes running through the residential areas wherever possible.

4.6.3 Removing barriers

When checking a network for cohesion and integration, it is advisable to assess the barrier effect. Although this phenomenon has already been discussed in the examination of densification options (in section 4.3.1), the problem of barriers is important enough to merit further explicit attention. There is good reason for the essential policy elements in the National Traffic and Transport Strategy to state that in the construction and management of primary infrastructure, the government is co-responsible for maintaining and improving crossing routes for bicycle traffic.

The number of physical barriers for both utilitarian and recreational cyclists has grown rapidly in recent years. The reasons for this growth include:
- the construction of ring-roads around cities;
- completion of major infrastructural work;
- upgrading of secondary roads (reduction of the number of intersections);
- closing down of ferry services;
- closing of level crossings.

Apart from physical barriers, there are also visual and psychological barriers. Examples include business parks and motorways. In the latter case, the physical barrier is formed by the embankment under the road; the psychological barrier, however, is far greater and is formed by the zone in which the road is experienced. For motorways, this could be due to the noise that can be heard for many hundreds of metres on either side of the road. Finally, city centres and pedestrian precincts can also form a barrier for cyclists. For more information on this special form of barrier, see section 5.7.

When designing the network, it is important to take these barriers into account. In the assessment of networks, major barriers (such as main roads, railway lines, artificial waterways, rivers, et cetera) are often regarded as a constant factor which can or cannot be changed, probably because their removal would require a major effort and possibly cost a great deal of money. It would, however, be wise to look into this more specifically. Incidentally, it is not only important to remove barriers from utili-

tarian networks. If the importance of a connection so requires, recreational routes can also form reason enough to remove these barriers, by building tunnels, for example. These kinds of solutions are not reserved solely for utilitarian amenities!

Measures

The removal of barriers will not always be possible, but it can alleviate the problem. The options available include:

- The construction of large-scale residential areas. This will limit the number of main roads and hence the number of barriers that have to be crossed.
- The construction of good crossing amenities (central traffic island, roundabout), tunnels and fly-overs. Line barriers (road, canal, railway line, et cetera) can be avoided by constructing a bridge or tunnel. The considerations that play a role in this aspect are discussed in chapter 6.
- The coupling of facilities for cyclists and pedestrians to engineering structures for the train, car or inland shipping. Examples are the 'attachment' of cycling bridges to railway bridges, widening lock gates to accommodate a cycle track and building new cycle connections under road bridges.
- Opening existing or planned parallel roads and tracks along waterways and railway lines to slow traffic. Although parallel amenities do not cross the barrier in question, this measure may reduce the detour distance.
- Co-use of ecological connection passages such as eco-bridges and fauna tunnels. The defragmentation of areas of natural significance also holds opportunities for bicycle traffic. It may be possible to use eco-bridges and fauna passages for cyclists.
- Level crossings which are due to be closed should only be closed to motorised traffic and converted for exclusive use by cyclists, pedestrians and horse riders. The same applies to bridges.
- The construction of small-scale short cuts and connections for cyclists and pedestrians.
- The introduction of simple, self-operated chain ferries.

5 Road sections

5 Road sections

Bicycle connections consist of a series of road sections and intersections. Since the issues associated with roads differ from those related to intersections, the two are discussed in two separate chapters. This chapters looks at the design of road sections. The connection of road sections to intersections is dealt with in chapter 6 'Intersections'.

This chapter begins with the decisions that need to be taken in the design of road sections. They involve striking a balance between function, form and use (section 5.1). Subsequently, attention is paid to the general requirements that may or must be set for road sections (section 5.2). Sections 5.3 to 5.7 cover the solitary cycle track and the combinations of bicycle/car, bicycle/public transport, bicycle/moped and bicycle/pedestrian. Finally, section 5.8 briefly discusses the combination of bicycles with a number of 'special groups' of road users, such as skaters and horse riders.

V 8, 12 Starting with chapter 5, each chapter concludes with a number of facility sheets. The text contains references to the relevant facility sheet marked by this symbol.

5.1 Function, form and use

When designers think about facilities for cyclists on road sections, the first thing they think about is functions. For each road section, policy should dictate what function it is to serve for both bicycle and other traffic. The combination of functions results in the right basic form, within which the actual appropriate layout is determined. Three factors play a role in this process:

- the intensity of the bicycle traffic;
- the speed of the motorised traffic;
- the intensity of the motorised traffic.

The linking up of road sections and intersections may lead to conditions on a connection that change substantially (such as intensities, available space, et cetera). This is not a problem in itself, as long as each individual road section meets the requirements set for it. For main and other cycle routes, it is also essential that the continuity and recognisability of the route is guaranteed (see chapter 4 'Networks and routes').

5.2 Requirements for a road section

An elementary function of a road section is to provide a connection. Other functions include access to adjacent plots of land or allowing residential activities. If the quality of the connection function is related to the main requirements for bicycle-friendly infrastructure, directness, safety and comfort are the major factors of importance at road section level, where residential quality is also important. This is why the main requirement 'attractiveness' plays a role.

5.2.1 Directness

A distinction is made between directness in terms of distance and time.

Directness in distance
A road section running from A to B should form as direct a connection as possible for cyclists (ideally a straight line). A bicycle connection is not diverted around every obstacle (such as a petrol station). Although it is hardly productive to talk about detour distances at road section level, bends in the road become more detrimental as the connecting function of the road section gains in importance. A point for special attention in this regard are roads that are extremely difficult for cyclists to cross (a distributor road or a district access road with two carriageways, for example). Restricted crossing possibilities can impact the directness of a connection. Allowing two-way traffic on cycle tracks along this kind of road may be a solution to this problem ('2x2 for cars is 2x2 for cyclists').

Directness in time
Apart from directness in distance, directness in time is also important. At road section level, a design takes account of the function of the road section for bicycle traffic and the associated design speed. One of the results is that the road section facility meets the requirements in terms of width, the view of the road and traffic flow speed. The flow speed in turn sets requirements of its own, particularly for the curve radii that are applied. The width of facilities is important because if the road section is

too narrow, cyclists are forced to ride more slowly than they want to. The Bicycle Balance shows that the 5 and 95 percentile values for 'involuntary slow cycling' on routes inside the built-up area apply 8 and 20% of the time, respectively. There is, therefore, sufficient reason to pay particular attention to this aspect. An effective way of minimising delay is by creating possibilities to continue cycling at intersections, but that is dealt with in more detail in chapter 6.

5.2.2 Safety

The following requirements are set to ensure safety on road sections.

Avoid conflicts with oncoming traffic
The result of conflicts with oncoming traffic (head-on collisions) is usually serious. When designing road sections that permit two-way traffic, it is, therefore, imperative to look closely at the width, view of the road, guidance and possible carriageway separation. If the view of the road is restricted at certain points on a road section, the designer will have to make this clear to road users in the design. Where necessary, use can be made of additional signposting and markings, as well as a recommended speed limit.

Avoid conflicts with crossing traffic
Normally, there is no crossing traffic on road sections, since vehicles cross roads at intersections. However, conflicts may arise at entrances and crossings. To ensure road safety, requirements are set for the view of the road, comprehensibility and speed.

Separate vehicles types
In situations where speeds differ considerably, cyclists and motor vehicles preferably do not use the same traffic space, so they should be separated. If it is not possible or advisable to separate traffic in the cross section profile, speed differences will have to be minimised. Conversely, the separation of different vehicle types may lead to an increase in speed on road sections, which may in turn have an undesirable effect near intersections.

Separation of traffic types can also be considered in the case of major differences in mass. If the differences in speed between the various types of traffic are not too great, traffic separation for safety reasons is not essential. However, separation of cyclists from other traffic types (buses or farm vehicles, for example) may result in more comfort or better subjective safety, which makes it an integral part of a bicycle-friendly policy.

Reduce speed at conflict points
At locations where serious conflicts can occur, the speed of motorised traffic is adjusted to the speed of cyclists in order to keep speed differences to a minimum. This reduces the risk of accidents and, if accidents do happen, the risk of serious injury.

Avoid cyclists being forced off the road
Cyclists should not be forced off the road. This sets requirements for the road surface, view of the road, curve radii and visibility. The road surface must be smooth enough to avoid the necessity of evasive manoeuvres and sudden, unexpected changes of direction caused by potholes, et cetera If an evasive manoeuvre is required, however, the width of the pavement or the verge must allow cyclists enough room to perform it. The horizontal and vertical course must run in such a way as to meet the requirements for a cyclist's view of the road appropriate to the function and hence the design speed of the road section. The curve radii applied are also in line with the design speed.

To make sure cyclists are not forced to leave the cycle track or road, requirements are set for the visibility of the road surface, and the edges and pavement in particular, especially at dusk and in the dark.

Ensure recognisable road categories
Recognisability and predictability are important requirements in a traffic system based on sustainable safety. These requirements gain in importance – and the same applies to the uniformity requirement – the higher the function of a road or the speed of the traffic becomes. After all, higher speeds allow people less time to react and create a bigger risk of making errors. Recognisability at road section level is primarily down to the design of the bicycle facility. Each specific facility should be recognisable as such for all road users.

Ensure unambiguous traffic situations
Unequivocalness in traffic situations ensures that road users are aware of how they are expected to respond in certain circumstances, which improves road safety. Unequivocalness is more relevant in the application of rules, signposts, markings and design principles than in an actual design. After all, local circumstances are generally unique, which means that designs can almost never be identical either, although the underlying principles and facilities in place can. Accordingly, it is important for similar situations to be designed in the same way.

5.2.3 Comfort

In terms of comfort, the following requirements are set for road sections:

Prevent lost time
Depending on the function a road section fulfils in the cycle network, requirements are set for the design speed. A good design ensures that in normal conditions, cyclists are not forced to cycle at speeds below the design speed. That sets requirements for curve radii and the width of facilities. A bicycle facility or carriageway should be wide enough to prevent or at least minimise delays.

Avoid bends
On road sections that form part of a cycle route or main cycle route, extreme bendiness should be avoided as much as possible. Cyclists should be able to ride on these kinds of routes without being impeded by bends, having to swerve and make rightangled movements. At the same time, exclusively straight connections are not ideal either. Gentle bends can have a positive effect on the perception of a route.

Ensure a smooth road surface
The paving of the road surface should meet the requirements set for smoothness. Apart from the paving itself, this also applies to transitions from one type of paving to another.

Minimise incline nuisance
The maximum gradient on inclines should not be exceeded. The number of inclines per unit of length should also be limited; several inclines located too close to one another detract from the cycling comfort (even if they each meet the gradient requirements).

Minimise traffic nuisance
When designing a road, every effort is made to keep the nuisance caused to cyclists by motorised traffic to a minimum. This basic premise applies particularly to road sections with bicycles and limited car traffic. Where there is more motorised traffic, a separate track for bicycle traffic is preferred to protect cyclists from nuisance caused by aspects such as noise and the emission of exhaust fumes.

Minimise weather nuisance
To some extent, cyclists can be protected from the effects of wind and rain if road sections are sheltered by vegetation, buildings or specific protective structures.

5.2.4 Attractiveness

The main requirement attractiveness concerns how cyclists perceive their surroundings, so the assessment of the attractiveness of a bicycle road section is by definition highly personal. Furthermore, the quality of the surroundings determines the perception of a specific connection, far more so than the road section itself; an ideal route (restricted motorised traffic, wide enough, asphalt, right of way) can be seen as highly unattractive if cyclists have to ride through a disreputable area. Designers have hardly any influence at road section level. They can, however, affect the extent to which cyclists can enjoy cycling without being bothered by the other traffic. A connection is more attractive if cyclists are not bothered by motorised traffic, which is why it is preferable not to mix bicycles in busy flows

of motorised traffic. However, even if speed differences are minimal, the main requirement attractiveness may require bicycles and motorised traffic to be separated.

V 1, 2, 3, 4 5.3 Solitary cycle track, cycle track and cycle and moped track

Solitary or isolated tracks follow their own route and are solely intended for cyclists (cycle track) or for cyclists and moped riders (cycle and moped track). These are connections through a park, a short cut between districts or a connection through the countryside.

Table 13. A summary of the main requirements for road sections

Main requirement	Important aspects	Explanation
Directness	Directness in distance	Avoid unnecessary bending and winding of road sections.
	Directness in time	This concerns the average speed and the opportunity to keep riding. Indicators in this case are the average speed on a road section and the delay (being forced to slow down). The latter aspect should not exceed about 15%. For road sections on cycle routes and main cycle routes, the design speed is 30 km/h, for road sections in the basic network, this is 20 km/h.
Safety	Risk of accidents	The risk of accidents is reduced if the number of confrontations with motorised traffic is minimised on each road section (in the longitudinal and lateral direction). In the case of major speed differences, traffic types are separated, without which the speed differences are kept to a minimum. In the case of major differences in direction, the speed differences are minimised. The requirements for sight and visibility are met. Design principles are applied unambiguously and are appropriate to the function of the road section. Road sections are sufficiently visible, both during the day and in the dark. Road sections meet the technical requirements with regard to rideability (roughness, construction, foundations, et cetera).
Comfort	Preventing delays	In normal conditions, cyclists can ride on road sections at the intended design speed.
	Passage	Road sections are wide enough. Curve radii take account of the design speed appropriate to this function. Extreme bendiness is avoided.

Table 13. A summary of the main requirements for road sections (continued)

Main requirement	Important aspects	Explanation
	Smoothness	Road sections meet the requirements of smoothness.
	Incline nuisance	Maximum gradients are not exceeded.
	Traffic nuisance	Cyclists are not bothered by the other traffic. In busy situations with a lot of fumes and noise, designers look for a separate route for cyclists.
	Weather nuisance	Nuisance due to wind and rain is minimised.
Attractiveness	Social safety	Road sections meet the requirements of social safety: they are lit, they are visible to the vicinity, the surroundings are visible and the public space is well maintained (see section 7.5 for more information).
	Traffic nuisance	The attractiveness of a route may require separation of cyclists and busy motorised traffic, even if the speed difference is limited.

Solitary tracks are sometimes confused with separate tracks. An important difference is that the latter are related to an adjacent carriageway, whereas solitary cycle tracks are not. Case law shows that in legal terms, a cycle track is not part of a carriageway if it is situated more than 10 metres away.

In theory, solitary bicycle facilities are intended for traffic moving in two directions. This sets requirements for the width: at least 1.50 m at extremely low traffic intensities if only cyclists use it; at least 2.00 m if mopeds can use the track as well. The centre of the track should be marked to make it clear that oncoming traffic can be expected.

Co-use by pedestrians
If there is no pavement, pedestrians may also use the cycle track. This is often the case on solitary cycle tracks through a park or outside the built-up area. When there is a lot of traffic, this shared use may lead to irritation. For reasons of comfort, it is advisable to separate cyclists and pedestrians in these situations.

Lighting required
A point for special attention on solitary tracks is social safety. Because these kinds of tracks follow their own route that is often located outside the sphere of influence of buildings, social safety is relatively quickly undermined. This can be improved by lighting. It is advisable to light cycle tracks, particularly solitary tracks inside the built-up area that form part of a main or other cycle route network.

V 5 *Illicit use by other traffic*
Solitary tracks may be attractive to traffic other than cyclists (and possibly pedestrians and mopeds). Illicit use must be prevented, however. There are different ways of doing so, and the bollard, be it in hinged or retractable form, appears to be the most popular. For cyclists, however, bollards are a source of danger and they also restrict the freedom of movement, so they are only recommended when other measures are not possible.

5.4 Bicycles and motorised traffic

5.4.1 Inside the built-up area

If both cyclists and motorised traffic make use of a road section, it is, of course, vital to determine the most appropriate layout. The function of the road section for both cyclists and motorised traffic is of primary importance. If the road for motorised traffic is a district access road, it sets different requirements for the road design than if the road is an estate access road. The same applies to the function of the road for bicycle traffic. A road section

that forms part of a main cycle route is subject to different requirements than a road section that is part of the basic network.

General principle
The general principle is that road sections fulfilling a distributor function for motorised traffic (district access roads) require specific bicycle facilities and that road sections exclusively designed to fulfil an estate access function do not normally require such facilities due to the low speed of motorised traffic; bicycles can then be combined with the motorised traffic. However, this general principle can be interpreted in a number of different ways. A road section that forms part of a main cycle route should offer more cycling quality and comfort than a road section only used incidentally by a few cyclists. In addition, a wide profile usually offers different design options than a narrow one. In other words, there are sometimes various alternative solutions for a specific situation, which is why designers always have to determine the best solution for bicycle traffic in a given situation, taking account of the actual conditions.

For each road section, designers have to ask themselves what traffic facilities are required to guarantee cyclists a safe and pleasant situation. Table 14 shows an option diagram for bicycle facilities on road sections inside the built-up area. This diagram is an initial guideline for making choices for each road section and is based on three basic premises:

1. The most preferable situation for cyclists is key.
2. For a bicycle-friendly infrastructure, the entire traffic situation is important, and not only the specific bicycle facility, which is why the diagram covers more than just the bicycle facility.

Table 14. Option diagram for road sections inside the built-up area

Road category	Max. speed of motorised traffic (km/h)		Motorised traffic intensity (pcu/day)	Cycle network category: basic network ($I_{bicycle}$ > work 750/day)	Cycle network category: cycle route ($I_{bicycle}$ 500-2500/day)	Cycle network category: main cycle route ($I_{bicycle}$ > 2000/day)
	n/a		0	solitary track		
Estate acces roead	walking pace or 30 km/h		1 - 2.500	combined traffic		cycle street or cycle lane (with right of way)
			2.000 - 5.000			
			> 4.000	cycle lane or cycle track		
District acces road	50 km/h	2x1 lanes	irrelevant		cycle track or parallel road	
		2x2 lanes				
	70 km/h			cycle track, moped/cycle track or parallel road		

3 There is often more than one possible solution and the boundary between possible solutions is not always fixed. This is expressed in the diagram by limit values that overlap.

In the diagram, both functional road categories and traffic engineering factors (speed, intensity) can be chosen as a point of departure. Although a relationship between these two aspects can be assumed, practice has shown that this is not always the case. Speed is a particularly unreliable factor, as speed limits are often exceeded [25], which is why the road authority should make sure that either the actual speed corresponds with the maximum speed limit, or should allow for the actual speed, regardless of the road's function. In any case, it is important for designers to focus on the actual or expected situation and not only on the functional category.

Basic premise 1: the best situation for cyclists
The option diagram for road sections inside the built-up area indicates the situations that are good for cyclists. In practice, this means as safe and comfortable as possible. The recommendations in the diagram will not always be feasible, despite the fact that the diagram often provides various solutions. As a result, the designer may come up with a plan that is less favourable from a cyclist's point of view. If the situation arises, the designer can try and find a better solution by shifting to a different cell in the diagram. After all, there are theoretically three variables in the diagram that can be influenced: bicycle intensity, car intensity and car speed. If one of these factors changes, the designer could 'end up in a cell' where the facility in question can be achieved in a bicycle-friendly manner.

Basic premise 2: the entire traffic situation is relevant
Cycle policy is not the same as building specific bicycle facilities. Whether traffic situations are safe and pleasant for cyclists not only depends on the presence and quality of facilities made for cyclists; the entire traffic situation is relevant. And designers cannot always resort to general principles. It is too simple to suggest that a low speed of motorised traffic always allows bicycles and cars to be combined. It may be possible in terms of safety, but in terms of cycling comfort, more may be required. This is why some aspects of the general principles of separating and mixing traffic have been subdivided and itemised in the option diagram.

Basic premise 3: more solutions, overlapping boundaries
Traffic engineering is not an exact science in the sense that there is always only a single solution to every problem. There are often a number of good solutions to the situation in question, which is why there are no fixed

boundaries in some parts of the diagram. Because the intensity categories overlap, there are different kinds of solutions for various areas of application. The diagram is only a tool, which the designer can use to tailor a solution to the specific situation.

Road categorisation and influence factors
The option diagram uses two kinds of criteria to distinguish traffic situations. Firstly, there are the influence factors that are known to have a significant impact on the safety or bicycle friendliness of a traffic situation: the speed and intensity of the motorised traffic. Secondly, there are the functional categorisations. The basis of the diagram is formed by the division into estate access road and district access road for cars, and basic network, cycle route and main cycle route for bicycles.

The basic principle of separating types of traffic in the case of major differences in speed and mass (district access roads) and mixing traffic when the differences in speed are minor (estate access roads) is also applied in this diagram. This distinction is somewhat subdivided and itemised in response to the conclusion that in the Netherlands, there are still many road forms that are neither one nor the other (the 'grey roads'). These roads have properties of a district access road as far as their function in the network and their use by motorised traffic are concerned, but they also have properties of an estate access road due to adjacent buildings and amenities. On these kind of roads, it is advisable to introduce some form of separation as facilities for the benefit of cyclists.

A separate facility regime is proposed for main cycle routes. On such routes, where bicycle traffic intensities are high, bicycle traffic merits special treatment. The 'cycle street' has been introduced on a number of main cycle routes in the Netherlands. Main cycle routes, including cycle streets, have right of way on intersections with residential streets to guarantee the flow of traffic and comfort on main cycle routes. Main cycle routes should also have right of way on intersections with district access roads, but this is not always possible.

V 6, 7, 8, 9 **Combined traffic**
An estate access road, usually a traditional residential street, has a speed limit of 30 km/h. In the case of quiet, normal bicycle use, intensities of motorised traffic of up to about 5,000 pcu/day and particularly a speed pattern that is appropriate to the function of the road, no special bicycle facilities are necessary. If intensities of motorised and bicycle traffic are low, a narrow profile is the point of departure. This contributes to the intended low speed, but is not by definition sufficient; a narrow profile may also require additional speed reduction measures.

A narrow profile means that a motorist is forced to remain behind a cyclist if there is oncoming traffic (see also the text box 'Dimensional segments and indicative use' in section 5.4.2). This is possible up to relatively high intensities. Table 15 provides an impression of the number of encounters on a road section for the period in which a driver drives on the road section (during rush hour) and hence an impression of the possibilities of applying a narrow profile. The figures listed in the table are the total number of encounters, so for drivers travelling in both directions for the period in which a car covers a road section at a speed of 30 km/h.

Example to illustrate table 15

- On a road section measuring 1 km in length, a vehicle drives for 2 minutes (speed is 30 km/h).
- Assuming 1,500 pcu/day, for example, 150 vehicles an hour drive along this road section during rush hour (according to a popular rule of thumb), 100 vehicles in one direction and 50 vehicles in the other.
- In the 2 minutes referred to above, an average of 11 encounters will occur on the road section in question.
- Depending on the local conditions (cycling intensity, parking situation), the choice for a suitable profile can be made.

Table 15. Average number of encounters between motor vehicles

	Daily intensity (pcu/day)				
Length of road section (in m)	**I = 500**	**I = 1,500**	**I = 2,500**	**I = 3,500**	**I =5,000**
100	0	0	0	1	1
250	0	1	2	4	8
500	0	3	8	15	31
750	1	6	17	34	69
1.000	1	11	31	61	123

Average number of encounters between motor vehicles on a road section of a given length for the period in which a vehicle drives along the road section during rush hour (= 0.1*daily intensity). The speed of the motor vehicles is 30 km/h and the intensity in direction 1 is twice as high as in direction 2.

The table does not provide a concrete answer to the question of what situations require a narrow or wide profile. This is subject to a great many factors other than the intensity of motorised traffic, such as the intensity of bicycle traffic and the presence of parked vehicles. If the intensity of bicycle traffic is included in the decision process, the graph in Figure 19 shows an indication of the area of application for a wide or narrow profile. Because no clear boundaries can be drawn between the various solutions, the graph also shows a transitional zone, within which designers will have to ask themselves which profile is most suitable. If they opt for a wide profile, they must bear in mind that this will induce motorists to drive at higher speeds. Accordingly, the need for speed reduction measures to ensure the safety and comfort of the cyclist is higher on wide profiles than on narrow profiles.

V 10, 11 *Parking*

In the case of combined traffic, particularly inside the built-up area, the parking situation is an aspect that requires special attention. Parked vehicles not only hinder cyclists, but also form a source of danger due to opening doors and the resulting evasive manoeuvres. An occasional car parked on a carriageway is not a problem, but if more than about 20% of the length of road is used for parking, it is advisable to build a parking lane or parking bays. This restores a straight riding

line for cyclists and the width of the traffic path is limited for motorised traffic. To ensure the safety of cyclists, it is advisable to build a critical reaction strip on the parking lane.

Possible solutions for combining bicycle and motorised traffic

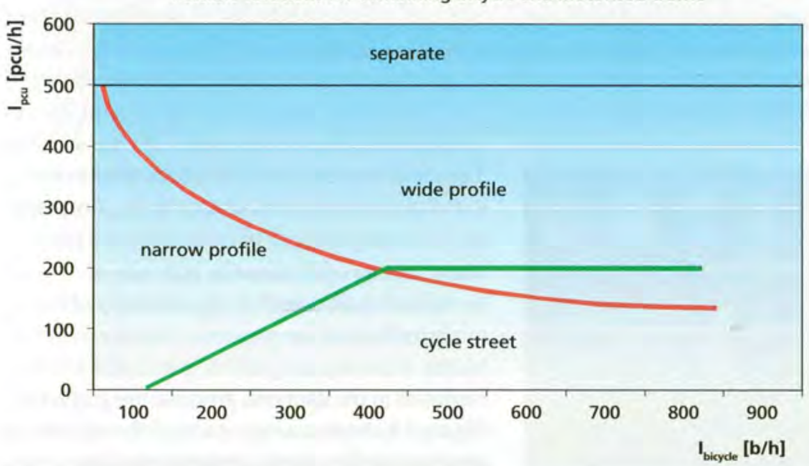
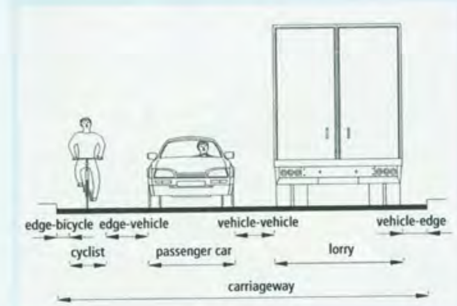


Figure 19. Possible solutions (indicative) for choosing a profile for combined bicycle and motorised traffic

Dimensional segments and indicative use

In order to compile a profile, designers can use dimensional segments and indicative use. Indicative use means the indicative combination on a road section, a combination of a car and two cyclists, for example. Dimensional segments are the dimensions required for a specific user in the cross section profile. The dimensional segments that apply to an estate access road are shown below.

The value of the cyclist/edge dimensional segment refers to the minimum distance a cyclist wants to keep from the kerb. If the cyclist passes cars parked on the right, the value of this dimensional segment is about twice as high. Almost all motorised traffic will overtake bicycle traffic when the value of the



cyclist/vehicle dimensional segment is 0.85 m or more and, in addition, the width of the vehicle is left. If the cyclist/vehicle distance is smaller, motorists will hesitate: some overtake, others stay behind the cyclist. This is then a critical profile, which leads to a dangerous, unwanted situation. The remaining width next to the cyclist should, therefore, be restricted in such a way as to make it clear that every motorist has to remain behind the cyclist. The cyclist/moving vehicle dimensional segment is larger than the vehicle/vehicle dimensional segment, because the behaviour of bicycle traffic is harder to predict than that of motorised traffic. When motorists overtake, they take a cyclist's zigzagging into account. Bicycle traffic is also more vulnerable.

Dimensional segment	Required width profile (m)
cyclist[2]	0.75
car[2]	1.75
lorry[2+3]	2.60
cyclist/edge (kerb)[1]	0.25
cyclist/parked vehicle[1+4]	0.50
cyclist/cyclist (both riding)	0.50
cyclist/driving vehicle[1+4]	0.85
vehicle/vehicle (both driving)[2+4]	0.30
driving vehicle/kerb[2+4]	0.25

1) value determined on the basis of research
2) source: Recommendations for Traffic Provisions in Built-up Areas (ASVV)
3) in this context, buses are counted as lorries
4) a vehicle refers to: all motor vehicles with at least three wheels

V 12, 13, 14 **Cycle streets**

Main cycle routes are often part of main routes for motorised traffic. In older cities in particular, the radial connections often have an important function for both bicycle and motorised traffic. However, it is also possible that main cycle routes and access roads for motorised traffic are not combined or

have deliberately been separated because cycling on busy roads is neither safe nor attractive for cyclists. In that case, the main cycle route should run through the residential area via estate access roads. This introduces a specific type of main cycle route: the cycle street.

The cycle street is a functional concept: an estate access road that forms part of a main cycle route whose design and layout is recognisable as such, but where motorised traffic does occur to a limited extent and as subordinate traffic [26]. Because these are main cycle routes, the superior numbers of bicycles are more or less self-evident. In any case, the additional quality for the main cycle route is right of way. At the moment, installing right of way provisions in residential areas is generally not permitted, but in the implementation regulations of the Administrative Road Traffic Provisions Decree (BABW), legislators have made an exception for main cycle routes that are recognisable as such.

A cycle street can be laid out in a variety of ways. It is advisable to:

- minimise nuisance caused by parked vehicles;
- use a closed surface paving (preferably asphalt);
- provide a form of guidance in situations where choices have to be made.

Advantages of the cycle street

The safety and attractiveness of a cycle street can only be matched by a solitary or separate cycle track. Compared to these, however, the cycle street has a number of advantages:

- Less use of space
  A cycle street is open to motorised traffic and requires less space than a solitary cycle track or a separate cycle track next to the main carriageway. This makes a cycle street suitable for more locations and makes it cost-effective.

- Improved accessibility
  Unlike full closure of a street or route to motorised traffic, cycle streets allow motorised traffic access to functions situated along the road or further away from the road. Furthermore, the often scarce parking spaces remain accessible.
- Better social safety
  A route through a residential district with a combined use of bicycle and car provides more social safety than a solitary cycle track or a separate cycle track next to an urban main road.

Cycling intensity

An important condition for designating a road section as a cycle street is that the bicycle traffic really has to dominate the streetscape. Although little experience has been gained with cycle streets, the dominant position of bicycle traffic appears to be sufficiently evident when there are twice as many cyclists as motorists on a road section. If this requirement is not met while policy calls for additional quality for cyclists, the road authorities may try to reduce the intensity of motorised traffic to ensure that the intensity ratio is achieved. A large number of cyclists have to be present – not only relatively speaking but also in absolute terms – to qualify the road as a main cycle route. Although local relationships play a role, in order for a road section to qualify as a cycle street, it must carry at least 1,000 cyclists a day.

Car intensity
Practical studies [24] have shown that at a car intensity level of up to 500 pcu/day on a main cycle route, the superiority of bicycle traffic can easily be achieved, without modifications to the profile. In other words, on main cycle routes on residential streets that are used almost exclusively by access traffic, the superiority of bicycle traffic over motorised traffic is self-evident.

There is as yet no definite answer to the question of how much motorised traffic is acceptable on a cycle street. In Germany, the maximum for cycle streets is set at 3,000 pcu/day, and means of transport other than the bicycle are only permitted on cycle streets as an exception and should be restricted to local residents [27]. In situations in the Netherlands, the maximum intensity is either 1,000 or 2,000 pcu/day. Based on the experience with existing cycle streets, it advisable to assume as limited a number of motor vehicles as possible, up to a maximum of 2,000 pcu/day.

If the intensity of motorised traffic is over 2,000 pcu/day and there are no options available to reduce this number, a different solution has to be found for the main cycle route. This may be a cycle track or an entirely new route. However, the new route may not be any longer than the route initially envisaged.

V 15, 16, 17, 24

Cycle lanes
Cycle lanes are possible on sections of district access roads with relatively low bicycle use and on sections of estate access roads with a high or overly high intensity of motorised traffic. Although bicycle and motorised traffic are normally combined on estate access roads, the actual situation on the street may be a reason to ensure the safety of bicycle traffic. In city centres or on urban sections of a through road with a high intensity of motorised traffic, it may be advisable to construct a cycle lane to ensure the safety and comfort of cyclists.

A cycle lane is characterised by:
- sufficient width;
- a red colour;
- the bicycle symbol.

These characteristics may sometimes not be possible in practice, so a suggestion lane could be built under the motto of 'anything is better than nothing'. However, that is not necessarily true for cycle lanes. Research [28] conducted in the 1980s by the Dutch Institute for Road Safety Research (SWOV) showed that not only were cycle tracks beside main arterial roads safer for cyclists than cycle lanes, even a total lack of bicycle facilities (cyclists on the carriageway) was safer than cycle lanes. On cycle tracks next to road sections, 50% fewer injurious accidents occurred per bicycle kilometre ridden than on lanes. On road sections with no bicycle facilities, the number of injurious accidents per bicycle kilometre was also 50% lower than on cycle lanes. It should be noted that the kinds of cycle lanes studied in this research was somewhat diverse: narrow and wide cycle lanes as well as suggestion lanes, with and without parallel parking were combined.

In Danish research, a pre-and post-study [78] evaluated the construction of real or suggestion cycle lanes on 37 road sections. The number of accidents involving bicycles and mopeds fell by 35% and 52%, respectively, after construction of the cycle lanes (the analysis took the amounts of motorised and bicycle/moped traffic into account). The study did not establish whether these cycle lanes are safer or more dangerous than cycle tracks in the post-construction situation, nor did it demonstrate how the number of accidents developed on roads without bicycle facilities, since no control group was involved in the research. The researchers did find, however, that narrow cycle lanes (less than 1.2 m across) are two to three times more dangerous that wider cycle lanes (expressed in the number of accidents per bicycle kilometre cycled).

Width and parking

Because of the above, it is only advisable to build cycle lanes if the width requirement (at least 1.50 m, no more than 2.50 m) is met. A second important condition concerns the road surroundings. Cycle lanes are not recommended in combination with parking bays, because opening car doors form a source of danger. If parking is really necessary, a critical reaction strip is recommended (width ≥ 0.50 m). In that case, however, designers should check whether a cycle track would not be a better solution, with or without a pavement or footpath at the same level (see also section 5.7.2): a width of 1.50 m for the cycle lane + 0.10 m of markings + 0.50 m of critical reaction strip also provides room for a cycle track with a width of 1.80 m + 0.30 m of partition verge (at the same level as the cycle track so that no space is 'lost' by the critical reaction distance as the result of a kerb). If the width of the pavement can also be used by cyclists, the cycle track is a good alternative to a cycle lane.

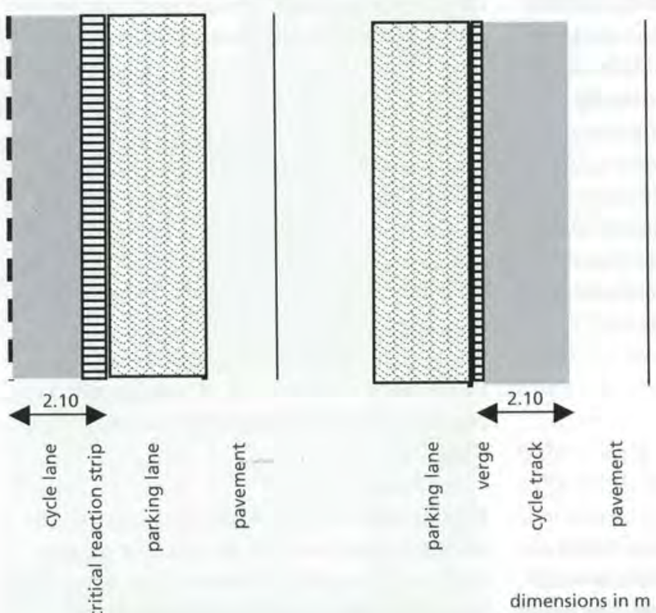


Figure 20. Cycle lane and critical reaction strip versus adjacent cycle track

V 18, 24

Suggestion lanes

Since cycle lanes make parking and stopping of motor vehicles (including loading and unloading) impossible, suggestion lanes are often used as an alternative. The key question then is whether the suggestion lane can be regarded as a fully fledged bicycle facility and, consequently, may or must have properties of the cycle lane. There are different opinions on this matter.

Some people say that suggestion lanes for cyclists should provide a maximum of comfort and safety. For that reason, suggestion lanes should be red and wide enough. Others believe that there should be a maximum distinction between the cycle lane and the suggestion lane to avoid confusion among road users. It also improves road safety. For this reason, the suggestion lane should not be coloured red.

This design manual recommends keeping the red colour exclusively for the cycle lane to ensure maximum distinction with the suggestion lane and to prevent a devaluation of the red colour and the cycle lane. The following recommendations apply to suggestion lanes:

- no red colour;
- width between 1.50 and 2.00 m;
- preferably in combination with a parking ban (which does allow loading and unloading).

V 19 to 24

Cycle tracks

On sections of district access roads, cycle tracks are the safest solution, being preferable to cycle lanes. Because cyclists are separated from motorised traffic, the risk of (passing) conflicts between both groups is kept to a minimum. The design of the cycle tracks depends on the function (design speed) and the use (width).

A disadvantage of cycle tracks that are separate from the carriageway is that cyclists are outside the direct field of vision of motorists, and this disadvantage grows as the distance between the cycle track and the carriageway increases. On road sections, the reduced eye contact is not a problem, since cars and bicycles are separated. However, when the car and bicycle encounter each other again, at intersections, problems may arise. Because motorists on road sections do not have to allow for cyclists, there is a danger that they will not do so at intersections either. To avoid this situation, eye contact at points where the two meet should be 're-established'. This is discussed in chapter 6 'Intersections'.

An alternative for the cycle track is the parallel road (see below). A drawback to the parallel road compared to a cycle track is that motor vehicles are allowed on them. This has a negative effect on the safety and particularly the comfort of cyclists.

Two-way cycle tracks
In principle, cycle tracks next to carriageways are designed for one-way traffic. At intersections, two-way bicycle traffic leads to traffic movements from an unexpected direction. This makes the situation difficult to oversee, hence jeopardising safety. However, there may be good reasons to allow cycle tracks for two-way traffic, for example if:

- a two-way traffic cycle track shortens the route for cyclists and/or forms a logical short cut in the route;
- a two-way traffic cycle track prevents crossing movements;
- there is not enough room for a cycle track on both sides of the road.

A condition for a two-way cycle track is that sufficient attention is paid to its design, particularly at the intersections. The cycle crossing should preferably be slightly elevated. If the cycle track has right of way, the pavement, signposting and marking should support it. This reduces the chance of road users failing to notice cyclists coming from an unexpected direction (see chapter 6 'Intersections'). If necessary, a two-way cycle track can

be combined with a cycle lane on the other side of the road. This ensures that cyclists whose point of departure and destination is on the other side of the carriageway do not have to cross the carriageway twice on their journey. A risk in this situation is that cyclists travelling in the opposite direction will do the same. This risk must be weighed against the risk of crossing the carriageway twice.

V 6, 7, 8, 9

V 16, 17, 18

Parallel road
In functional terms, a parallel road next to a district access road or distributor road can be designated as an estate access road, which has been described above. A point for special attention in the case of parallel roads inside the built-up area is the parking situation. Parked vehicles must not jeopardise the interests of cyclists.

V 12, 13, 14

Parallel roads may comprise cycle lanes or suggestion lanes. Parallel roads are often designed for one-way traffic, particularly inside the built-up area, but it is inadvisable for

this to apply to cyclists as well. In these cases, at least a cycle lane for bicycle traffic from the opposite direction should be considered. If the parallel road is part of a main cycle route, the road can also be laid out as a cycle street (see above).

5.4.2 Outside the built-up area
For district access roads outside the built-up area with a speed limit of 80 km/h, bicycle traffic should definitely travel off the carriageway for motorised traffic, on a separate cycle track or a parallel road. As a basic premise, that is less definite for estate access roads (60 km/h).

Table 16. Option diagram for road sections outside the built-up area

Function		Speed (km/h)	Intensity (pcu/day)	Bicycle traffic road section function: basis network	Bicycle traffic road section function: (main)cycle route (I_{cycle}> 2,000/day)
Motorised traffic road section function	Estate access road	60	1 - 2.500	combined traffic	cycle street, if I_{pcu} < 500 pcu/day[1)]
			2.000 - 3000	cycle lane or cycle track	cycle track, or perhaps lanes
			> 3000	cycle track	
	District access road	80	irrelevant	cycle/moped track parallel road	

1 Plus any additional requirements in the area of safety

The general premise for estate access roads is that traffic is combined. At low intensities of motorised traffic and a driving speed that corresponds with the speed limit, this does not present a problem. The 'Handbook for Road Design' designates this type of road as a type b estate access road [29]. It should be noted, however, that from the point of view of safety and comfort, a speed of 60 km/h (for motorised traffic) is far from ideal for cyclists. Bicycle facilities should then be considered, particularly in situations involving a lot of cars or cyclists (type a estate access road).

Table 16 is a tool that can be used to decide on the right facility. When using this table, the same considerations apply as to the table for road sections inside the built-up area.

V 6, 9 **Combined traffic**

Outside the built-up area, speed differences between cars and cyclists are considerable, even if the speed limit is 'only' 60 km/h. This means that the basic premise of combining traffic is only possible if the intensities of motorised and bicycle traffic are low and the maximum speed is in fact limited to 60 km/h.

If a road section on an estate access road outside the built-up area forms part of a cycle route or main cycle route, combined traffic is possible at a low intensity and speed. At extremely low intensities of motorised traffic, it may be worth considering a cycle street as a solution, also referred to outside the built-up area as a cycle road. A point for special attention in that case is the speed of the motorised traffic: 60 km/h, combined traffic, high bicycle intensities and comfortable cycling do not go hand in hand. In other words, the speed of the motorised traffic will have to be controlled (reduced) still further.

From an intensity of about 2,500 pcu/day, bicycle facilities should be considered; in the case of a cycle route, preferably in the form of a separate cycle track, but cycle lanes are also acceptable in certain situations.

Farm traffic

Another issue that has to be addressed on sections of estate access roads outside the built-up area is the presence of farm vehicles. When there is a relatively high level of farm traffic, a wider road profile than is necessary from a traffic engineering point of view could be preferable, in order to meet the main requirement safety. In that respect, preventing the destruction of the edges of the pavement is also a safety aspect. The extra width required could be provided by paving the verge, in order to keep the traffic path for car traffic narrow. In that case, however, the situation should be avoided in which motorists regard the paved verge as a 'real' pavement. Use of ribbed asphalt is not recommended for that reason, nor is rubble paving. If cyclists are forced off the road, this kind of paving does nothing to heighten the chances of a happy ending. The most suitable material for verge paving, therefore, are cellular concrete blocks.

V 16 **Carriageway with one traffic path for motorised traffic**

A common profile on estate access roads outside the built-up area is one in which road sections are constructed with suggestion lanes with one traffic path remaining for motorised traffic. The reasons for laying suggestion lanes are the visual narrowing of the carriageway, the centring of the traffic on the carriageway or a combination of the two. The lanes themselves do not reduce the speed, which is why it is advisable to apply this solution on cycle routes always in combination with speed reduction measures.

Edging strips and visual narrowing

More and more estate access roads outside the built-up area have edge markings designed to make the carriageway look narrower than it actually is. This entails the application of uninterrupted edge markings a few decimetres away from the verge paving. If the distance between the markings and the verge paving exceeds 0.30 to 0.40 m, both cyclists and motorists may get the impression that the edging strip is intended for cyclists. Cyclists then feel obliged to cycle on the narrow strip, which not only requires a great deal of mental and physical effort, but also leads to unintended traffic behaviour. This is why edging strips are applied no more than 0.30 m away from the verge paving.

The critical intensity of motorised traffic for a road with one traffic path can be seen from two angles. In the first situation, the question is how many motor vehicles a single individual motorist encounters on a road section (so how often the motorist has to move out onto the cycle or suggestion lane. This number partly depends on the driving speed and the length of the road section. Table 17 indicates how many passing and hence evasive moments occur on a road section of a certain length at varying intensities, assuming a speed of 60 km/h (of the motorised traffic), thus providing an impression of the number of encounters on a road section in the period the motorist drives on this section.

Example
A vehicle driving at 60 km/h covers a read section measuring 1 km in a period of 1 minute. Assuming a total of 3,000 vehicles a day, for example, in rush hour (according to a well-known rule of thumb), 300 vehicles an hour drive on this road section (200 vehicles in one direction and 100 vehicles in the other). This comes down to an average of 3.33 vehicles a minute in one direction and 1.67 in the other. In the 1.0 minute period referred to above, there will be an average of 11 encounters on the 1 km road section in question. On a road section measuring 2.5 km, that figure will rise to 69 encounters in 2.5 minutes.

Table 17. Average number of encounters between motor vehicles on a road section

	Daily intensity				
Length of road section	I = 750	I = 1,500	I = 2,250	I = 3,000	I = 5,000
0.5 km	0	1	2	3	8
1.0 km	1	3	6	11	31
2.5 km	4	17	39	69	193
5.0 km	17	69	156	278	772

Average number of encounters between motor vehicles on a road section is the period the vehicle drives on the section during rush hour (= 0.1 x daily intensity). Furthermore, V = 60 km/h and the intensity in direction 1 is twice that in direction 2.

The second angle of approach focuses on the total number of encounters between all motor vehicles. The passage density (the number of encounters per hour per kilometre) depends on the driving speed and the intensity of the motorised traffic flows there and back. On the basis of these figures and an estimate of the passage time and length, a theoretical estimate of the capacity loss of cycle lanes caused by passing cars can be made. This loss depends to a large extent on the intensity of the motorised traffic and less so on driving speeds.

On the basis of the second angle of approach, the following, indicative recommendations can be made:

- at an intensity of motorised traffic < 300 pcu/h, one traffic path is acceptable;
- at an intensity of motorised traffic of between 300 en 400 pcu/h, one traffic path is doubtful (transition zone);
- at an intensity of motorised traffic > 400 pcu/h, one traffic path is unacceptable.

V 12, 13, 14 **Cycle street/cycle road**

Main cycle routes that run through residential areas occur outside the built-up area as well. These estate access roads can be subjected to the same function requirements as cycle streets inside the built-up area (see section 4.4). A difference from the situation inside the built-up area is the speed of motorised traffic. A maximum speed of 60 km/h is too high to

Zeeland experiment with cycle road

The Zeeuwse Eilanden water board built a sort of cycle street outside the built-up area and called it a 'cycle road'. In many respects, the route in question, which connects Heinkenszand and the Stelleplas recreation area, is a regular estate access road outside the built-up area, although on average, a great many cyclists use it, especially during the summer months. A new, separate cycle track was considered less suitable for this route, because the intensity of motorised traffic was extremely low (an average of < 700 pcu/day) and there were no speed problems. However, the cyclists merited a little extra attention than on an ordinary estate access road, particularly on those days that they appeared in large numbers.

A design was selected in which a central reservation that is difficult to cross forces motorists to adapt their driving behaviour to the cyclists, only allowing drivers to overtake at low speed and with greater distances between the overtaking points. After some time, it turned out that some cyclists were not fully aware of the purpose of the cycle road with the central traffic island. A survey showed that a considerable number of cyclists found that the cycle road had no positive aspects, in spite of the fact that the speed of the motorised traffic had fallen somewhat [30]. What this means for the design was not analysed. However, it can be concluded that solutions that affect the freedom of movement of the cyclist must be dealt with carefully.

ensure optimum safety and a comfortable cycling environment. In order to do so, the speed of the motorised traffic has to be adjusted. Contrary to common belief, it is possible to set the maximum speed limit at 30 km/h outside the built-up area as well. The statutory conditions (implementation regulations of the Administrative Road Traffic Provisions Decree (BABW)) for outside the built-up area are no different to those for inside the built-up area.

V 20 **Cycle/moped tracks**
On district access roads outside the built-up area, separate bicycle facilities in the form of cycle/moped tracks or parallel roads are always essential. The fact that mopeds use the track may have consequences for the width. Mopeds are usually not permitted on separate tracks next to estate access roads (60 km/h). They are required to ride on the carriageway.

V 21, 22 *Partition verge*
As far as the distance between the cycle track and the main carriageway is concerned, cyclists find it best if they can cycle as far away from motorised traffic as possible. However, the distance must not be so great that the cycle track is outside the sphere of influence of the main carriageway. To maintain social control, motorists should have a clear view of the cycle track. The space between the cycle track and the carriageway is referred to as the partition verge. This verge functions as a 'receptor' for vehicles that run off the main carriageway and as a 'buffer' for preventing accidents between cyclists and motorised traffic. Table 18 recommends a number of widths for an effective partition verge.

Table 18. Widths for partition verges (carriageway – cycle track) outside the built-up area

	Width of partition verg (m)	
Road category	recommended distance	minimum distance
District acces road	6.00	4.50
Estate acces-road	>1.50	1.50

V 4 *Two-way traffic*
On cycle/moped tracks on which traffic runs in two directions, cyclists and moped riders approaching one another represent a potential risk situation. To reduce the chance of head-on collisions, centre line markings are always recommended on two-way tracks. Additional attention should also be paid to side roads and other connections. For all these aspects, it is important to make it clear to all road users that traffic can be expected from both directions (see also chapter 6 'Intersections').

V 6, 9 **Parallel road**
In functional terms, a parallel road next to a district access road is seen as an estate access road. The diagram in table 16 can be used to help determine the road section solution for this situation. A particular issue concerning parallel roads outside the built-up area is the speed of the motorised traffic. A parallel carriageway is sometimes a quicker route than the functional main carriageway, but function, design and use are then not in balance. In that case, traffic regulation or speed reduction measures should be introduced to restore the balance.

The use of parallel roads by farm vehicles is another point that requires the designer's special attention. More and more farm vehicles are forced to use a parallel road, although the mandatory licence plate for farm vehicles is expected to curb this tendency to a certain extent. The difference in mass between cyclists and farm vehicles is considerable, but there are relatively few accidents involving both types of traffic. According to the statistics, however, if things do go wrong, the result is often serious: of the accidents in which a cyclist is fatally injured, an average of 1.5% is the result of a collision with a farm vehicle, while farm vehicles only account for 0.5% to the total kilometres driven [31].

Another issue is that combining farm traffic with a lot of cyclists creates a feeling of discomfort, which often leads to a situation of subjective danger. On roads or parallel roads that are used by a farm vehicles and a relatively high number of cyclists, bicycle facilities may be worth considering. Separate tracks are the safest solution, but use up a lot of space. Furthermore, a solution consisting of a main carriageway, parallel roads and separate cycle tracks is expensive. An alternative may be cycle lanes or suggestion lanes. Although these are less safe than cycle tracks, the fact that cyclists are more attentive when riding on them could make conditions for cyclists safer. In these kinds of situations, the best possible solution should be sought by including all of the interests in the equation.

5.5 Bicycles and public transport

When public transport combines with the other motorised traffic, the option diagrams in section 5.4 can be used to find solutions for the road sections. If the public transport system has its 'own' infrastructure, these option diagrams are not suitable; in that case, this section provides the designer with a number of ideas. In future, a distinction will be made between road sections for buses and road sections for trams/light rail.

5.5.1 Bicycles and buses

Bicycles and buses in the same space?
On estate access roads, bicycles and buses both use the same infrastructure. This not a problem, assuming that the speed differences between bicycles and buses are small; buses are not permitted to go faster than 30 km/h. Depending on the intensity of the motorised traffic, bicycle facilities are essential on district access roads and bicycles and buses are separated. There are also road sections that are closed to motorised traffic, with the exception

Table 19. Function combinations of bicycle and bus traffic

		Function of road section for bicycle traffic	
		(main) cycle route	other routes (basic network)
Function of road section for motorised traffic	connecting	- high-speed bus wanted - high requirements for cyclists' comfort → separate cycle and bus	- high-speed bus wanted - no high requirements for cyclists' comfort → separate cycle and bus
	access	- no high-speed bus wanted - high requirements for cyclists' comfort → cycle and bus preferably separated, but this is not necessary	- no high-speed bus wanted - no special requirements for cyclists' comfort → separation of cycle and bus not necessary or desirable

of buses. The question is whether these types of connections should be open to cyclists. If buses travel slowly (30 km/h), this is not a problem in terms of safety. However, there are situations in which it is worth considering separation of bicycles and buses for reasons of comfort and subjective safety. The choice depends on the function of the road section for both buses and bicycles. Table 19 shows that four situation can be distinguished.

Connecting public transport
On connecting bus lines, higher speed of bus traffic (> 30 km/h) is often the basic requirement. If that requirement also applies to road sections used by bicycle traffic, separation is necessary. Otherwise, differences in mass and speed will be excessive. The necessity of separation in this situation is irrespective of the function of the road section for bicycle traffic.

Access public transport
If the road section is only used by access public transport, low speed is the basic requirement. In terms of safety, bicycle and bus traffic can be combined on cycle routes, main cycle routes and other routes. For reasons of comfort, however, it is worth considering separate bicycle facilities on main cycle routes and/or routes with high bus intensities. When there are a lot of buses on a route, cyclists will soon feel 'threatened'.

School routes
The designer is required to pay extra attention to road sections that form part of a school route. Schoolchildren are inclined to cycle in groups and often behave unpredictably. The difference in mass and the relatively poor manoeuvrability of buses mean that the risk of collision should be avoided whenever possible. In this situation again, it is preferable to separate bicycles and buses.

Bus lanes and bus carriageways
A bus lane is a section of the carriageway indicated by markings and reserved for buses. Use by cyclists depends on the same criteria as for road sections: if bus traffic does not travel faster than 30 km/h, a combination with bicycle traffic is theoretically possible. However, bus lanes are usually laid to better ensure the quality of the service timetable. By allowing bus traffic on specific road sections to travel away from the other traffic, higher speeds are possible, and where buses travel at high speed, allowing cyclists onto the bus lane is unacceptable.

Cyclists may be permitted to ride on bus lane carriageways if they have their own separate lane. It is, however, essential to avoid a situation in which they are shut in between the bus lane on the one side and the carriageway for other motorised traffic on the other.

Apart from bus lanes, there are also bus carriageways. These are road sections (such as a bus lock between two residential neighbourhoods) designated exclusively for bus traffic. Again, buses and bicycles can be combined on bus carriageways if the speed of bus traffic does not exceed 30 km/h.

Dimensions

In order to determine the width of a bus lane (when it is enclosed between raised kerbs), a width of 3.20 m can be assumed for a standard bus on a road section travelled in a single direction and 6.50 m for a road section that is travelled in two directions. If the boundaries of a bus lane are indicated with road markings, 3.00 m is sufficient for a single direction and 6.10 m for two directions. If driving speeds exceed 50 km/h, the width is increased by 0.40 m for each direction. The width of 3.20 m referred to above for a one-way bus carriageway does not allow bicycle traffic in two directions, so the bus carriageway should be widened to 4.60 or 6.20 m, depending on the intensities of bus and bicycle traffic.

In general terms, it is advisable to ensure that traffic regulation on bus carriageways and lanes corresponds as closely as possible with the regulation of traffic on the parallel traffic lane. If that is not the case, fellow road users can have the wrong expectations about the driving behaviour of bus drivers. A related topic is the location of the bus carriageway on the road. In some municipalities, the bus carriageway is built in the middle of the road and in others, it is situated on the edge of the road. Both locations have advantages and disadvantages, such as the driving direction in accordance with traffic on the adjacent traffic lane and the need for bus passengers to cross over. This makes it difficult to decide which of the two is preferable. For the expectation pattern of fellow road users, it is important that once a solution has been chosen, it should be maintained consistently, so that the design of bus lanes is as uniform as possible in as large an area as possible.

Bus stops
In terms of bicycle traffic, two elements are important at bus stops: stopping buses and crossing pedestrians.

Stopping buses
On estate access roads, buses usually stop on the carriageway, causing problems for cyclists. In general, this situation is undesirable, but on main cycle routes, this applies even more. For reasons of safety and comfort, it is, therefore, advisable to have buses stop off the carriageway.

On district access roads, buses stop in stopping bays situated off the carriageway in accordance with the recommendations. When cycle lanes are present, buses have to merge with the passing cyclist. Although this creates a conflict, it is not serious and hence acceptable. Attention should be paid to the design of the stopping bay. It must be wide enough to pre-

vent buses having to stop on part of the cycle lane. In the case of separate cycle tracks, it is advisable to curve the cycle track around the bus stop so that stopping buses do not cause problems for cyclists.

Crossing pedestrians
The second element concerns the fact that bus stops produce a concentration of crossing pedestrians. Given the limited difference in mass between pedestrians and cyclists, this is not a serious conflict. In the case of a separate cycle track, a platform for waiting and alighting passengers will be required. This platform should be at least 2.00 m wide. If the bus stop has a shelter, the platform will be wider (2.50 m), with the distance between the cycle track and the shelter being at least 0.65 m. In that case, attention should be paid to the bendiness of the track (main requirement directness) and riding visibility for the cyclist, which should not be blocked by the bus shelter.

5.5.2 Bicycles and tram/light rail
In principle, cyclists and trams can use the carriageway on condition that the tram travels very slowly. This combination of tram and bicycle is not recommended, however. Because

cyclists cannot react to a vehicle coming from behind and trams are not able to swerve, a tram must be able to stop extremely quickly in the case of an emergency. The braking distance of a tram moving at 30 km/h is comparable to that of a car travelling at 50 km/h. A safe tram speed for conflict situations is, therefore, lower than 30 km/h, around 20 km/h [32].

The combination of tram/light rail and bicycle requires extra care during the design phase. Tram rails make it considerably harder to cycle. Cyclists have to make sure they do not cross the rails at too small an angle, particularly in wet weather. Tram rails also contribute indirectly to risky situations:

- Cyclists sometimes have to concentrate so much on not falling (especially when they are following rails at points and in bends) that they miss other dangers.
- Cyclists are not always able to choose a safe track, far enough away from parked cars, for example.
- Tram rails restrict the freedom of movement during evasive manoeuvres.

The above means that a combination of both types of traffic in a profile may be considered if there is enough room in the cross-section profile. The situation in which a less attentive cyclist gets a wheel caught in a rail should also be avoided. This is why the tramway should preferably be physically but at least visually screened off. In the latter case, this could be a different sort of paving under the tramway, conspicuous road markings (0.30 m wide) or a slight elevation of the tramway (3 to 5 cm).

If at all possible, a mixed profile of tram, car and bicycle on through cycle connections should be avoided and a solitary, physically separated tramway built. If this is not possible, the following design principles apply:

- Cyclists ride to the right of the tram. There are critical reaction strips on either side of the cycle connection (so between both the cyclist and the tram and between the cyclist and verge paving or parked cars). On cycle routes or main cycle routes, but preferably off them as well, two cyclists can travel alongside each other in the same direction without a problem.
- Car intensity is low so that cyclists have the chance to swerve.
- Stopping on the road section should be prohibited.
- Where a tramline or cycle connection bends away, cyclists should be able to cross the rails at an angle of at least 45 but preferably 60 degrees. The cycle connection should be at least 2.50 m wide.

5.6 Bicycles and mopeds

Since 15 December 1999, mopeds are no longer permitted on cycle tracks inside the built-up area. This has created a pleasant cycling environment on cycle tracks and the traffic situation for mopeds is safer, particularly at intersections.

The situation outside the built-up area is completely different. Because of the greater speed differences between mopeds and cars, a combination of these groups of road users on district access roads is unacceptable, so mopeds have to ride on the cycle/moped track. This may have consequences for the design of the track, particularly its width.

V 3, 4 One of the issues regarding cycle/moped tracks is when and where two-way traffic can be allowed. Given the seriousness of a head-on collision (bicycle/moped and moped/moped), two-way traffic should only be permitted when the track is wide enough. Centre line markings are mandatory. In the case of two-way traffic, the situation at side roads and entrances merits the designer's specific attention (see chapter 6).

5.7 Bicycles and pedestrians

Inside the built-up area, cyclists do not normally use the same space as pedestrians. After all, most roads and streets have pavements or walkways. Outside the built-up area, pedestrians often use the cycle track, but given the extremely low numbers that do, this does not cause many problems. Inside the built-up area, however, there are a number of situations in which the relationship between cyclists and pedestrians requires further thought. In many municipalities, there is the dilemma of

whether or not to allow cyclists in pedestrian precincts; this is discussed in section 5.7.1. It may be useful to allow cyclists and pedestrians to use the same space in other situations as well; these are discussed in section 5.7.2.

5.7.1 Shopping streets and pedestrian precincts

Pedestrian precincts can be found in many city centres. Although this measure was prompted by the annoying presence of motorised traffic, many of these precincts are now only open to pedestrians, in order to create a pleasant and safe shopping atmosphere. However, the question is whether it is always necessary to prohibit bicycles as well as motorised traffic. After all, compared to the latter, cyclists cause hardly any nuisance. Another issue is that central areas and pedestrian precincts that are closed to cyclists often form a major barrier. Furthermore, these areas also accommodate a great many destination points for cyclists. Bicycle-friendly policy ensures that these destinations remain accessible to cyclists.

Cyclists in car-free zones?

The question of whether bicycle and pedestrian traffic can be combined is of particular importance in pedestrian precincts, streets and parks. Usually, the issue is confined to either banning bicycles altogether or combining bicycle and pedestrian traffic. However, it is also possible to allow both categories, but to separate them from each other. It is, therefore, important to answer the following questions:

- Should/can cyclists be permitted in the car-free zones?
- If so, should bicyclist and pedestrian traffic be combined or separated?
- If they are to be separated, should that separation be 'hard' or 'soft'?

Bicycle traffic can be categorised as through traffic and destination traffic. Both groups benefit from access to car-free zones. For through traffic, a car-free zone is an attractive, safe and, in some cases, fast connection. This applies to city centres in particular.

In the case of destination bicycle traffic, cyclists are able to reach their destination in the car-free zone without delay. They can also keep their bicycle close by (less chance of it being stolen) and transport things on their bicycles. The benefits for cyclists if they are permitted in car-free zones must be weighed against the nuisance they cause to pedestrians.

For the permissibility of cyclists in a pedestrian precinct, a series of boundaries can be indicated based on use and profile. The layout of the street is just as important as the number of pedestrians; obstacles such as pavement cafes and bicycle racks restrict the available profile width. A traffic path and especially a sectional profile encourage pedestrians and cyclists to remain in their own 'domain' [33]. The average number of pedestrians related to the available profile width provides a good indication of the possible degree of combination. It is, therefore, primarily the intensity of pedestrian traffic in relation to the profile width (pedestrian density) that determines the answer to whether or not the two forms of traffic can be combined. Table 20 shows what solution can be recommended for what value.

Table 20. Possibilities for combining bicycle and pedestrian traffic

Number of pedestrians per hour per metre of profile width[1]	Recommended solution [33]
< 100	Full combination
100 - 160	Separation; traffic path with continuous profile (no differences in height)
160 - 200	Separation; traffic path with sectional profile
> 200	No combination possible

1) the number of pedestrians that pass an imaginary line straight across a street in an hour, divided by the total profile width in metres

Bicycle and pedestrian traffic can be combined if there are fewer than 200 pedestrians per hour per metre of profile width. Other pedestrian intensities do not allow an effective combination of the two flows. The designer will then have to look at whether there are other options, bearing in mind that pedestrian densities can fluctuate considerably. Late night shopping evenings and Saturdays may pose a problem that does not exist at other times. Although a design is based on an indicative moment, another traffic regime may apply at non-indicative moments. In other words, if cyclists are not permitted on late night shopping evenings and Saturdays, it does not mean that they should be banned for the rest of the week as well.

At a pedestrian density of under 100 pedestrians per hour per metre of profile width, full combination is possible without additional facilities. At a density of between 100 and 200 pedestrians per hour per metre of profile width, separation is recommended. At up to

160 pedestrians, visual separation will suffice (use of material, markings). From 160 pedestrians up, it is advisable to lay a traffic path for bicycle traffic.

The advantage of combining bicycle and pedestrian traffic is maximum freedom of movement in sideways directions for both categories of traffic. The advantage of separation is that pedestrians and cyclists experience less nuisance from one another. It also reduces the risk of accidents involving pedestrians and cyclists. However, the nuisance and danger caused by combining bicycle and pedestrian traffic should not be overestimated. A German study showed that the initial aversion among the public to allowing cyclists in pedestrian zones eased significantly after a year of practical experience. Another German study revealed that cyclists tend to adapt their riding behaviour, even dismounting when pedestrian densities are high. This study also refuted the assumption that once cyclists are allowed to travel in pedestrian zones, they will start riding faster. Finally, it showed that accidents involving cyclists and pedestrians are seldom and hardly ever serious.

Design for separation

At densities of 100 to 160 pedestrians an hour on a metre of profile width, a simple marking indicating the traffic path for cyclists suffices. At the same time, good spatial design of the street is advisable. This design should be such that the traffic path for cyclists is easy to recognise. Furthermore, this separation should not be 'too hard'. Nor should it be backed by legal measures, to avoid the creation of mutual intolerance because both groups 'invoke their rights'.

At intensities of more than 160 pedestrians an hour, it is advisable to give cyclists their own traffic path through the middle of the zone. To make it easily recognisable, it should have its a different paving and/or colour. At the same time, however, the separation between the bicycle and pedestrian domains should not be too restrictive, because cyclists have to be able to park their bicycles and leave their domain with ease to do so. A 'soft' separation also prevents cyclists and pedestrians falling over it. In practice, a soft separation, where the boundaries of the two zones flow into each other, so to speak, results in a flexible interaction between cyclists and pedestrians.

5.7.2 Soft separation between cyclists and pedestrians?

Apart from pedestrian zones where the bicycle is permitted, it is possible to consider combining bicycle and pedestrian traffic in other situations. This applies particularly to situations in which space is at a premium. In city centres and on peripheral roads around it, it is often not possible to allocate space to every category

Time windows for allowing cyclists

Practice has shown that in pedestrian precincts, there is a great deal of self-regulatory capacity. This means that it is only worth prohibiting cyclists when cycling is no longer possible and there is a reasonable alternative available. In that case, the vast majority of cyclists will decide to take the alternative route.

In the case of a cycle route through a pedestrian zone (and if bicycle traffic intensities require), this route can be designated as a cycle track with signpost G11. The recommended profile is then sectional, with pavements for pedestrians. A continuous profile with a traffic path is also possible.

If the intensity of pedestrian traffic fluctuates considerably so that the possibility to combine the two forms of traffic varies accordingly, secondary signs on existing signposts can be used to regulate the days and times that cyclists are permitted or prohibited. These window regulations must be unambiguous and comprehensible to avoid confusion. There must also be room for self-regulation: when prohibiting bicycle traffic (in time windows), a certain amount of restraint is required. Also remember that provisions for prohibiting bicycle traffic can never be fully geared to all fluctuations. This means that the insight and common sense of the traffic engineer remains important. To sum up, cycling in pedestrian zones should only be prohibited in those periods when the capacity for self-regulation has reached its limits and obvious problems can occur between cyclists and pedestrians.

of traffic that would ideally be necessary. This often leads to less than optimum solutions for cyclists and pedestrians, such as a pavement, a cycle lane or a suggestion lane that is just too narrow. In the latter case, cyclists are regularly forced to use the traffic path designated for motorised traffic, with the obvious risks as a result.

In these kinds of situations, the designer will have to think about whether a cycle or suggestion lane is the most appropriate solution. A combination of cyclists with motorised traffic, with any necessary traffic control measures, may be a safer solution. Another possibility may be to avoid a situation in which cyclists are forced onto the carriageway but can make use of the pavement or footpath. After all, cyclists and pedestrians are far more suited to one another in terms of mass and speed than cyclists and motorised traffic.

In a traditional design (suggestion lane with a narrow pavement), this latter manoeuvre is impossible due to the height difference. However, if the cycling and walking area are built at the same height or only differ by a matter of one or two centimetres, the manoeuvre can be made. Another step further is to construct the space reserved for cyclists and that for pedestrians at the same height, separated only by a sunken kerb or markings. It is even worth considering no separation at all or only by means of different kinds of paving materials, but this is only relevant when the quality of the urban planning so requires.

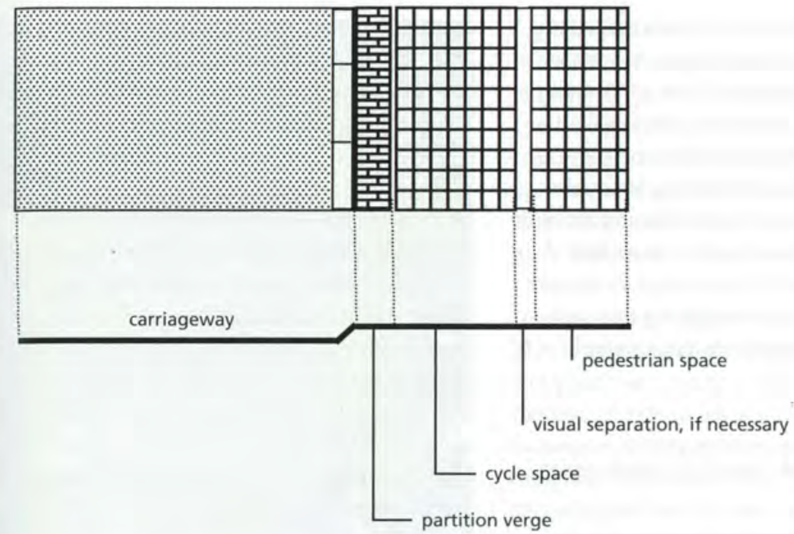


Figure 21. Layout of the space on a combined track

Combined track
In the Netherlands, the solution of a footpath and cycle track/lane at the same level, referred to as a combined track, is only used on a limited scale. Their use is far more widespread in neighbouring countries, where they also have their own statutory signposting. The lack of practical experience in the Netherlands means that this design manual is unable to make any recommendations based on practical experience. However, given the results of the study of cyclists in pedestrian zones, it seems reasonable to assume that a combined cycle/pedestrian lane is in any case possible at low pedestrian intensities (up to about 25 pedestrians per hour per metre of pavement width) and when bicycle intensity is not too high. To reiterate, additional values are not yet known.

Apart from the fact that more physical space is made available to cyclists and pedestrians and that cyclists will encounter fewer conflicts with motorised traffic, the combined track has another remarkable advantage. A common cause of unilateral bicycle accidents is that cyclists hit the edge of the pavement with their pedal. If there is no kerb, this type of accident will no longer happen. Finally, another advantage may occur when vehicles park at the side the carriageway. It is safer for cyclists to be led around the right-hand side of the parked vehicles than to ride past the left-hand side, as the chance of a motorist opening a door on the driver's side is far greater than on the other side.

A combined cycle/pedestrian lane is inadvisable when there is a lack of space, when the pavement is used by people who wish to stay in the area (to play, shop, use catering facilities, et cetera). These activities would continuously conflict with through bicycle traffic, a situation which is unpleasant for both groups. When there is a lack of space and many old people use the pavement, designers should think twice about applying this solution, because old people are quick to feel 'endangered'.

5.8 Bicycles and 'special' road users

Carrier tricycles
In theory, carrier tricycles are subject to the same rules as other bicycles. However, a special provision states that riders of bicycles with more than two wheels (including carrier tricycles) and bicycles with trailers that are wider than 0.75 m including the load are permitted to use the carriageway. This also applies when a compulsory cycle track is present.

Skaters
Skaters are not referred to separately in the 1990 Dutch Highway Code (RVV). In a formal context, they can be regarded as pedestrians, which means that they are subject to the same rules as pedestrians. If a pavement or footpath is present, skaters are required to use it. If there is no pavement or footpath, skaters are permitted to use the cycle track or cycle/moped track. Skaters coming from the right have no right of way.

The fact that skaters often use the cycle track, particularly if it has a closed surface paving, does not detract from the above. The question is whether – illegal – use of cycle or cycle/moped tracks by skaters should have an influence on the design. If a great number of skaters make frequent use of a cycle track and regular conflicts occur between cyclists and skaters, it is advisable to widen the cycle track to reduce the risk of mutual nuisance.

Skaters include inline speed skaters, roller skaters and people with a scooter or a pedal go-kart.

Light mopeds
In terms of their place on the road, light mopeds (V_{max} = 25 km/h) are the same as bicycles. The rules of the Dutch Highway Code concerning cycling and bicycles also apply to light mopeds and their riders. However, light mopeds are only allowed on the optional cycle track with their engines turned off.

One-seat cars with a moped engine
This is a moped with more than two wheels and a car body. Section 2a of the 1990 Dutch Highway Code states that the rules that apply to motor vehicles and drivers and passengers of motor vehicles also apply to these one-seat cars and their drivers and passengers. This means that unlike drivers of 'normal' mopeds, drivers of one-seat cars are required to comply with the rules that apply to car drivers laid down in the 1990 Dutch Highway Code. In other words: one-seat cars use the carriageway (and not the cycle track) and are not allowed to park on the cycle track or pavement.

Vehicles for the handicapped
According to Section 7 of the 1990 Dutch Civil Code, drivers of invalid vehicles have complete freedom of choice as to their place on the road. They may use the pavement, the footpath, the cycle track, the cycle/moped track or the main carriageway. If the carriageway has a cycle lane, however, this must be used. This means that apart from cyclists, drivers of invalid vehicles are the only road users permitted to use a cycle lane demarcated with a continuous line. Since the maximum permissible width of an invalid vehicle is 1.10 m and that of a bicycle 0.75 m, the minimum width for a cycle lane with a continuous line is 2.00 m (including 0.15 m for shy distance).

Horse riders
Under the 1990 Dutch Highway Code, horse riders are categorised as drivers. Their place on the road is the bridle path. If there is no bridle path, they use the verge or the carriageway. Since the carriageway is defined as 'every road section intended for driving/riding vehicles with the exception of cycle tracks and cycle/moped tracks', they do not use the cycle track. In practice, however, horse riders do use the cycle track quite frequently. In situations where this happens a lot (near riding schools, for example), it is advisable to lay a bridle path, because riders and their horses can cause discomfort and danger for cyclists.

Description	Indication of bicycle facilities
Function	indication of legal status
Application	• G11 compulsory cycle track, G12 end of compulsory cycle track • G12a compulsory cycle/moped track, G12b end of compulsory cycle/moped track • G13 optional cycle track (prohibited for mopeds and light mopeds with engines on), G14 end of optional cycle track
Implementation	• G11, possibly with secondary sign 0406, for two-way cycle tracks • centre line marking advisable on two-way utility tracks • traffic decree required for all signs • cannot be applied zonally
Dimension	• G11 to G 14 may be placed on the right or left of the track • G13 and G14 on solitary tracks in parks, et cetera may be a different size (0.60 x 0.20 m) • G11 and G12a on solitary tracks in parks, et cetera may be a different size (diameter less than 0.40 m)

G11
compulsory cycle track

G12
end of compulsory cycle track

G12a
compulsary cycle/moped track

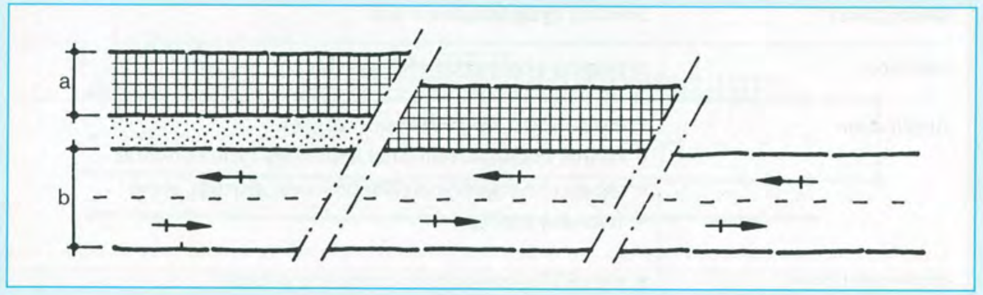
G12b
end of compulsary cycle/moped track

G13
optional cycle track

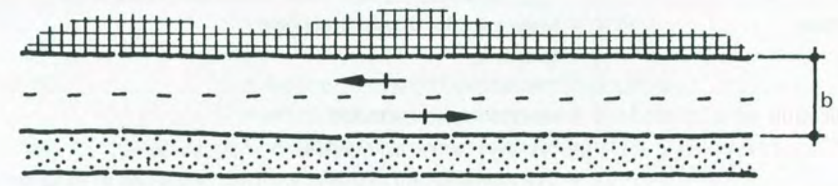
G14
end of optional cycle track

(0406)
secondary sign for two-way cycle track

Description	Solitary cycle track
Function	providing a connection for cyclists
Application	• inside and outside the built-up area • in recreational and utility cycle networks • short cut between neighbourhoods, districts, areas • two-way traffic
Implementation	• sign G11 (compulsory cycle track) or G13 (optional cycle track) • design speed 30 km/h for cycle routes/main cycle routes and 20 km/h for basic network • centre line marking advisable on utility tracks • preferably closed surface paving (asphalt or concrete) • utility tracks inside the built-up area preferably with lighting
Dimensions	rush hour intensities (two directions) (b/h) / track width: 0 – 50: 2.00 m[1] 50 – 150: 2.50 m[1] > 150: 3.50 m 1 up to a width of 2.50 m, a track has a crossable verge on either side so that cyclists can make evasive manoeuvres • centre line marking: 30-270 on straight sections, 270-30 on bends • width of any footpath (a) ≥ 1.00 m
Considerations	• comfortable for bicycles • safe for bicycles • mutual nuisance between cyclists and pedestrians if there is no pavement or footpath • lack of social safety when remote • nuisance caused by prohibited use by mopeds and motorcycles
Combination options	• bollards • footpath • moped speed hump (speed reduction for light mopeds)
Alternatives	solitary cycle/moped track

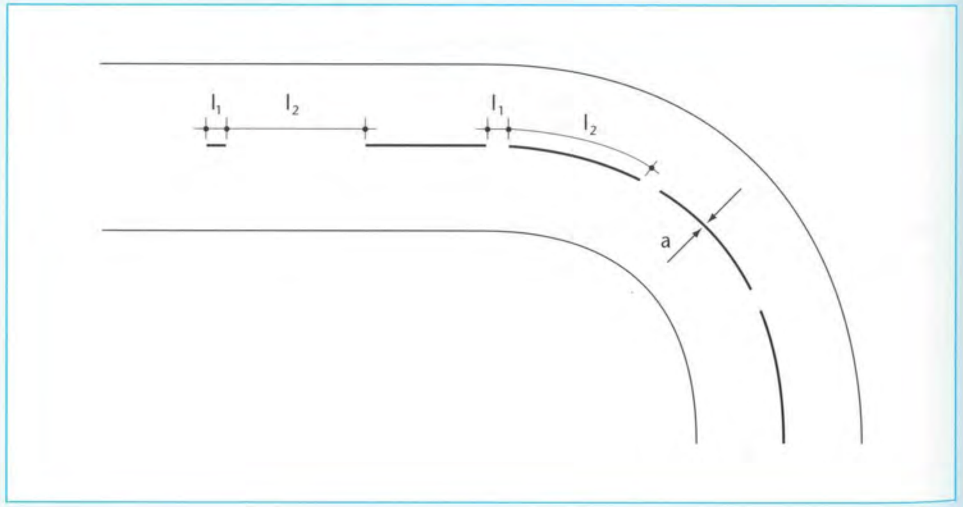


Description	Solitary cycle/moped track
Function	providing a connection for bicycles and mopeds
Application	• inside and outside the built-up area • connection in recreational and utility cycle networks • short cut between neighbourhoods, districts, areas • two-way traffic
Implementation	• sign G12a (compulsory cycle/moped track) • design speed 30 km/h for cycle routes/main cycle routes inside the built-up area and 40 km/h outside the built-up area • centre line marking • preferably closed surface paving (asphalt or concrete) • utility tracks inside the built-up area preferably with lighting
Dimensions	rush hour intensities (two directions) (b/h) — track width 0 – 50 — 2.00 m 50 – 100 — 3.00 m > 100 — 4.00 m • centre line marking: 30-270 on straight sections, 270-30 on bends • width of possible footpath (a) > 1.00 m
Considerations	• comfortable for bicycles and mopeds • safe for bicycles and mopeds • mutual nuisance between cyclists and moped riders • mutual nuisance between cyclists/moped riders and pedestrians if there is no pavement • lack of social safety when remote • nuisance caused by prohibited use by motorcycles
Combination options	• bollards • footpath • moped speed hump
Alternatives	• solitary cycle track



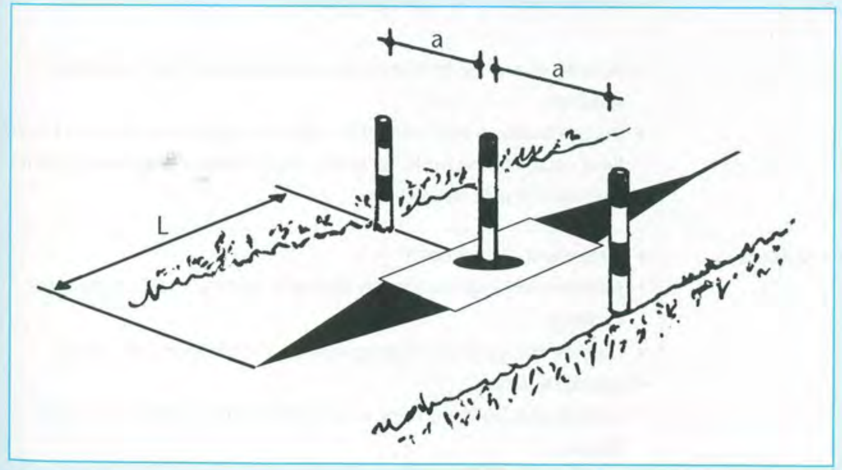
V 4

Description	Centre line marking on cycle tracks
Function	• separation of riding directions • guidance
Application	• on two-way cycle tracks • on cycle tracks ≥ 2.00 wide • as a warning line in places with increased risk of head-on collisions (for example on bends with restricted visibility)
Implementation	• thermoplastic material, road paint or paving material (profile inadvisable) • at side roads preferably thermoplastic material due to a high chance of wear
Dimensions	• a = 0.10 m for thermoplastic material and road paint; in the case of paving material, dependent of the width of the material (0.15 to 0.30 m) • normal centre line marking: l_1 = 0.30 m, l_2 = 2.70 m • warning line: l_1 = 2.70 m, l_2 = 0.30 m
Considerations	• it should be clear that traffic comes from two directions • good guidance



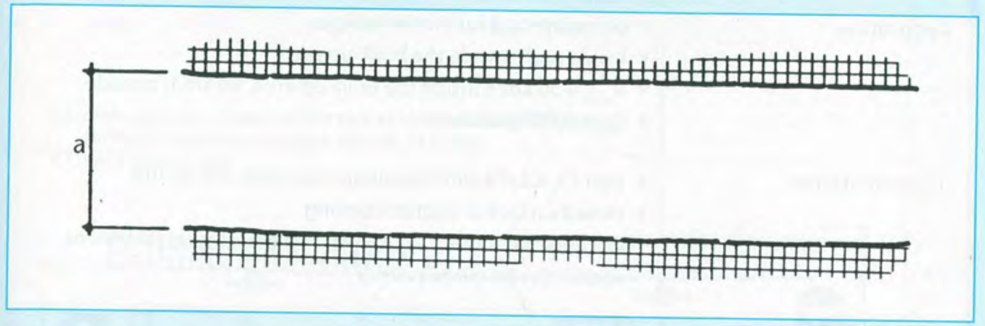
V 5

Description	Bollard
Function	keeping out unwanted motorised traffic
Application	• if other measures have proved ineffective • on cycle tracks inside and outside the built-up area • as supplementary measure for sign G11, G12a or G13
Implementation	• in a colour that contrasts with the surroundings for the visually impaired (red-white) • retractable, foldable or removable for wide vehicle access (fire brigade, maintenance traffic) • introductory corrugated marking required for central bollard • good lighting essential
Dimensions	• effective width next to bollard (a) = 1.50 (1.00) m; in the absence of alternative route, a passage of 1.20 m (to allow invalid vehicles) • length of introductory marking (L) ≥ 5.00 m
Considerations	• keeping out traffic • nuisance for cyclists (width restriction) • dangerous for cyclists (risk of collisions) • nuisance on gritting routes
Alternatives	• no bollard (if motorised traffic is only sporadic) • physical narrowing on both sides of the cycle track • uncrossable central traffic island on cycle track



Description	Carriageway for combined traffic
Function	providing a connection for all vehicle types
Application	• estate access road • inside and outside the built-up area • V_{max} = 30 km/h inside the built-up area, 60 km/h outside • I_{pcu} < 5,000 pcu/day
Implementation	• closed surface or element paving • outside the built-up area, part of the required paving width may be verge paving • parking outside the carriageway
Dimensions	width of carriageway (a) inside the built-up area: • 3.85 m (based on a combination of car/bicycle): only in conditions of extremely low intensity • 4.60 m (based on a combination of car/car) • 4.85 m (based on a combination of car/bicycle/bicycle) width of carriageway (a) side the built-up area: • 4.50 m (based on a combination of car/bicycle; possibly consisting of 3.50 carriageway + 2 x 0.50 m verge paving) • 5.50 m (based on a combination of car/bicycle/bicycle, possibly consisting of 4.00 m carriageway + 2 x 0.75 m verge paving) • possible edge marking (1-3) a maximum of 0.25 m from side paving
Considerations	• narrow profile helps reduce speed • at low car and cycle intensities, a narrow profile is relatively spacious • in combination with car traffic that is subject to a 60 km/h speed limit (outside the built-up area), the situation is not really comfortable or safe for cyclists
Combination options	• pavement or footpath • parallel parking bay (preferably with critical reaction strip for cyclists) • outside the built-up area: guidance (delineators) on bends • speed reducers • outside the built-up area: reinforced verge, cellular concrete blocks • outside the built-up area: possible edge marking

Description	Carriageway for combined traffic
Alternatives	• carriageway for combined traffic with partial one-way traffic • carriageway for combined traffic with partial one-way traffic and oncoming cycle lane

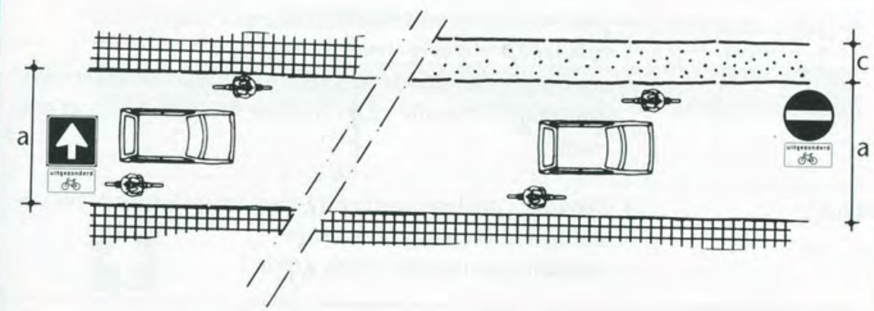


V 7

Description	Carriageway for combined traffic with partial one-way traffic
Function	• providing a connection for all vehicle types • influencing motorists' choice of route without hindering bicycle traffic
Application	• one-way road for motor vehicles • inside and outside the built-up area • V_{max} = 30 km/h inside the built-up area, 60 km/h outside • I_{pcu} < 5,000 pcu/day
Implementation	• sign C2, C3, C4 with supplementary sign 101 or 103 • closed surface or element paving • outside the built-up area, part of the necessary pavement width may be verge paving
Dimensions	inside the built-up area: • 3.85 m (based on a combination of car/bicycle) • 4.85 (based on a combination of car/bicycle/bicycle) outside the built-up area: • 3.50 m carriageway + 2 x 0.50 m verge paving (based on a combination of car/bicycle) • 4.00 m carriageway + 2 x 0.75 m verge paving (based on a combination of car/bicycle/bicycle)
Considerations	• low speed due to narrow profile • by allowing cyclists to ride in the opposite direction, they do not have to make a detour • at low car and cycle intensities, a narrow profile is relatively spacious
Combination options	• pavement or footpath • parallel parking bay (preferably with critical reaction strip for cyclists) on the right-hand side of the carriageway (looking in the direction the motorised traffic is travelling) • outside the built-up area: guidance (delineators) on bends • speed reducers • outside the built-up area: possible edge marking (1-3) a maximum of 0.25 m from side paving
Alternatives	• carriageway with mixed profile, with partial one-way traffic and oncoming cycle lane

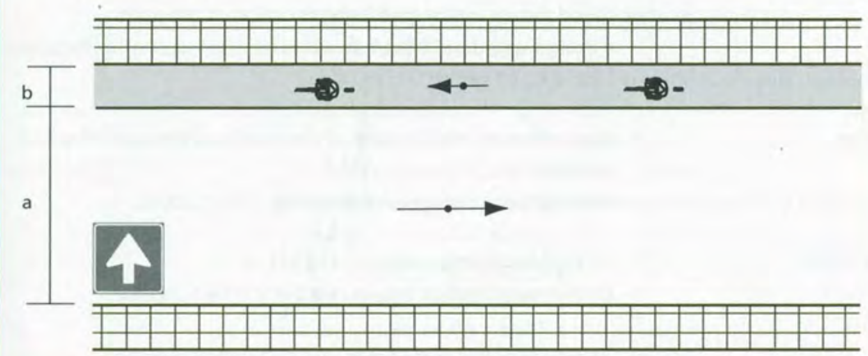
V 7

C2: one-way road, closed on this side to vehicles, horse riders and guides for riding or draught animals or cattle
C3, C4: one-way road

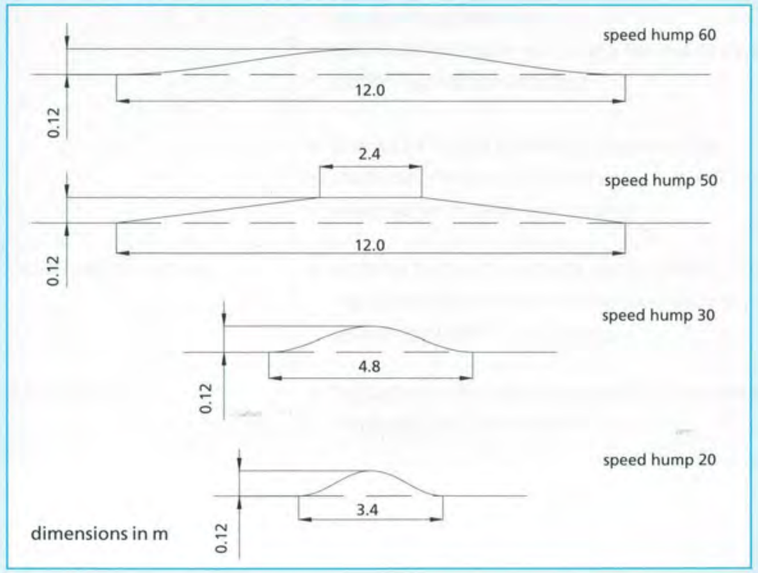


Description	Carriageway for combined traffic with partial one-way traffic and oncoming cycle lane
Function	• providing a connection for all vehicle types • influencing motorists' choice of route without hindering bicycle traffic
Application	• estate access road with one-way traffic for motor vehicles • inside and outside the built-up area • no parking on the carriageway
Implementation	• sign C2, C3, C4 with supplementary sign 101 or 103 • cycle lane in the opposite direction • cycle lane preferably in red • possible physical separation between cycle lane and carriageway (only if cycle lane ≥ 2.00 m wide); if necessary only at side roads
Dimensions	• design of cycle lane: see facility sheet for cycle lane (V 16) • width of carriageway (a) ≥ 3.50 m • width of cycle lane (b) 1.50 to 2.00 m
Considerations	• marked space for cyclists, with legal status • road users other than cyclists and drivers of invalid vehicles are not allowed on the cycle lane (with continuous marking line) or only if cyclists are not impeded (with interrupted marking line) • vehicles are not allowed to stop on the cycle lane or the adjacent carriageway • cyclists do not have to make a detour as a result of one-way traffic (for motor vehicles) • chance of illegal loading and unloading • chance of motor vehicles driving faster if carriageway is widened to include a cycle lane
Combination options	• parking bay (with critical reaction strip), preferably on the right-hand side of the carriageway looking in the direction the motorised traffic is travelling
Alternatives	• carriageway for combined traffic with partial one-way traffic (no oncoming cycle lane)

C2: one-way road, closed on this side to vehicles, horse riders and guides for riding or draught animals or cattle
C3, C4: one-way road



Description	Bicycle-friendly speed reduction facilities
Function	reducing speed difference between bicycle and motorised traffic
Application	• estate access road inside and outside the built-up area • district access road inside the built-up area • crossing location with cycle route or main cycle route
Implementation	• by means of vertical or horizontal speed reducers • for bicycle-friendly implementation, there are two options: - cyclists past the side of the speed reducer - design incline in sinus form • speed reducer must match the function of the road • a design speed of 30 km/h is recommended at conflict locations with a lot of cyclists
Dimensions	• depending on the function of the road and the type of speed reducer • width of possible bypass for cyclists: 1.50 (1.20) m
Considerations	• vertical facilities usually most effective • sinus-shaped incline causes relatively little nuisance • vertical facilities sometimes cause vibration nuisance • bypass with restricted width is a nuisance for cyclists
Combination options	• visual support

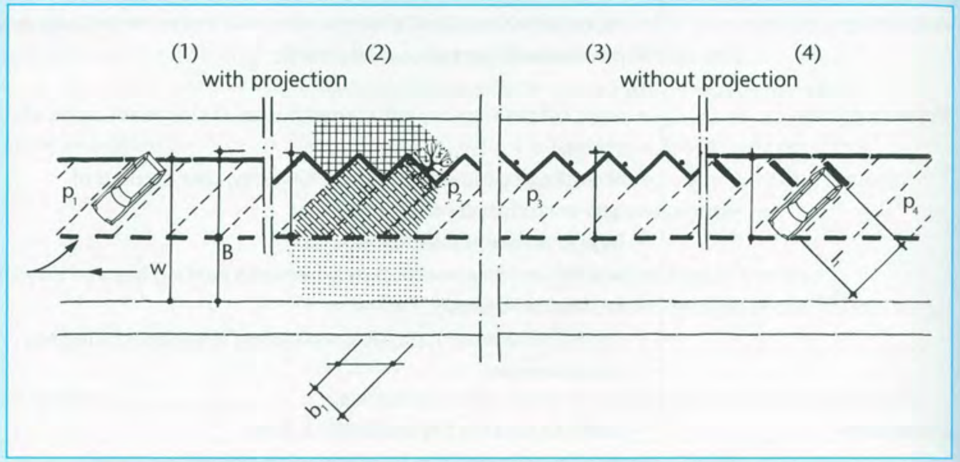


Description	Parallel parking bay with reverse parking (parking angle > 30°)
Function	providing bicycle-friendly parking place for motorised traffic
Application	• estate access road and district access road inside the built-up area • possibly with partial one-way traffic
Implementation	• mark off parking bay with raised humps at side roads, exits, et cetera • at the beginning/end of the parking bay, take account of approach visibility from side street • bays in different paving material • possibly a critical reaction strip between parking bay and bicycle facility/carriageway • height difference or physical separation between parking bay and pavement
Dimensions	• width of parking bay (b_1) 2.30 – 2.50 m • length of parking bay (m) depending on parking angle: (see table below) • traffic path for motorised traffic (w) > 4.00 m (room for parking manoeuvre)
Considerations	• reverse parking manoeuvre easier than in the case of parallel parking • safe for cyclists: no problem with opening doors • good visibility of cyclists when parking and leaving • no pedestrians on carriageway/cycle lane • in the absence of parked vehicles, no unnecessarily spacious road profile • more parking spaces on each length of road compared to parallel parking • poor view of crossing pedestrians • parked/stationary motor vehicles on carriageway can make getting out impossible • high parking intensities hinder access to buildings • boutside homes: exhaust fumes closer to homes

	60°	45°	30°
p_1	4.75	4.45	3.90
p_2	4.80	4.65	4.15
p_3	5.30	5.05	4.45
p_4	5.15	4.85	4.20

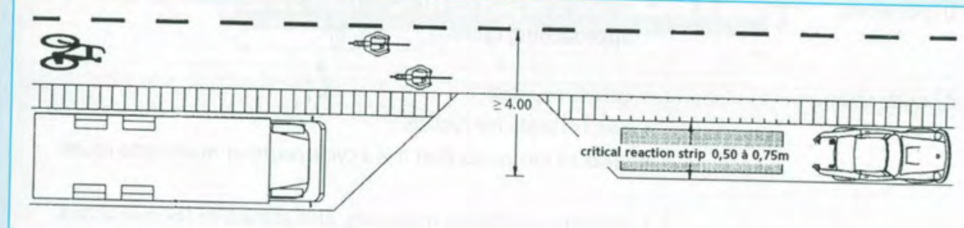
V 10

Description	Parallel parking bay with reverse parking (parking angle > 30°)
Alternatives	parking bay parallel to carriageway

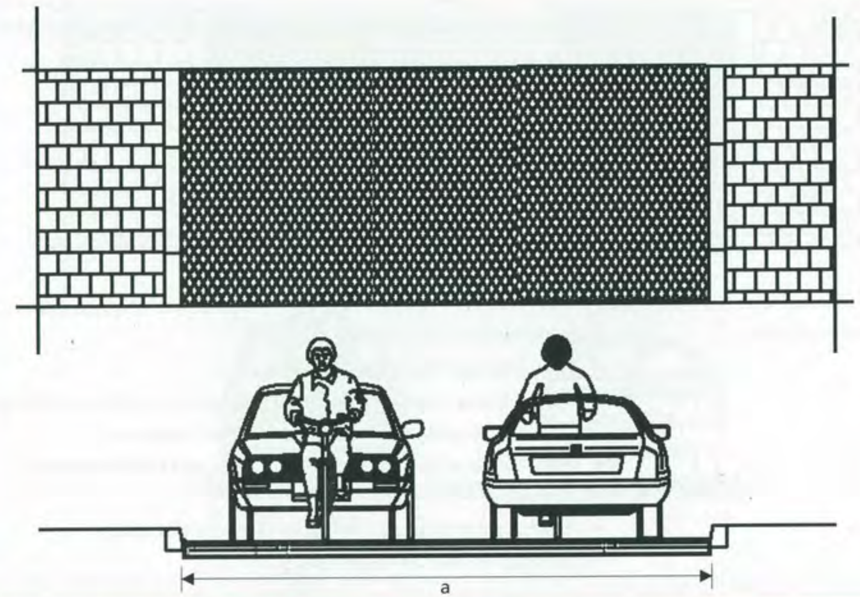


V 11

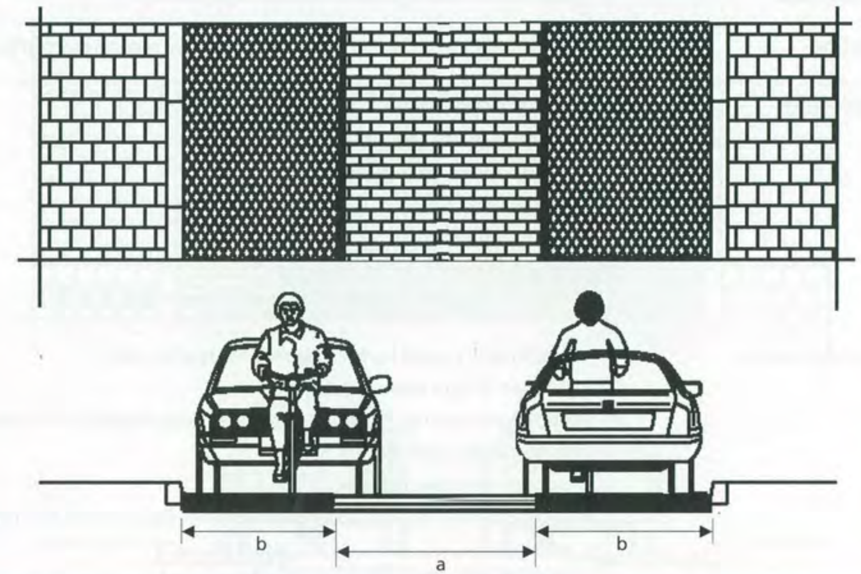
Description	Critical reaction strip
Function	buffer space for the safety of cyclists near parked motor vehicles
Application	• inside and outside the built-up area • 'buffer space' between carriageway-cycle lane and parking bay • if the total pavement width (a) ≥ 4.00 m
Uitvoering	• lane in different paving compared to carriageway/cycle lane and parking bay
Implementation	• width of critical reaction strip 0.50 to 0.75 m
Considerations	• safe for cyclists (less chance of accidents caused by opening doors and resulting evasive manoeuvres) • lane can also be used for drainage • additional use of space



Description	Cycle street with combined profile
Function	high-quality cycle connection, partly used by motorised traffic
Application	• estate access road inside and outside the built-up area • cycle route or main cycle route • $I_{bicycle} \geq 2 \times I_{pcu}$ • I_{pcu} < 500 pcu/day • V_{max} = 30 km/h (inside and outside the built-up area)
Implementation	• preferably closed surface paving • preferably red paving (for recognisability of cycle track/main cycle route) • right-of-way regulation at intersections (cycle street has right of way), possibly with speed reduction measure • route guidance at option points (where necessary) • no parking on the carriageway
Dimensions	• width of traffic path (a) 4.50 m (plenty of room for 2 x 2 approaching cyclists)
Considerations	• safe for cyclists • comfortable for cyclists • clear to motorists that it is a cycle route or main cycle route • without additional measures, also attractive for motorised traffic
Combination options	• parking bay with critical reaction strip • speed reducers • alternating one-way traffic for motor vehicles
Alternatieven	• cycle street with cyclists more in the middle • cycle street with cyclists at the side

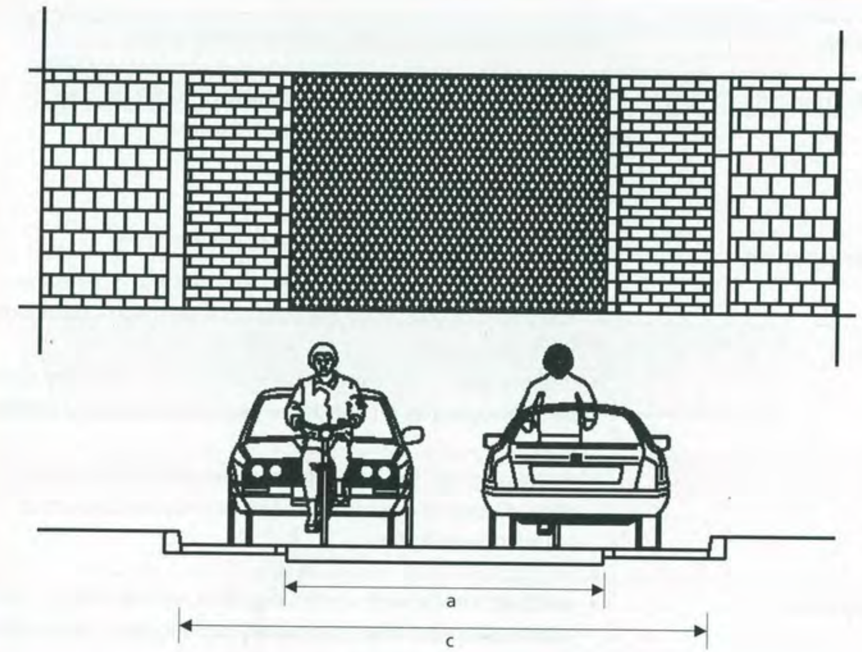


Description	Cycle street with cyclists at the side
Function	high-quality cycle connection partly used by motorised traffic
Application	• estate access road • inside and outside the built-up area • cycle route/main cycle route • $I_{bicycle} \geq 2 \times I_{pcu}$ • I_{pcu} < 500 pcu/day in two-way traffic • I_{pcu} < 2,000 pcu/day in one-way traffic • V_{max} = 30 km/h
Implementation	• preferably closed surface paving • cycle lane paving preferably red • right-of-way regulation at intersections (cycle street has right of way), possibly with speed reduction measure) • smooth transition between cycle lane and lane for motor vehicles • route guidance at option points (where necessary) • parking off the carriageway
Dimensions	• width of cycle lanes (b) 2.00 m • width of traffic path for motorised traffic (a) maximum of 3.50 m
Considerations	• safe for cyclists • comfortable for cyclists • clear to motorists that it is a cycle route/main cycle route • without additional measures, also attractive for motorised traffic
Combination options	• parking bay with critical reaction strip • speed reduction measures • alternating one-way traffic for motor vehicles
Alternatives	• cycle street with cyclists more in the middle • cycle street with combined profile (when I_{pcu} < 500 pcu/day



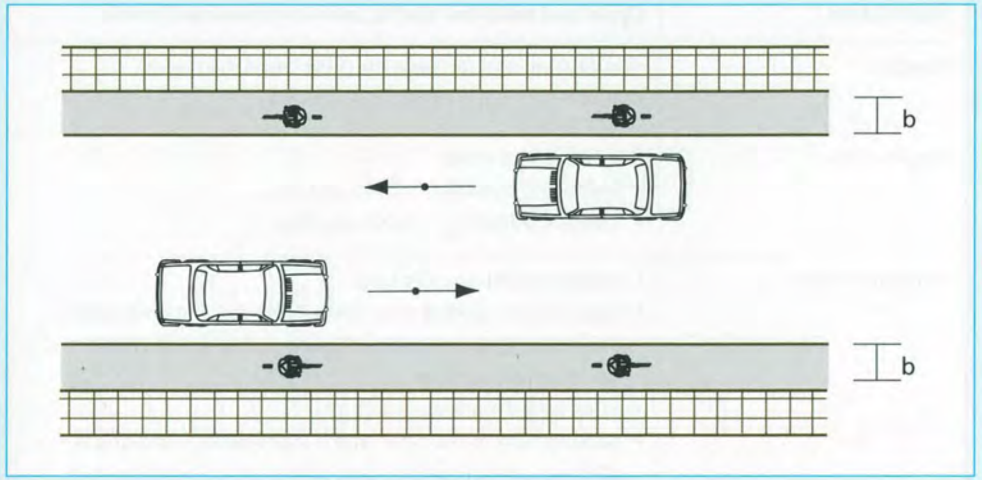
Description	Cycle street with cyclists more in the middle
Function	high-quality cycle connection partly used by motorised traffic
Application	• estate access road • inside and outside the built-up area • cycle route/main cycle route • $I_{bicycle} \geq 2 \times I_{pcu}$ • I_{pcu} < 2,000 pcu/day in one-way traffic • V_{max} = 30 km/h • do not apply in the case of two-way motorised traffic
Implementation	• preferably closed surface paving for traffic path • border strip in element paving • cycle lane paving preferably red (for recognisability of cycle route/main cycle route) • border strip black/grey • right-of-way regulation at intersections (cycle street has right of way) • smooth transition between cycle lane and lane for motor vehicles • route guidance at option points (where necessary) • parking off the carriageway
Dimensions	• carriageway width (a) 4.50 m • width of border strip (b) 0.75 m • width of traffic path (c) 3.00 m
Considerations	• safe for cyclists • comfortable for cyclists • clear to motorists that it is a cycle route/main cycle route • without additional measures, also attractive for motorised traffic
Combination options	• carriageway separation • parallel parking lane with reverse-in parking • parking bay with critical reaction strip • speed reducers
Alternatives	• cycle street with cyclists at the side • cycle street with combined profile (at I_{pcu} < 500 pcu/day)

V 14

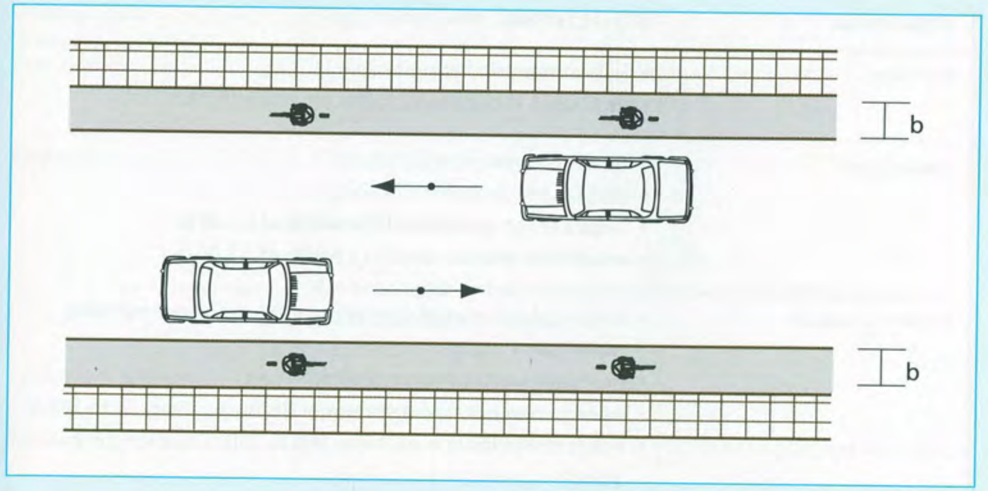


Description	Cycle lane with two traffic paths for motorised traffic
Function	indicating and securing the position of the cyclist
Application	• estate access road inside and outside the built-up area • district access road inside the built-up area • cycle route/main cycle route • I_{pcu} > 2,000 pcu/day
Implementation	• red pavement on cycle lane • apply bicycle symbol after every side road and if necessary, every 50 to 100 m inside the built-up area or 500 - 750 m outside the built-up area • interrupted (1-1) or continuous marking line; the latter should be interrupted by 1-1 line at the location of exits and parking bays • parking next to the cycle lane is inadvisable; if parking is allowed, only in combination with a critical reaction strip (width 0.50 to 0.75 m)
Dimensions	• width of lane (b) with continuous marking line 2.00 to 2.50 m • width of lane (b) with interrupted marking line 1.50 to 2.00 m • width of marking line 0.10 to 0.15 m
Considerations	• clear place in cross section profile (increase noticeability) with legal status • road users other than cyclists and drivers of invalid vehicles may not be on the cycle lane (with continuous marking line) or only if cyclists are not impeded (with interrupted marking line) • vehicles may not stop on the cycle lane or the adjacent carriage-way • chance of illegal loading and unloading • chance of motor vehicles driving faster if carriageway is widened to include a cycle lane • co-use by motorised traffic (interrupted marking line) • no physical protection • channelling the roadscape may raise speeds
Combination options	• speed reduction measures
Alternatives	• suggestion lane • separate cycle track • wide marking line (0.25 m instead of 0.10 m)

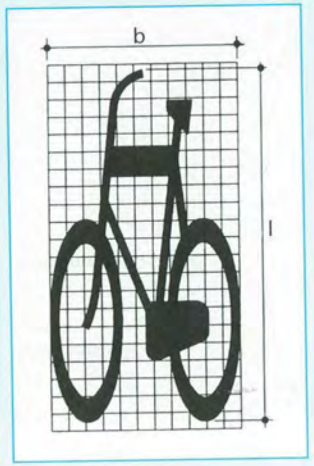
V 15



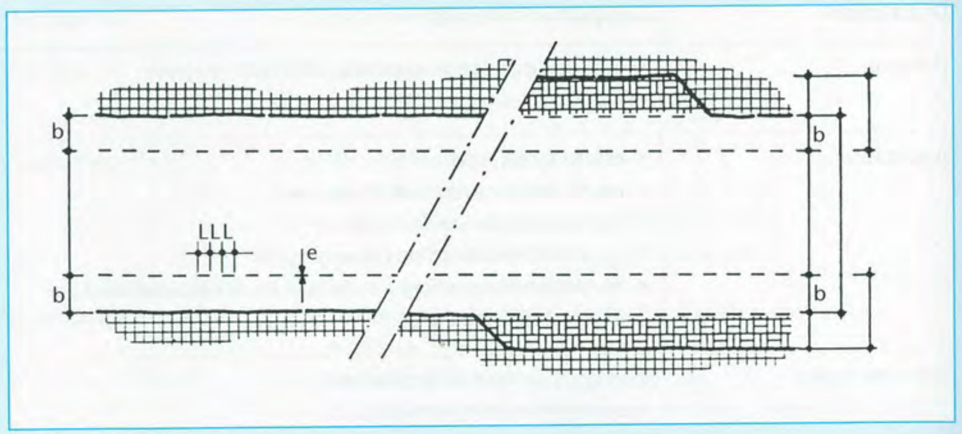
Description	Cycle lane with one traffic path for motorised traffic
Function	• indicating and securing the position of the cyclist • visual narrowing of the carriageway
Application	• estate access road • inside and outside the built-up area • 2,000 pcu/day < I_{pcu} < 4,000 pcu/day
Implementation	• red pavement on cycle lane • apply bicycle symbol after every side road and if necessary, every 50 to 100 m inside the built-up area or 500 to 750 m outside the built-up area • interrupted marking line (1-1) • parking next to the cycle lane is inadvisable; if parking is allowed, only in combination with a critical reaction strip (width 0.50 to 0.75 m)
Dimensions	• width of lane (b) at interrupted marking line 1.50 to 2.00 m • width of 1-1 line 0.10 to 0.15 m
Considerations	• clear place in cross section profile (increase noticeability) with legal status • road users other than cyclists and drivers of invalid vehicles may only be on the cycle lane if cyclists are not impeded • vehicles may not stop on the cycle lane or the adjacent carriageway • chance of illegal loading and unloading • chance of motor vehicles driving faster if carriageway is widened to include a cycle lane • co-use by motorised traffic (interrupted marking line) • no physical protection • channelling the roadscape may raise speeds
Combination options	• speed reduction measures • wide marking line (0.25 m instead of 0.10 m)
Alternatives	• suggestion lane • separate cycle track



Description	Bicycle symbol
Function	• indicating cycle lane • indicating expanded cycle stacking lane (ECSL)
Application	• on cycle lanes • on ECSLs • large version on lanes with a width of ≥ 1.80 m • small version on lanes with a width of < 1.80 m
Implementation	• thermoplastic material, road paint or preformed marking material • mandatory after every paved side road • as a supplement, apply at regular distances: every 50 to 100 m inside the built-up area, every 500 to 750 m outside the built-up area
Dimensions	• b = 1.10 m (small version) or 1.50 m (large version) • l = 2.00 m (small version) or 2.75 m (large version) • in special cases (narrow introductory lanes to ECSL, for example), b can be 0.75 m and l = 1.35 m
Considerations	egal status
Combination options	• it is advisable only to apply the bicycle symbol only in combination with red paving • standard arrow markings on stacking lanes



Description	Suggestion lane
Function	• indicating and securing the position of the cyclist • visual narrowing of the carriageway
Application	• estate access road • inside and outside the built-up area • cycle route/main cycle route • I_{pcu} > 2,000 pcu/day for one-way traffic • on road sections where a cycle lane is not required due to a (limited) need to park
Implementation	• suggestion lane paving not red • cycle symbol not permitted • with interrupted marking line (1-1) in thermoplastic material, road paint or paving material • parking next to suggestion lane is inadvisable; if parking is allowed, preferably in combination with a critical reaction strip (width 0.50 to 0.75 m) • parking ban if no separate parking bays are present
Dimensions	• width of lane (b) 1.50 m • L = 1.00 m • width of line (e) 0.10 to 0.15 m
Considerations	• clear place in cross section profile • no legal status • lane may be seen as a parking lane • on narrow traffic paths, frequent use of the lane by motor vehicles • chance of illegal loading/unloading • chance of motor vehicles driving faster if carriageway is widened to include a cycle lane • co-use by motorised traffic (interrupted marking line) • no physical protection • channelling the roadscape may raise speeds
Combination options	• speed reduction measures
Alternatives	• at a width of > 1.50 m, cycle lanes are possible • separate cycle track

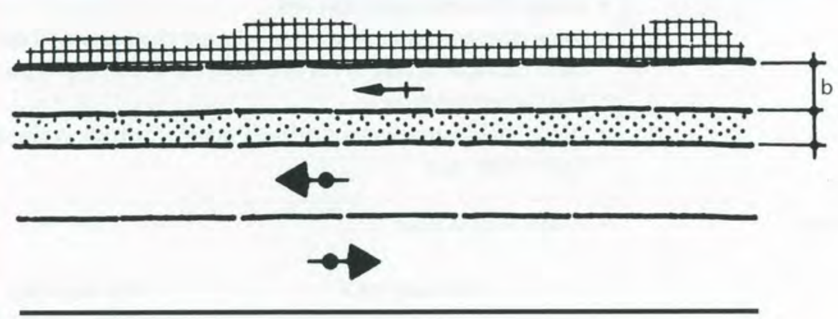


Description	Separate cycle track
Function	separation of motorised and bicycle traffic for the safety and comfort of cyclists
Application	• district access road inside and outside the built-up area • estate access road inside and outside the built-up area
Implementation	• design speed 30 km/h for main cycle routes and 20 km/h for the basic network • partition verge between cycle track and main carriageway (elevated or on a level) • in the case of two-way traffic on cycle track or utility cycle track, centre line marking may be advisable • preferably closed surface paving (asphalt or concrete) • sign G11 (compulsory cycle track) or G13 (optional cycle track) • colour of paving preferably red • same right-of-way regime as for adjacent carriageway; if cycle track has right of way across side road, continuous paving of cycle track across junction • if V_{max} main carriageway ≤ 70 km/h, bend cycle track in about 30 m before side road
Dimensions	• width of cycle track

One-way track		Two-way track	
rush hour intensity in one direction (b/h)	width (b)	rush hour intensity in two directions	width (b)
0 – 150	2.00 m	0 – 50	2.50 m
150 – 750	3.00 (2.50) m	50 – 150	2.50 to 3.00 m
> 750	4.00 (3.50) m	> 150	3.50 to 4.00 m

Considerations	• comfortable for cyclists (if wide enough) • safe for cyclists on road sections (no conflicts with motorised traffic) • no nuisance from parked vehicles • illegal cycling in the opposite direction (one-way traffic) • limited crossing options for cyclists (only at side roads, exits and gaps in the partition verge) • conflict situations with motor vehicles at intersections and exits (cyclists out of sight)

Description	Separate cycle track
	• in two-way traffic on cycle track, extra conflicts at intersections and exits (cyclists from unexpected direction) • in two-way traffic, possibly more crossing movements; may be combined with cycle lane (on one side) • mutual nuisance between cyclists and pedestrians if there is no pavement
Combination options	• bollards • speed hump at cycle crossing in side road
Alternatieven	• cycle lane • cycle/moped track • combined track (soft separation of cycle track and pavement)

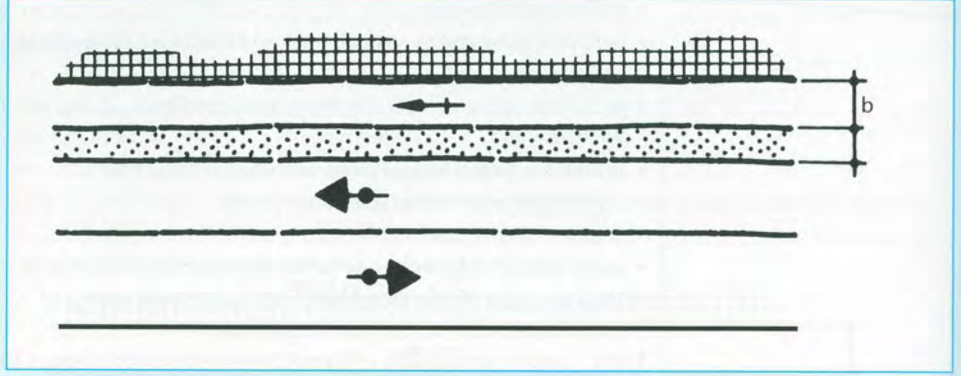


Description	Separate cycle/moped track
Function	separation of motorised and bicycle/moped traffic for the safety and comfort of cyclists and moped riders
Application	• district access road inside and outside the built-up area • estate access road inside and outside the built-up area
Implementation	• design speed 30 km/h • partition verge between cycle track and main carriageway (elevated or on a level) • in the case of two-way traffic on cycle/moped track, always centre line marking • preferably closed surface paving (asphalt or concrete) • sign G12a (compulsory cycle/moped track) • colour of paving preferably red • same right-of-way regime as for adjacent carriageway; if cycle track has right of way across side road, continuous paving of cycle/moped track across intersection area • if V_{max} main carriageway < 70 km/h, bend cycle track in about 30 m before side road
Dimensions	see table below
Considerations	• comfortable for cyclists and moped riders (if wide enough) • safe for cyclists and moped riders on road sections • mutual nuisance between cyclists/moped riders and pedestrians if there is no pavement • mutual nuisance between cyclists and moped riders • illegal cycling in the opposite direction (one-way traffic) • limited crossing options for cyclists (only at side roads, exits and gaps in the partition verge)

Dimensions:

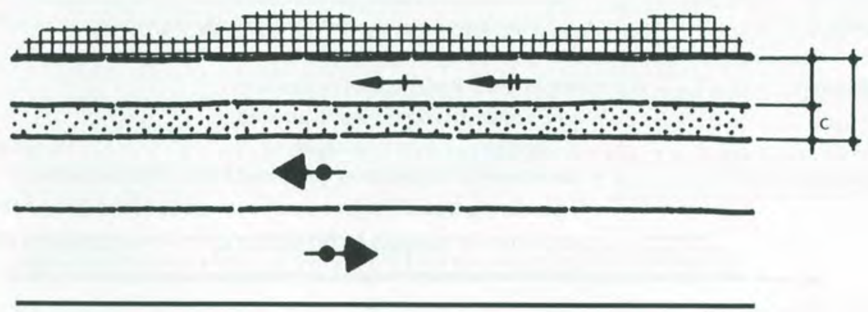
One-way track		Two-way track	
rush hour intensity in one direction (b/h)	width (b)	rush hour intensity in two directions	width (b)
0 - 150	2.00 m	0 - 50	2.50 m
75 - 375	3.00 m	50 - 150	3.00 m
> 375	4.00 m	> 100	4.00 m

Description	Separate cycle/moped track (continued)
Combination options	• bollards • speed hump at cycle crossing in side road • speed hump for mopeds (before crossing on a busy side road)
Alternatives	parallel road (combined profile)



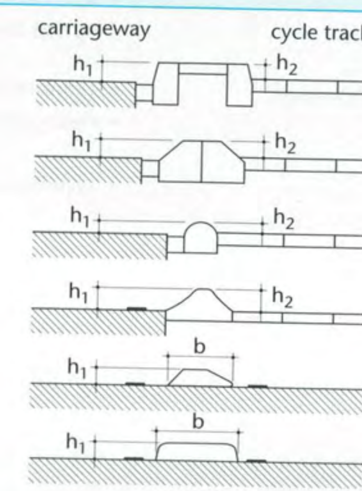
Description	Partition verge between cycle track and carriageway
Function	physical separation of motorised and cycle traffic
Application	• for separate cycle track • inside and outside the built-up area
Implementation	• paved verge, unpaved verge, raised kerb, fence or barrier • if necessary, paved verge can serve as evasion lane (if on a level) • verge may be suitable for street furniture, low vegetation and/or trees
Dimensions	width (c) inside the built-up area: • at least 0.35 m • in the presence of lamp posts and/or two-way cycle track > 1.00 m • in the case of vegetation or parking > 2.30 m • from 30 m before side road < 0.35 m (for roads with V_{max} < 70 km/h) • with fence > 0.70 m • with barrier > 1.10 m width (c) outside the built-up area: • at V_{max} main carriageway 60 km/h ≥ 2.50 (1.50) m • at V_{max} main carriageway ≥ 80 km/h ≥ 6.00 (4.50) m • at V_{max} main carriageway ≥ 100 km/h > 10.00 m
Considerations	• separation of motor vehicles and bicycles is safe • with raised kerb, risk of one-side accidents involving cyclists (pedal against the kerb) • limited crossing options for cyclists (only at side roads, exits and gaps in the partition verge) • wider paved verge can be used to park
Combination options	• anti-dazzling protection • public lighting

V 21



V 22

Description	Narrow paved separation of cycle track and main carriageway
Function	physical separation of motorised and bicycle traffic
Application	• on separate cycle track • inside the built-up area • if insufficient room for partition verge
Implementation	• ((1), (2), (3) and (4) for cycle track with element paving • (5) and (6) with continuous asphalt paving • interruption of paving for drainage • interruption at side roads and exits • kerbs or edge may be painted white or black and white
Dimensions	• width varies • $h_1 \leq 0.10$ to 0.12 m • $h_2 = 0.05$ (0.07) m; if 0.07 m, choose a profile that prevents pedals striking the separation
Considerations	• separation of motor vehicles and bicycles is safe • on narrow profiles, separate cycle track is still possible • limited crossing options for cyclists (only at side roads, exits and gaps in the partition verge) • incorrect dimensioning causes dangerous edge for cyclists • motorised traffic may cross
Combination options	combined track (soft separation between cycle track and pavement



(1) two concrete kerbs with tiles or clinkers in between

(2) two concrete kerbs back to back

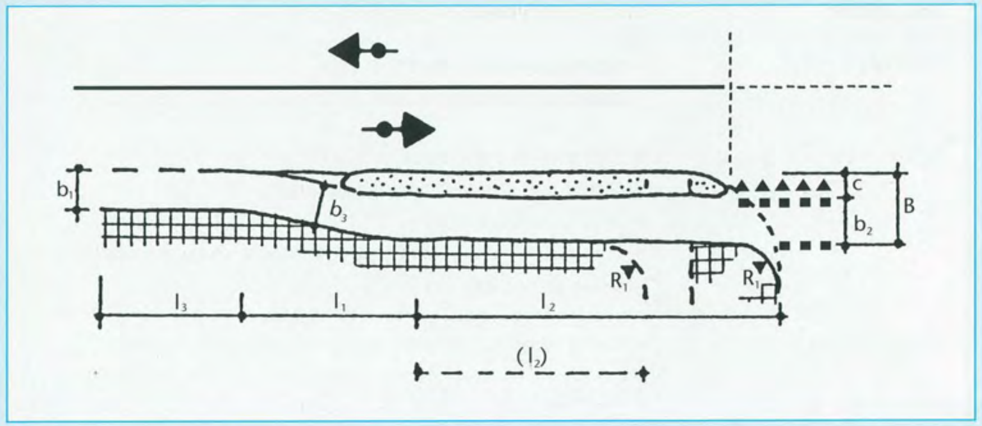
(3) semi-round concrete kerb

(4) hollow kerb profile

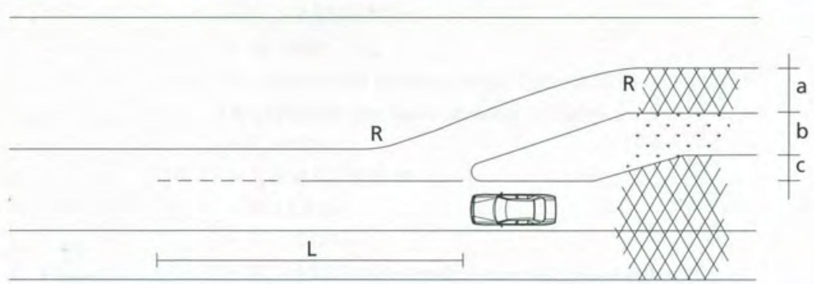
(5) asphalt ridge

(6) wide concrete kerbs or slabs

Description	Streamed cycle track
Function	• guiding cyclists at intersections • guiding cyclists at transition from combined profile to separate cycle track
Application	• district access road inside the built-up area • estate access road inside and outside the built-up area • cycle tracks along crossing road or along road section on the other side of intersection • on approach road sections at intersections with a traffic control system
Implementation	• right-of-way situation on cycle track and carriageway the same; if cycle track has right of way across side road, continuous paving of cycle/moped track • verge or physical separation from main carriageway • preferably closed surface paving (asphalt or concrete) • sign G11 or G12a
Dimensions	• for b_1, see facility sheet for cycle lane or suggestion lane (V 16) • $b_2 \geq 2.50$ (1.75) m • $b_3 \geq b2$ • c (inside the built-up area) 0.50 – 2.00 m or ≥ 4.50 m • c (outside the built-up area) ≥ 6.00 m • $l_1 = 10 \times c$ • l_2 and $l_3 \geq 5.00$ m • B ≥ 3.50 m • $R_1 \geq 5.00$ m • $R_2 \geq 10.00$ m(depending on design speed)
Considerations	• comfortable for cyclists and moped riders (if wide enough) • clear guidance of cyclists • cyclists outside the direct field of vision of motorists



Description	Transition from cycle track to cycle lane
Function	• guiding cyclists • indicating profile change
Application	• on separate cycle track and/or cycle lane • inside and outside the built-up area • area boundary • transition from cycle or suggestion lane to cycle track (1) or vice versa (2) and (3)
Implementation	• thermoplastic material, road paint or paving material
Dimensions	• l = 1.00 m • L_1 = (10 to 12) x b • L_2 = 10 to 20 m • b = 0.40 to 0.50 (0.35) m • R ≥ 10 m (depending on design speed)
Considerations	cover is safe for cyclists



6 Intersections

This chapter deals with cyclists intersecting and crossing roads. The need to pay close attention to this subject is evident from accident statistics. Collisions between cyclists and cars are the most significant cause of serious traffic accidents involving cyclists (fatalities and hospitalisations). Over half of these accidents occur at intersections within built-up areas (58%) and of these particularly at intersections with 50 km/h roads (95%).

Section 6.1 discusses the functional requirements for intersections, after which 6.2 deals with the five main requirements. In (a very detailed) section 6.3 a total of seven intersection combinations of estate access roads, district access roads, solitary cycle tracks and public transport lanes are discussed. The intersection of cycle connections with a distributor road is not discussed because a grade-separated solution is always preferable in such cases.

V 25, 26 Each chapter concludes with a number of facility sheets. The text contains references to the relevant facility sheet marked by this symbol.

6.1 Function, form and use

The function of an intersection is to enable interchange. Traffic at an intersection is given the choice to turn off or cross (if only the option to cross is provided then it is a crossing, not an intersection). The design of an intersection should optimally support the interchange function. Earlier design philosophies were based on the assumption that it would be beneficial to the road user if any sub-conflicts arising here were disentangled as far as possible. But that idea is now considered outdated. Disentangling sub-conflicts can lead to complex, incomprehensible and unexpected traffic situations, resulting in a high risk of accidents.

The design of an intersection must be comprehensible to road users. This aim is best achieved with a well-organised situation with a minimum number of conflict points. The basic principle to limit the number of conflict points as much as possible can be at odds with other requirements, for example in relation to traffic flow. If additional lanes are built for this reason the result can be that the traffic situation is no longer sufficiently comprehensible and 'aids' (such as traffic lights) are needed. Although such solutions are not within the scope of the design philosophy of this Design manual, they are discussed as these solutions are seen frequently.
It is important that the speed of the various road users is minimised during interchanging. In a collision with a car at low speed, the chance of survival is significantly greater than when the car is travelling at a high(er) speed. Figure 21 shows the relationship between the likelihood of a pedestrian being killed as the result of a collision with a car and the collision speed at that time. Although these details cannot be directly applied to cyclists, the picture for cyclists will not differ in a significant way. It is evident that the risk of death can increase significantly with a relatively small increase in the collision speed.

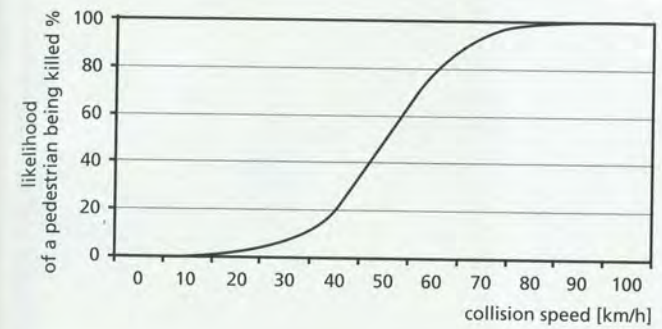


Figure 21. The likelihood of a pedestrian being killed in a collision with a car as a function of the collision speed [20]

6.2 Requirements for an intersection

The main requirements of directness, safety and comfort are significant at intersection level. The cohesion requirement is primarily related to safety and is therefore not dealt with separately. Attractiveness plays a lesser role at intersection level.

6.2.1 Directness

As with road sections a distinction can be made between intersections according to directness in time and directness in distance.

Directness in time

Directness at intersection level is, in the first instance, related to design speed. By using the correct curve radii the cyclist can perform a turn-off movement at the required speed. Directness in time also plays a role at intersections in routes that are used by large numbers of cyclists. Directness (preventing delays) can be achieved by giving cycle flows that travel via the intersection right of way where possible. Where this is not possible, the risk of waiting can be minimised by building a central traffic island on the road to be crossed for example, or by installing traffic lights with 'remote detection' on the cycle directions.

Crossability

The (quality of the) crossability of a road is determined by the waiting time, which in turn depends on the crossing distance and the intensity of the traffic flow to be crossed, or to be more precise, the gap distribution. The designer thus has a number of direct instruments at his disposal to influence crossability. Crossability can be improved by situating crossings at suitable places, realising short crossing lengths and using short waiting times (at TCSs).

The crossing time is the quotient of the crossing distance (m) and the speed of the crossing cyclist (m/s). Where appropriate the time that is required to get started is also included. In order to cross, the gap in the traffic flow to be crossed must be at least as great as (that is, last as long as) the required crossing time plus a certain safety margin. A Poisson-distributed traffic flow is usually assumed here, as this is the easiest method to describe processes. But it is also a known fact that in specific situations, (including heavy traffic and congestion) the arrival process occurs according to a different process, certainly within built-up areas.

With a balanced distribution of the traffic, the following is true for a Poisson-distributed traffic flow with 1x2 lanes:
- up to an intensity of 800 pcu/h, crossability is reasonable without a central traffic island;
- from 800 to approximately 1,600 pcu/h, crossability is reasonable provided crossings can be made in two stages;
- from 1,600 to approximately 2,000 pcu/h, crossability is moderate to poor;
- above 2,000 pcu/h, crossability is (very) poor.

A situation within a built-up area and a speed of 1 m/s for the cyclist is assumed here. When a cyclist comes riding up and does not have to stop or brake this speed will be significantly higher (approximately 5 m/s), improving the qualification somewhat.

For intersections in general, and for intersections that form part of a (main) cycle route in particular, the chance that the cyclist has to stop should be minimised. At the design level, the average and/or maximum delay time at the intersection applies as the criterion. This means that crossability (see text box) and, in the case of traffic lights, the cycle time of the traffic light regulation are subject to requirements, particularly with respect to the maximum waiting time for cyclists.

Directness in distance

It is important that at intersection level, cyclists are, wherever possible, able to follow the most direct route. Directness is threatened in situations where cycle tracks are bent (significantly) outward for example, or in a crossing controlled by traffic lights where traffic movements must occur in several stages.

6.2.2 Safety

Safety at intersections is a crucial issue for cyclists. This means that in principle, the safety requirements have priority in a design; naturally, other requirements are not ignored.

Avoiding conflicts with oncoming traffic

In the prevention of conflicts with oncoming traffic it is important that the road user recognises conflicting traffic flows and conflict points. The designer's task is to minimise the number of sub-conflicts. For this reason streamed cycle tracks, short cuts, unnecessary markings, and so on, are avoided as much as possible in the design. Particularly where bicycle facilities are concerned, the design is aimed at visibility; cyclists must be in the motorists' field of vision so that the latter can react to their presence in good time.

Avoiding conflicts with intersecting and crossing traffic

At intersections conflicts with intersecting traffic are unavoidable due to the interchange function. The design of an intersection, however, has a significant impact on the number and nature of the conflicts. Grade-separated facilities completely eliminate conflicts with intersecting and crossing traffic, but in most situations this is not a viable solution. If the interchange of traffic flows takes place at the same level, all traffic participants must be able to observe the intersection in good time (driving visibility); in addition, crossing traffic must have a good view of the traffic flow to be crossed (approach visibility). Crossing conflicts can be partially converted into (generally less serious) passing conflicts if an intersection is converted into a roundabout. At Y- or T-intersections, fewer crossing movements are possible than at four-way intersections. The former is preferred in terms of a safety.

Minimising and bundling sub-conflicts

It is beneficial to safety if the number of sub-conflicts is minimised and the cyclist is maximally within the motorists' field of vision. It is (partly) for that reason that T-intersections and bayonet intersections are preferred over full intersections. Roundabouts also score better than normal (four-way) intersections with regard to safety.

For the safety of cyclists on an intersection it is extremely important that they are noticed by the other traffic. For this reason it is recommended that on roads within built-up areas and estate access roads outside built-up areas separate cycle tracks are bent in 20 to 30 metres before an intersecting road (bending-in is defined as bending a separate cycle track toward the carriageway, with the distance between the cycle track and the side of the main carriageway measuring between 0 and 2 m).
If a separate cycle track is next to or a short distance from a main carriageway, this creates optimal conditions for a good view of the cyclists.

On district access roads outside of the built-up area, bending-in is not recommended. This is not because visibility is not so important there, but because, as a result of bending-in, traffic turning off does not have stacking space between the carriageway and the cycle track. On roads where cars drive at speeds in excess of 60 km/h, this could lead to serious conflicts, given the large differences in speed between through traffic and vehicles turning off.

Reducing speed at conflict points
Because a great many (crossing) conflicts are possible at an intersection it is recommended that the speed difference between the various types of traffic is minimised, based on the speed of the cyclist (20 to 30 km/h).

Avoid cyclists being forced off the road
This requirement places demands on the (rideability of) the road surface, curve radii and visibility. Evenness is especially important as far as rideability of the road surface is concerned. An uneven road surface with holes and bumps can lead to falls. During rain puddles will form on a road surface that is not smooth. When they freeze, this can force cyclists off the road, particularly on bends. Evenness is also clearly related to the main requirement of comfort; after all, cyclists have most pleasure in cycling on a smooth road surface.

Create recognisable road categories
Using a limited number of types of intersection when designing intersections can contribute to the recognisability of a road category. Road users are then better aware of the behaviour that is expected of them. Equality between road users is characteristic of intersections between estate access roads. Right of way is characteristic of roads with a district access function and for main cycle routes. Grade-separated crossing is often implemented on distributor roads.

Table 21. Requirements arising from Sustainable Safety with regard to visibility, clear layout, rideability and comprehensibility

		Relationship to			
	Requirements arising from sustainable safety with regard to intersections	visibility	clear layout	rideability	comprehensibility
1	avoid conflicts with intersecting and crossing traffic	x			x
2	minimise and bundle sub-conflicts		x		
3	reduce speed at conflict points				x
4	avoid cyclists being forced off the road	x	x	x	
5	ensure recognisable road categories				x
6	create uniform traffic situations wherever possible				x

Ensure uniform traffic situations
Uniformity of solutions is not required at the design level for intersections and it is also generally not possible. As stated for road sections, uniformity mainly relates to the application of (right of way) rules, signposts, marking and design principles. Uniform application of these types of elements results in an intersection design that is comprehensible to the road user.

In old design requirements [77], requirements were set for intersections in relation to visibility, clear layout, comprehensibility and rideability. Although these old design requirements are still relevant, they are no longer mentioned separately as they are integrated into the requirements pursuant to Sustainable Safety. If the safety principles of Sustainable Safety are complied with, the old intersection requirements are also met (see table 21).

6.2.3 Comfort
In terms of comfort, intersections should meet the following requirements.

Ensure a smooth road surface
The pavement of intersections must meet the requirements set for evenness. This is especially important for junctions between a main road and side roads.

Maximise ability of proceeding unhindered
It is comfortable for cyclists if they can view the road (or cycle track) to be crossed from as far away as possible so that they can cross it by

Table 22. Summary of the main requirements for intersections

Main requirement	Important aspects	Explanation
Directness	Directness in time	Directness in time concerns the design speed. It also relates to the prevention of delays. Delays can be limited by minimising the chance of stop (maximum rights of way) and by minimising the (risk of) waiting times (by using central traffic islands and good adjustment of the TCSs, for example).
	Directness in distance	Cyclists having to make illogical movements at intersections or being diverted around intersections must be avoided.
Safety	Risk of (serious) conflicts	The number of conflicts with motorised traffic is minimised. Where large speed and/or mass differences are involved crossing traffic movements are carried out at different levels. With same-level crossings, the speed differences are minimised. Where possible, conflicts are bundled so that an unambiguous situation is created. Cyclists are within the motorists' field of vision. The requirements for visibility and evenness are met. Design principles and basic principles are applied in a uniform manner appropriate to the function of the intersecting roads. Intersections are sufficiently visible, also in the dark.
Comfort	Evenness of the road surface	The paving is sufficiently smooth and different types of paving join each other correctly.
	Minimising delays	The risk of waiting is minimised (see delays under 'Directness').
	Passage	Curve radii take account of the design speed appropriate to the function concerned. Ongoing cyclists at intersections are not hindered by stationary cyclists or vehicles.

Table 22. Summary of the main requirements for intersections (continued)

Main requirement	Important aspects	Explanation
Comfort (continued)	Traffic nuisance	Cyclists are not subjected to nuisance from other traffic. In busy situations with substantial fume and noise emissions, a separate route is sought.
	Weather nuisance	Nuisance due to wind and rain is minimised.
Attractiveness	Social safety	Intersections meet the requirement of social safety: they are lit, there is supervision from the surrounding area, the surroundings are visible and the public space is well maintained. See section 7.5 for more information.

accelerating or slowing down if necessary and without stopping. However, this requirement is often not realistic, especially inside built-up areas, as this requires large visibility triangles and, consequently, a large amount of space.

Curve radii must also be sufficiently wide to enable cyclists to proceed across intersections unhindered. Bends are widened if necessary.

Being able to proceed unhindered also involves avoiding delays at intersections. That is why the risk of waiting and, where waiting is unavoidable, waiting times are to be minimised.

Minimise traffic nuisance
Traffic nuisance at intersections mostly concerns hindrance to through cycle traffic movements in the form of stationary cars or cyclists who have to give right of way to traffic on the main carriageway. This must be avoided as much as possible.

Minimise weather nuisance
Minimising nuisance from wind and rain is always a point of attention for the designer, although this will be very difficult to achieve at intersections. It may well be possible to use vegetation so as to minimise nuisance from the wind at least to a degree, without compromising safety.

The main requirement 'attractiveness' is hardly relevant at intersection level. The requirement of social safety, however, always applies. See section 7.5 in this respect.

The main requirements for intersections are summarised in table 22.

Table 23. Summary of intersection combinations

	Estate access road	Area access road	Solitary cycle track
Estate access road	§ 6.3.1	§ 6.3.2	§ 6.3.4
District access road	§ 6.3.2	§ 6.3.3	§ 6.3.5
Solitary cycle track	§ 6.3.4	§ 6.3.5	§ 6.3.6
Public transport carriageway	n/a	n/a	§ 6.3.7

6.3 Intersections by road type

Assuming two road categories for motorised traffic (estate access roads and district access roads), it is possible to distinguish between three different intersection combinations. If the crossing of a solitary cycle track is added, six situations can be distinguished. The intersection combination with a public transport carriageway creates a seventh possible situation. The combinations and the sub-section in which they are discussed are shown in table 23.

6.3.1 Estate access road - estate access road intersection

The basic principles for estate access roads inside built-up areas are that motorised traffic does not travel faster than 30 km/h and that all drivers are equal. Right of way is not regulated: drivers coming from the right have right of way. There is only one general exception to the rule of equality in residential areas inside built-up areas. This concerns the presence of main cycle routes and solitary bus carriageways. Right of way may be regulated in favour of these types of cycle routes and bus carriageways. In this respect, it is important that the design optimally supports the right of way; the introduction of a speed reduction measure is also recommended.

60 km/h road and 60 km/h zone

A situation still common nowadays is that the maximum speed of 60 km/h only applies to through roads in rural areas and not to an entire rural area. The reason behind this is that it is exactly on this type of road where speeding occurs and where problems arise. The connecting rural roads have a maximum speed of 80 km/h in that case. Because of the heavier traffic and the wider road profile, the 60 km/h roads normally have right of way, although that – taking the maximum speed into account – is actually illogical: a 60 km/h road that has priority over an 80 km/h road. In terms of the safety of cyclists, who generally use the same through routes, it is recommended that these right of way situations are continued unchanged until the entire area has been set up as a 60 km/h zone.

The design speed for estate access roads outside built-up areas is 60 km/h. As for right of way, the same rules apply in residential areas (60 km/h zone) as inside built-up areas. At equally ranked intersections, a speed of 60 km/h is, however, too high for the interchange to be considered safe. It is better to assume a design speed of 30 km/h at intersections for these roads, especially as the danger to cyclists occurs mainly at intersections.

Approach road with bicycle facility

The basic principle for estate access roads is that traffic is combined: cyclists and motorised vehicles use the same carriageway. But there are many examples of situations where a bicycle facility is still found in addition to an estate access road (see also the text box 'Informal right of way behaviour'). Inside built-up areas it is often the 'grey roads' that have bicycle facilities and outside built-up areas a bicycle facility is actually included in the recommendations for a type a estate access road. These roads have often had bicycle facilities for a long while.

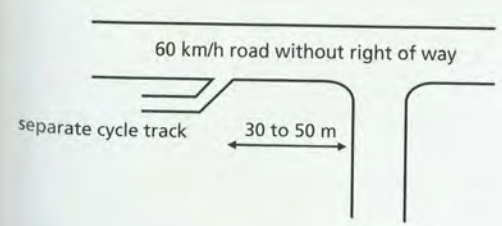


Figure 22. Principal of truncating cycle tracks

Informal right of way behaviour

Although the right of way on estate access roads is usually not regulated by means of signs, road users still demonstrate right-of-way behaviour in practice. Informal right-of-way behaviour is the result of an assumed division into a main road and a side road and often happens where there is a significant difference in the allure of both roads. This difference can be a result of:

- spatial characteristics (buildings, vegetation and suchlike);
- traffic characteristics (car and bicycle intensities);
- road characteristics (road profile, paving, design of intersection).

Informal right-of-way behaviour must be discouraged on roads where the basic principle is equality. This can be achieved by altering the road profile of the most important road and/or by modifying the design of the intersection. In addition, speed reduction measures that interrupt the through passage of traffic (taking right of way) can be considered. If the aforementioned measures are not successful or are not possible, the designer must consider bringing the statutory regulation into line with the informal situation by introducing a right of way provision.

If an approach road to an intersection without a right of way measure has a bicycle facility it is important that this bicycle facility is *not* continued across the intersection area. The use of cycle lanes or suggestion lanes could then create the impression of a priority road. In the case of separate cycle tracks, the continuation of the cycle track without an associated right of way provision conflicts with the requirement to bundle conflicts. In terms of safety, it is recommended that in this case the cycle track is truncated or bent-in 30 to 50 metres before the intersection.

6.3.2 District access road – estate access road intersection

Right of way is always regulated where district access roads cross. The basic principle here is that traffic on the district access road has right of way in relation to the traffic from the estate access road. Marking, signposting and design support this regulation.

Four prototypes can be distinguished for the combination of these types of roads:
- (same-level) right of way intersection, preferably designed as a T-intersection or (left) bayonet intersection, with or without additional measures (central traffic island, plateau);
- roundabout;
- intersection with traffic lights;
- grade-separated intersection.

The designer can use table 24 [34] to determine possible solutions. This table provides various solutions to the different situations; the correct choice depends on:
- the intensity on the estate access road;
- the intensity on the district access road;
- the function of the roads for bicycle traffic.

Table 24. Option table: district access road – estate access road intersection solutions

<table>
<tr><td rowspan="7">Section 1: district access road, with or without (main) cycle route</td><td></td><td colspan="4">Section 2: estate access road or solitary path</td></tr>
<tr><td></td><td colspan="3">I_{pcu} < 500 pcu/h</td><td>I_{pcu} > 450 pcu/h</td></tr>
<tr><td>hourly intensity</td><td>no cycle route</td><td>cycle route</td><td>main cycle route</td><td>all situations</td></tr>
<tr><td>1-1,000 pcu/h</td><td>right of way intersection</td><td></td><td rowspan="2">right of way intersection + supplementary measures or roundabout</td><td rowspan="3">roundabout</td></tr>
<tr><td>800 - 1,500 pcu/h</td><td colspan="2">right of way intersection + supplementary measures</td></tr>
<tr><td>1,200 - 1,750 pcu/h</td><td colspan="3">right of way intersection + supplementary measures, roundabout, intersection with TCS or grade-separated intersection (only for main cycle route where appropriate)</td></tr>
<tr><td>> 1,500 pcu/h</td><td colspan="3">intersection with TCS or grade-separated (only for main cycle route where appropriate)</td><td>roundabout, intersection with TCS or grade-separated solution</td></tr>
</table>

V 25, 26, 27

6.3.2.1 Right of way intersection, without supplementary measures

A normal intersection is built where a relatively quiet district access road meets an estate access road. A T-intersection is preferred over a full intersection. An alternative for a full intersection is the bayonet junction (two T-intersections a short distance from each other). Here, the left bayonet is preferred to the right. In a left bayonet cyclists can cross the traffic flows at right angles and - when mixing with the motorised traffic - they no longer need to weave. Moreover, in left bayonets, unlike in right bayonets, a frontal conflict is prevented. It is frontal conflicts in particular that must be avoided where possible.

From a legal perspective, cycle tracks are part of the carriageway. This means that, in principle, the same right of way rules apply to the cycle track as apply to the main carriageway.

Right of way must always be regulated, for example by signage or by using an exit construction. Strictly speaking, exit constructions do not regulate right of way but rather the passage. A driver coming out of an exit must allow all road users to pass. In terms of traffic safety, neither of the solutions is preferred. An advantage of the exit is that, apart from the right of way (passage) it also marks the entrance to a residential area (gate function) in situations where the side road is the entrance to such an area. A disadvantage is that an exit forms an obstacle to cyclists because of the height difference, and in certain weather conditions even presents a danger; the use of exit structures is, therefore, discouraged on (main) cycle routes.

If the main carriageway with right of way and a maximum speed up to 60 km/h has a one-way cycle track, it is recommended that this is bent in 20 to 30 metres before a side road. The result is that the cyclist comes optimally into the motorist's field of vision, which has a favourable effect on road safety. An additional effect is that a vehicle that is turning off (and any vehicles driving behind it) has to brake when a cyclist is present. This has a favourable effect on safety at the intersection and creates more possibilities for traffic from the side road to merge. A disadvantage can be that vehicles coming from the side road have to stop to give right of way and thus hinder the passage of cyclists going straight ahead on the cycle track. This disadvantage can, however, be limited by proper marking. Moreover, this problem can also arise if the cycle track is situated further from the road and more than one vehicle emerges from the side road.

Bending-in is not recommended on roads with a maximum speed of more than 60 km/h. The speed difference between vehicles turning off that are stopping because they have to wait for a cyclist, and through vehicles then becomes so great that a considerable risk arises of nose-to-tail accidents. For this type of situation, it is recommended that the cycle track near a side road is situated at least 5 to 7 m from the side of the main carriageway so that a vehicle leaving the main carriageway can stack between the carriageway and the cycle track.

6.3.2.2 Right of way intersection with supplementary measures

When designing intersections between a district access road and an estate access road with supplementary measures, a distinction is made between situations inside and outside built-up areas.

V 28 to 39 **Inside built-up areas**
Crossability at intersections with busier district access roads inside built-up areas can be improved if a central traffic island (≥ 2.5 m wide) is built on the main carriageway. Without a central traffic island, crossability becomes poor at intensities in excess of 800 pcu/h on the district access road.

Cycle tracks or lanes next to district access roads are bent in and continued across the intersection, so that there is no discontinuity for cyclists on the main carriageway. Where motor vehicle intensity in two directions exceeds approximately 1,200 pcu/h and with busy cycle routes next to district access roads, the stacking space for cyclists from the side road wishing to cross the district access road is a point of attention. In order to avoid crossing cyclists hindering cyclists going straight ahead, the cycle track can be built 2.0 to 2.5 m from the main carriageway in order to create some stacking space. That does, however, increase the risk of stationary vehicles on the side road blocking the passage of the cyclist going straight ahead. Given the vulnerability of cyclists at intersections, it is therefore recommended that the main requirement of safety is given priority over the directness of an unhindered passage for cyclists.

There are situations in which the side road (estate access road) is part of a main cycle route while the district access road is not. On main cycle routes, stringent requirements must be met with regard to flow and comfort of the cyclists. The aim must be to give right of way to the main cycle route. In situations as referred to above, this can only be achieved if the design of the intersection supports the required right of way regulation and if the intensity on the district access road to be crossed is not too high.

V 40, 41 The following conditions must be met to ensure that motorists on the district access road find the right of way regulation to be logical and respect it:

- The traffic flow from the side road is relatively large in comparison with that coming from the district access road. Lateral intensity is, for example, at least half the intensity on the district access road.

- The design of the intersection supports the (unexpected) right of way arrangement, for example by having the pavement of the estate access road continue and putting give-way road markings and block markings on the main cycle route, increasing the allure of the route in traffic engineering terms. The construction of a plateau and, possibly, a central traffic island is also very highly recommended.
- The right of way for the lateral direction (main cycle route) should preferably be supported by urban development and landscape elements, introducing the right of way situation as logical from a spatial perspective.
- If the district access road has cycle tracks, these should preferably transition into cycle lanes 20 to 30 metres before the intersection, so that cyclists can weave for a left turn and become more easily visible for motorists. If necessary, the entire plateau can be made of red asphalt, to emphasise that cyclists can be expected across the entire road width (weaving plateau).

V 28, 29, 30

Outside built-up areas

A central traffic island is desirable if the intensity of a district access road to be crossed outside built-up areas exceeds 350 pcu/h. If large numbers of cyclists cross, a speed reduction measure on the main carriageway can be considered in addition to the central traffic island.

Outside built-up areas the right of way on district access roads is *never* arranged in favour of the crossing main cycle route, as this type of measure does not fit in with the expectation pattern of the road users and could therefore lead to serious conflicts. Construction of a central traffic island of sufficient width (≥ 3.50 m) is always recommended for main cycle routes, both to increase motorists' attention level and to achieve an easier crossing with shorter waiting times. A central traffic island is sufficient up to an intensity of motorised traffic on the road to be crossed of approximately 800 pcu/h. In this case, the average maximum waiting time is 5 s for a necessary gap of approximately 6 s for crossing a single lane (based on a driving speed of 80 km/h). As mentioned, it is always preferable that the speed of the motorised traffic is lowered by additional speed reduction measures.

With a motorised vehicle intensity in excess of around 800 pcu/h, a district access road with only a central traffic island is no longer 'easily crossed', as the average waiting time is more than 5 s. The following options are available in this case:

- Accept a higher average waiting time. By way of illustration: with an intensity on the carriageway to be crossed of a total of 1,200 pcu/h, the average waiting time is 10 s when a central traffic island is used.
- Introduce a TCS or a controlled cycle crossing. This option applies up to an intensity of approximately 1,600 pcu/h on the carriageway to be crossed. The average waiting time will then be approximately 20 s. This is a reasonable waiting time at a controlled crossing.
- Construct a roundabout. Outside built-up areas (where cyclists on the roundabout never have right of way) the crossing situation is comparable with that of a central traffic island. However, an important advantage of the roundabout is that the speed of the motorised traffic is (considerably) lower, enabling the cyclist to better anticipate the vehicle flow to be crossed.
- Introduce a grade-separated cycle crossing. This reduces the waiting time to zero, but this solution is very expensive and often difficult to fit in the available space.

6.3.3 District access road - district access road intersection

Two crossing district access roads are equal from a functional perspective. If this is combined with the general basic principle for right of way, there are three options:

- roundabout;
- traffic control system (TCS);
- grade-separated solution.

Table 25 helps the designer to find the correct solution. Various considerations play a role when choosing between a roundabout, traffic lights and a grade-separated solution. In practice, the choice will generally be between a roundabout and a TCS. The individual solutions have many different safety consequences.

Table 25. Option table: district access road – district access road intersection solutions

Section 1: district access road, with or without (main) cycle route		Section 2: district access road, with or without cycle route ($I_2 \leq I_1$)			
		I_2 < 1,200 pcu/day			I_2 > 1,000 pcu/day
	hourly intensity (I_1) pcu/h	no cycle route	cycle route	main cycle route	all situations
	500 - 1,500		single lane roundabout		roundabout (if necessary with bypass or two-lane) or TCS
	1.200 - 1,750		roundabout (if necessary with bypass or two-lane) or TCS		(multi-lane) roundabout with cycle tunnel in busiest lateral direction (or TCS)
	> 1,500		(multi-lane) roundabout or TCS	(multi-lane) roundabout with cycle tunnel in busiest lateral direction (or TCS)	TCS or grade-separated

Many accidents occur at full (four-branch) intersections with traffic lights (field of application approximately 10,000 to well over 30,000 pcu/day); in terms of safety their use here should actually be avoided. The remaining types of intersection overlap to a significant degree in relation to accident levels in the field of application between 3,000 and 8,000 pcu/day, so that from a safety perspective no preference can be given to any one of these solutions. Between 10,000 and 20,000 pcu/day, four-branch roundabouts are safer than four-branch intersections with traffic lights.

V 42, 43, 44

6.3.3.1 Roundabout

The roundabout is a solution that is now used on a large scale. This is with good reason, as a roundabout offers various advantages. A roundabout:

- avoids encounters between motor vehicles driving in opposite directions
- simplifies conflict situations
- ensures low speeds at conflict points.

These characteristics make a roundabout a safe solution. In combination with the large capacity and the relatively quick flow, the roundabout is very suitable for intersecting district access roads.

The single-lane roundabout is the safest type of intersection. Two-lane roundabouts also achieve a high but slightly lower score due to the increased complexity of the traffic situation compared to single-lane roundabouts. Two-lane roundabouts are safer than intersections with a traffic control system (TCS) and almost just as safe as a grade-separated intersection outside built-up areas.

Number of lanes

The number of lanes is particularly important to the capacity. Single-lane roundabouts can handle 2,000 to 2,400 pcu/h. The precise capacity depends on such factors as the distribution of the volume of traffic, the proportion of left-turn movements and the right of way regulation for bicycle traffic [35]. For greater traffic volumes, two-lane roundabouts are appropriate; they can handle capacities up to approximately 4,000 pcu/h. The approach roads to the roundabout are single-lane or two-lane, depending on the volume of traffic. In view of the safety of cyclists, the exits should preferably be single-lane. Two-lane exits must *never* be used if cyclists with right of way cross the exit.

Facilities for bicycle traffic

At relatively quiet roundabouts, up to approximately 6,000 pcu/day, facilities for cyclists are not required, but are possible if this creates a better fit with the connecting roads. In that case, a separate cycle track is preferable. On busier roundabouts, the use of a separate cycle track is recommended. Cycle lanes are not recommended on roundabouts. Drivers of lorries turning off in particular have too restricted a view of cyclists and moped riders riding alongside them because of their blind spot. In addition, the following points of attention apply to bicycle facilities:

- the design of the cycle track must stimulate the attentiveness of cyclists;
- the location where cyclists cross the carriageway must be sufficiently clear and conspicuous;
- cyclists must be clearly visible near the location where they cross the carriageway.

On roundabouts inside built-up areas, it is recommended that cyclists on separate paths continue to have right of way. After all, this corresponds with a cyclist-friendly policy. The design of the cycle tracks around the roundabouts must be tailored to the right of way regulation. Outside the built-up area, cyclists have their own separate cycle track without right of way [36].

V 45, 46 The design of bicycle facilities requires extra attention if the volume of traffic on sections of a roundabout necessitates a two-lane roundabout. The most elegant solution is to use grade separation, where a lowered cycle track in combination with an elevated carriageway is the preferred option. If necessary, simply a tunnel can be used on the main cycle route. Cyclists on the side roads can then – depending on the intensities – cross at the same level, provided this involves a single-lane exit; the cycle track should preferably be built on a plateau.

Two-way tracks on a roundabout are avoided whenever possible, because drivers of motorised vehicles do not expect cyclists from unexpected (opposite) directions. If a two-way cycle track is nonetheless used on a roundabout, elevating the cycle track to lead it over the approaches and exits is highly recommended, using the design, marking and signposting to draw maximum attention from the road users to the cyclists coming from two directions. Implementing cycle/moped tracks in two directions with right of way is not recommended.

Roundabout with bypass
The single-lane roundabout with one or more bypasses could be an alternative to the two-lane roundabout. The speed on the roundabout can be controlled better, motorists do not have to weave on the roundabout and the approaches and exits can be designed as single lanes. However, little practical experience has been gained with roundabouts with bypasses. It does appear that with a bypass, cyclists often have to relinquish their right of way, which in effect means the flow and safety of the motorised traffic would be at the expense of the flow of the cyclists. This is contrary to a bicycle-friendly policy. If a bypass is introduced for motorised traffic and this bypass crosses a cycle track, the following applies:

- the speed of the motorised traffic at the cycle crossing must be low (approximately 30 km/h);
- cyclists and motorists must be able to detect each other in good time, which sets requirements for the angle at which both flows cross each other.

6.3.3.2 Traffic lights
Traffic lights are usually installed to guarantee the quick and safe flow of motorised traffic; on district access roads this will involve intersections where between 10,000 and 30,000 pcu/day have to be handled. Traffic lights are a less (sustainably) safe solution than roundabouts or grade-separated intersections and must therefore be regarded as second best in terms of safety.

As motorised traffic is generally most dominant on intersections controlled by traffic lights, control engineers will concentrate mainly on motorised traffic. This means that the time available for slow traffic is often limited at intersections with traffic lights. The combination of short green light times for cycle and pedestrian traffic and the long time that is necessary to process motorised traffic result in long waiting times for slow traffic. This is, however, generally not necessary. Research on behalf of the Dutch Bicycle Council [37] has shown that cyclists not only regularly wait for long periods, but that this is often unnecessary; there are measures to prevent this.

The following sections first discuss the criteria and design requirements for traffic lights. After this, process and policy matters important for bicycle-friendly traffic provisions are addressed. Finally, control technology options for improving the position of bicycle traffic in traffic provisions are examined.

Criteria and design requirements
The location criteria, flow capacity, the average and the maximum waiting time, the chance of stop/chance of proceeding and the premises in relation to sub-conflicts and a combined flow are all significant.

Location of traffic lights
It is outside the scope of this Design manual to discuss the criteria for positioning traffic lights in great detail. Only the considerations from the point of view of the bicycle as a means of transport are addressed. In the interest of the bicycle, traffic lights can be considered with a view to safety and flow of bicycle traffic. Safety is an issue particularly on intersections and crossings: traffic lights can be considered if the volume and/or speed of the traffic flow to be crossed is so great as to hinder cyclists; but only if it has become apparent that other measures (including construction of a roundabout) are not feasible.

The flow could also be a reason for installing traffic lights, particularly in situations where a main cycle route crosses a busy district access road. On such intersections, cyclists should preferably have right of way over the motorised traffic. If this right of way does not appear logical to the road users and is therefore not (adequately) respected, traffic lights can support this right of way situation.

Flow capacity
The flow capacity of cycle tracks is high: approximately 3,300 cyclists per hour for a width of 1.00 m and approximately 4,700 cyclists per hour for a width of 1.80 m. This means that delays for cyclists only occur as a result of queues and saturation due to very high bicycle intensities.

Waiting time and chance of stop
The terms waiting time and chance of stop/possibility of proceeding (for the cyclist) are of great significance for assessing the bicycle-friendliness of traffic control systems. Waiting for traffic lights appears to be the most significant source of delay, certainly in the larger cities [50]. Stopping leads to braking and accelerating again, with inevitable loss of energy and discomfort.

The *chance of stop* is determined by the total number of times that a cyclist has to stop at a traffic light. In a fixed provision, the chance of stop is easy to determine: the red-light time is divided by the cycle time. In a non-fixed provision the chance of stop can be calculated by dividing the total red-light time in a (representative) observation period by the total length of the observation period.

When it is still necessary to stop, the *waiting time* is a significant measure for bicycle-friendliness. Both the average and the maximum waiting time are significant here. When a cyclist has to stop for a red light, the waiting time is determined by the red-light time and the moment during the red-light phase at which the cyclist arrives. The average (for all arrivals) is the average waiting time on stopping. This is the waiting time as experienced by cyclists. The average waiting time for a fixed provision is simply half the red-light time; the calculation is somewhat more complicated for a non-fixed provision[1]. The maximum waiting time is simply the maximum red-light time.

The (mathematical) average waiting time is shorter than the waiting time on stopping, because in the mathematical average waiting time regards the times that cyclists can continue because of a green light as a waiting time of zero seconds. Rational policy chiefly attempts to minimise the average waiting time. The following formula always applies here:
average waiting time = chance of stop • average waiting time on stopping

The average waiting time can, therefore, be improved by reducing the chance of stop and/or reducing the waiting time on stopping (the red-light time). An average waiting time of less than 15 s can be called good, while one of more than 20 s is poor. Times between these are considered average. The associated values for chance of stop and waiting time on stopping are shown in figure 23.

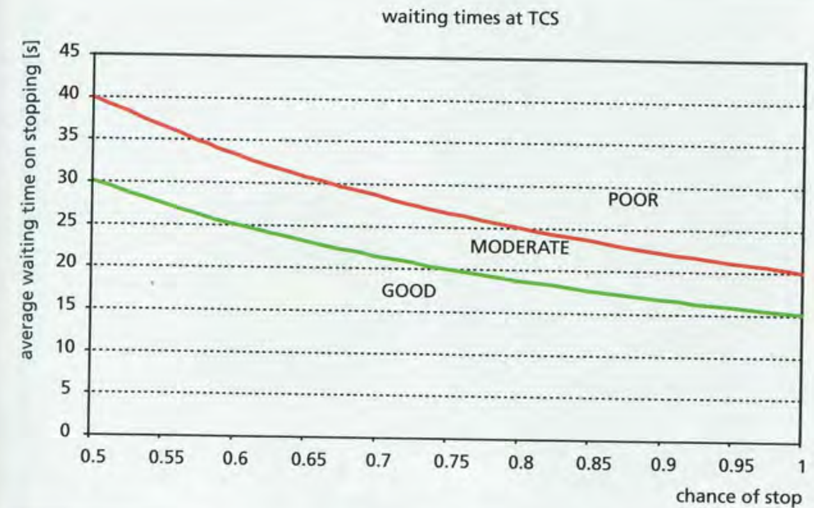


Figure 23. Relationship between chance of stop and average waiting time at traffic lights.

1 The following applies for a non-fixed cycle:

Average waiting time on stopping = $\frac{1}{2}\frac{\langle R^2\rangle}{\langle R\rangle}$

Where < > represents average.

This value is not equal to, but always greater than half the average red-light time.
Example: if the successive red-light times are alternately 10 and 20 seconds, then the average waiting time on stopping is 8.33 seconds (and not 7.5 seconds).

The aforementioned waiting times at traffic light provisions are, in almost all cases, longer than the waiting times when crossing main roads without traffic light provisions. From the perspective of (the directness for) the cyclist, the construction of a traffic lights control system (TCS) is hardly ever a good idea. An advantage of a TCS is, however, that the maximum waiting time is limited. This is not the case when crossing main roads (without TCS), where cyclists may have to wait four times as long as the average waiting time when it is very busy. Consequently, cyclists accept somewhat longer (average) waiting times at traffic lights. But there is a limit: maximum waiting times in excess of 90 to 100 s are not credible. The following waiting times are therefore recommended as the maximum (regardless of the type of provision, such as traffic dependent, VETAG, etcetera) :

- inside built-up areas: maximum waiting time < 90 s
- outside built-up areas: maximum waiting time < 100 s

Cycle time

The waiting time for cyclists is also connected to the cycle time of a traffic lights control system. Research at 24 intersections in provincial capitals [37] has proven that green light times for motorised traffic at many intersections are set too long 'as a precaution'. In many cases it proved possible to set a shorter cycle time, which not only improved the flow of bicycle traffic, but also that of other vehicle types. The following applies to bicycle-friendly control: the shorter the cycle time the better, but preferably not longer than 90 s. The generally accepted time of 120 s for motorised traffic is therefore too long for cyclists.

Sub-conflicts between motor vehicle and bicycle

It may be desirable for a number of reasons to permit sub-conflicts between motor vehicles and bicycles in a situation with traffic lights, for example to reduce waiting times or due to lack of space. Such sub-conflicts must only be permitted between cyclists continuing straight on and motor vehicles turning off from the parallel traffic flow (or vice versa). Good visibility of cyclists is of vital importance here.

Sub-conflicts between motor vehicles and bicycles are not recommended if:

- the intensity of motorised traffic turning off is higher than 150 pcu/h
- a two-way cycle track is involved, as some of the cyclists will then appear from an unexpected direction
- it concerns a situation outside built-up areas where the speeds are higher and cyclists are less dominant in the roadscape (which means that they are more easily overlooked)
- a lot of lorries are turning right (because of the risk of a blind spot accident).

Cycle track, cycle lane or combine cyclists with other traffic?

Three main movements can be distinguished for cyclists at an intersection: they turn right, they ride straight on, or they turn left. The choice of type of bicycle facility on a controlled intersection depends on the bicycle facilities present on the approach roads, the existence of sub-conflicts and the motorised traffic intensities that occur.

Figure 24.
Basic principle of 'right turn past red'

V 47, 48 **Cyclists turn right**

At an intersection with traffic lights, delays for cyclists turning right can be limited by leading these cyclists around the provision (right turn past red) or if necessary by permitting 'right turn through red'. In that case, cyclists turning right must not be hindered by cyclists riding straight ahead (and vice versa). Attention must also be paid to cyclists merging (use protected area, if necessary).

V 49 If neither 'right turn past red' or 'right turn through red' are possible then the stacking space for the cyclists is important. Cyclists who are stacked in front of a red light with the intention of turning right must not hinder cyclists proceeding straight ahead or turning left. To increase the flexibility of the provision, it may be desirable for cyclists turning right to be allocated their own signal group. In that case it is desirable that they have their own stacking lane.

V 50 **Cycles ride straight on**

With a combined profile and in the absence of cycle lanes on the approach road, cyclists riding straight on can flow parallel to the motorised traffic. It can be advisable to construct a streamed cycle track or streamed cycle lane, so that cyclists can pass waiting cars. It is also possible to give cyclists riding straight on their own green phase. In that case, in a combined profile, it is recommended that a streamed cycle track or a bicycle stacking lane is introduced. It is important that cyclists remain within the motorists' field of vision. If the cyclist flow is directed via a cycle track there are options for cyclists riding straight on to flow with other, non-conflicting, signal groups. This offers more possibilities for the bicycle-friendliness of a controlled intersection.

V 51, 52, 53 **Cyclists turn left**

Cyclists turning left often draw the short straw in a traffic control situation, especially when, in the case of separate cycle tracks, turning left is considered as two different movements. The waiting time can be shortened considerably if this manoeuvre is regarded as a through movement. Where there is a combined profile (with a relatively low motorised vehicle intensity on the approach roads) an ECSL can be built (fewer than 500 pcu/h on a section or 800 pcu/h on an intersection). An ECSL should preferably be combined with central traffic islands so that a physically protected stacking facility for bicycles is created on the approach roads. Lights

on green for all directions simultaneously for cyclists can also be a good solution where there are large numbers of cyclists turning left.

Maximum waiting time for motorised traffic

Naturally, the criteria for the flow of motorised traffic should also be considered together with the criteria and design requirements for bicycle-friendly traffic control systems. The quality requirements for motorised traffic also determine the options of shortening waiting times for bicycle traffic. In general, an average waiting time of 60 s and a maximum waiting time of 120 s is used for motorised traffic.

Policy and management

One of the most significant improvement options for bicycle traffic in traffic lights control systems is at the level of policy development, or more concretely, in the formulation of clear basic policy principles. Experience has shown that many traffic light provisions are created by a traffic control engineer with a large degree of independence. Taking account of the interests of all traffic participants and based on their own knowledge and expertise, engineers create a traffic control system that is always a 'compromise' [38]. Such an approach means that the control engineer has a significant influence on traffic policy of the road management authority concerned.

In order to avoid this, but also so as not to leave such dilemmas to the engineer during the design process, road management authorities responsible for various traffic control systems should develop 'TCS policy'. This should state what priorities are assigned to the various categories of traffic participants in the various road situations. A basic principle that can be applied is that (sections with) main cycle routes have right of way at intersections inside the built-up area. It is also possible to indicate maximum values for waiting times or cycle times. If such basic principles are recorded in administrative regulations, the control engineer has very clear goals, which can also be tested easily.

In many situations, current practice often results in unnecessary and unnecessarily long waiting times for cyclists, without this having any basis in policy. Research [37] has shown that at almost all intersections where waiting times for cyclists were judged to be unacceptable this was the result of priority for other traffic (green waves or priority to public transport); in most cases, this was not based on adopted policy.

Another important measure is carrying out regular maintenance of the control system. Once a traffic control system 'is up and running', it is all too often neglected. Carrying out regular maintenance and checking on the street to see whether specifications are still satisfactory helps to ensure that a system is optimally adjusted to the traffic situation.

V 54 to 67, 76, 77

Options for bicycle-friendly provisions

The facility sheets of this Design Manual contain many measures to improve the situation for cyclists at intersections with traffic lights. A large number of these measures concern shortening the waiting time for cyclists. A minimum waiting time is essential for bicycle-friendly control. The various measures can be implemented individually, but often also in combination (see table 26). The effects of the various options can differ from situation to situation. Consequently, every situation must be thoroughly analysed to determine the most appropriate measures.

Table 26. Possible combinations of bicycle-friendly measures at traffic lights

Number	Measure	Can be combined with number(s)
1	shorten cycle time	2-16
2	include additional green light options for cyclists	1, 3, 4, 7-9, 11-16
3	permit right turn through red	1, 2, 3-11, 14, 15, 16
4	give all cycling directions a green light at the same time	1, 2, 3, 10-13, 15
5	accept motorised vehicle/ bicycle sub-conflicts	1, 3, 7-9, 11-13
6	set favourable standby time for cyclists	1, 3, 4, 9, 11-13, 15, 16
7	increase cycling directions with priority along with public transport	1, 2, 3, 5, 8, 9, 11-16
8	increase cycling directions with priority along with other directions	1, 2, 3, 5, 7, 9, 11-16
9	set favourable phase sequence for cyclists turning left	1, 2, 3, 5, 7, 8, 10-13, 15, 16
10	set green wave for bicycle traffic	1, 3, 4, 5, 9, 11-16
11	keep mutual conflicts between slow traffic outside of the control	all measures
12	implement right turn through red	all measures, except 3
13	introduce long distance detection/pre-request for cycle traffic	all measures
14	introduce ECSL	all measures, except 6, 7, 8,
15	increase flow capacity for motorised traffic	all measures, except 5
16	set two-way green light	all measures, except 4, 5, 14

V 68, 69, 70

6.3.3.3 Grade-separated solution

Grade-separated facilities are advisable or necessary when other intersection solutions cannot meet the design requirements in relation to directness and safety. This does not only apply to main cycle routes, but to the basic network as well - particularly for parts of a basic network that intersect (busy) district access roads or district access roads with a maximum speed of 70 km/h or higher. However, there will often not be enough space for a grade-separated solution. In that case, safe crossing can only be realised if the speed differences are reduced or if the volume and direction differences are separated in time using traffic lights.

Bridge or tunnel?
Once it has been decided to build a grade-separated intersection for bicycle traffic, there is choice between a tunnel and a bridge. The possible advantages and disadvantages of both alternatives are shown in table 27.

Table 27. Bridge versus tunnel

Aspect	Bridge	Tunnel	Explanation
Bridging		+	In tunnels, there is a descent first. This height difference builds up speed that helps the cyclist ride uphill.
		+	With a tunnel the height difference to be bridged is smaller than with a bridge, as the headroom required for cyclists is smaller than that for lorries/cars.
Social safety	+		A tunnel often gives users a somewhat uneasy feeling, as the surroundings do not give sight of what is happening in the tunnel. A bridge is in open space and therefore has more options in regard to supervision and view.
	+		A tunnel can cause cyclists to feel claustrophobic, especially when the tunnel is long, bends and/or is narrow. This is not a factor with a bridge.
	+		A tunnel is much more attractive for graffiti and for young people to loiter in than a bridge.
Spatial fit		+	In terms of landscape or urban development a tunnel may have many advantages over a bridge. A tunnel has a less drastic influence on the surroundings: the incline can be shorter than that of a bridge (because of the smaller height difference) and it is, in addition, below surface level.
	+		A bridge offers the option of an architecturally pleasing solution. Far more more so than with a tunnel, a bridge can be developed as a special and recognisable object.

Table 27. Bridge versus tunnel (continued)

Aspect	Bridge	Tunnel	Explanation
Comfort		+	In a tunnel, a cyclist suffers less wind nuisance than on a bridge and, if necessary, cyclists can shelter in a tunnel.
		+	A narrow, high and long (cycle) bridge can cause fear of heights in cyclists.
			The height difference in a tunnel is usually limited (certainly in a semi-buried location).
Costs	+		A bridge is generally cheaper than a tunnel, certainly as measures have to be taken in connection with the groundwater.
Other		+	Cycle and pedestrian tunnels in rural areas can also fulfil a function for (smaller) animals. A landscape policy that provides for the defragmentation of forest areas and nature reserves gives rise to a need for fauna passages. Sometimes these can be combined with tunnels for (recreational) bicycle traffic. In that case, it may be desirable to build an unpaved lane in the tunnel with a width of approximately 2 m.

The importance that must assigned to the advantages and disadvantages of a tunnel or bridge depends mainly on the characteristics of the surroundings and the exact design of the grade-separated intersection. The social safety argument, for example, will be less important in an environment where a lot of activity is taking place than in an isolated area.

The ideal solution for the cyclist is to have cars, not bicycles, bridge the height difference. If cyclists remain at ground level and motor vehicles are led through a tunnel, cyclists are not hindered by the intersection at all. If this is not possible, an alternative is to construct the road to be crossed a little below the surface. This also reduces the height difference that a cyclist has to overcome in the case of a bridge. Naturally the road can also be slightly 'elevated' so that a cycle tunnel needs to be built less deep and it is therefore easier to survey the situation.

Special solutions

The use of grade-separated intersections for bicycle traffic is often limited to a cycle tunnel or cycle bridge for crossing a main road, possibly combined with a nearby level intersection for motorised traffic. Cycle bridges or cycle tunnels are generally not built if an intersection is to accommodate a multitude of cycle movements. The fact that grade-separated intersection in situations like these are possible is shown in the Berenkuil in the city of Utrecht, for example. This solution comprises a semi-elevated major roundabout with traffic lights over which motorised traffic flows, while bicycle traffic can ride through semi-buried, short tunnels under the roundabout road sections to the open space in the middle of the roundabout.

Bicycle lifts, escalators and ramps

A bridge or tunnel almost always involves a height difference that must be bridged while cycling. Cycle lifts or escalators/stairs are sometimes used as a 'stopgap measure' for large height differences (such as a bridge over a major waterway). But this can only be a supplementary measure, as not everyone is comfortable using a lift or escalator. An alternative

Table 28. Recommendations for the design of cycle tunnels

Environment and fit

1 Assuming there is a need to cross, a tunnel is preferably built in an area with a lot of social activity, where you can consequently expect plenty of people. If possible and worthwhile, the cycle tunnel should preferably be combined with a function for pedestrians. In that case, cyclists and pedestrians are each given their own space.

2 In connection with supervision, openness and cycling comfort, a semi-buried location is preferred, with the road connection to be crossed 'elevated' approximately 2 m. The structure can be designed as a viaduct in the road. If, moreover, the road to be crossed has been designed with separate lanes, an open structure is created through which light can also enter.

3 The path of the cycle route is as straight as possible to offer sufficient perspective. Sufficient perspective means that the exit of the tunnel is visible upon entering the tunnel (so no bends in a tunnel).

4 The slopes on either side of the tunnel entrances are not too steep (maximum 1 : 1). This reduces the feeling of being cooped up.

5 No high vegetation is used at the entrance to the tunnel, so that attackers are not given the opportunity to hide there.

Design of the structure (tunnel)

6 Tunnels should be as short as possible. Not only because this makes them more surveyable but also because daylight has more chance in a short tunnel than a long tunnel. Naturally, this also means that the length of time the cyclist is in the tunnel is shorter.

7 The tunnel offers no opportunities to hide there so there are no recesses or blind spots.

8 The walls of a tunnel recede to the top.

9 The minimum height of a cycle tunnel is 2.50 m.

10 A balanced relationship between width and height is desired. As a guideline the width should be at least 1.5 times the height. A tunnel entrance where the height dimension clearly exceeds the width dimension gives the observer the impression of narrowness and can therefore be found oppressive. Conversely, tunnels that are very broad in relation to their height give users the feeling that they may bump their head.

11 The tunnel floor has a lateral slope of 1 to 2% to drain rainwater quickly.

Tunnel furnishings

12 Tunnels must be well lit. Both road safety and social safety require that tunnels are not noticeably darker than it is outside.

Table 28. Recommendations for the design of cycle tunnels (continued)

13 In the evening, the transition from outside to inside of the tunnel (and vice versa) must be even. This means that there should be lighting outside the tunnel too, so that the cyclist can adjust to the changing light intensity.

14 In addition to the intensity of the light, the colour of tunnel walls is also important: light, friendly colours have a more favourable effect on subjective social safety than drab and cold colours. A colour change from dark at the ends to light in the middle of the tunnel results in better subjective social safety.

15 In order to prevent vandalism it is recommended that the light fittings are sunk into the wall or ceiling wherever possible. It is also important to ensure that damaged light fittings can be repaired or replaced quickly and easily.

16 Drainage requires careful design. Rubbish such as leaves and paper often remains lying at the transition from the incline to the tunnel floor. A tunnel must therefore be quick and easy to sweep clean.

could be found in moving ramps (travelator). The spiral ramp can be an alternative for situations that lack the space for a 'normal' ramp.

Socially safe tunnel solutions

The following basic premises are used for the design of a socially safe, bicycle-friendly tunnel (see also chapter 7):

- optimum visibility from the surroundings
- the design minimises the length of time cyclists remain in the tunnel
- the design counters any feeling of being cooped up as far as possible
- the design, lighting and colour scheme ensure an 'open appearance'.

These premises lead to the design guidelines as shown in table 28.

6.3.4 Estate access road - solitary cycle track intersection

Since the introduction of the 'cyclists from the right have right of way' measure, intersections of solitary cycle tracks with estate access roads are subject to the same right of way stipulations as intersections between two estate access roads (all drivers from the right have right of way). Both types of intersection can be addressed in the same way. However, the design of intersections with solitary cycle tracks requires special attention, because informal right-of-way behaviour easily develops here (see the text box in section 6.3.1). More specifically: if drivers on the estate access road 'fail to notice' the solitary cycle track (unwittingly), they are unlikely to give right of way to crossing cyclists. Where there is a real possibility of this type of behaviour, measures should be taken to guarantee visibility and equality. If the solitary cycle track is a main cycle route the track could have right of way over the estate access road to be crossed. See section 6.3.1 for the measures to be taken in this case.

6.3.5 District access road - solitary cycle track intersection

Intersections between solitary cycle tracks and district access roads are to be addressed in the same way as intersections between estate access roads and district access roads. In principle, traffic on the district access road has right of way. See table 24 for the measures to be applied.

There is only one exception as far as right of way is concerned. If the solitary cycle track is a main cycle route and the intersection with the district access road is located *inside* the built-up area, the main cycle route may, under certain conditions, have right of way. These conditions are that the design must take into account any informal right-of-way behaviour and that the safety of the crossing cyclists is effectively guaranteed (low speed of motorised traffic). See section 6.3.2 for a more detailed explanation. *Outside* built-up areas, right of way for a solitary cycle track is never acceptable on an intersection with a district access road; in that case crossing cyclists will always have to give right of way to motorised traffic.

6.3.6 Solitary cycle track - solitary cycle track intersection

An intersection between two solitary cycle tracks can be considered an intersection between two estate access roads. One difference in relation to 'normal' estate access roads is that there are no large differences in mass between the traffic participants. Therefore there is little reason to lower the speed and a normal T-junction or a full intersection will suffice. For intersections with one or two cycle (and moped) tracks it may be advisable to reduce the speed because of the mopeds.

As with estate access roads, the basic principle is equality of the intersecting roads. This means that in theory, no right of way regulation is necessary. Only if one of the routes is a main cycle route can right of way be considered in favour of the cyclists on this connection. The design of the intersection should be adjusted for this, by using small traffic islands on the subordinate cycle tracks, for example. Consideration can also be given to realising two T-junctions instead of a four-branch intersection. This will emphasise the difference in function and the right of way regulation. Such a solution is, however, only acceptable if it does not jeopardise the design requirements in relation to directness.

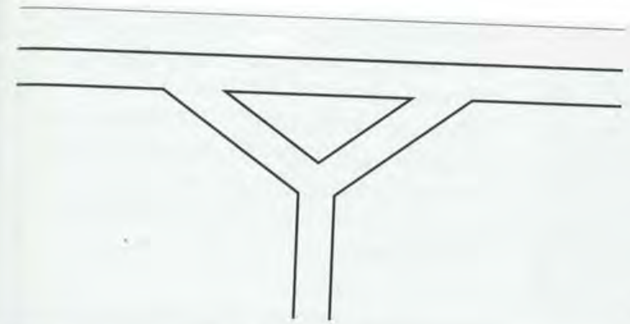


Figure 25. Principle of a triangular junction

If the intersection involves two main cycle routes, a bicycle roundabout can be considered. A triangular junction (see figure 25) is also a solution for this.

6.3.7 Public transport carriageway – solitary cycle track intersection

At intersections between a solitary cycle track and a public transport carriageway a distinction can be made between intersections with a bus carriageway, a tramway or a railway line.

6.3.7.1 Bus carriageway

As far as traffic characteristics are concerned, a bus carriageway can best be compared with a district access road with a (very) low intensity. This means that the solutions mentioned in section 6.3.2 apply.

A high concentration of slow-traffic crossings of a public transport carriageway generally signifies a cycle route or main cycle route. In both cases a (wide) central traffic island in the bus carriageway is recommended for cyclists crossing the road, in combination with a speed reducer for the bus. A right of way intersection is recommended for main cycle routes, with a wide central traffic island in the bus carriageway, a speed reducer and right of way for the cycle route. If intensive and fast public transport is using the public transport carriageway,

supplementary traffic lights can be used, with favourable control for bicycle traffic.

If right of way for bicycles is not appropriate in the interest of the bus route, a grade-separated intersection or a traffic lights control system can guarantee the safety and flow of cyclists. At traffic lights, the method of control then becomes a point of attention. As mentioned earlier, priority is often given to public transport without good reason to do so. However, it is recommended that the interests of both groups be taken into account and that control is organised on that basis. Good detection is essential as it can help limit the waiting time for both groups. Especially when the standby green light control is set for the main cycle route, a favourable crossing situation is created for bicycle traffic.

6.3.7.2 Tramway

For a separate tramway, the type of the crossing (with a solitary cycle track) depends on the speed of the tram. The braking distance of a tram is considerably longer than that of a car. Only if the tram travels faster than approximately 20 km/h at conflict points can the same solutions be used as on an intersection between a solitary cycle track and a 'normal' district access road (table 24) or a bus carriageway (see section 6.3.7.1). If tram speed is higher, the requirement of 'low speed at conflict points' cannot be met, which means that safety is not adequately guaranteed. The crossing should in that case be controlled by means of traffic lights.

What makes situations surrounding tramways special is that the tramways are often situated between or next to the carriageways for motorised traffic and that trams can appear from various directions, including from directions that are not permitted for other traffic. This complicates the design of an intersection, making it difficult to meet the basic requirement of a clear layout. Extra safeguarding of the crossing is advisable in such complex situations. A 'standard' traffic lights control system can be chosen or a warning system that has been specially developed for the tramway (or bus carriageway). 'Tram lights' are often used at intersections with a separate (fast) tramway. They consist of a warning light containing a tram symbol; the light starts to flash when a tram is approaching.

In a bicycle-friendly design, the cycle route has right of way at intersections between main cycle routes and separate tramways. However, because tramways often fulfil an important function in the public transport network, the interests of flow of cyclists and the tram can be at odds. In that case, the preferred solution is a grade-separated intersection. But as remarked earlier, this is often not feasible. The appropriate solution in that case is a level intersection equipped with a traffic lights control system, preferably with a standby green light control for cyclists and a green-light-on-request for the tram (and/or bus).

The angle between the tram rails and the cyclists' riding line is important at intersections between tramways and solitary cycle tracks. This angle should be as square as possible to avoid cyclists getting a wheel caught in a rail. A minimum angle of approximately 45 degrees can be used as a guideline, but larger angles are, of course, preferred.

6.3.7.3 Railway crossings

The absolute priority of the train on railways is not open to discussion. At each passage of a train – be it an intercity or a single locomotive – all other road users will have to give right of way as the railway barriers close. If a main cycle route crosses a railway line, this is preferably done at different levels, so that cyclists are not delayed as a result of railway traffic.

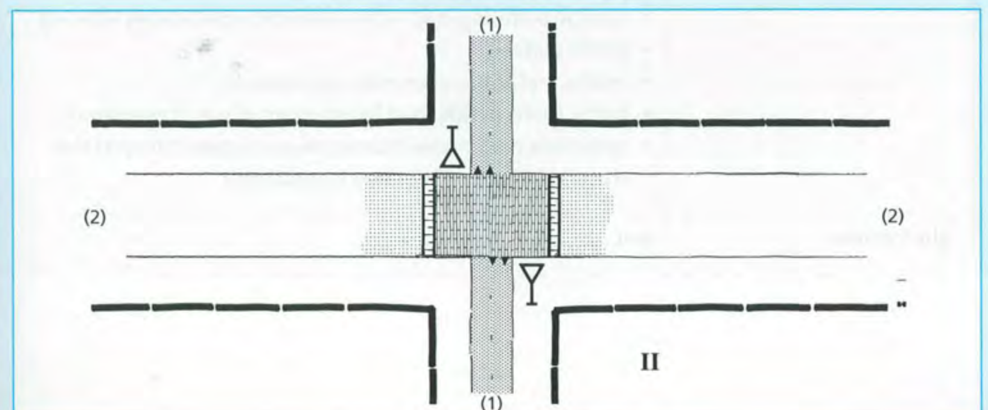
For other cycle routes, if grade-separated crossing is not possible, the railway crossing should always be equipped with automatic half barriers (AHBs). On school routes in particular, railway crossings without (half) barriers are potential hazard points. Unguarded railway crossings on bicycle connections are

not recommended; automatic flashing light systems (AFLs) should be installed as a minimum. This does not mean, however, that crossings that do not have these facilities should simply be closed. It is exactly this preservation of sufficient railway crossings that is of great importance to the cyclist, especially in terms of cohesion and directness.

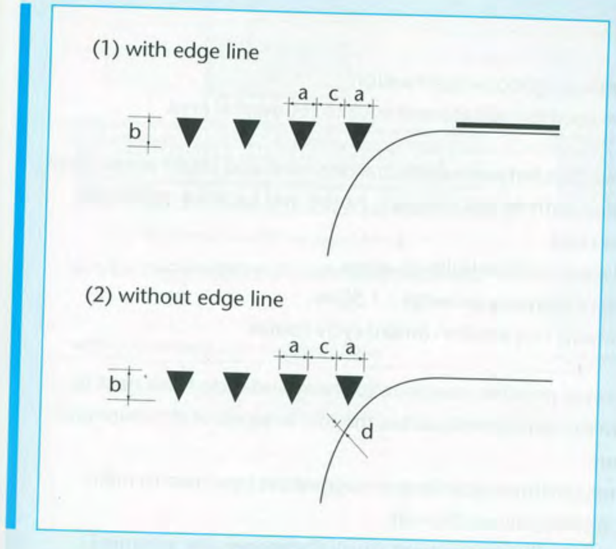
At intersections between cycle connections and railways the angle between the rails and riding line of the cyclists is as square as possible to prevent bicycle wheels getting caught between the rail and the pavement. A minimum angle of approximately 45 degrees can be used as a guideline.

An additional point of attention are two-way cycle tracks. Central reservations are built at the railway crossing location to prevent cyclists bypassing the closed half barriers on the left when the barriers have just closed or the train has just gone by. On busy (school) cycle routes, the reservation should be as long as the average queue of bicycles. This helps prevent cyclists or moped riders riding past the queuing cyclists.

Description	Elevated intersection without right of way for cyclists
Function	• improving the crossing situation for bicycle traffic • limiting the speed of motorised traffic • indicating the crossing situation
Application	• estate access road • inside and outside built-up areas
Implementation	• do not continue the colour and type of pavement of the cycle route across the surface of the intersection • do not use block marking or channel marking • if necessary, narrow the road (2) just before the intersection • if necessary, use a speed reducer on the main carriageway
Dimensions	• difference in level 0.10 to 0.12 m • L = 5.00 to 6.00 m
Considerations	• effective speed reduction of crossing traffic (safe) • increase of noise nuisance and vibrations (particularly from lorry traffic) • poor flow of cyclists (no right of way) • possible influencing of route choice • inconvenient for cyclists on (2) when straight incline is used
Combination options	• visual support • traffic lights (at busy crossing) • lighting
Alternatives	• roundabout • cycle crossing with right of way

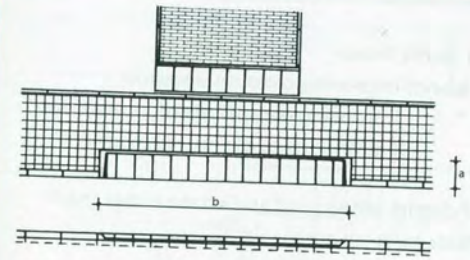


Description	Give-way road markings (triangular marking)
Function	indicating right of way situation
Application	• intersection of district access road and estate access road/solitary cycle track • inside and outside built-up areas • on 30 km/h roads and inside 30 km/h zones, give-way road markings in combination with sign B6 are only used on roundabouts and on intersections with: - a separate bus carriageway - a main cycle route that is recognisable as such (cycle street) • use of give-way road markings without sign B6 (Article 80 of the 1990 Netherlands Traffic and Road Signs Regulations) is limited to: - cycle tracks and parallel roads if the signs could confuse other drivers - the side section of a T-junction that is subordinate to a through road, provided the informal right-of-way behaviour matches the right of way regulation
Implementation	• thermoplastic material, road paint, preformed adhesive material or paving material • traffic decree is required
Dimensions	• a = 0.50 m • b = 0.60 to 0.70 m • c = approximately 0.50 m • d > 0.20 m
Considerations	• give-way road markings invisible after snow
Combination options	• sign B6 • outside built-up areas: right of way triangle as early warning • traffic plateau • central traffic island on main carriageway • traffic island in side road (where right of way is regulated) • cycle track next to main carriageway on speed bump at the crossing (where right of way is regulated)
Alternatives	exit

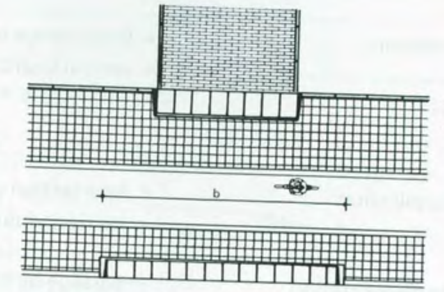


Description	Exit
Function	• indicating right of way situation • can be used to indicate entrance to residential area
Application	• intersection between district access road and estate access road • junction with estate, car park, house and suchlike on estate access road • inside and outside built-up areas • width of footway or verge ≥ 1.50 m • preferably not used on (main) cycle routes
Implementation	• wherever possible, continue footway and cycle track next to the main carriageway across the exit in terms of structure and colour • do not continue cycle lane or suggestion lane next to main carriageway across the exit • use more robust pavement (thick flagstones, for instance) where there is heavy traffic • at a junction with a street or estate, also use bevelled kerbing on the rear (no inclined paving) • do not use bend kerbs
Dimensions	• a = 0.80 (0.50) m • b is variable
Considerations	• easily recognised • clear legal status • clear delimitation • relatively costly • bevelled kerbing is a nuisance for cyclists • greater risk of falling when slippery
Combination options	• central traffic island on main carriageway
Alternatives	• statutory regulation (sign B6)

V 27

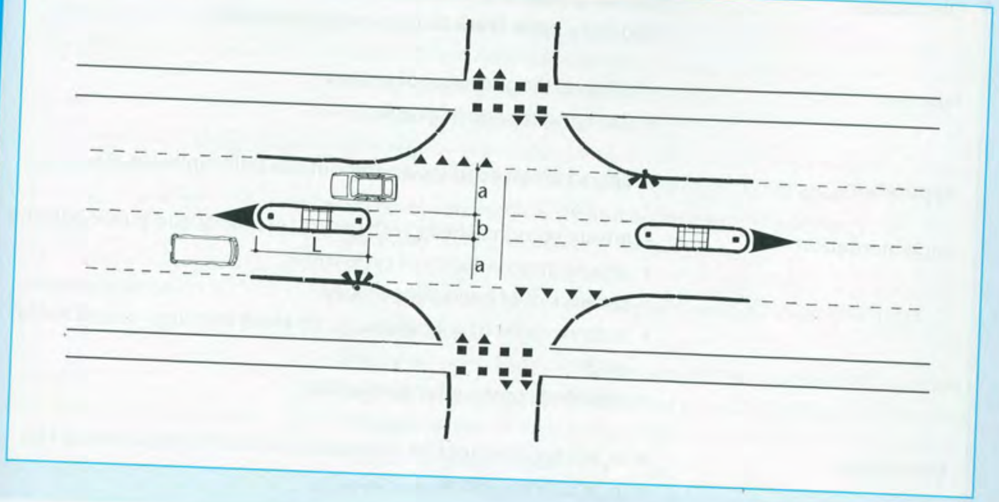


with combined traffic and cycle lane

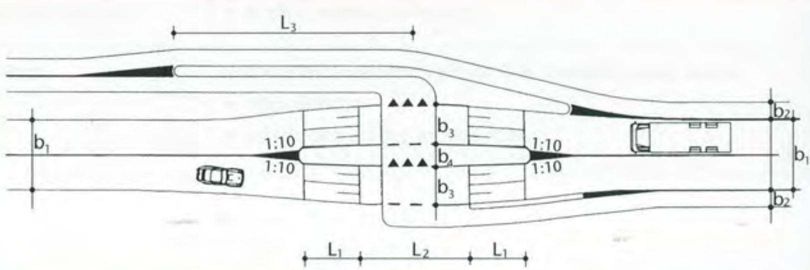


with separate cycle track

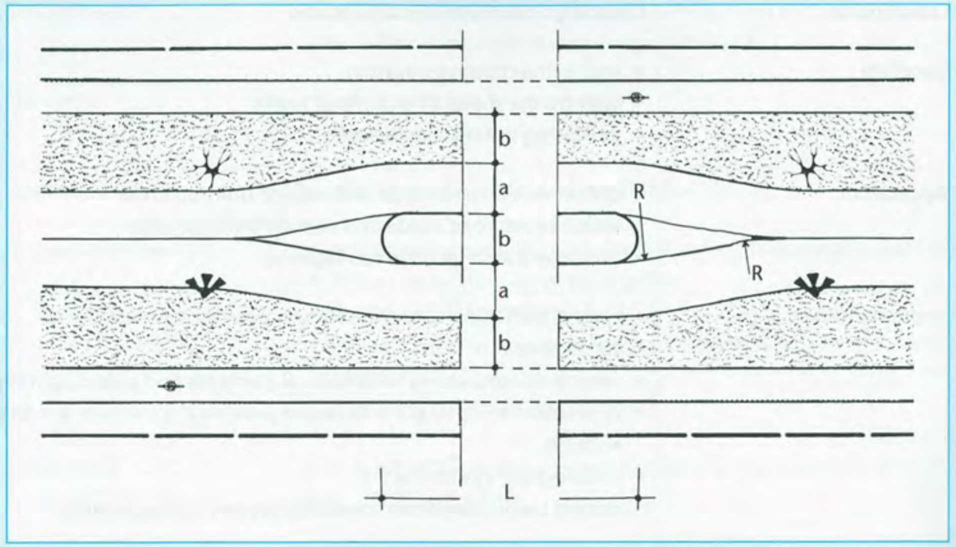
Description	Right of way intersection with central traffic island
Function	• interchange of traffic flows • central traffic island: improving crossing situation improving conspicuity of intersection limiting speed of through traffic
Application	• intersection of district access road and estate access road • inside and outside built-up areas
Implementation	• passage by means of exit or right of way by means of traffic measure (sign B6) • central traffic island preferably symmetrical in carriageway • ensure recognisability with vertical elements and lighting • central traffic island not elevated at cycle crossing location • give-way road markings and block marking on the continuing (red) pavement of any main cycle route across the intersection
Dimensions	• width of central traffic island (b) inside built-up areas ≥ 2.50 (2.10) m and outside built-up areas ≥ 3.50 m; if the central traffic island is also needed as a refuge for motorised traffic (b) = 7.00 m • width of traffic path for motorised traffic next to central traffic island (a) 2.75 to 3.50 m • take account of lorry towline • length of central traffic island (L) 5.00 to 10.00 m
Considerations	• improved conspicuity of intersection • central traffic island improves crossing situation (crossing in stages) • some speed reduction possible • wider connecting curves required in connection with manoeuvrability of lorry traffic
Combination options	• traffic plateau or hump
Alternatives	• intersection with right of way for main cycle route • roundabout • grade-separated intersection



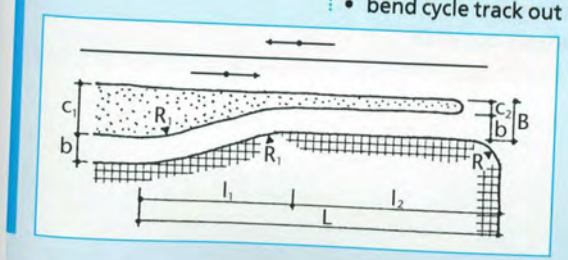
Description	Crossing with transverse central island, with transition from two-way cycle track to one-way cycle track
Function	• safeguarding crossing of cyclists • clarifying change of profile
Application	• district access road inside and outside built-up areas
Implementation	• ensure recognisability with vertical elements and public lighting • ensure good visibility of cycle traffic • cyclists out of have right of way • indicate right of way situation, no block marking, no red traffic path • elevated construction preferable
Dimensions	• b_2 see facility sheet for separate cycle track or cycle lane (V16) • b_3 = 2.75 to 3.50 m • $b_4 \geq$ 2.50 m • L_1 = depending on design speed • L_2 = 5.00 to 10 m • L_3 = 10 to 20 m • R = 5.00 m
Considerations	• low speed for all traffic at crossing • cyclists within field of vision of other traffic • cyclists can cross in stages because of transverse central island
	• lack of space • increased noise nuisance and vibrations • cyclists cross diagonally
Combination options	• area boundary



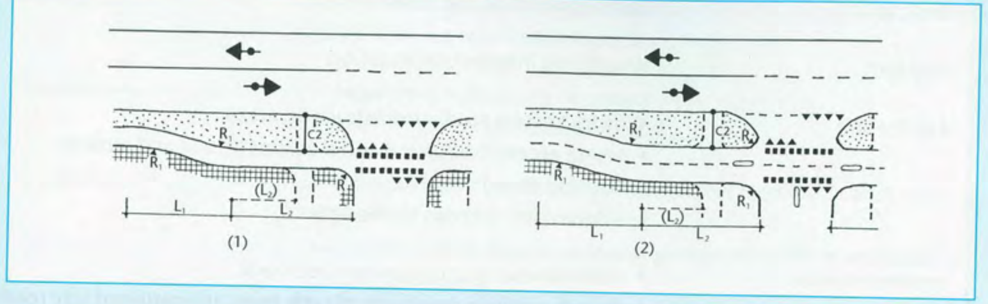
Description	Crossing with central traffic island
Function	• improving crossing situation • limiting the speed of motorised traffic • indicating the crossing situation
Application	• district access road inside and outside built-up areas • estate access road inside and outside built-up areas • two-way traffic on main carriageway
Implementation	• central traffic island preferably symmetrical in centreline of carriageway • ensure recognisability with vertical elements and public lighting • vegetation on central traffic island possible if dimension b is large enough • ensure good eye contact • central traffic island not elevated at cycle crossing location
Dimensions	• a = 2.75 to 3.50 m, depending on the function for motorised traffic • width of central traffic island (b): • at $V_{max} \leq$ 50 km/h > 3.00 (2.10) m • at V_{max} > 50 km/h > 3.50 (3.00) m • if b = 10 to 20 m: carriageway division • L = 5.00 to 20 m = 35 to 50 m, at b > 10 m • chamfer of outward bends depending on design speed, but at least 1: 5 • R = 30 to 40 m, depending on manoeuvring room of design vehicle • height of any vegetation on central traffic island < 0.60 m
Considerations	• increased attention • lack of view • moderate to good speed reduction, depending on width of central traffic island • crossing in stages • the speed reduction effect is small with dimensioning for heavy traffic • poor visibility from pavement of approaching traffic • possible obstacle effect • attention of motorists may be directed too intently at the outward bend of the carriageway
Combination options	• visual support • crossing facility • speed reducer



Description	Bending cycle track in/bending carriageway out
Function	• improving conspicuity of cyclists • improving visibility of cyclists • clarifying right of way situation
Application	• district access road (inside built-up areas) • estate access road (inside and outside built-up areas)
Implementation	• continue pavement of cycle track across side road • give-way road markings and block marking • no parking or high vegetation in L
Dimensions	• b see dimensions for separate cycle track (V19) • c_2 = at V_{max} main carriageway ≤ 60 km/h 0.35 – 2.00 m = at V_{max} main carriageway > 60 km/h 6.00 m • l_1 = 15 m • l_2 > 10 m • L = 25 to 30 m • B > 2.50 m • R ≥ 5.00 m • R_1 > 12 m, depending on design speed
Considerations	• optimal visibility of cyclists in the conflict between cyclists proceeding straight on and motorised traffic turning right • optimal visibility of cyclists on the cycle track for (motorised) traffic from the side road • smaller intersection area • with parallel control or uncontrolled intersection: conflict between cycle traffic proceeding straight ahead and motorised traffic turning right and nose-tail collisions if no separate right turn area is present • little stacking space for cyclists turning left • at c_2 < 6 m, risk of cyclists proceeding straight ahead being blocked by stationary traffic on the side road
Alternatives	• continue cycle track • bend cycle track out

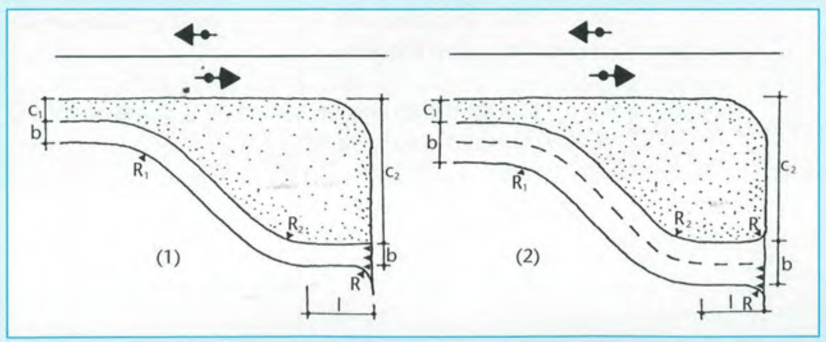


Description	**Bend cycle track slightly outward**
Function	• improving conspicuity of cyclists • clarifying right of way situation
Application	• district access road inside built-up areas • estate access road inside and outside built-up areas
Implementation	• continue pavement across side road • give-way road markings and block marking • no tall vegetation • on two-way cycle track apply centreline marking on either side of central traffic island and additional signposting for easy recognition by motorists
Dimensions	• width of cycle track, see separate cycle track (V19) • width of partition shoulder (c_2) inside built-up areas 4.00 to 5.00 m; outside built-up areas 6.00 to 7.00 m • L_1 = approximately 30 m • $L_2 > 5.00$ m • $R \geq 5.00$ m • $R_1 \geq 12.00$ m
Considerations	• comfortable for cyclists • stacking space for cyclists turning left with cycle tracks around • stacking space for conflicting vehicles • large-scale intersection • detour (left-turning) cyclists in (1) • with parallel control or no TCS in (1) cyclists are vulnerable in conflict • if no conflict-free control in (2), continuing conflicts for cyclists in the opposite direction
Combination options	• streamed cycle track • elevated cycle path (on speed hump)
Alternatives	• bend cycle track in • bend cycle track out wide



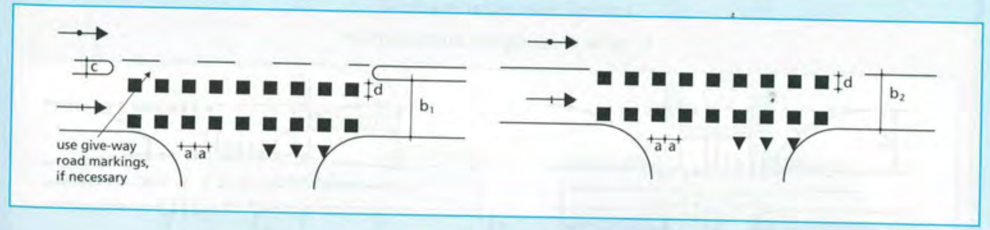
V 33

Description	Bend cycle track out wide
Function	simplifying intersection situation
Application	• district access road outside built-up areas • estate access road on industrial estates (inside and outside built-up areas) • intersection without traffic lights
Implementation	• subordinate right of way for cycle track • do not continue pavement of cycle track at location of side road • no block marking or channel lines on crossing • give-way road markings on cycle track
Dimensions	• for b see facility sheet for separate cycle track (V19) • for c_1 see facility sheet for partition shoulder (V21) • $c_2 > 10.00$ m • R_1 = approximately 15 m • R_2 = approximately 8.00 m • R > 5.00 m • L > 5.00 m
Considerations	• no traffic lights required • disadvantageous for cyclists (detour and no right of way) • requires a lot of space
Combination options	• with (2) central traffic island in cycle track
Alternatives	• bend cycle track in • bend cycle track slightly outward • roundabout • traffic lights • small tunnel



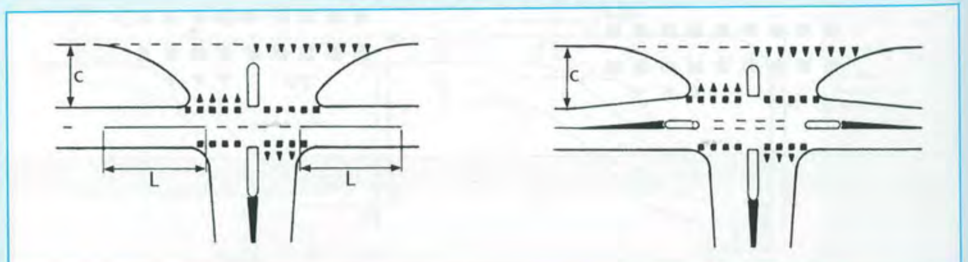
V 34

Description	Cycle crossing over side road with cycle lane, suggestion lane or road with narrow outer separator
Function	• improving conspicuity of cyclists • clarifying right of way situation
Application	• junction district access road/estate access road inside built-up areas • junction estate access road/estate access road inside and outside built-up areas
Implementation	• pavement of cycle track continues across side road • markings in thermoplastic material, road paint, preformed adhesive material or paving material • sign B6 • if c > 0.70 m, use give-way road markings on both approach directions on the cycle track
Dimensions	• a = 0.50 m • for b_1 see dimensions for separate cycle track (V19) • for b_2 see dimensions for cycle lane or suggestion lane (V16) • c = 0.00 – 2.00 m • d = 0.50 m
Considerations	• cyclists clearly visible • optimal directness for cyclists • crossing is unambiguous and easily recognisable • risk of motor vehicles blocking cycle track or cycle lane • no stacking space on cycle track or cycle lane for cyclists turning left • increased risk of nose-tail accidents on main carriageway
Combination options	• sign B7 instead of sign B6 (and then with a stop line instead of triangular marking)



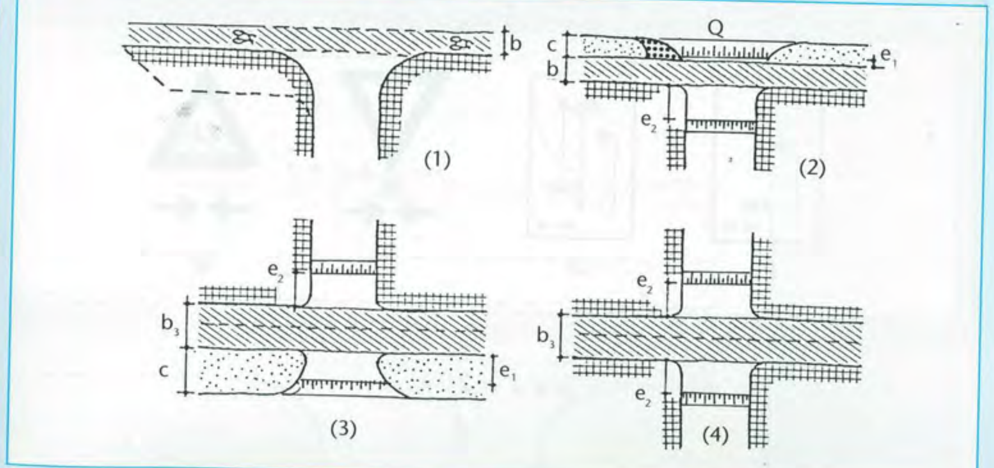
V 35

Description	Cycle crossing (two-way traffic) over a side road, in road with partition shoulder
Function	• improving conspicuity of cyclists • clarifying right of way situation
Application	• junction district access road/estate access road • inside and outside built-up areas
Implementation	• pavement on cycle track continues across side road • markings in thermoplastic material, road paint, preformed adhesive material or paving material • supplementary signposting (see facility sheet 'drawing attention to cyclists using signposting') • centreline marking on cycle track • drawing attention to two-way path • give-way road markings on both approach directions of the cycle track
Dimensions	• c = 4.00 to 5.00 m (inside built-up areas) • c = 6.00 to 7.00 m (outside built-up areas) • L = approximately 10.00 m
Considerations	• reasonable view of cyclists • little risk of motor vehicles blocking cycle track • ample stacking space for cyclists turning left • central traffic island in (2) emphasises two-way traffic • motorists sometimes don't expect bicycle traffic from the 'wrong' direction, which increases the risk of accidents for cyclists from this direction
Combination options	• arrows on the road surface to illustrate the two-way traffic • B7 signs instead of B6 signs; with stop line instead of the front row of triangular marks • cycle crossing on an elevation

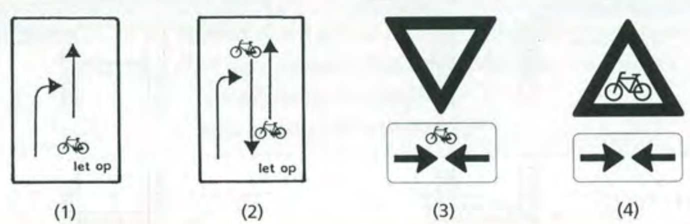


V 36

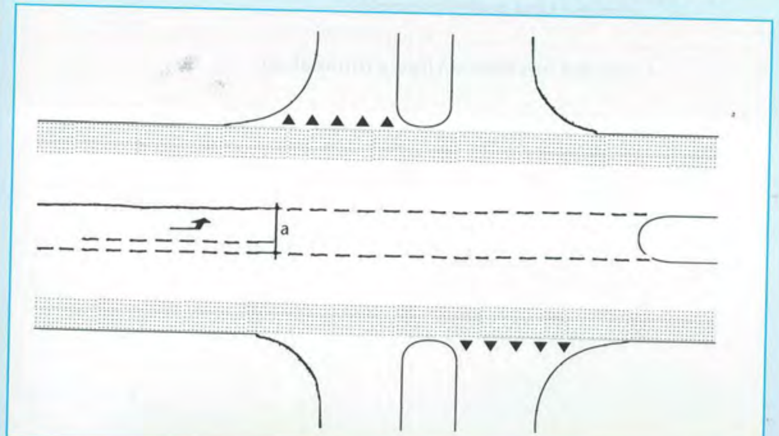
Description	Continue bicycle facility pavement at the side road
Function	• improving conspicuity of cyclists • clarifying right of way situation
Application	• district access road and estate access road with bicycle facilities • (2), (3) and (4) not with traffic lights control system
Implementation	• continue (colour of) pavement of bicycle facility across the side road (if the bicycle facility has the same colour and texture as the side road, give a short section of the bicycle facility a different colour) • equal right of way status of cycle track and carriageway • for marking, see facility sheets V4 and V17
Dimensions	• for width of bicycle facility, see facility sheets V16 and V19 • c = 0.00 – 2.00 m (inside built-up areas) • c = 6.00 – 7.00 m (outside built-up areas) • $e_1 \leq c$ and ≤ 5.00 m • $e_2 = 5.00$ m
Considerations	• continuity of roadscape • good visibility of bicycle facility • support to right of way regulation • (2), (3) and (4) speed reduction of motorised traffic
Combination options	• bend cycle track slightly outward • transverse central islands • partially different paving of partition shoulder in (2): rumble splay (Q)



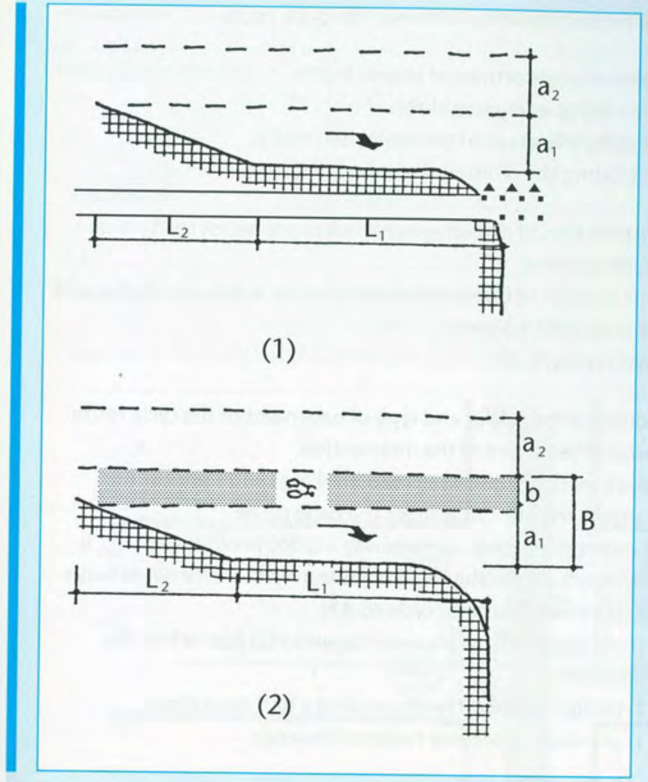
Description	Signposting at cycle crossing
Function	drawing attention to cyclists
Application	• intersection with separate cycle track • inside and outside built-up areas • (3) and (4): with a two-way track the secondary sign indicating two-way traffic is mandatory (Administrative Road Traffic Provisions Decree, BABW). • (1) one-way cycle track at ≤ 8.00 m from the carriageway and no or parallel control of conflict type cyclist proceeding straight ahead and car turning right • (2) ditto for two-way cycle track and motorised traffic turning left • (2) conflict types cyclist proceeding straight ahead and car turning left and cyclists proceeding straight ahead and car turning right from the other side • (3) two-way cycle track or solitary cycle track with right of way • (4) two-way cycle track or solitary cycle track without right of way
Implementation	• (1) and (2) white (and red, traffic turning off) on blue • (3) and (4) black on white (secondary sign) • (1), (2) and (3): continue cycle track pavement, block marking and give-way road markings on intersection area
Considerations	• increased attention, which is beneficial to safety of cyclists • signposting alone has little effect
Combination options	• transverse central islands • visual support • cycle crossing on plateau



Description	Weaving of cyclists turning left
Function	safe weaving of cyclists and motor vehicles
Application	• intersection on district access road inside built-up areas • intersection on estate access road inside and outside built-up areas • cycle lane • maximum of one lane for motorised traffic proceeding straight ahead
Implementation	• preferably also include cycle lane in left turn area
Dimensions	• width of left-turning lane (a) 2.75 – 3.25 m • for width of cycle lane see cycle lane facility sheet • length of cycle lane in left-turning lane depends on length of left-turning lane, but at least approximately 15 m
Considerations	• no conflict on intersection • elderly people and children experience the crossing situation as unsafe • at a high intensity of motorised traffic it is difficult to reach the left-turn lane • conflict between cyclists getting into lane and traffic approaching from behind
Combination options	• traffic plateau
Alternatives	• no cycle lane in turning lane for left-turning traffic (position of bicycle is unclear) • convert intersection into a roundabout

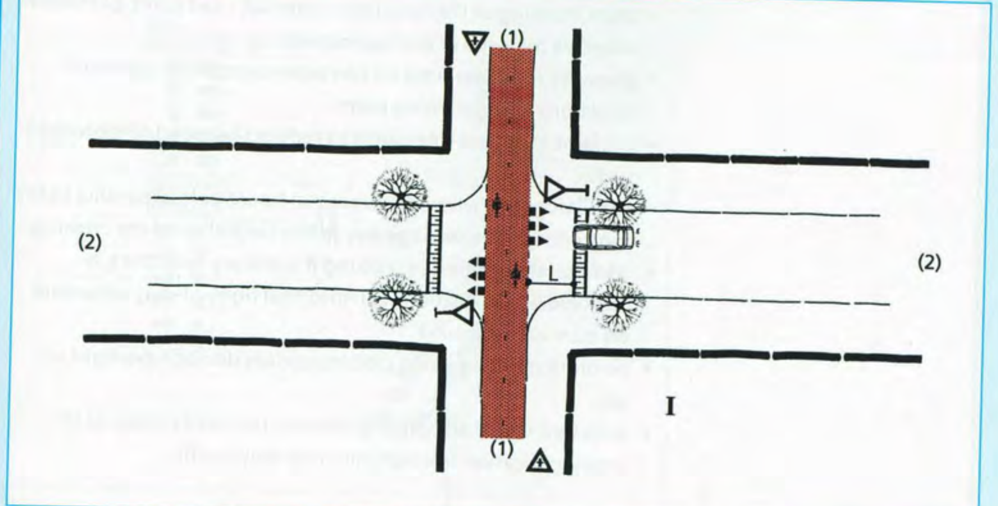


Description	**Weaving cyclists and motorised traffic turning right with right-turning lane**
Function	safe weaving of cyclists and motor vehicles
Application	• intersection on district access road • (1) inside and outside built-up areas • (2) inside built-up areas • cycle lane or separate cycle track • many conflicts between cyclists proceeding straight ahead and motorised traffic turning right
Implementation	• continue pavement and cycle track marking across side road • (1) with separate cycle track • (2) with cycle lane • where there are large numbers of cyclists turning right, a cycle lane in the right-turning lane can be included • in (1) distance cycle track - side of right-turning lane ≤ 2.00 m
Dimensions	• $a_1 \geq 3.00$ (2.75) m • $a_2 = 3.00 - 3.25$ m • for b see cycle lane or suggestion lane • for width of cycle track (b) see separate cycle track • L_1 is variable • $L_2 = 5$ to 7 times a_1
Considerations	• no conflict on intersection • weaving is experienced as unpleasant and unsafe
Combination options	• in (1): 'Hague' hump (oblique speed hump between right-turning lane and cycle track)
Alternatives	• convert intersection into a roundabout



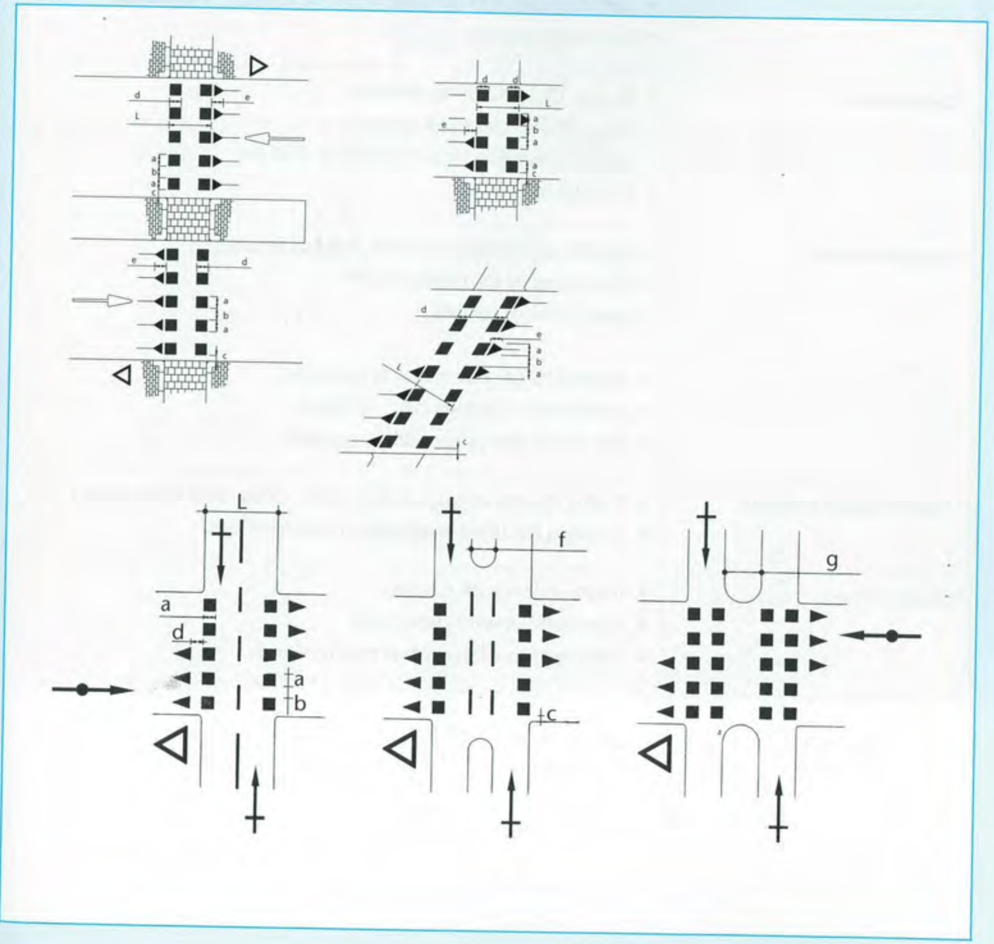
Description	Intersection with right of way for cycle route
Function	• optimising directness of bicycle traffic • improving safety of cyclists • limiting the speed of the motorised traffic • indicating the crossing situation
Application	• intersection of district access road/estate access road inside built-up areas • intersection of estate access road/estate access road inside and outside built-up areas • main cycle route
Implementation	• continue the colour and type of pavement of the cycle route across the surface of the intersection • block marking, give-way road markings and signposting support the right of way for the cycle route • if intensity on main carriageway > 5,000 pcu/day and V_{max} is ≥ 50 km/h, preferably in combination with traffic lights (with favourable control for cycle route) • if necessary, narrow main carriageway (2) just before the intersection • (2) bridge height differences using a half sinus shape • (1) gradually overcome height difference
Dimensions	• L ≥ 3.00 m • a = 0.50 m • b = approximately 0.50 m • c ≥ 0.5 x a • d = 0.50 (> 0.30) m • f < 1.50 m • g ≥ 1.50 m • centreline and side marking 1 - 1
Considerations	• high-quality cycle route (no delay when crossing main carriageway) • good speed reduction of crossing traffic • increase of noise nuisance and vibrations (particularly from lorry traffic) • possible influence of route selection by motorised traffic • nuisance to cyclists on (2) when ramp is used

Description	Intersection with right of way for cycle route (continued)
Combination options	• visual support from spatial elements • traffic islands or central traffic island in main carriageway • arrows on cycle track at the crossing (drawing extra attention from motorist) • traffic lights • lighting
Alternatives	• roundabout • grade-separated crossing

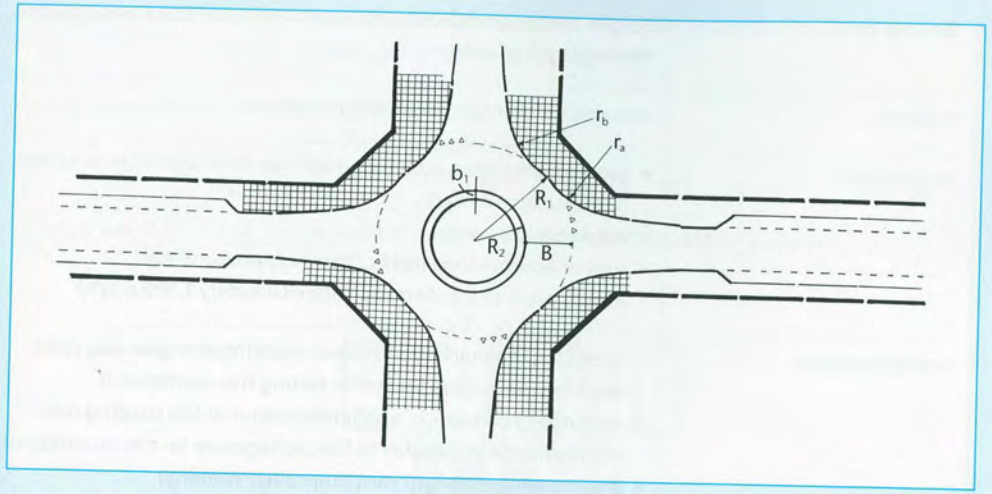


Description	Cycle crossing road marking on road section with right of way for cycle route
Function	indicating right of way situation
Application	• district access road inside built-up areas • estate access road inside and outside built-up areas • main cycle route • when crossing traffic has to give right of way to crossing cyclists
Implementation	• sign B6 on crossing direction of travel • continue cycle route pavement across carriageway (if possible) • block marking of thermoplastic material, road paint, preformed adhesive material or paving material • give-way road markings on carriageway on both approach directions to the crossing point • preferably physical measures to reduce the speed of motorised traffic • parallelograms where the sides run (more or less) parallel to the centreline of the carriageway or the centreline of the crossing. • additional attention to crossing if a solitary cycle track is involved (in connection with informal right-of-way behaviour on main carriageway) • *no* block marking when crossing cyclists do not have right of way • with two-way track, place arrows on the road surface at the crossing location to emphasise two-way traffic
Dimensions	• L > 1.50 m (for one-way traffic) • L ≥ 3.00 m (for two-way traffic) • a = 0.50 m • b = approximately 0.50 m • c ≥ 0.5 x a • d = 0.50 (> 0.30) m
Considerations	• accentuation of crossing point • reduction of speed leads to improved safety (only if a speed reducer is also applied) • when block marking is used in situations where the cyclist does not have right of way, this might the unjustly create the suggestion of right of way for bicycle traffic

Description	Cycle crossing road marking on road section with right of way for cycle route (continued)
Combination options	• visual support • elevated crossing point section • speed reduction facilities • shorten length of crossing • traffic lights
Alternatives	• roundabout • grade-separated intersection

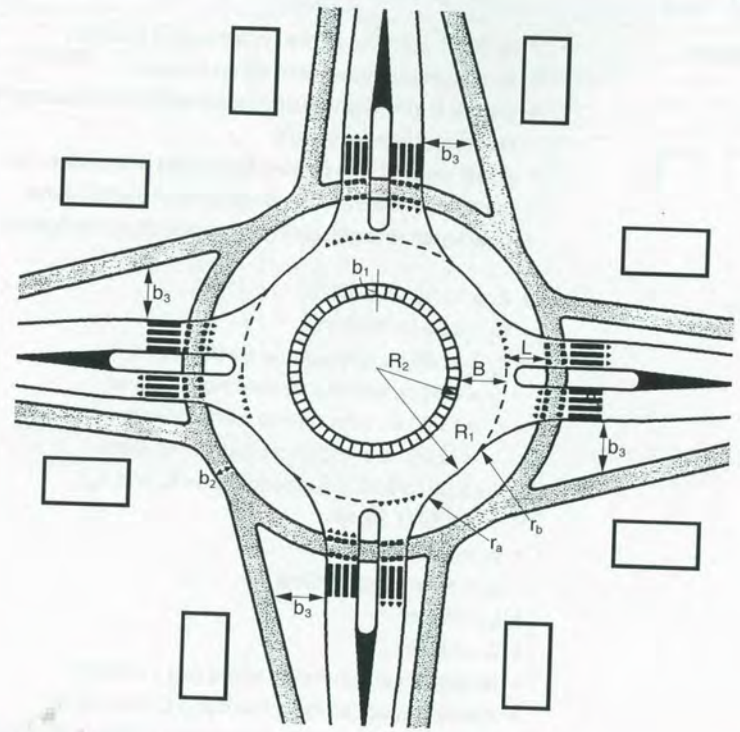


Description	Roundabout for mixed traffic
Function	safe and quick interchange of traffic flows
Application	• intersection of estate access road/estate access road • inside and outside built-up areas • up to an intersection intensity of approximately 6,000 pcu/day
Implementation	• cyclists on the carriageway (not in lane) • bend-in/truncate any bicycle facilities along approach road sections at 20 to 30 m before the roundabout • vertical elements on central traffic island, if necessary • lighting required
Dimensions	• $R_{outside}$ (R_1) = 12.50 to 20.00 m • R_{inside} (R_2) = 6.50 to 15.00 m • width of rumble strip (b_1) 1.00 to 1.50 m • B = 5.00 to 6.00 m
Considerations	• cyclists remain in motorists' field of vision • low speed of motorised traffic • good flow of cyclists • possibility of cyclists being boxed in • possibility of cyclists cutting bends • can cause delays to public transport
Combination options	• traffic islands in connecting roads, drive-over if necessary • crossing facilities in approach road sections
Alternatives	• intersection with plateau • roundabout with cycle track • intersection with central traffic islands

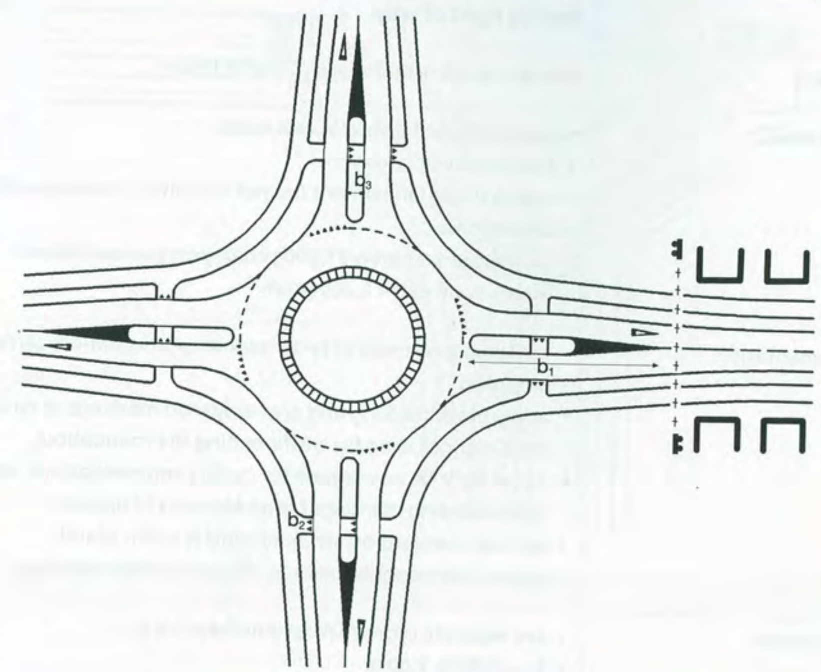


Description	Single-lane roundabout with separate cycle track and cyclists having right of way
Function	safe and quick interchange of traffic flows
Application	• junction of district access road with another district access road or estate access road • inside built-up areas • sum of approaching traffic flows < approximately 25,000 pcu/day (conflict load approximately 1,500 pcu/h)
Implementation	• cycle crossing marked with block marking and give-way road markings, including for traffic exiting the roundabout • continue cycle track in a different colour at the crossing over the roundabout, parallel to the carriageway on the roundabout • if necessary with slight cant (improved visibility) • remove cyclists no longer following the roundabout from the cycle track around the roundabout as early as possible; see dimension b_3 • equal right of way regime for cyclists and pedestrians (zebra-crossing) • vertical elements on elevated central traffic island • guarantee recognisability by means of public lighting • possibly no central traffic island(s) on quiet section(s)
Dimensions	• R_1 = 12.50 to 20.00 m • R_2 = 6.50 to 15.00 m • r_a = 12,00 m, with central traffic island = 8.00 m, without central traffic island • r_b = 15.00 m, with central traffic island = 12.00 m, without central traffic island • B = 5.00 to 6.00 m (depending on R_1 and R_2) • b_1 = 1.50 (1.00) m • b_2 = 2.00 to 2.50 m • b_3 = as large as possible • L = 5.00 m • C = 2.00 m
Considerations	• relatively safe: fewer conflict points than with traditional intersection • relatively high capacity • improved conspicuity of intersection • considerable speed reduction • good flow of bicycle traffic • difficult for lorries to negotiate with small R_1 and R_2

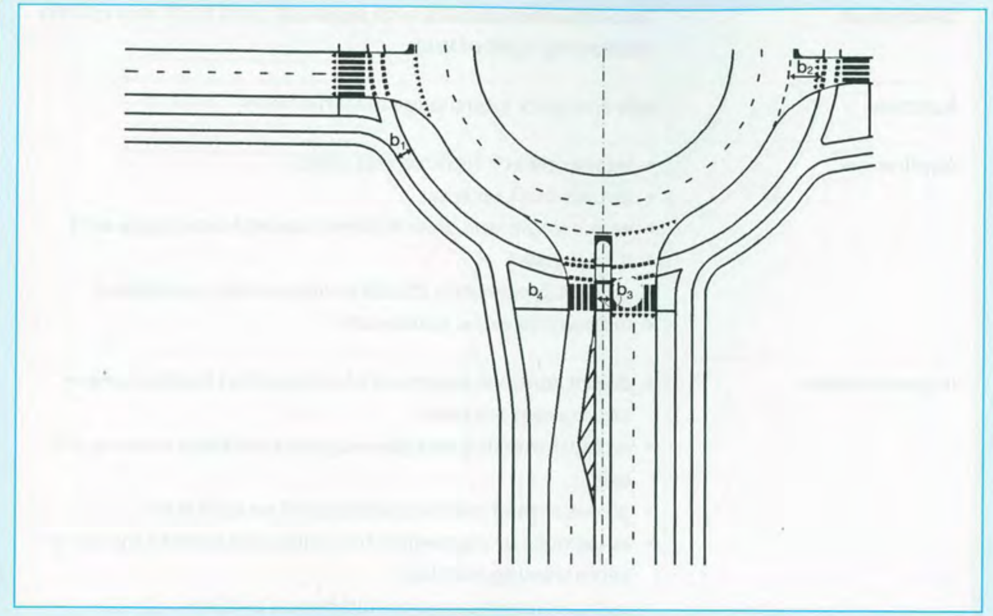
Description	Single-lane roundabout with separate cycle track and cyclists having right of way (continued)
Combination options	• crossing facility • two-way cycle track • bus lane on approach section
Alternatives	• right of way intersection with central traffic island



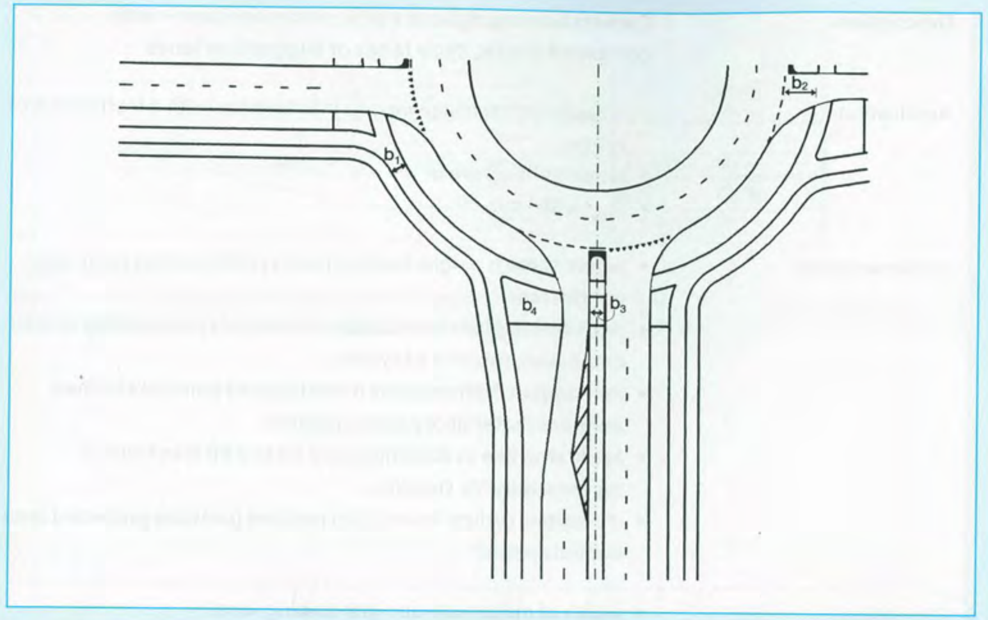
Description	**Single-lane roundabout with separate cycle track and cyclists not having right of way**
Function	safe and quick interchange of traffic flows
Application	• intersection of district access road with estate access road or another district access road • outside built-up areas • sum of approaching traffic flows < approximately 25,000 pcu/day (conflict load approximately 1,500 pcu/h)
Implementation	• no block marking at the cycle crossing location • no continuous pavement on cycle track • central traffic islands sufficiently wide in connection with stacking space for cyclists • equal right of way regime for cyclists and pedestrians • vertical elements on elevated central traffic island • guarantee recognisability by means of public lighting
Dimensions	• R_1 = 12.50 to 20.00 m • R_2 = 6.50 to 15.00 m • r_a = 12.00 m, with central traffic island = 8.00 m, without central traffic island • r_b = 15.00 m, with central traffic island = 12.00 m, without central traffic island • B = 5.00 to 6.00 m (depending on R_1 and R_2) • b_1 = 1.50 (1.00) m • b_2 = 2.00 to 2.50 m • b_3 = as large as possible • L = 5.00 m • C = 2.00 m • length of central traffic island (b_1) ≥ 6.00 m • stacking space on cycle track (b_2) 2.10 to 3.0 m • width of central traffic islands (b_3) 2.50 to 3.00 m (2.10 m)
Considerations	• very good increase in attention • effective speed reduction • increased safety, few accidents with injuries • poor flow of bicycle traffic
Combination options	• moped openings (moped on carriageway) if roundabout is in a place where the speed regime changes • vegetation
Alternatives	• traffic control system



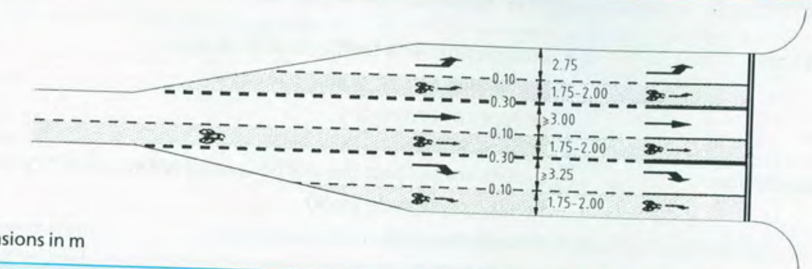
Description	**Two-lane roundabout with separate cycle track and cyclists having right of way**
Function	safe and quick interchange of traffic flows
Application	• intersection of district access roads • inside built-up areas • with a single lane on exit (do not use with a two-lane exit) • if no bypass • up to approximately 25,000 pcu/day on the roundabout • intensity on exit < 1,200 pcu/h
Implementation	• continue pavement of cycle track at location where carriageway is crossed • apply block marking and give-way road markings at cycle crossing, including for traffic exiting the roundabout • equal right of way regime for cyclists and pedestrians; apply zebra crossing markings for pedestrians (if present) • vertical elements on elevated central traffic island • guarantee recognisability by means of public lighting
Dimensions	• see separate cycle track facility sheet for b_1 • b_2 = 5.00 to 7.00 m • $b_3 \geq$ 2.50 m • R $\geq$ 5.00 m
Considerations	• good flow of cyclists • high capacity • improved conspicuity of intersection • (limited) speed reduction • cyclists are not boxed in • relatively safe • easily negotiated by lorries and public transport • pedestrian crossing (zebra crossing) leads to improved conspicuity of the crossing (only if footpath exists) • uses a lot of space • danger of cyclists being hidden • risk of weaving accidents for motorised traffic • relatively high speed at quiet times
Combination options	• crossing facilities • cycle/pedestrian tunnel (on main cycle route) • cycle crossing with speed ramp
Alternatives	• intersection with traffic control system • roundabout with bypass



Description	**Two-lane roundabout with separate cycle track and cyclists not having right of way**
Function	safe and quick interchange of traffic flows
Application	• intersection of district access roads • outside built-up areas • with a single lane on exit (do not use with a two-lane exit) • if no bypass • up to approximately 25,000 pcu/day on the roundabout • intensity on exit < 1,200 pcu/h
Implementation	• do not continue pavement of cycle path at location where carriageway is crossed • no block marking and give-way road markings on ramp and exit • give-way road markings and sign B6 on cycle track • equal right of way regime for cyclists and pedestrians (so no zebra crossing marking) • vertical elements on elevated central traffic island • guarantee recognisability by means of public lighting
Dimensions	• see separate cycle track facility sheet for b_1 • $b_2 = 5.00$ to 7.00 m • $b_3 \geq 2.50$ m • $b_4 \geq 2.50$ m
Considerations	• high capacity • improved conspicuity of intersection • speed reduction • cyclists are not boxed in • easily negotiated by lorries and public transport • uses a lot of space • danger of cyclists being hidden • risk of weaving accidents • relatively high speed at quiet times
Combination options	• crossing facilities • cycle/pedestrian tunnel • cycle crossing with speed hump
Alternatives	• intersection with traffic lights control system • roundabout with bypass

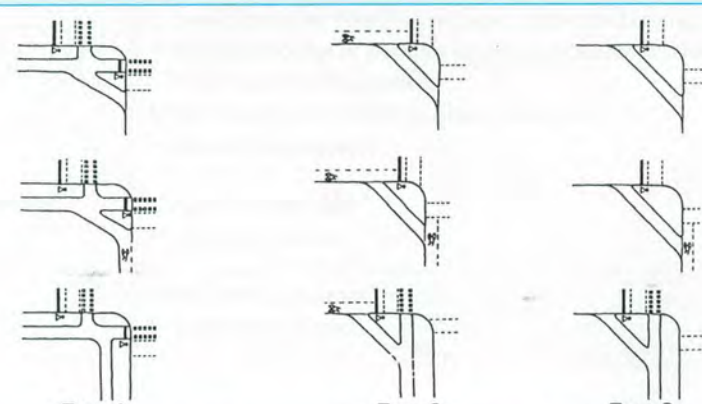


Description	Cyclists turning right at traffic control system – with combined traffic, cycle lanes or suggestion lanes
Application	• on approach carriageways to intersections with a traffic control system • inside built-up areas • V_{max} = 50 km/h
Implementation	• where there is a right-turning lane, cyclists turning right also use this lane • right-turning lane to include cycle lane or cycle stacking lane to emphasise presence of cyclists • markings in thermoplastic material, road paint, preformed adhesive material or paving material • apply stop line in stacking lane 2.00 to 3.00 m in front of motorised traffic stop line • if possible, cyclists free to turn past red (consider protected area behind cyclists)
Dimensions	• width of motor vehicle right-turning lane: > 3.25 m without cycle lane or cycle stacking lane; > 2.75 m with cycle lane or cycle stacking lane • width of stacking lane ≥ 1.50 (1.00) m • length of stacking lane (l) ≥ 10 m • m = lane marking line 1-1, width 0.10 m, transitioning into continuous line • n = lane marking line 1-1, width 0.30 m, transitioning into double continuous line (3 x 0.10 m)
Considerations	• own stacking lane for cyclists • improved visibility • possible quicker flow (less nuisance from other traffic) • moving stop line of stacking lane forward leads to better view of cyclists (limit 'blind spot') • right-turn past red offers optimal directness • greater flow capacity
Combination options	• right-turn past red • right-turn on red
Alternatives	• streamed cycle track • separate cycle track



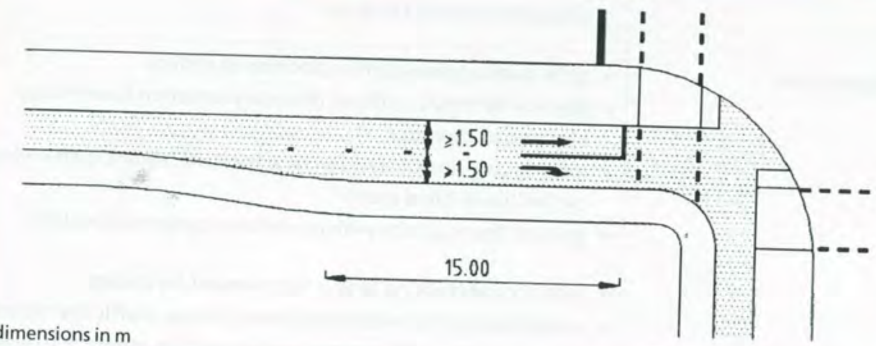
dimensions in m

Description	Cyclists free to turn right past red
Application	• intersection with traffic control system • inside and outside built-up areas • all types of provisions
Implementation	• cyclists are led past the traffic control system via a bicycle facility (small cycle track) • smooth merging • cyclists turning right arrive on cycle track, cycle lane or have an adequate protected area behind them • where there are large numbers of pedestrians aim for as much space as possible between the non-controlled and the controlled crossing • modification of traffic control system is not required • regulate right of way with conflicting cycling directions
Dimensions	• width of right-turning track depends on intensity (see V19), but at least 1.50 m
Considerations	• good flow of cyclists turning right (no waiting time) • less ignoring red lights • misuse of right-turning track by other cyclists • additional space occupation • inconvenient for crossing pedestrians
Combination options	• can be combined with any provision (except free right-turn for cyclists)
Alternative	• right-turn through red



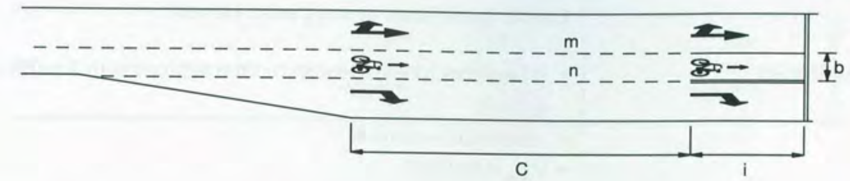
Type 1 (from separate cycle track) Type 2 (from cycle lane) Type 3 (from carriageway)

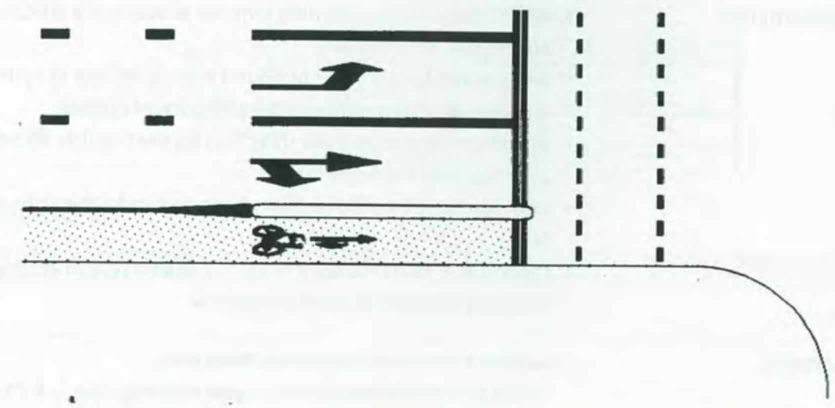
Description	Stacking lane for cyclists on cycle track in front of traffic control system
Function	stacking place for cyclists at traffic control system
Application	• intersection with traffic control systems and separate cycle tracks • inside and outside built-up areas
Implementation	• area indicated by means of (longitudinal and get-into-lane) marking • markings in thermoplastic material, road paint, preformed adhesive material or paving material • stationary cyclists must not block cyclists who can ride through; this applies to both crossing cyclists and cyclists wanting to turn right (past red or outside of the provision)
Dimensions	• length of area depends on intensity and traffic control, but at least 5.00 m: with loop detection ≥ 15.00 m • width ≥ 1.50 m
Considerations	• unequivocal for cyclists • more opportunities for additional provisions (shorter waiting time)
Combination options	• right-turn past red • right-turn through red



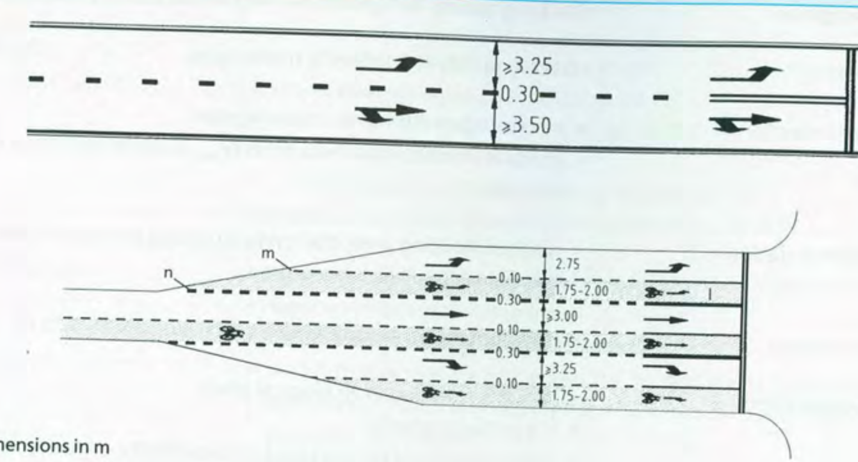
dimensions in m

Description	**Cyclists riding straight on at traffic control system – with combined traffic, cycle lanes or suggestion lanes**
Application	• on approach carriageways to intersections with a traffic control system • inside built-up areas • V_{max} main carriageway 50 km/h
Implementation	• maximum of one lane per direction • preferably with cycle stacking lane at stop line, if no cycle lane or suggestion lane on the carriageway (length approximately 10.00 m) • markings in thermoplastic material, road paint, preformed adhesive material or paving material • preferably with small physical delineator just in front of the stop line (width approximately 0.50 m, length ≥ 5.00 m, see detail) • in case of conflict between cyclists proceeding straight ahead and a,motor vehicle turning right, apply the stop line of the stacking area 2.00 to 3.00 m in front of the stop line for motorised traffic
Dimensions	• width of motor vehicle lane: > 3.25 (3.00) m, without stacking lane; > 2.50 m with stacking lane • width of cycle stacking lane (b) ≥ 1.50 (1.00) m • length of stacking lane (i) ≥ 10.00 m • m = lane marking line 1-1, width 0.10 m, transitioning into continuous line • n = lane marking line 1-1, width 0.30 m, transitioning into double continuous line (3 x 0.10 m)
Considerations	• cycle stacking lane clarifies position of cyclists • physical delineator affords physical protection (preventing blocking of passage) • moving stop line of stacking lane forward leads to better view of cyclists (limit 'blind spot') • greater flow capacity with presence of cycle stacking lane • lack of cycle stacking lane is not pleasant for cyclists • unsafe for cyclists: with more lanes and busy traffic the motorist is focused on the traffic control system and can overlook a cyclist
Combination options	• ECSL
Alternatives	• streamed cycle track • separate cycle track



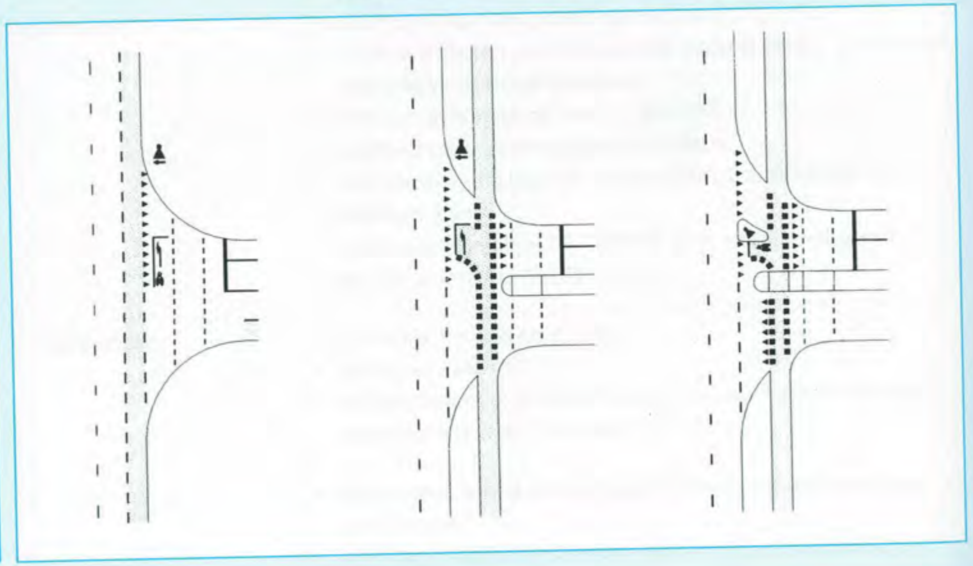


Description	Cyclists turning left at traffic control system – with combined traffic, cycle lanes or suggestion lanes
Application	• on approach carriageways to intersections with a traffic control system • inside built-up areas • V_{max} = 50 km/h
Implementation	• where there is a left-turning lane for motorised traffic, cyclists also weave into this lane • left-turning lane is to be provided with cycle lane or cycle stacking lane to emphasise the presence of cyclists • maximum of one lane per direction (so that cyclists do not have to cross more than one lane) • with one lane for all directions keep cyclists to the right of the lane • markings in thermoplastic material, road paint, preformed adhesive material or paving material
Dimensions	• width of motor vehicle left-turning lane: > 3.25 m without cycle lane or cycle stacking lane; > 2.75 m with cycle lane or cycle stacking lane • width of cycle stacking lane ≥ 1.50 (1.00) m • length of cycle stacking lane (l) ≥ 10.00 m • m = lane marking line 1-1, width 0.10 m, transitioning into continuous line • n = lane marking line 1-1, width 0.30 m, transitioning into double continuous line (3 x 0,10 m)
Considerations	• own stacking lane for cyclists • improved visibility • quicker flow of bicycle traffic (less nuisance from other traffic), resulting in greater flow capacity • elderly people and children experience this situation as less comfortable • weaving of cyclists and motor vehicles can be dangerous
Combination options	• ECSL
Alternatives	• streamed cycle track • separate cycle track (where cyclists turning left cross in two stages: straight ahead – left)



dimensions in m

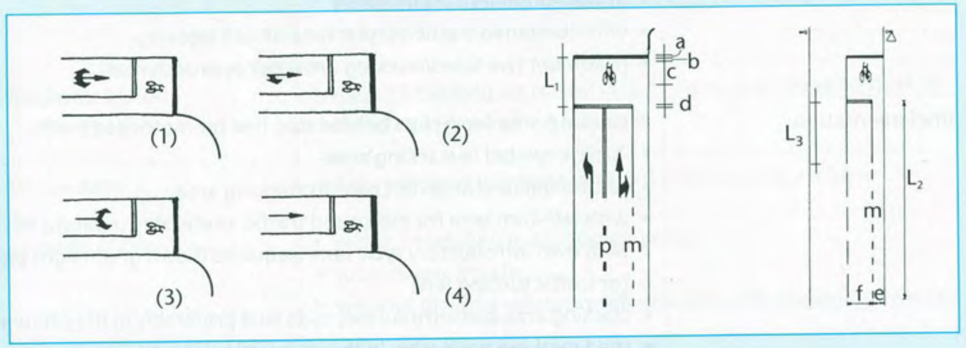
Description	Stacking facility for cyclists turning left at traffic control system
Function	stacking facility for cyclists at traffic lights
Application	• intersection with traffic control system • inside and outside built-up areas (V_{max} outside built-up areas 60 km/h)
Implementation	• marked stacking area; if all cyclists turning left have to stack in this area a 'gap light' is required
Dimensions	• depending on intensity; width of stacking area > 1.20 m
Considerations	• cyclist is standing in an illogical place • subjectively unsafe • without physical refuge unsafe should traffic control system fail
Alternatives	• green light for all directions • ECSL (when maximum of two lanes per section)



Description	ECSL (expanded cycle stacking lane)
Application	• intersection with traffic control system • inside built-up areas • with a relatively large number of cyclists turning left • at well-organised intersection • with combined traffic or cycle lane on carriageway • maximum two lanes/stacking areas per approach road
Implementation	• stacking area for cyclists behind stop line for motorised traffic • bicycle symbol in stacking area • central delineator on left next to stacking area • with left-turn lane for motorised traffic, preferably separate ECSL with own introductory cycle lane (required if own green light phase for traffic turning left) • stacking area and introductory cycle lane preferably in the colour red • road marking preferably in thermoplastic material
Dimensions	• length of stacking area 4.00 to 5.00 m • width of stacking area for cyclists = width of motorised traffic lane (plus width of cycle lane, if any) • introductory cycle lane ≥ 25 m • width of stop line (a) 0.30 m • space between stop line and bicycle symbol (b) 0.50 m • height of bicycle symbol (c) 2.75 m • lane marking line (m) 1-1, 0.10 m wide • lane marking line (p) 1-3, 0.30 m wide
Considerations	• quick flow of (left-turning) cycle traffic • maximum visibility of cyclists (safe) • ample stacking place on red-light • less nuisance from exhaust fumes while waiting • fewer conflicts between motor vehicles and bicycles on the intersection • less nuisance on approaching stop line • limiting of motorised traffic capacity, particularly with a lot of motorised traffic turning right • ECSL is not always respected by motorists • subjectively unsafe (cars overtaking on right during left-turn cycling movement) • possibility of red light being ignored by cyclists (because it is easier to get to the stop line) • no separate phase possible for bicycle traffic turning left, this can lead to longer waiting time

V 53

Description	ECSL (expanded cycle stacking lane) (continued)
Combination options	• cycle lane or suggestion lane • free right-turn past red • cyclists free to turn right



V 54

Description	Reduce waiting time for cyclists – using short cycle time
Application	• intersection with traffic control system • inside and outside built-up areas • with combined traffic, cycle lane on carriageway or separate cycle tracks • with all types of control
Implementation	• maximum cycle time is 90 s • critical consideration of green light time and clearance times • the more compact the intersection, the easier it is to realise a short cycle time
Considerations	• short cycle time leads to short (maximum) waiting time • quick flow of all traffic, including cyclists • short cycle time with quick phase changes is subjectively dynamic • possibility of double stop in busiest directions

V 55a

Description	**Reduce waiting time for cyclists – by concurrent extension of public transport priority**
Application	• intersection with traffic control system • inside and outside built-up areas • traffic control with priority for public transport
Implementation	• when public transport is registered, (non-conflicting) parallel cycle directions are also registered, so that they are given a green light simultaneously • build into control as standard
Considerations	• extra options for cyclists, which reduces waiting time • no negative effect on other directions • additional possibility of running red lights due to the often very short green light and clearance time for PT systems

V 55b

Description	**Reduce waiting time for cyclists – by increasing motorised traffic flow capacity**
Application	• busy intersections with traffic control system • inside and outside built-up areas • with cycle lane and separate cycle tracks • with conflict-free provisions
Implementation	• by increasing the motorised traffic flow capacity (more stacking and flow lanes) the cycle time can remain limited (preferably to a maximum of 90 s) • critical consideration of green light time and clearance times • despite extra lanes, keep intersection as compact as possible
Considerations	• shorter cycle time leads to shorter (maximum) waiting time • quick flow of all traffic, including cyclists • short cycle time with quick phase change is subjectively dynamic • increasing flow capacity leads to larger – and therefore less safe – intersection

V 56

Description	**Reduce waiting time for cyclists – by concurrent extension of green phase for cycle directions along with other directions**
Application	• intersection with traffic control system • inside and outside built-up areas • separate cycle tracks • with all types of provisions
Implementation	• by concurrent extension of the green phase with non-conflicting motor vehicle directions, cyclists area offered more green light time, which reduces waiting time • build into control as standard • critical consideration of green light time and clearance times
Considerations	• extra options for cyclists, which limits waiting time • no negative effect on other directions • greater risk of cyclists running red light with shorter green light times

V 57

Description	Reduce waiting time for cyclists – by favourable phase sequence for cyclists turning left
Application	• intersection with traffic control system • inside and outside built-up areas • relatively large numbers of cyclists turning left on at least one section • with separate cycle tracks • with all types of control
Implementation	• by considering all traffic flows that are turning left as a single combined direction within the control (instead of as one direction straight ahead and one direction left-turn), cyclists turning left can continue without stopping. • critical consideration of green light and clearance times
Considerations	• quick flow of left-turning cycle direction, movement is possible without stopping • may result in additional waiting time for other directions and therefore a longer cycle time

V 58

Description	Reduce waiting time for cyclists – using cycle crossings in two directions
Application	• intersection with traffic control system • inside and outside built-up areas • relatively large numbers of cyclists turning left on at least one section • with separate (two-way) cycle tracks • with conflict-free control
Implementation	• if a cycle crossing is permitted in two directions this can limit the waiting time for cyclists turning left • cycle crossing is sufficiently wide • critical consideration of green light and clearance times
Considerations	• extra possibility for cyclists turning left • cyclists appear from an unexpected direction, therefore only conflict-free provisions are permitted; this can lead to a longer cycle time • possibility that cyclists continue to use a one-way cycle track, in the wrong direction, after the crossing

V 59

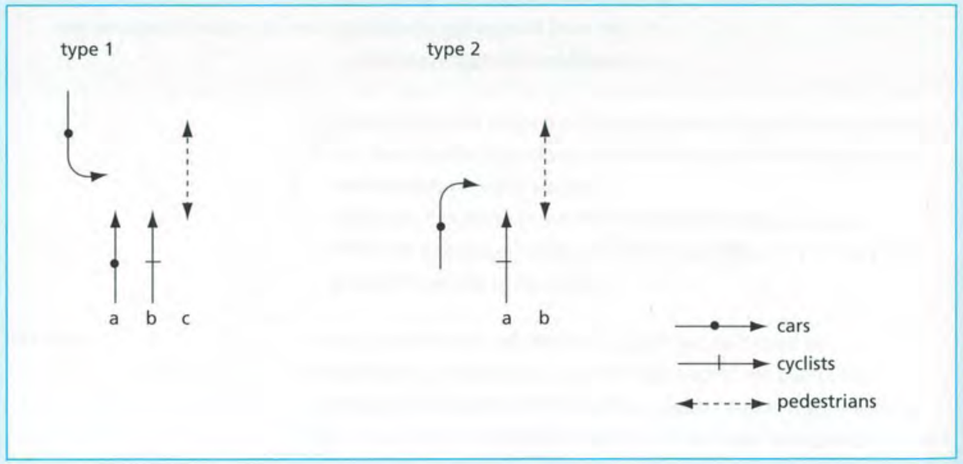
Description	Reduce waiting time for cyclists – using green wave for bicycle traffic
Application	• intersections with traffic control system located at a short distance from each other (maximum 100 metres, see remarks below) • inside and outside built-up areas • with through cycle flow • with combining, cycle lane on carriageway and separate cycle paths
Implementation	• by linking the traffic provisions, the through cycle flow (straight-ahead, right turn or left turn) can ride on without stopping. • the signal for starting or extending the green light phase of the second light is given by the detector that is situated in front of the first light • take account of the average cycling speed or design speed • if necessary introduce extra detectors between both cycle lights; if no signal is received, the green wave is interrupted • critical analysis of green light and clearance times
Considerations	• quick flow of through cycle direction, movement is possible without stopping • cyclists less inclined to ignore rights • cyclists and light moped riders cannot be 'caught' in a single wave • can lead to additional waiting time for other directions and thereby longer cycle times • at longer distances between the intersections or speed differences between the cyclists 'group diffusion' occurs (the group of cyclists is separated)
Remarks	In the Danish town of Odense a green wave is used at intersections that are at a greater distance from each other. Cyclists are reminded of the cycling speed required by means of 'accompanying' LED lights. Cycling at the same speed as the speed at which the lights are moving , cyclists can continue without stopping at the next traffic light (see www.fietsberaad.nl)

V 60

Description	Reduce waiting time for cyclists – using long-range detection/ pre-request
Application	• intersection with traffic control system • inside and outside built-up areas • with cycle lanes or separate cycle tracks • traffic- or vehicle-dependent control
Implementation	• by using detection a good distance before the stop line, traffic control can react to approaching cyclists more effectively; the distance between detection and stop line depends on the control, 40 to 50 metres for example • with two-way tracks implement direction-dependent detectors or separate cycling directions using central traffic island • critical analysis of green light and clearance times
Considerations	• cyclists can be given a green light earlier and the green light can be extended if necessary • possibility of leaving out a cycle direction is limited • holding green light for cyclists in detection area (greater possibility of cycling through) • less nuisance than a pushbutton • can lead to additional waiting time for other directions and therefore a longer cycle time

V 61

Description	Reduce waiting time for cyclists - by permitting sub-conflicts
Application	• intersection with traffic control system • inside and outside built-up areas • not in case of crossing conflicts with motorised traffic • only if there is little turning motorised traffic • not with two-way cycle track • (1) not with two left-turn lanes • (1) not with separate cycle track
Implementation	• by permitting sub-conflicts (conflict matrix) in the control, the cycle time can be limited (preferably to a maximum of 90 s) • do not use arrow lights with conflicting directions (so full lens); with warning if necessary • crossing conflicts between slow traffic can be kept outside of the control • critical consideration of green light and clearance times
Considerations	• shorter cycle time leads to shorter (maximum) waiting time • quicker flow of all traffic, including cyclists • possibly less safe (cyclists not free from conflict)



V 62a

Description	Reduce waiting time for cyclists – by realising additional cycle directions (green light twice per cycle)
Application	• intersection with traffic control system • inside and outside built-up areas • with cycle lanes or separate cycle tracks
Implementation	• by realising extra cycle directions the waiting time for cyclists in the direction(s) concerned can be halved • critical consideration of green light and clearance times
Considerations	• waiting time for cyclists is shortened (increasing the possibility of continuing without stopping) • risk of longer waiting times for motorised traffic

V 62b

Description	Reduce waiting time for cyclists – by keeping mutual conflicts between slow traffic outside of the control
Application	• intersection with traffic control system • inside and outside built-up areas • separate cycle tracks • all types of control
Implementation	• on separate cycle tracks mutual conflicts between cyclists and between cyclists and pedestrians can be kept outside of the control • critical consideration of green light and clearance times
Considerations	• quick flow of cycle directions • cyclists are less inclined to ignore red lights • this decreases delays and thereby the cycle time, which is beneficial to all directions • higher risk of mutual conflicts between cyclists and between cyclists and pedestrians

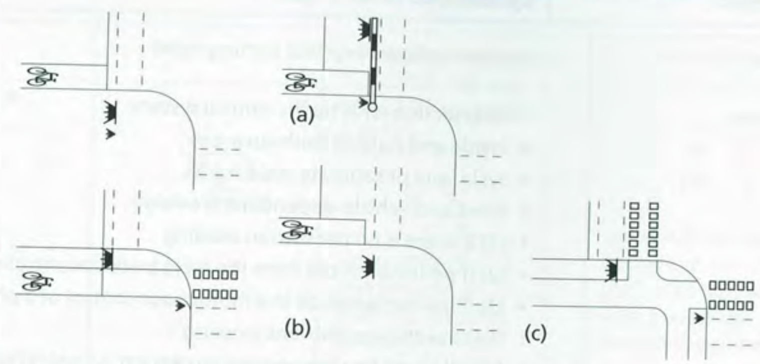
Description	Reduce waiting time for cyclists – using green light for all directions
Application	• intersection with traffic control system • inside built-up areas • cycle lanes or cycle tracks situated close to the main carriageway • better organised, more compact intersection situation • two-phase or three-phase control for motorised traffic • with a relatively large number of cyclists turning left (> 10%)
Implementation	• all cycling directions are given a green light simultaneously • two green lights per cycle • critical consideration of green light and clearance times (particularly clearance times for motorised traffic: at the start of the green light for cyclists, no motor vehicles should be in the intersection area). • if necessary, use narrow physical separation between motorised and bicycle traffic on approach roads • indication using sign VKL04 (Administrative Road Traffic Provisions Decree)
Considerations	• favourable for cyclists turning left (diagonal crossing, without additional stop) • no sub-conflicts with motorised traffic: safe for cyclists • cyclists can be given green light earlier • 'severely' cross-conflicting cycling directions in the same green light phase; possibility of bicycle/ bicycle accidents • waiting time for motorised traffic increases • difficult to integrate pedestrians with 'green light for all cyclists'

Description	Reduce waiting time for cyclists – by favourable hold for cyclists
Application	• intersection with traffic control system or main cycle route crossing on a busy road • inside and outside built-up areas • on separate cycle tracks or on a main cycle route • fixed or vehicle-dependent control • (1) with controlled crossing two systems linked halfway; cyclists are given the green light as soon as there is a gap in the traffic flow • (2) if cyclists cross in groups (school route or suchlike) or with regular flow of bicycle traffic, where capacity for other traffic would be decreased too much; detection of cyclists is necessary for extension.
Implementation	• type 1: hold green light on cycle track: control is motor-vehicle-dependent if there is no flow of other traffic, the main directions for bicycle traffic are given the green light; unless other traffic is reported the bicycle light remains green; effective detection of motorised traffic is required so that vehicles can continue without stopping if there are no cyclists • type 2: hold green light on carriageway for motorised traffic: control is bicycle-dependent (long-range detection of bicycle is required) if there is no flow of bicycle traffic the motor vehicle direction is given the green light; effective detection of bicycle traffic is required so that cyclists can continue without stopping if there are no motor vehicles • type 3: hold red-light: direct influence; control is motor-vehicle- and cycle-dependent • critical consideration of green light and clearance times
Considerations	• possibility for cyclists to continue without stopping increased • there is an indication that hold red-light is safer than hold green light in terms of traffic safety • with type 3 the green light is given immediately after signalling (no clearance on conflicting directions) • with type 1 the waiting time for motorised traffic increases at quiet times (due to clearance time for cycling directions) • with type 1 risk of motorised traffic ignoring red light (driver expects light to turn green, which is not, however, always the case; potential hazard because of this)

This traffic light gives an indication of the maximum time cyclists still have to wait until the light turns green

Description	**Countdown signal**
Function	improving ease of use for cyclists
Application	• intersection with traffic control system • inside and outside built-up areas • cycle lanes or separate cycle tracks • fixed and vehicle-dependent control • particularly in places where cyclists tend to ignore red lights • at intersections where the waiting time for cyclists is in accordance with the recommendations
Implementation	• the countdown signal gives cyclists an indication of the remaining waiting time • the speed at which the illuminated lamps in the time-bar extinguish gives cyclists an indication of the waiting time • install waiting time predictor next to green bicycle light or incorporate into push-button • the signal may not count up • critical consideration of green light and clearance times
Dimensions	not applicable
Considerations	• improvement in service: perception of waiting time leads to a subjective reduction • cyclists less inclined to ignore red lights • no negative effects on other traffic • in vehicle-dependent control, the waiting time is difficult to predict, which means that counting down may be very irregular • extra installation costs • susceptible to breakdown • still little experience

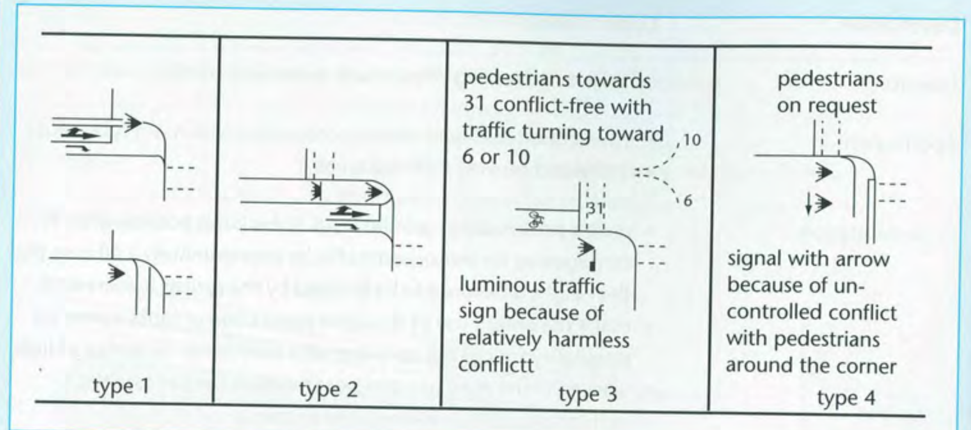
Description	Early start
Function	improving visibility (safety) of cyclists
Application	• intersection with traffic control system • inside and outside built-up areas • cycle lane or separate cycle tracks • fixed and vehicle-dependent provision • (2) only if distance to mutual conflict point is short, as otherwise the motor vehicle will arrive earlier due to the speed difference • if visibility of the cyclist is poor • with a lot of motorised traffic turning right (cyclists do not have a chance to proceed straight ahead) • when conflict-free control is desirable, but not possible (no space for right-turn lane)
Implementation	• early start in such a way that cyclists arrive at the conflict point before the right-turning motorised traffic arrives there • early start not too long, as cyclists wanting to turn left will otherwise come into conflict with quickly accelerating motor vehicles from the opposite direction • type 1: bicycle direction given green light before light for other traffic • type 2: early start by moving stop line, simultaneous green light for cyclists and other traffic • preferably implement types 2a and 2b with ECSL or with physical separation • critical analysis of green light and clearance times
Considerations	• cycles better in motorists' field of vision, with possible increased road safety for cyclists (limiting blind spot) • type 1 is at the expense of green light time for motorised traffic or leads to longer cycle time • no benefit to cyclists who do not set off immediately when given the green light



type 1: early start controlled by separate traffic lights

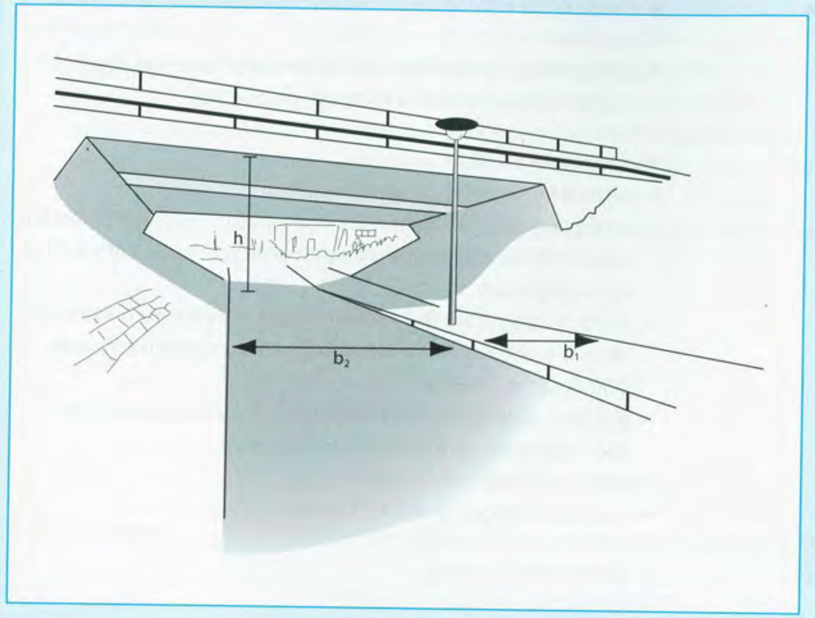
type 2: early start by moving stop line

Description	Cyclists free to turn right
Function	improving flow of cyclists turning right
Application	• intersection with traffic control system • inside and outside built-up areas • cycle lane or separate cycle tracks • fixed and vehicle-dependent provision • (1) if there is no pedestrian crossing • (2) if pedestrians can cross the cycle track uncontrolled • (3) if use can be made in a multiphase control of a phase in which there are no pedestrians crossing • (4) with a pedestrian control on request, at points with few pedestrians and many cyclists
Implementation	• where there is sufficient space for cyclists on the side road • modify road marking with (1) and (2); if possible no stop line for cyclists turning right; fix sign with 'free right-turn for cyclists' next to the traffic light; preferably position the bicycle light on the left • with (3) and (4) a separate three-colour light with arrow is used (4) only if cyclists and the pedestrians around the corner can cross without conflict or uncontrolled; a luminous traffic signal (3) is advised if a relatively harmless conflict arises with the pedestrians around the corner or with traffic from other directions, provided that it is not illuminated simultaneously with the green bicycle light • critical analysis of green light and clearance times
Considerations	• no waiting time for cyclists turning right • provision fits in better with actual road behaviour • no enforcement problems • problematic for pedestrians crossing (particularly the blind and visually impaired) • (3) and (4): expansion with lampposts is not always possible in an existing system • (1), (3) and (4): use limited in practice



Description	Cycle tunnel
Function	conflict-free crossing of cycle and motorised traffic
Application	• intersection between district access road with main cycle route • inside and outside built-up areas
Implementation	• cyclists preferably at ground level. If this is not possible elevate carriageway for motorised traffic by approximately 2.00 m so that the height difference to be bridged by the cyclists is decreased • make maximum use of daylight: separation of lanes opens up possibility for central opening with additional incidence of light • viaduct in the road or open box structure for pedestrians • no high vegetation near tunnel entrance • vandal-proof (sunken) lighting in the tunnel • no corners/recesses • walls recede toward top • straight path; the exit must be visible upon entering the tunnel • inclines in front of the tunnel must not give individuals with malicious intent the opportunity to conceal themselves (no vegetation, corners, et cetera) • if necessary in combination with footway for pedestrians • could be combined with fauna facility outside built-up areas
Dimensions	• where there is a footpath $b_1 > 1.00$ m • width of cycle track (b_2) if there is no footpath: 2 x 0.625 m (obstacle distance closed wall) + width of approach cycle track, with 3.50 m as the minimum • width of cycle track (b_2) if there is a footpath (on one side): 0.625 m (obstacle distance closed wall) + width of approach track, with 3.00 m as the minimum • h > 2.50 m • incline < 1 : 20 • tunnel floor 2% (drainage)
Considerations	• conflict-free crossing (safe) • multiple approach routes possible • unobstructed view through tunnel • good lighting situation • shorter inclines than with a bridge (because of smaller height difference) • when the road is elevated there are generally no groundwater problems • phased construction required in existing situation • social insecurity • susceptible to vandalism

Description	Cycle tunnel (continued)
Combination options	• stairs (with cycle channel on both sides) • stepped incline
Alternatives	• cycle bridge (less favourable for cyclists than a tunnel) • traffic light controlled crossing



V 69

Description	Cycle bridge
Function	conflict-free crossing of cycle and motorised traffic
Application	• intersection of district access road and main cycle route • inside and outside built-up areas
Implementation	• keep height difference to be overcome by cyclists as small as possible • with a bridge across the road: if necessary lower the road • may be combined with a footpath on one side
Dimensions	• headroom ≥ 4.50 m • width of footpath (if present) > 1.00 m • width of cycle track if there is no footpath: 2 x 0.325 m (obstacle distance handrail) + width of approach cycle track, with 3.50 m as the minimum • width of cycle track (b_2) with footpath on one side: 0.325 m (obstacle distance handrail) + width of approach track, with 3.00 m as the minimum • width of cycle track with footpath on both sides = width of approach track, with 3.00 as the minimum • inclines < 1 : 20 • height of bridge handrail ≥ 1.20 m
Considerations	• conflict-free crossing • often cheaper than a tunnel • option for architecturally pleasing solution • no social insecurity (overview from road is possible) • often longer inclines than with a tunnel (because of greater height difference) • possibility of fear of heights with a high bridge • wind nuisance
Combination options	• stairs (with cycle channel on both sides) • phased ramp • escalator • travelator on incline • wind screen
Alternatives	• cycle tunnel (often more favourable for cyclists than a bridge) • traffic light controlled crossing

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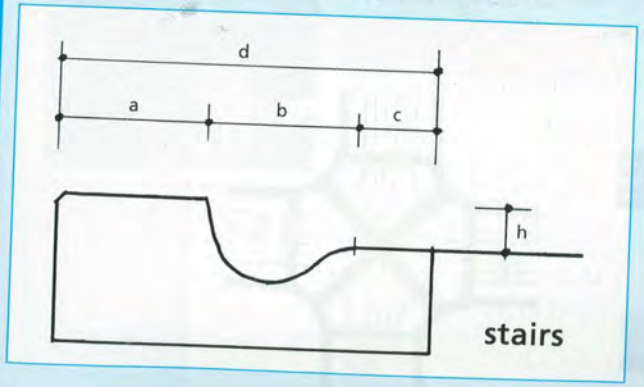
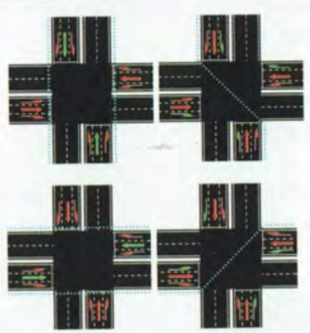
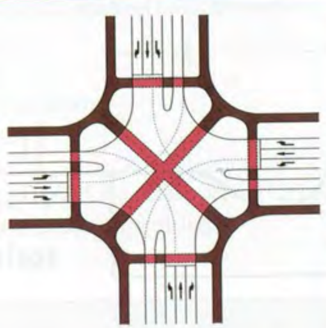
Description	bicycle channel next to stairs
Function	increasing accessibility of bridge or tunnel for cyclists
Application	• in combination with stairs • if ramp is not possible • in bicycle storage facilities
Implementation	• channels on both sides of the stairs • preferably constructed from concrete • top of channel level with top of stair tread • if necessary with stair handrail close to the wall, to prevent the handlebars coming into contact with the handrail; handrail does not bend toward the ground at the ends • incline of stairs not steeper than 25%; use 'transition arch' with steeper inclines
Dimensions	• a ≥ 0.20 m • b = 0.08 to 0.12 m = 0.10 m (with metal channel) • c = 0.03 to 0.05 m • h = 0.03 m = 0.04 m (with metal channel)
Considerations	• preferably only use as supplementary measure for ramp • requires a lot of effort from cyclists
Combination options	• stairs
Alternatives	• phased ramp • escalator • travelator on incline



Description	Reduce waiting time for cyclists – using diagonal cycle crossing
Application	• intersection with traffic control system • inside built-up areas • separate cycle tracks • with a relatively large number of cyclists turning left • no combined directions on the intersection • sufficient space in intersection area • sufficient space next to the carriageway for two cycle stacking areas
Implementation	• by guiding cyclists diagonally across the intersection area, simultaneously with motorised traffic, no separate bicycle provisions are needed • the control scheme works as follows (see the figure also): • phase 1: cyclists and motor vehicles in straight-ahead direction • phase 2: motor vehicles left and right and cyclists diagonally • phase 3: motor vehicles and cyclists in the other straight-ahead direction • phase 4: motor vehicles right and left and cyclists across the other diagonal • cyclists in two directions across the intersection area
Considerations	• reduction of waiting time for cyclists turning left (maximum one stop when turning left) • always across the intersection in a single cycle (short waiting time) • longer clearance times for motorised traffic • subjectively unsafe for cyclists (bicycles in an illogical place (in the middle of the intersection area) between oncoming motorised traffic turning left)
Remarks	experimental facility; experiences with this solution are not yet known





Description	Blind spot mirror below traffic light
Function	• improving the visibility (and thus safety) of cyclists at intersections with traffic lights
Application	• intersection with traffic control system • fixed and vehicle-dependent control • with combined traffic or cyclists in cycle lane or in suggestion lane • with relatively high volume of lorry or bus traffic turning right
Implementation	• installing a (curved) mirror below the green light improves the view from a cab of cyclists standing next to and in front of a vehicle • preferably as addition to infrastructural facilities (such as physical screening)
Considerations	• mirror shows what is happening directly in front of a lorry • mirror reduces the blind spot • mirror is possibly susceptible to vandalism and requires maintenance
Remarks	• experimental facility; although some municipal authorities use the mirror (including Amsterdam and Rotterdam) no details are known concerning its effect

7 Design, maintenance and furnishings

V 66, 67 Each chapter concludes with a number of facility sheets. The text contains references to the relevant facility sheet marked by this symbol.

7.1 Road surfacing and paving

7.1.1 User requirements

Cyclists have five main requirements in terms of infrastructure. Translated into road surfacing and paving, these requirements concern:

- the evenness of the paving surface (unevenness and texture);
- skid resistance;
- drainage.

The designer must realise that these requirements not only apply to cycle tracks, but also to cycle lanes and roads for mixed traffic. When roads of this nature have an important function for bicycle traffic, a good road surface is vital here too.

Evenness

The evenness of the paving determines the horizontal and vertical vibrations experienced by cyclists and, as such, forms an important condition for a comfortable cycling infrastructure. To an important extent, evenness also determines the resistance that cyclists experience and, consequently, their energy consumption.

Skid resistance

The skid resistance of the paving is largely determined by the texture. Texture, then, is not only important for cycling comfort and energy loss, but also for the safety of cyclists and traffic in general. The macrotexture offers space for the storage of (rain)water and dirt, so that proper contact is maintained between the bicycle tyre and the road surface. The microtexture determines the roughness of the individual stone particles in the paving material.

Drainage

Because cyclists cycle in the open air and are not protected from weather influences, careful consideration must be given to proper drainage. It is very uncomfortable to have to cycle through big puddles. Moreover, this is dangerous because, where puddles have formed, a cyclist is unable to see how deep the puddle is or whether there are any (deeper) potholes or ruts in the road surface; this can cause evasive manoeuvres or falls.

7.1.2 Types of paving

In principle, designers can choose from four different types of paving. Research [39] has shown that cyclists prefer the following paving types successively: asphalt, concrete, tile paving and paviours. Translated into report figures, asphalt scores 8.5, cement concrete and surface treatment both 7.5, concrete slabs 6+ and paviours 6-. The report figures are median values: the value at which 50% of the measurement values is better and 50% is worse. See table 29 for a brief description of the most important characteristics of the four mentioned types of paving.

V 71 Cyclists have a clear preference for closed surfacing, such as asphalt and concrete, as these offer the greatest evenness and the least resistance and, consequently, the most comfort. Modular paving, such as clinkers/clinker bricks, concrete paviours and concrete tiles, generally retains its texture and skid resistance, but has a clearly poorer evenness than closed surfacing. Clinker bricks score worse than other modular paving in the winter months. Modular paving is only recommended if provided with kerbing.

Table 29. Paving characteristics (part 1)

Asphalt paving

Asphalt is the paving construction most appreciated by cyclists, one of the reasons being that it consists of a single surface, which guarantees optimal evenness.

As regards skid resistance and rolling resistance, the surface course in particular is important in asphalt paving. A grading of 0/6 or 0/8 (or 0/11) is the preferred choice for this layer (the grading indication 0/8 means particles with a diameter of 0 to 8 mm). The surface of asphalt paving can be treated with a layer of bitumen, which is then strewn with crushed aggregate or pea gravel. A wearing course or sealing coat of this nature results in a slightly higher rolling resistance and is therefore not recommended, certainly not on important cycle connections. However, if a wearing course is applied, it is important to remember that the bitumen may become soft in high temperatures and adhere to bicycle tyres. Small, loose stones could also be problematic in this situation. If laid carefully (appropriate chipping material at the right grading, a proper bond between bitumen and chipping material, the removal of any loose material), these problems will be kept to a minimum. However, some ravelling may occur over time.

Drainage is not usually a problem with asphalt paving. However, it is important for the asphalt pavement to have proper foundations, so that no potholes or ruts emerge (for example in the event of co-use by heavy traffic; see also section 7.1.3).

Cement concrete

Just like asphalt, concrete is a closed surfacing and offers cyclists a high level of evenness and, consequently, comfort. However, shrinkage joints, terminal joints and construction joints must be installed carefully. The rolling resistance of concrete is slightly higher than that of asphalt, as a result of which concrete scores slightly less well in terms of cycling comfort.

Concrete cycle tracks generally do not cause any problems with skid resistance. The preferred finishing for this surface is fine brooming.

In principle, drainage is not a problem with cement concrete. Owing to the durability of this material, the chance of potholes or ruts is minimal, as a result of which cement concrete scores better than asphalt in this respect.

Besides the relatively great bicycle-friendliness and durability, concrete cycle tracks have the advantage that they require barely any maintenance. In comparison with other types of paving, concrete is barely affected by tree roots, although the roots of some tree types can also affect concrete cycle tracks in time.

One disadvantage of concrete is the high cost involved in laying.

Table 29. Paving characteristics (part 2)

Concrete tiles

Tile paving can be used on subgrades with a good load-bearing capacity. However, due to the many joints, this type of paving offers less evenness than closed surfacing and is therefore less bicycle-friendly. The tiles used in cycle connections are approximately 6.0 cm thick. Tiles thinner than 6.0 cm move easily and are more likely to break during maintenance work. Kerbing should always used to avoid damage to the edges and longitudinal joints. The tiles must be laid transversely, in order to avoid inconvenient longitudinal joints. Generally, tile texture is good, ensuring sufficient skid resistance.

With tile pavements in particular, special attention must be given to proper drainage. In the absence of proper drainage, rainwater will penetrate between the joints, wash away the sand under the tiles and loosen the tiles. This makes it even easier for water to get under the tiles and the quality of the tile track rapidly deteriorates as a result.

Instead of tiles, it would also be possible to use larger elements. If concrete slabs the width of the entire cycle track are used, there are fewer seams and joints than when tiles are used. Cable and pipe managers can remove and replace individual slabs, but in that case it is important to ensure the proper (flush) transition with the other slabs.

Paviours

The evenness (and, consequently, the comfort) of clinkers and concrete paviours is almost similar to that of tiles, but is assessed as slightly less favourable by users. Therefore, just like slabs, these materials should only be used for cycle tracks in exceptional circumstances. Clinkers are often used in streets for mixed traffic. When a street forms part of a through traffic cycle connection, asphalt will be the preferred choice from the point of view of bicycle-friendliness.

The skid resistance of concrete paviours is usually good. However, when using clinker paving in streets for mixed traffic, the designer must keep in mind that clinker bricks can be slippery in wet weather and frost. This problem is not as big with concrete paviours.

It is also important for paviours and clinkers to be 'laid tightly', so that the joints are not too wide. Just as with tiles, kerbing must be used with paviours in order to avoid damage to the edges and pavement 'creep', which causes the joint width to increase.

7.1.3 Choice of paving type

Although there is a very marked preference for closed surfacing in relation to bicycle-friendliness, other paving types are also chosen. The following factors may play a role [39]:

a. spatial quality and traffic-related considerations;
b. pavement dimensions;
c. foundations;
d. damage risks;
e. cables and pipes;
f. rainwater drainage;
g. paving appearance;
h. requirements applicable to the materials to be used;
i. costs.

The most relevant aspects – for the designer – will be discussed briefly below.

a. Spatial quality and traffic-related considerations

The spatial quality required or traffic-related considerations may be the reason to opt for a certain type of paving. For example, in the context of the Sustainable Safety initiative, modular paving is generally preferred for estate access roads. However, if an estate access road forms part of a (main) cycle route, it is recommended that closed surfacing is used.

b. Pavement dimensions

When deciding on the dimensions of paving for cycle tracks, the traffic load by cyclists is rarely a criterion. This means that – in order to avoid damage as a result of overload – particular consideration must be given to (the improper) use of the paving by heavy traffic; incidentally, this traffic is often unavoidable (consider, for example, ice and snow clearing and maintenance to paving, verges and green areas). Based on resistance to heavy traffic, asphalt or concrete paving are generally preferred, with which the requirements of cycling comfort can be (continually) met.

c. Foundations

When considering any foundations for bicycle facilities, it must be borne in mind that heavy traffic is usually indicative of the load. Therefore, in general, it is wise to use foundations under the paving. Foundations decrease the chance of subsidence and the risk of edge damage. Naturally, a prerequisite is that the foundations are laid properly, which particularly means that they must be sufficiently wide. Foundations wider than the paving will help control edge damage and will also reduce the risk of accidents involving individual cyclists, because cyclists have the opportunity for correction in the event of evasive manoeuvres or incorrect steering movements.

Where subgrades have a very limited load-bearing capacity, tile paving (even with foundations) will only be considered when it will definitely not have to bear any heavy loads. Closed surfacing (asphalt and concrete) can be continuously modified to the load-bearing capacity of the subgrade.

d. Damage risks

Trees in particular present a risk of damage. The types of tree that cause the most root damage are poplars, willow, birch, robinia and Scots pine. Therefore, these types of tree should preferably not be used along cycle routes. Lime and ash trees are less undermining types of tree.

Due to the thin paving generally used, cycle tracks are extra sensitive to tree-root growth. Condensing moisture underneath the paving attracts root growth, with the result that, over time, the paving is pushed up. This then leads to bumpiness and cracks, which negatively affects safety and comfort.

It would be beyond the scope of this Design manual to look at this problem in more detail. Suffice it to say that the most effective measure against tree-root growth is the use of coarse, granular foundations immediately under the paving and preferably with a draining effect (for example, a grading of 5/40). Varying experiences have been gained with the use of anti-rooting mats and root screens.

V 72 It is a myth that it is technically impossible to control the growth of tree roots. A closed (asphalt) surfacing above tree roots is an effective cover provided it has a good foundation in the form of a layer of broken stone or rubble approximately 25 cm thick.

e. Cables and pipes

In general, no cables and pipes should be placed under cycle tracks. Within built-up areas, these should preferably be laid under footways. Outside built-up areas, they can be located in the road verge (where no trees or shrubs have been planted). Special cable and pipes tracks are advisable, but usually not feasible.

Virtually without exception, cable and pipe managers have a strong preference for modular paving without road foundations, so that the underground infrastructure can be accessed relatively easily, quickly and cheaply. In principle, this is not the concern of the road authority. On the other hand, the road authority is responsible for the proper repair of paving after digging work and the deteriorating quality of the road surface as a result of digging work. However, both the road authority and managers of cables of pipes serve the general interest, making optimisation desirable. These considerations must also include the interests of road users (including comfort for cyclists).

In general, the road authority is free in its choice of paving. When a cable and pipe manager does not wish to lay the underground infrastructure under the paving chosen, he will not usually be able to exact any other paving, but he can decide to lay or move the cables and pipes elsewhere. The agreements and regulations applicable will determine which party is responsible for the corresponding costs (or how they are divided). These may vary considerably, both per municipality and per cable and pipe manager. However, road authorities are, in principle, always allowed to lay asphalt paving or concrete paving above cables and pipes; if and how much movement costs are due is to be determined on a case-by-case basis.

Gas pipes form a special group within cables and pipes. From the point of view of safety, it is not advisable to lay closed surfacing above gas pipes (gas could build up under this pavement), and national guidelines even disallow it. As such, this safety requirement is contrary to the wish for closed surfacing for cycle tracks. However, exceptions can be made in consultation with the gas mains manager, for example when closed surfacing (such as for a cycle track) is of a limited width. Cables and non-gas pipes can be installed under asphalt without any danger.

It is impractical and expensive to open up closed surfacing. Therefore, the road authority will always have to weigh up the cost of cable and pipe management on the one hand and the comfort of cyclists, on the other.

f. Rainwater drainage
The various types of paving have different characteristics as far as rainwater drainage is concerned. Modular paving should preferably not be used on subgrades with poor load-bearing capacity, due to the high risk of subsidence – and, consequently, insufficient rainwater drainage. Closed surfacing, especially concrete, is the most durable, also in terms of rainwater drainage.

g. Paving appearance
The area in which the road is situated can impose special requirements on the paving used. In old city centres, it may be desirable to use clinker bricks, 'forfeiting' bicycle-friendliness. However, in this type of situation, special attention should be given to the subgrade and to laying the paving as tightly as possible, particular where (main) cycle routes are concerned.

h. Requirements for the materials to be used
Apart from the mentioned aspects, the road authority also imposes requirements in terms of durability, management and maintenance. This may be a reason not to use high-maintenance materials.

i. Costs
Cost comparisons often unjustly consider investment costs. An accurate cost comparison is only possible if all life cycle costs are taken into consideration, which means not only the investment costs for construction, but also the cost of major and minor maintenance, annual management (including ice and snow clearing and weed clearing) and the residual value or demolition costs at the end of the planned service life.

When considering the cost of laying and maintenance of the various types of paving for cycle tracks, the cost of kerbing plays a major

role. Well-laid tile paving (including kerbing) is more expensive than asphalt or cement concrete paving. When no separate kerbing is required, paviours are a competitive option.

When considering construction costs alone, asphalt paving is cheaper than cement concrete paving. However, when maintenance is considered as well, cement concrete is more advantageous owing to its long, low-maintenance service life (it is assumed that this will also be achieved). However, these cost comparisons depend on traffic load and subgrade, as these are decisive for the layer thicknesses of the various materials.

As regards weed clearing, closed surfacing is clearly preferable to modular paving. No clear differences exist between the paving types in terms of ice and snow clearing. When breaking up paving, elements can often be reused at little extra cost. Thus, modular paving can have a good residual value. Closed surfacing can be processed into granulate, which can be used as a secondary, high-grade raw material. However, for the owner, the residual value of closed surfacing is virtually nil.

If the laying costs alone are concerned, there is not much difference between asphalt, concrete, tile paving and paviours. Sometimes, modular paving (tiles, paviours) is cheaper, sometimes asphalt is. The outcome depends chiefly on the question of whether separate kerbing needs to be added. Well-laid tile paving (including kerbing) is more expensive than asphalt paving or cement concrete paving. In principle, the differences in laying costs do not necessarily stand in the way of providing cycling comfort (with asphalt or concrete).

Weighting table

Clearly, a large number of different factors affect the choice of the appropriate paving type. These factors vary considerably, making it impossible to measure them according to the same criterion. However, in order to achieve some degree of organisation and cohesion, the Dutch Bicycle Council, in a study of the bicycle-friendliness of different types of paving [39], brought together the influence factors in table format by allocating relative assessments (++, +, 0, –, —) to the different types of paving to be distinguished, per factor and per weighting aspect (see table 30). This table can be used as an initial guideline for selecting paving.

Table 30. Weighting table for bicycle-friendly paving [39]

	wf	no foundations				unbound found.				bound found.			
		AS	CC	CT	PA	AS	CC	CT	PA	AS	CC	CT	PA
Load bearing capacity[1]		+	+	– –	–	++	++	–	0	++	++	–	0/+
Riding comfort		+	+	–	–	++	+	–	–	++[4]	+	–	–
Accessibility of cables & pipes[1]		–	–	++	++	–	–	+	+	– –	– –	–	–
Aesthetics after repair		0	– –	+	+	0	– –	+	+	0	– –	+	+
Chance of damage by tree roots[2]		– –	–	– –	– –	++	++	0	0	++	++	0	0
Chance of damage by overload[1,2]		0	– –	– –	–	++	+	–	–	++	+	–	–
Chance of damage from foundations[1,2]						0	0	0	0	+	+	+	+
Chance of indirect [1,2] damage		0	–	– –	– –	+	0	–	–	+	0	–	–
Chance of weed growth[2]		+[3]	+	– –	– –	++[3]	++	–	–	++[3]	++	–	–
Ease and speed of minor maintenance (local repairs using the same material)		–	– –	+	+	– –	– –	0	0	– –	– –	0	0
Ease and speed of major maintenance		++	0	0	0	+	–	–	–	0	– –	– –	– –
Cost of laying[1,5,6]		+	–	0	0	0	– –	–	–	0	– –	–	–
Cost of management and maintenance		+	+	–	–	+	+	–	–	+	+	–	–
Demolition costs minus residual value of materials		+	+	++	++	–	–	0	0	– –	– –	–	–
Ice and snow clearing		only porous friction course less favourable											
Appearance of paving		depends strongly on local fit and preferences											

wf = weighting factor
AS = asphalt (with and without surface treatment)
CC = cement concrete
CT = concrete tiles
PA = paviours (concrete, clinker bricks or natural stone)
1 depending on layer thickness used
2 ++ = the most favourable, so little chance of damage
3 with the exception of porous friction course
4 if the risks of damage in respect of ridges and bumps have been covered properly
5 strongly dependent on the need to use kerbing
6 ++ = the most favourable, so the cheapest

7.1.4 Aesthetic aspects

Although there is an evident preference for closed surfacing in terms of cycling comfort, cultural and historic awareness, blending in with the landscape or urban quality may mean that paving is chosen that is not optimal from the point of view of safety and comfort for cyclists (such as clinker bricks, cobblestones, shells, enamelled tiles or natural stone).

The evenness and skid resistance of these materials may be below standard, jeopardising the safety and comfort of cyclists. These materials are, therefore, not recommended on main cycling routes. This should only be deviated from in very valuable areas, such as a protected cityscape. However, even in these situations, it is recommended that less bicycle-unfriendly alternatives are sought, such as asphalt with a pea-gravel wearing course or a colour appropriate for the area in question.

Recreational routes

Recreational routes often run through nature conservation areas and agricultural areas. Here, it is often the vulnerability of the area that determines which type of paving is possible. With a view to cycling comfort and maintenance-friendliness, closed surfacing is the preferred choice here as well, and given the chance of damage from tree roots, perhaps even more than in other situations.

If closed surfacing cannot be used in very vulnerable areas, a permeable loose-fill paving or narrower paving in ruts is a possibility. However, loose-fill paving is sensitive to co-use by motorised traffic or agricultural traffic and require regular maintenance. Advantages of paving ruts are that the area retains its rural character, cyclists are offered level paving and durability is good. A disadvantage that could be mentioned is the limited width; in the recreational sphere in particular, cyclists prefer to cycle next to each other (incidentally, this fact also applies if ruts are not paved).

7.1.5 Paving colour

Colour is an aid the designer can use to make something clear to road users. Red is now the national 'standard' for cycle tracks and cycle lanes, although there is no statutory basis for this. In fact, any colour is possible. By using a (red) colour, cycle provisions become more recognisable and more visible. It is believed that this has a favourable effect on cycling comfort (ease of use) and traffic safety. The use of colours can also support the continuity of a through traffic route.

Incidentally, the usefulness of colour for traffic safety is not unequivocally evident from accident statistics. Research in the 1980s showed that red-coloured lanes do increase the recognisability of the cyclists' domain and (partly as a result) motorists do maintain slightly more distance from cyclists when passing them. However, at the same time, the speed of car traffic on the stretches of road in question increased slightly. The added value of colour was found to be minimal. A more recent study from Denmark reaches other conclusions [78]. In Copenhagen, the effect of coloured cycle lanes at intersections was assessed. There were four colour options, which, together, resulted in 36% fewer bicycle accidents. The blue cycle lane scored the best.

Disadvantages

There are also disadvantages to the use of colour on stretches of road. Besides the increase in speed evident in the case of cycle lanes on longer stretches of road, a space that has been channelled by means of marking and colour can also give the impression that the non-coloured space is intended exclusively for cars, which is not by definition true.

Field of application

The following recommendations apply for the use of coloured (usually red) paving:

- Cycle tracks alongside roads and cycle lanes are laid in red; this colour is less vital for separate cycle tracks; suggestions lane are not laid in red.
- In order to emphasise the right-of-way situation, the red paving used for cycle lanes and cycle tracks will be continued at the point of a side road across the intersection. If cyclists do not have right of way, continued colour and marking would be inappropriate.
- Red asphalt paving can be used over the entire road width if the role of the car is subordinate. This may be the case, for example, where loading and unloading alone are permitted, in a shopping centre or in a cycle street.
- In places where two main cycling routes interchange, the entire intersection could be laid in red (a 'weaving plateau').

In other situations, the use of red asphalt paving is confusing and, as such, not advisable.

7.1.6 Paving transitions

The evenness of paving is very important for cyclists. In this respect, special attention is required for transitions in road surfacing. This may concern intersections, exits, speed humps and places where cycle connections come out onto roads for mixed traffic. Obviously, the junction between two different types of paving must be as flush as possible, with an imperceptible transition (≤ 5 mm). Uneven transitions are uncomfortable and sometimes even unsafe.

At intersections, it is customary for the paving used on the main road to be continued and for the paving on the side-road to be interrupted. However, in situations where cyclists on a crossing main cycling route have right of way, the road surfacing of the side road (that is, the main cycling route) must be continued across the intersection in order to support the deviant right-of-way regime.

Exits in particular are often subject to unevenness because the foundation of the cycle track is not geared to heavy crossing traffic. Therefore, it is recommended that cycle tracks on exits have proper foundations and, where necessary, that additional provisions be put in place.

The transition between different types of paving is also a point for attention if there is a curved drainage channel or a narrow, paved separator alongside a cycle lane or suggestion lane. Often, a deliberate choice is made here for a limited difference in height, with a view to drainage or the separation envisaged between the carriageway and the verge. This difference in height should not exceed several centimetres in order to minimise the risk of slipping or falling.

7.1.7 Marking material

Marking is an aid for the road user and is intended as a guide or to indicate or clarify an actual traffic situation. As such, the recognisability and visibility of the marking are essential. This applies even more strongly for marking in relation to bicycle facilities than for markings for other traffic, since marking for cyclists indicates:

- where other road users can expect cyclists;
- where (visual) protection for cyclists is in place and, consequently, the area where cyclists enjoy protection.

> **Extra attention for drains**
>
> Very often, drains, storm drains and the like are the cause of unevenness: it is difficult to install flush paving around a drain and sometimes the road subsides while the drain does not. In order to prevent major unevenness, dangerous evasive manoeuvres and slipping on manhole covers, the designer must take the following points into consideration:
>
> - No drains to be placed in bends.
> - Drains do not belong in the carriageway, the cycle lane or the cycle track, but in the kerb, on-street parking spaces or the nearest verge.
> - Other drains, such as sewer drains and water manholes, should preferably not be located in areas used by cyclists. This applies to cycle tracks, cycle lanes and the right-hand side of the carriageway. However, if drains are to be located in areas used by cyclists, level transitions are a precondition. Discomfort can be limited by opting for a flat type of manhole cover.

Markings produced from thermoplastic materials are the most durable. This type of marking remains visible and skid-resistant in the event of a wet road surface, is colourfast and not subject to much wear and tear. Thermoplast is more expensive to install, but cheaper in terms of maintenance. Therefore, at intersections, which have relatively much wear and tear to marking, the preferred choice is thermoplastic material. One disadvantage is that it is more slippery than road paint and also protrudes several millimetres above the surface, resulting in reduced evenness. Road paint is, therefore, the preferred choice for solitary bicycle facilities, as these are subject to less wear and tear than roads for mixed traffic.

In modular paving, white paviours can be paved in as marking. Their visibility is good and maintenance costs are negligible.

Profiled marking materials are used to give extra emphasis to the division between a cycle lane and carriageway and to introduce bollards on a cycle track. Possibilities include a separation beam, road surface reflectors, white ribbed tiles and ribbed reflex strips. A separation beam can be used in tight bends to divide a carriageway and cycle lane. However, in these situations, the cycle lane must be at least 2.00 m wide in order to prevent a situation where cyclists hit the material and lose control of bicycle. Hitting edges and obstacles with the pedals is one of the most important causes of accidents involving individual cyclists. For the reason mentioned, the use of road surface reflectors as a permanent marking for bicycle facilities is not recommended. Moreover, the reflector effect occurs chiefly when shone on by car headlights, not by bicycle lamps.

White ribbed tiles can be used to announce a bollard in the path surface of a tiled cycle track. Incidentally, bollards on cycle tracks are the cause of many accidents. This applies particularly when there is a lot of traffic on a cycle track or where cyclists tend to ride in groups: in these situations, only the cyclists at the front are able to see the bollard on time. On asphalt cycle tracks, ribbed reflex strips can be used for the same purpose. A ribbed reflex strip is a strip of thermoplast with ribs on the upper side.

7.2 Green and verges

In general, green areas are intended to strengthen landscape characteristics and the residential quality of an area. The following functions apply specifically for cyclists:

- to enhance the cycling experience and residential quality;
- to provide protection by reducing wind nuisance;
- to reduce glare from oncoming cars and to provide visual protection from car traffic (where a cycle track runs alongside a carriageway).

These positive effects are accompanied by negative effects, chiefly in the sphere of social control and safety. Green areas alongside a cycle connection can:

- impede supervision/the view from the area or from the road on the cycle connection;
- limit or block cyclists' view of the area;
- provide somewhere to hide for people with bad intentions.

For each individual situation, consideration of the various advantages and disadvantages will depend on the type of use of the cycle connection in question and on the area in which it is situated. Cycle connections used solely or in part for utilitarian purposes must safe in all circumstances. Where connections are used only for recreational purposes, a pleasant atmosphere (during the day time) is most important.

Planting

A sufficient view can prevent an oppressive feeling and a view in every direction is desirable. Dense shrubs must be kept at some distance (> 3.00 m) from the cycle connection. Because shrubs eventually grow to a height of approximately 2.00 m from the stem, young shrubs must be planted at a distance of at least 5.00 m from the cycle connection. If there is no room to do this, no shrubs should be planted, but vegetation that does not obstruct the view, such as trees or ground-covering shrubbery. It is recommended that planting is chosen with roots that do not damage cycle tracks (see also section 5.2.4).

Informal supervision and social control from houses or from the main carriageway may deter potential attackers and make cyclists feel safe(r). Therefore, situations must be avoided where shrubs hide cyclists from the view of the carriageway or houses situated close to a cycle track.

Sightlines

Besides social safety, traffic safety plays a role too. Planting may not interrupt the required sightlines. This applies to (horizontal) bends and at intersections and crossings. Freestanding shrubs are not advisable in the vicinity of intersections. They grow so fast that it is often difficult to prune them sufficiently to maintain the required sightlines. Ground-cover and low-level shrubs are suitable, as are solitary trees.

Verges

Verges alongside cycle tracks may not cause any hindrance. For this reason, an obstacle-free area of at least 1.00 m must be maintained. Within this space, there must not be any branches or sections of trunk that could impede bicycle traffic. Planting must be pruned to a distance of at least 0.50 m from the edge of the paving in order to maintain the profile of the free space. Naturally, sufficient clearance is also important.

As regards verges themselves, the section immediately adjacent to the cycle track must be flat and sturdy, particularly where a cycle track is narrower than 2.00 m. A reinforced verge will reduce the chance of an accident if a cyclist comes off the cycle track as the result of an evasive manoeuvre. This is one of the reasons why foundations should be wider than the width of the paving used.

7.3 Lighting

7.3.1 Lighting by function

The chief functions of lighting are:

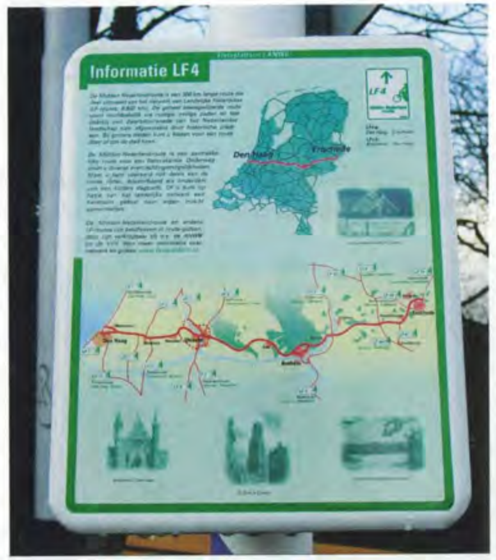
- to increase traffic safety;
- to improve traffic flow;
- to increase (cycling) comfort;
- to improve social safety;
- to make the area visible.

(Main) cycle routes

(Main) cycle routes are used most intensively in the network of connections between villages, districts, neighbourhoods and urban districts. This is the reason why these connections are subject to strict requirements in terms of traffic safety and social safety and, as a result, lighting. It is recommended therefore that lighting always be provided for main cycle routes. The higher the design speed, the greater the sight distance required, which may, in turn, influence the level of lighting.

Basic network
Standard street lighting will usually suffice for the basic network. The primary function of this lighting is to provide orientation possibilities. With a view to social safety, special attention must be given to lighting for short cuts and (by-)paths that are out of sight of local residents and other traffic.

Recreational network
Recreational bicycle rides usually occur during the day, which means that recreational tracks need not be lit. In valuable (nature conservation) areas, lighting is even unwanted. Lighting may be considered if sections of the



recreational network are also used by utilitarian cyclists. However, where this is the case, efforts must be made to limit light nuisance by using low light fittings and a low lighting strength. Turning off lighting completely at night may be considered.

7.3.2 Basic premises
Cycle connections in the basic network will usually be lit by standard street lighting. There are no additional requirements.

Separate cycle tracks that are situated no further than 2 m from the main carriageway can be lit by the lampposts on the main carriageway, provided that these are positioned in the partition verge. Where this is possible in terms of lighting technology, there is no objection to lighting the carriageway and the cycle track with the same lampposts, possibly with two brackets. Dedicated lighting will only be required in places where a cycle track deviates from the carriageway.

If a cycle track is situated more than 2 m away from the main carriageway or if the lampposts are not positioned in the partition verge, the cycle track need not automatically receive sufficient light. Particularly where the partition verge has been grown over, or where the cycle track is situated slightly further away from the carriageway, dedicated lighting may be necessary for the cycle track.

If consideration is being given to providing lighting for separate cycle tracks alone, the designer must ascertain whether or not this might be misleading for other road users; where a cycle track and a main carriageway follow a different route, cycle track lighting may lead to a confusing road image for road users on the main carriageway.

Cycle track lighting may be required in the event of considerable use (> 1,500 cyclists a day). Where cycle tracks are situated up to 2 m from the main carriageway, it is recommended that the carriageway is lit; if the distance is greater than 2 m, dedicated cycle track lighting is recommended.

Social safety

In order to ensure that social safety is sufficiently taken into account in the assessment of the need for lighting, the province of Noord-Holland is using a number of reduction factors. The general installation standard for cycle track lighting is 1,500 moped riders/cyclists a day on a two-way track and 2,000 moped riders/cyclists on a one-way track. This standard is adjusted with a reduction factor between 0.8 (in the case of clearly demonstrable average social unsafety) and 0.4 (in the case of extremely high social unsafety, based on objective data). In the latter case, lighting will be installed where tracks are used by just 600 (two-way) and 800 (one-way) moped riders and cyclists a day, respectively [40].

Tunnels
Tunnels must receive as much daylight as possible. There are a number of ways of achieving this, for instance by creating two shorter tunnels under the lanes with an open middle section instead of one long tunnel under a carriageway. Lighting is also recommended to promote social safety. The difference between the lighting level within and outside the tunnel may not be too excessive. Therefore, the lighting in the approach to the tunnel must be adjusted to the lighting level in the tunnel. Specific recommendations for tunnels have been drafted by the Netherlands Society for Lighting Technology [*Nederlandse Stiching door Verlichtingskunde (NSvV)*] [76].

Area alongside cycle tracks
As far as is known, the lighting envisaged for areas alongside cycle tracks has not yet been researched. Most lights and light fittings also provide enough light alongside the cycle track when the cycle track is sufficiently lit. In the case of lights that direct concentrated light onto a cycle track, this point deserves special attention.

Luminance
The visibility of the course of a cycle track is determined not so much by the amount of light that falls on it but by the amount of light that is reflected by the road surface (luminance). The visibility of road surfaces in the dark is largely determined by the brightness of the surface in question. From the point of view of proper luminance, the use of concrete paving is the preferred choice.

Lighting intensity

From the point of view of social safety, street lighting must generate enough light to recognise people and objects on or next to the road from a sufficient distance. Pedestrians are known to feel unsafe when they are unable to observe people's faces within a distance of 4 m. No figures are available for cyclists in this respect. The NSvV recommends an average horizontal lighting intensity (= the average amount of light that falls on the road surface) of 7 lux.

On routes that cannot be made socially safe, it may be decided to suffice with the less stringent requirements stipulated for lighting intensity on the basis of traffic safety. Depending on the possibility of glare from cars, the presence of mopeds and the number of traffic directions on the cycle track, the NSvV recommends an average horizontal lighting intensity of 2 to 5 lux.

Incidentally, the visibility of an area is not determined by the average horizontal lighting intensity, but by the amount of light that is reflected by the road surface (luminance). Luminance depends on a number of factors, including lighting intensity, the colour of the light and the reflection characteristics of the path surface. Lighting alongside cycle tracks must have a high colour recognisability (HPLN and TLD lamps).

Colour and uniformity
For reasons of social safety it is important that lighting contains different colours from the colour spectrum, so that faces can be recognised from a greater distance. From this point of view, white light is the preferred choice.

The lighting level on the road surface under a lamppost must not vary too much from the lighting level between two lampposts. Where this is the case, this will lead to poorer visibility of the road surface and to tiredness in cyclists, because their eyes will need to continually adjust to the changing lighting levels. The differences are determined by a number of factors, including the distance between and the height of the lampposts, the quality of the lamps and the optical system in the light fitting. In the case of the standard distance of 30 m between lampposts, sufficiently uniform lighting is possible. The NSvV states that, from the point of view of social safety, the lowest lighting intensity on the road surface must be at least 30% of the highest lighting intensity.

Glare
When cyclists could be subject to glare from oncoming motorised traffic (including mopeds), lighting intensity must be relatively high. In that case, the differences in intensity between street lighting and vehicle lighting will be reduced and cyclists' eyes will not have to adjust so much. Incidentally, street lighting can also produce glare sometimes. This can be avoided by ensuring that lampposts are of the correct height and of a good quality.

Extensively used cycle connections
Where people only cycle in the dark very rarely, it is not wise, from the point of view of efficiency and environmental consideration, to intensively light a cycle connection. However, the absence of lighting along a connection may not cause large groups of people to decide not to cycle there. The point to consider, then, is not only the actual use of a connection but its potential use as well.

Intensive lighting may only be omitted if each of the following conditions is met:

- the cycle connection is situated outside a built-up area and does not connect any residential centres over a distance of less than 5 km;
- the cycle connection is not situated on a home-school route or home-work route;
- the cycle connection is not situated on a route for evening destinations, such as entertainment centres and sports centres.

On routes that comply with this three requirements, lighting that is merely intended to indicate the course of the cycle connection (orientation lighting) will suffice. This type of lighting is important for cyclists' traffic safety. In any event, bends, intersections and obstacles at a distance of less than 0.50 m from the road or the cycle track must be lit. In the case of a separate cycle track, its connection with the main carriageway is also important: if elements of the cycle track are lit, the corresponding section of road must also be lit.

If orientation lighting alone is present, edge-of-track marking may have an important function. Given the limited power of a bicycle head light, it will be unnecessarily difficult (and often impossible for visually impaired and older cyclists) for cyclists to maintain their course in the dark without this marking.

7.4 Signposting

The most important function of signposting is to help cyclists unfamiliar with the local area to find their destination. A subordinate function of signs is that they help cyclists who are familiar with the local area understand the cohesion of the through route network.

The Netherlands has an extensive signposting system consisting of the familiar blue boards. These 'general' signs are intended for all types of traffic, but are geared particularly towards motorised traffic. From the point of view of the cyclist, this is not ideal because:

- the general signs do not always indicate the most direct route for cyclists;
- the signposts (which are primarily intended for motorists) are sometimes positioned less ideally for cyclists on cycle tracks;
- specific information for cyclists is often lacking. Cyclists have different signage needs because they travel more slowly and over shorter distances.

Dedicated signs for cyclists

The just mentioned limitations in respect of general signs can only be resolved by introducing a dedicated system of bicycle signs that links up with the cycle route network. A core question in this regard is when a dedicated system of signs is advisable. The basic premises are simple:

- Outside built-up areas, dedicated bicycle signs indicating all relevant cities, towns, villages and residential centres are always advisable. Major facilities and places of interest for cyclists must also be indicated, such as recreational areas, tourist attractions and campsites.

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- Within built-up areas, signs are advisable when urban districts and districts are clearly recognisable as spatial units. In this situation, signs indicate districts and urban districts, but also stations, recreational and sports facilities, the city/town centre, museums, the tourist board and other facilities that attract large numbers of cyclists.

Table 31. Step-by-step plan for signposting

1. Identify important departure and destination locations

This first step entails the identification of locations for inclusion in the signposting system. Outside built-up areas, these are all relevant cities, towns, villages and bicycle-attracting facilities, such as recreational areas, tourist attractions and campsites. Within built-up areas, this concerns districts, urban districts, stations, recreational and sports facilities, the city/town centre, museums, the tourist information office and other facilities that attract large numbers of cyclists.

2. Signs at decision points

Signs must be placed at all decision points and must enable cyclists to follow their chosen route. The system must be consistent: once a destination has been indicated, it must be repeated on subsequent signs until the cyclist has reached his destination. Therefore, on signs, destinations that have already been indicated on previous signs will have priority above all other destinations. Routes from the edge of a built-up area to the centre must be regarded as the final part of a route to a city, town or village. Therefore, signs bearing the word 'centre' must be continued right into the city centre.

3. In the event of different routes: opt for the most direct route

If different routes are possible from a departure point to a particular destination, the most direct connection will generally be the one indicated on the signs. This may be deviated from where the longer route is a far better alternative, but the extra distance must not amount to more than approximately 10% of the most direct route. If the extra distance is more than approximately 10%, the most direct route must be indicated on signs, however poor the quality of the route in question. In this case, a more attractive alternative may be indicated in green lettering instead of red lettering. Often, these alternatives will be less direct and less suitable for use at night. For financial reasons, routes are sometimes combined (resulting in a need for fewer fingerposts). Here, too, the route indicated may not be 10% longer than the quickest route.

4. In larger cities, indicate the centre too

All signs must indicate the distance to the destinations indicated. This concerns the distance to the edge of the built-up area in question. From a distance of five kilometres before this point, the distance to the centre will be indicated too.

Table 31. Step-by-step plan for signposting (continued)

5. Number routes (optional)

In cities in particular, where there are usually far more route options than in smaller places, route numbering may make it considerably easier to follow a route. Route numbering may entail the placing of 'reminder signs' between decision points with a full signpost.

6. Map on the edge of a built-up area

Motorists are already used to information panels and maps at the edge of a town, village or district. Cyclists often have to use these same maps. It is important, therefore, that cyclists are able to get off their bicycles and stop safely and that the map is also visible and accessible from the cycle track.

A dedicated map for cyclists could also be considered, certainly at the most important cycle entry-points to a town or city. Besides the centre and important facilities, these maps could also indicate cycle routes and salient landmarks.

7. Street signs on street corners and at intersections

Although the indication of street names does not actually form part of the signposting system, it is vital for cyclists that they can see clearly legible street signs on every street corner and intersection, enabling them to reach their destination as quickly as possible.

Signposting system

If it is decided to opt for a signposting system for bicycles, the step-by-step plan reproduced in table 31 may be useful.

Signs must at least contain the following information:

- the next destination(s) and, possibly, the name of a larger place situated further away;
- the corresponding distance in kilometres.

Near larger towns, the destination 'centre' will also be signposted from approximately 5 km before the edge of the built-up area (with the corresponding distance).

Recreational cycle routes

A national network of cycle routes has been developed for tourist bicycle traffic under the responsibility of the Dutch National Cycling Platform. When modifying signs, road authorities must consult this Platform. The Platform's routes are identified by means of small hexagonal boards with direction signs and can be followed in one direction. There are also a number of national cycle routes, which are identified by rectangular LF (NC) signs. These regional and sometimes international routes are signposted in two directions.

A special form of signposting is junction signposting, in which junctions (cycle track intersections) are numbered at regional level. At a junction, reference is made to the next numbered junction in every direction. This enables cyclists to put together their own recreational route with the help of a map indicating all numbers.

7.5 Social safety

Social safety (depending on the context also referred to as social *un*safety) is determined by the extent to which people are able to move free of the threat of any confrontation with violence in a particular area. This subject often plays a role for cycle connections situated in green, quiet or slightly remote areas. Social safety is indisputably linked to layout. People feel safer in places and connections where there are a lot of people and, consequently, a lot of supervision. Passers-by can intervene where necessary. What is even more important is that potential offenders are deterred by the presence of people.

The actual layout of the area in question is important too, since it has been found that actual intervention by people depends on the extent to which they feel responsible for the situation. In a well-kept small-scale living environment, people have been found to be more likely to feel involved than in a neglected area surrounded by large-scale flats. Another factor is that the better a (potential) victim can be seen by onlookers, the bigger the chance that these onlookers will actually intervene.

Given the above, it is best, wherever possible, to mark out cycle routes through areas where social activities are organised, preferably in the evening hours too. In principle, this can be achieved in two different ways: by running cycle routes alongside 'crowd pullers' and by bringing 'crowd pullers' to cycle routes. In this context, 'crowd pullers' are not so much large-scale buildings, but small-scale facilities, such as a postbox or telephone box; their presence can be very useful.

Moreover, surveyability may mean that potential danger is discovered at an early stage. Surveyability entails that the structure of the situation is clear and that no objects are situated along the connection behind which potential offenders could hide (thick shrubs, for example).

Unfortunately, even when all of the conditions have been met, social safety cannot be guaranteed. Even the busiest cycle route in a city can feel deserted and isolated at night. Someone with bad intentions will always find somewhere to put them into practice.

For the designer, the greatest yield in terms of social safety can be achieved at the level of network formation. By ensuring that cycle connections do not run through deserted and clearly socially unsafe places, the most important requirement can be met: ensure that there is supervision and social control.

Socially unsafe routes

If a route has been established and the spatial context at planning level can no longer be influenced, possibilities for the designer will be of a different order. Measures to remove unsafety must then focus on:

a. optimising the informal supervision of cyclists and optimising the view that cyclists have;
b. discouraging opportunist crimes;
c. offering an alternative route if an acceptable level of social safety is not achievable.

Re a. Optimising the supervision of cyclists and optimising the view that cyclists have

If possibilities exist to improve supervision of a cycle connection, this is the most important step that can be taken. The more people there are around, the less socially unsafe the situation becomes. It is also important for people to see 'escape routes' at an early stage. Optimising the cyclist's view of a cycle connection can be achieved by means of such measures as:

- moving the cycle route;
- installing lighting;
- removing objects that obstruct people's view (including planting).

Some of these measures also relate to the cyclist's view. For example, the removal of dense planting directly alongside a cycle track and the installation of lighting for cyclists improve their view and, as such, have a positive effect on social safety.

Re b. Discouraging opportunist crimes

A particular situation may encourage individuals with bad intentions to act on these intentions. The immediate surroundings of a cycle track play an important role in this respect too.

If no high objects or dense overgrowth is situated close to the cycle connection, people will be unable to conceal themselves. In a well-lit area, with supervision from homes or from the road, people will be less inclined to misbehave than in a poorly lit area with little supervision. The 'quality of the surroundings' also plays a role. Good design and a well-maintained situation reduces the risk of vandalism and is less likely to attract misconduct than a poorly maintained situation.

Re c. Offering an alternative route
Situations are imaginable in which it is not possible to sufficiently remove social unsafety. In these cases, there will be no other solution for the road authority than to offer an alternative route. This route will probably be longer than the socially unsafe route, but cyclists will, in any event, have a choice.

On existing routes, social safety can be improved by keeping planting low, providing crowd-pulling facilities, installing proper lighting and ensuring that the area is well-maintained and managed.

Discouragement policy not advisable
Deliberately discouraging use of socially unsafe connections (by removing lighting, for example) is not advisable, since routes that are socially unsafe at night may be comfortable and useful (and less socially unsafe) during the day and during busy evening hours. Besides, social unsafety is not the same for everyone. Some categories of people are not at any great risk on a socially unsafe cycle connection. For them, optimal organisation of the cycle connection with proper lighting really is important.

Social safety versus other interests
Measures designed to promote social safety may conflict with other interests. Several examples follow below:
- when shrubs are removed in order to gain a better view, this may detract from the landscape value of the area;
- when, for reasons of social safety, a cycle connection is not run through a park but alongside a busy road parallel to the part, this may result in detours and less comfort;
- the provision of lighting for a cycle track in a vulnerable nature conservation area leads to 'light pollution'.

Conflicts such as those make a thorough assessment vital. There is no general assessment method, as social safety depends on very specific local conditions.

Priority for busy, utilitarian routes
A connection with a primarily utilitarian purpose is more eligible for improvement than a recreational connection. Recreational cycling is mostly a daytime activity. Alternatives are often available for recreational connections and measures that promote social safety can also reduce the landscape (and recreational)

value. Social safety demands extra attention on routes to destinations that are often visited during the evening hours (for example, an entertainment centre, sports centre, city centre, district centre or community centre).

7.6 Other facilities

7.6.1 Shelters

Shelters offer protection against rain in particular. Naturally, places where cyclists regularly (have to) wait, will be eligible for these facilities first. Shelters are advisable:
- at cycle connections via ferries, locks and movable bridges;
- at places where cyclists are used to waiting for each other (small groups of school children);
- at bus stops where cyclists get on a bus (of course, good bicycle parking facilities will be needed too; see chapter 8);
- at places where no other shelter is available close by (connections outside a built-up area). In these situations, shelters could be combined with bus stops.

Shelters must be big enough to shelter in with a bicycle. When erecting shelters, it must be ensured that sheltering cyclists are able to see an approaching ferry, the bridge closing, etcetera, and also that people from the road can see what is happening in a shelter. This is necessary in connection with social safety.

7.6.2 Places to rest

Benches and picnic places are particularly advisable on long-distance green connections that attract a large amount of recreational bicycle traffic. It would seem obvious to choose peaceful locations for this, in places with an attractive landscape. Locations close to a railway, road, motorway or car park are less suitable.

7.6.3 Service at petrol stations

Petrol stations situated alongside through traffic cycle connections provide an ideal opportunity to offer cyclists very useful services, such as:

- the sale of standard cycling articles, such as tyres and repair sets, so that these are also available outside regular shop hours;
- the organisation of covered, lit stop places, where cyclists can shelter, wait for each other and do minor repairs;
- offering bicycle storage space, making the petrol station a suitable place to get on public transport or someone's car (' bicycle-car pooling').

The realisation of facilities of this nature is certainly possible through public-private collaboration between the road authority and petrol station owners.

7.6.4 Small-scale road furniture

It is recommended that postboxes, telephone boxes, rubbish bins, cash dispensers and the like be placed alongside cycle connections. Not only because this is attractive for cyclists (they can combine various trips), but also because these road design elements attract people in the evening hours, which improves social safety on cycle connections.

Bottle banks will be positioned at a distance of at least 5.00 m from the side of the paving in order to prevent punctures from pieces of glass.

Description	Pavement kerbs for cycle tracks
Function	• preventing modular paving from moving • protecting cycle track from other traffic areas
Application	• separation of cycle track from the kerb, carriageway or unpaved verge • necessary for cycle track in modular paving • A, B (1) and C in the event of a difference in height • B (2), (3) and (4) in the event of absence of a difference in height • (1) also for central island roundabouts
Implementation	• A (1) not with low side alongside narrow cycle track (in connection with fear of obstacles) • concave and/to convex joints (B also V joint)
Dimensions	A: • a x b x c (in cm) • (1) : 13 x 15 x 16/20/25 • (2) : 11 x 22 x 25; 18 x 20 x 16/20 • (3) : 13 x 15 x 10/12/14; 18 x 20 x 10/12/14 • working length 100 cm; h = approximately 11 cm B: • b x c (in cm) • (1) : 10 x 20/25/30; 12 x 25 • (2) : 10 x 25 • working length 100 cm • radius kerbs R = 0.50 / 1 / 2 / 4 / 6 / 11 m • (3) and (4) : 5 x 15; 6 x 15/20; 8 x 20; 10 x 20/30; 12 x 25 • working length 110 cm, radius kerbs R = 0.50 to 12 m C: • a x b x c (in cm) • (1) : 7 x 20 x 15, working length 100 cm • (2) : 6 x 12 x 10, working length 100 cm
Considerations	• pavement kerbs prevent tiles/clinkers from moving (in cycle track in modular paving) • A (1) alongside carriageway keeps other traffic away from the cycle track most effectively and gives the best guidance • C (1) shatter-proof profile • with A (1), cyclists can hit the pavement kerb with their pedals and fall off their bicycles • with A (1), a fear of obstacles in respect of the pavement kerb effectively results in a more narrow cycle track

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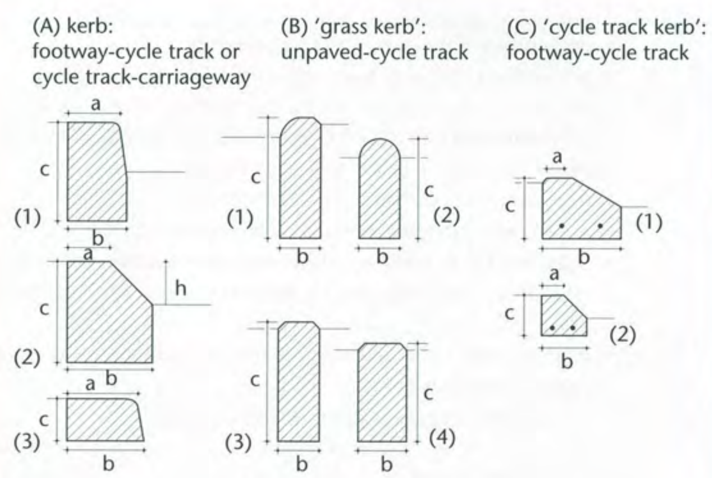

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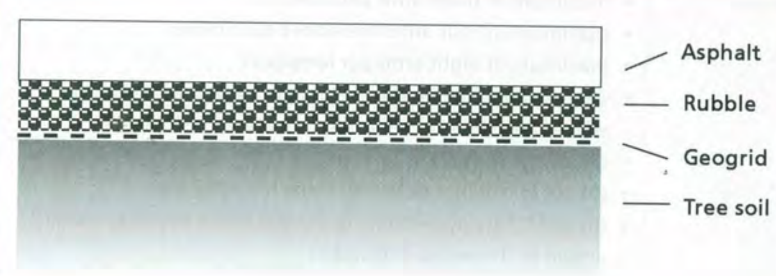
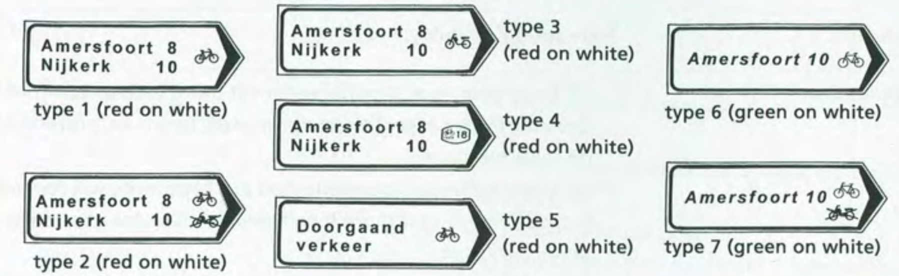
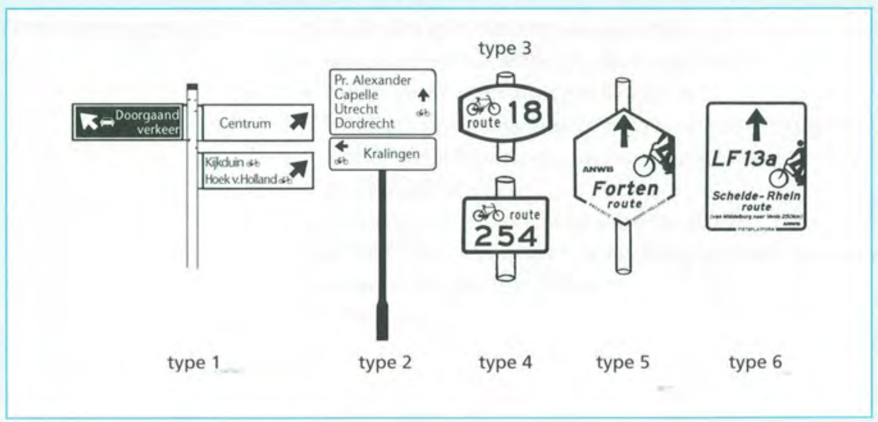
Description	Tree-root-resistant foundations for cycle tracks
Function	• preventing damage to paving caused by tree roots
Application	• separate or solitary cycle tracks with trees alongside them, situated within a distance of one-and-half times the crown width • other cycle tracks where tree-root pressure is to be expected
Implementation	• rubble foundation of 4/40 to 10/70 (particles with a cross-section smaller than 4 or 10 mm, respectively, have been sieved out) • preferably geogrid under rubble, to more evenly divide pressure • under this, tree soil (3 – 5% organic matter) to promote root growth • do not apply any soil between the rubble and asphalt!
Dimensions	• thickness of rubble 0.15 to 0.25 m, depending on the subgrade and on the load-bearing capacity required • asphalt thickness 0.06 to 0.10 m, depending on the subgrade and on the load-bearing capacity required
Considerations	• no root growth under asphalt due to airiness and draining effect of rubble • barely more expensive than traditional foundations • slightly lower load-bearing capacity than traditional foundations (can be compensated in the thickness) • required load-bearing capacity determined particularly by co-use by trucks and cars (for maintenance and ice and snow clearing) • not always possible with modular paving



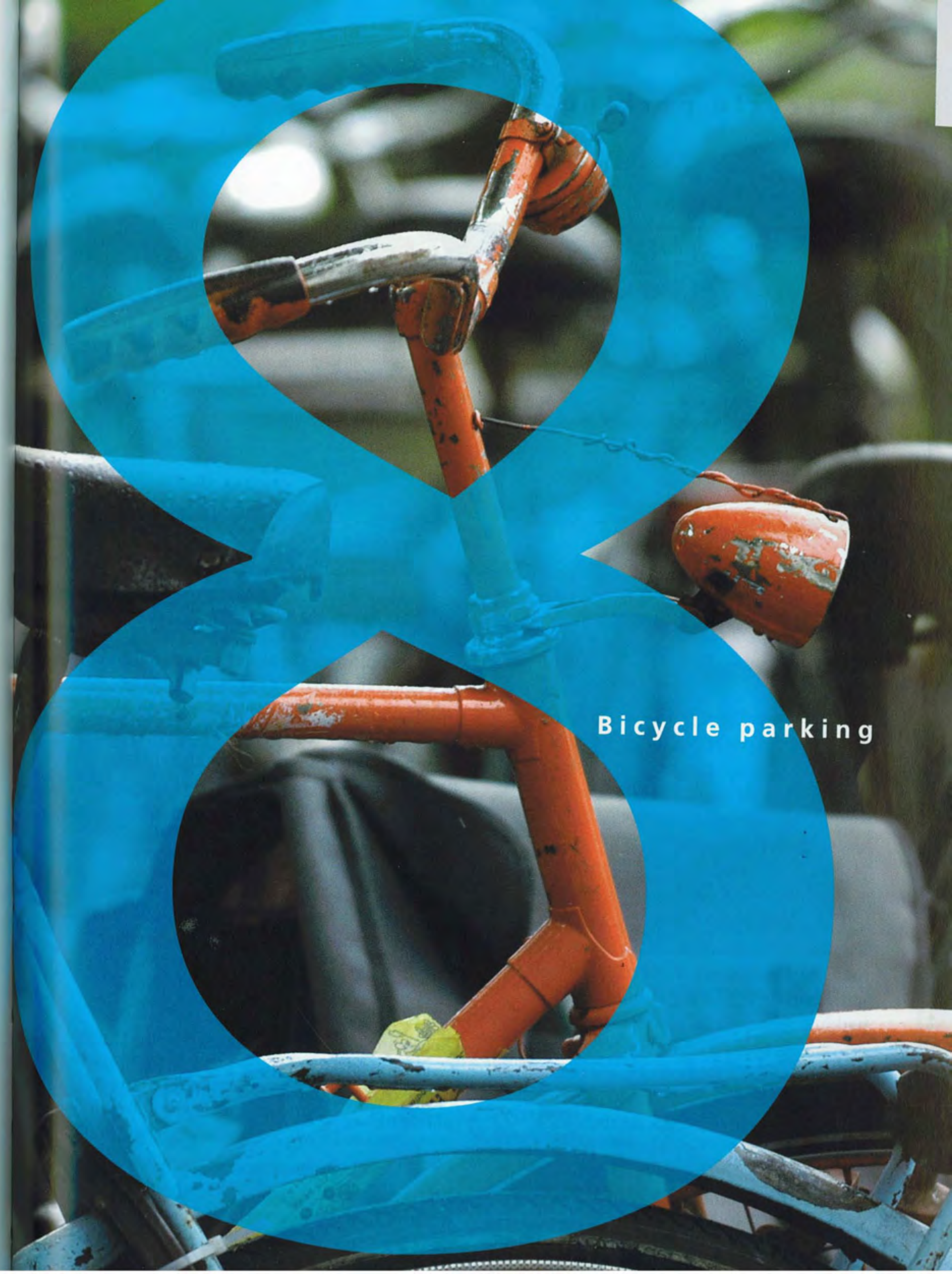
Description	bicycle fingerpost
Function:	improving findability
Application	• if route for cyclists deviates from general route signposted • if cyclists need extra information • for cycle routes with their own route
Implementation	• text and background non-retroreflective • front: background white • front: text, border, chevron and symbol red for utilitarian destinations, green for recreational destinations • text: lower case with initial capital; red text roman; green text italics • two lines of text pre fingerpost • back white (if no text)
Dimensions	• sign 0.75 x 0.22 m • height of lower post > 2.20 m • letters: see Signposting guidelines [79]
Considerations	• due to high positioning, not subject to high risk of graffiti or damage • barely any inconvenience for pedestrians • bicycle symbol ensures that motorists do not interpret the cycle route as a route for car traffic • little text space
Combination options	• maximum of three arms per direction • maximum of four arms one above each other • maximum of eight arms per lamppost • when attached to lamppost: post provided with painted white/blue streamer, in order to increase visibility • (3) always with (2) • (5) not in combination with other local signs • (6) and (7) always with (1) or (4); the green text may also be added to the red text (6 and 7) • with lamppost



Description	Examples of cycle signs
Function:	increasing findability
Application	• (1) fingerpost, in additional system at point where cycle route deviates from general route signposted; however, preferably on separate signs • (2) combined cycle sign positioned at a high level; will replace bicycle fingerpost if there is no room for this; also as an early announcement • (3) and (4) cycle route number, in signed and numbered urban (3) and national (4) cycle routes • (5) tourist circular route; in the case of one-way, closed circuit • (6) tourist long-distance route
Implementation	• (1) according to standard design of Signposting guidelines [79] • (2) the same as bicycle fingerposts; a box with a maximum of four destinations per direction • (3) and (4) colour the same as bicycle fingerposts • (5) and (6) green text on a white background
Dimensions	• according to Signposting guidelines [79]
Considerations	• (1) alternating confrontation with general and cycle signposting
Combination options	• (1), (2), (3) and (4) with a lamppost • (5) and (6) with any sign or any other fingerpost



Description	Examples of pictograms
Function:	increasing findability
Application	• (1) on cycle route; once on each fingerpost or each direction field of the sign • (2) at point where bicycle and moped route splits, on the sign that indicates the moped route • (3) on cycle route, in combination with (1) • (4) on main cycle route and/or through traffic route in urban area; in combination with destination, which can change under the same route number • (5) reference to bicycle storage facility • (6) reference to bicycle storage areas (bicycle racks) • (7) reference to station • (8) reference to ferry • (9) reference to information point • (10) reference to tourist information office • (11) reference to recreational area
Implementation	• all symbols in red (shortest route) or green (recreational route) • (1), (2) and (4): present once per fingerpost or direction field • (7), (9) and (10) possibly in different colours, according to the logo in question • (5) to (11) always behind destination interurban, local (district, centre) or object-based (name or description) and on the same line • where numbered routes converge, (4) will appear on a fingerpost a number of times • (5) sometimes with text ' bicycle storage facility' or 'secured storage facility'
Dimensions	• not standardised
Combination options	(3) never with (4)



8 Bicycle parking

8.1 Why a bicycle parking policy?

Cyclists not only need good and safe cycle routes, they also need facilities to park their bicycles safely, easily and tidily. This requirement is understandable when we consider the risk of theft of or damage to the bicycle. It is, moreover, a relevant requirement for mobility policy, as the fear of theft leads to reduced use of bicycles, whereas the bicycle is an important means of transport.

The need for good parking facilities appears to be ignored to an increasing degree, particularly in city centre areas. More and more often municipal authorities are developing their own initiatives for tighter regulation of bicycle parking. Although the aim of these initiatives is to enable cyclists to park their bicycles safely, easily and tidily, that is not possible in the place where cyclists want to park, namely as close as possible to their destination.

Bicycle theft has been the most common offence in the Netherlands for decades now. Each year at least 800,000 bicycles undergo an involuntary change of ownership, although the figures fluctuate according to source and year. Each year approximately five per cent of Dutch people over the age of 15 are victims of bicycle theft. However, not every bicycle owner runs the same risk of having their bicycle stolen. There is a greater risk of theft in large cities than in small towns and villages. But the difference in risk has clearly decreased; high risk figures are no longer limited to the largest cities alone.

bicycle theft is evidently a significant problem. For many cyclists, the risk of having their bicycle stolen is reason enough to leave it at home. National surveys [41] have shown that of the people who never cycle into the city centre, 31% give fear of theft as the reason. According to a survey conducted by the Dutch Cyclists' Union (February 2004), 32% of the respondents would not buy a new bicycle out of fear of having it stolen.

Of all bicycles that are stolen, approximately half disappear in the immediate vicinity of the home [42]. It is particularly in areas where there are few supervised bicycle parking facilities that bicycle thieves strike most. The remainder of the bicycle thefts take place mainly at stations, schools, shopping centres, entertainment facilities and sports grounds.

Terms

Most Dutch people park their car and store their bicycle. But when a bicycle is left on the street for a short time, this is also known as (bicycle) parking, certainly within the professional community. Furthermore, suppliers of bicycle racks and stands refer to their products more and more often as bicycle parking systems. In this Design manual, the various terms related to bicycle parking are defined as follows:

- *Parking* is leaving a vehicle stationary other than during immediate boarding or alighting or during loading and unloading.
- *Storing* is placing a bicycle in a bicycle storage facility.
- *Bicycle parking* means placing a bicycle in a bicycle parking facility, on its own stand or against any object that can provide support, such as a wall, fence, pole or tree.
- *Bicycle parking facility* means a bicycle parking system, a bicycle storage facility or a combination of them.
- *Bicycle parking system* is a structure that is intended to have one or more bicycles placed in or against it.
- *Bicycle storage facility* is a delineated and supervised space that is intended for placing bicycles.

Bicycle parking policy process

The process of developing effective parking policy comprises five steps:

Step 1: Bicycle parking is placed on the agenda
Step 2: Support and policy integration
Step 3: Policy aims
Step 4: Analysis and solutions
Step 5: From solutions to policy

It is mainly steps 4 and 5 that are relevant within the scope of this Design Manual. Please see ' Bicycle Parking Guideline' [70] for more information on steps 1, 2 and 3.

Analysis (step 4) is generally useful in bicycle parking policy because so much can be learned from practice. After all, cycling takes place everywhere and bicycles are being parked everywhere; the cyclists' requirements and problems can be seen to a large extent from the 'practice on the street'.

In section 8.2, the recommendations for the analysis are differentiated according to the various types of locations where bicycle parking policy may play a role. After all, this can involve 'solitary functions' (for example, a sports park that is so isolated that 'solitary bicycle parking measures' can be taken), but it can also involve locations where functions are so interwoven that an area approach to bicycle parking is required. The analysis is significantly more complicated in the latter case.

In relation to this, there are differences in the degree to which generally applicable guidelines exist (often for solitary functions) or to which empirical research is required (often with area analyses). The recommendations in section 8.2 basically concern intrinsic choices about capacity, location and bicycle parking systems. Section 8.3 looks into the choice of suitable bicycle parking systems.

8.2 Analysis of the number of bicycle parking facilities required

Locations can be classified in various ways:
- solitary functions versus interrelated functions/areas;
- homes (points of departure) versus companies/government agencies (destinations) versus transfer points ('intermediate destinations');
- employees/residents versus visitors;
- existing construction versus new construction.

If these classifications are related to each other, there appear to be five relevant categories for which – seen from the perspective of analysis recommendations for bicycle parking policy – bicycle parking policy can be developed in the Netherlands:
1 city centre areas/station areas
2 older residential areas
3 new housing
4 companies and institutes
5 public transport stops

Figure 26 shows this derivation of five categories.

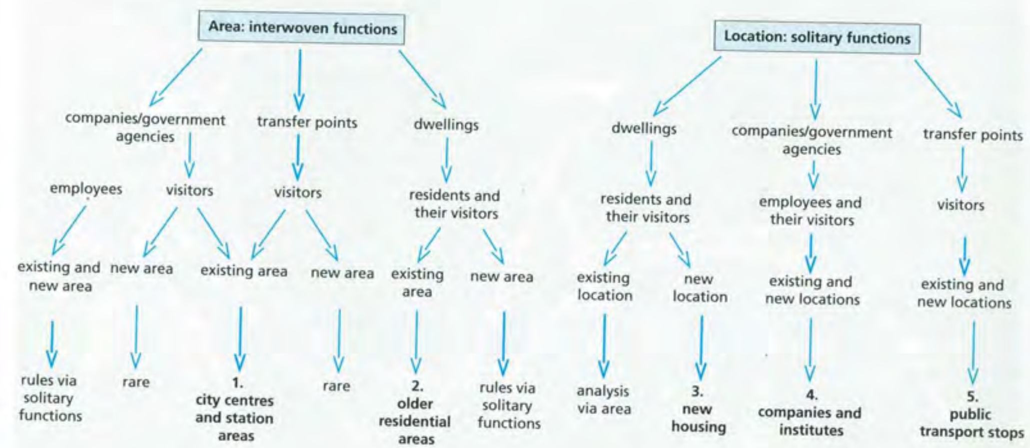


Figure 26. Derivation of analysis-classification into types of location

Monitoring capacity

The desired capacity of bicycle parking facilities does not appear to be a static fact. Patterns in numbers of parked bicycles per location appear to change regularly and substantially. Frequent monitoring is therefore also important in determining the correct capacity: which facilities overfill or are underutilised? A surplus is undesirable as the presence of large numbers of empty bicycle parking systems unnecessarily pollutes and 'uses' the street scene. A shortage is just as undesirable. Bicycles are then certainly left alone on the street, possibly in places where one would rather not see them.

8.2.1 City centres and station areas

This subsection outlines how an analysis of bicycle parking in city centres and station areas can be conducted in seven steps.

Step A: Definition of the research area

Defining an area that is too small can mean that destinations and/or parked bicycles are not included in the analysis, even though they may be relevant for the use of a new supervised storage facility, for example. The rule of thumb is therefore that it is better to define too large an area than one that is too small.

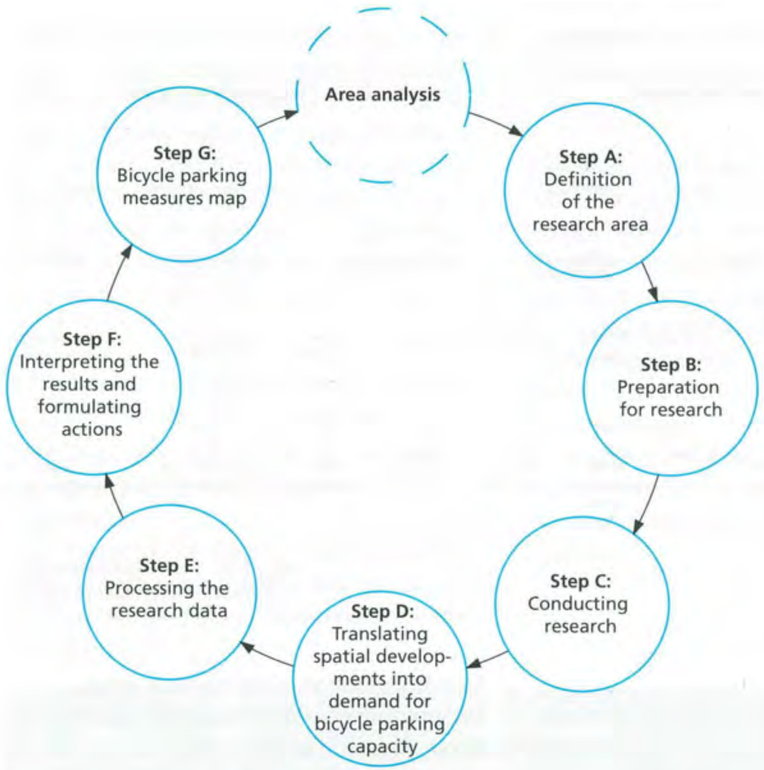


Figure 27. Analysis process for bicycle parking policy in city centres and station areas, in seven steps

Step B: Preparation for research

At many facilities, cyclists generally want to park their bicycle as close to their destination as possible. Bicycle use is, after all, very sensitive to detours and walking. For this reason, it is advisable to obtain as detailed an image as possible of the actual parking demand in the research area. This can be done by dividing the area into sections. The maximum length of a section could be set at approximately 50 m; as far as the width is concerned, both sides of a street can generally be included in one section, except if squares are involved. Local circumstances naturally play a significant role in determining the size of a section.

Step C: Conducting research

Actual counting on the street is central to this step. It is not only the parked bicycles that

should be counted. The capacity and quality of bicycle parking facilities are also relevant, as is the manner in which bicycles are parked: in a bicycle parking facility, next to or against it, or 'entirely separate'.

The bicycles in the research area must be counted on a representative day. In general, counts can best be taken in the months of April/May/June and September/October. When counting, it is important that no work is being carried out in the immediate vicinity and that the normal traffic circulation is not being disrupted by diversions. Finally, on the day of counting, no special events should be taking place in the research area.

A count must be taken at least at the representative (busiest) time. In order to obtain a reliable picture, it is recommended to repeat the research on a second research day. The representative time differs per type of destination:

- city centre area: on Thursday or Saturday at around 3 p.m.
- train station or bus station on Tuesday or Thursday at around 11 a.m.

Step D: Translating spatial developments into demand for bicycle parking capacity

Bicycle parking in city centres and station areas is related to bicycle use for shopping transport, for pre- and post- travel by public transport and for social-recreational destinations. The vast majority of such bicycle journeys are, in practice, over a distance of approximately 3 km. If a new housing estate is to be built within this distance of a city centre area or station areas, an increasing demand for bicycle parking facilities must be anticipated. If an existing city centre or a certain shopping

street is to be substantially improved, it is recommended to look at the current number and the number of city centre visitors expected after the revitalization (per day). Such prognoses are often made for large-scale revitalization projects. The percentage increase in the total number of visitors is a good indicator for the required increase in bicycle parking capacity. In general, the growth in the number of visitors due to the quality impulse of a revitalization project generally leads to corresponding increases in the various means of transport used by the visitors.

> *Example:*
> At a representative time, the bicycles parked in the city centre area are counted (1,000 for example). At the same time, an inventory is taken of the number of dwellings located within a 3-km radius of the area (5,000 for example). The average number of parked bicycles per dwelling is derived from this (0.2 in this example). If a new housing estate comprising 2,000 dwellings is built within the sphere of influence, the bicycle parking capacity in the city centre area will have to be expanded by 2,000 x 0.2 = 400 places.

Changes in the timetables and/or the construction of new (suburban) stations or stops can have a significant impact on the number of passengers and hence on the number of cyclists. A general prognosis of the anticipated changes in the total number of passengers can usually be requested from ProRail and/or the local transport companies. The distribution of modes of transport and pre- and post-transport can then be considered as a given. The bicycle share will increase proportionally.

In addition to spatial developments, there are two other factors that could be of influence:

- Demographic changes.
  In a planning term of, for example, ten years, there can be fairly substantial developments in numbers of residents in a municipality, even without large scale spatial developments.
- Far-reaching traffic policy
  Strict limits on the use of motorised vehicles in the city centre (for example, by introducing paid parking or a significant increase in the rate) can result in an increase in bicycle traffic by a few per cent.

Step E: Processing the research data
Normally, research results are shown in tables and/or graphs. Considering the spatial nature of research into required bicycle parking capacity it is, however, recommended that the results are presented on a map. This will make it clear at a single glance whether or not 'action' is required. Basic information for the map representation includes:

- the anticipated future demand per section, with or without stray bicycles (where the omission of stray bicycles implicitly means a choice for periodic clean-up actions).
- the fixed future capacity: that which currently exists and is not earmarked for removal.

An occupation level of between 50 and 80 per cent is considered to be a balanced supply. An occupation level of less than approximately 50 per cent is considered to be over-capacity. If the occupation level is 80 per cent or more (complexes of) bicycle parking facilities/storage facilities are regarded as being 'full'.

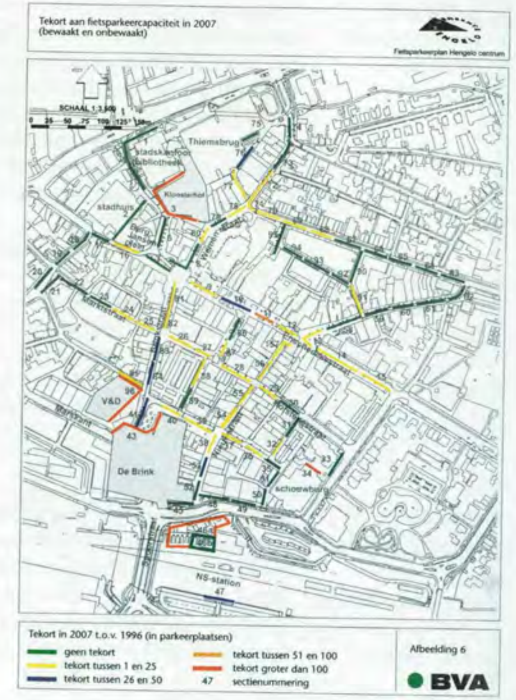


Figure 28. Analysis map of Hengelo

Step F: Interpreting the results and formulating actions
A correct interpretation of the results from the previous step will show which of the situations shown in table 32 applies.

Table 32. Possible analysis outcomes and resulting policy directions

Outcome/ conclusion	of research outcomes....	.. and the resulting policy direction
Sufficient (good) bicycle parking facilities	Comparison of the future number of parked bicycles and the number of available (good) parking places per location shows that the demand and supply are balanced. This means that at the representative time, the anticipated occupation level at each location with be at a maximum of approximately 80%.	It is not necessary to draw up an action plan as the situation is functioning as it should. What remains is periodic attention to management/ maintenance and capacity management.
Sufficient (good) bicycle parking facilities, wrong locations	In this situation, the anticipated occupation level for the entire research area lies in the region of 80%, but at some locations the anticipated occupation level is much higher and at others it is very low.	The action plan should focus on a shift of the existing bicycle parking facilities. Facilities can be removed at locations where a low occupation level is observed in order to move them to locations where the occupation level exceeds the ideal value (80% of anticipated occupation).
Sufficient (good) bicycle parking facilities, wrong distribution of supervised storage facilities/unsupervised parking	In this situation, too, the anticipated occupation level for the entire research area is good (approximately 80%), but the bicycle parking facilities with supervised storage clearly have too much or too little capacity.	If the supervised storage facility is full, the action plan should focus on expanding the supervised storage facility. Consideration must then be given to whether a separate new storage facility at another location will attract more customers than would be the case for expansion. If the supervised storage facility has a significant overcapacity, the reason behind this should be discovered.
Insufficient (good) bicycle parking facilities	In this situation, the anticipated occupation level for the entire area exceeds the value of 80%. This can be the result of a shortage of capacity at a large number of locations or a shortage of capacity at only a few concentration points.	(Good) bicycle parking facilities must be provided at the locations where there is an anticipated shortage, to the extent that a maximum occupation level of 80% is achieved.
Too many (good) bicycle parking facilities	It is conceivable that the supply of good bicycle parking facilities in a research area is much larger than demand for it. A rule of thumb is that a total occupation level lower than 50% indicates unwanted overcapacity.	Should there be an overcapacity situation, then the action plan should focus on removing bicycle parking facilities. Facilities that are of a lesser quality should be the first to be considered for removal.

Figure 29. Measures map for Rotterdam-West and indication of occupation of space in Hengelo

Step G: Bicycle parking measures map
Just as with the results of the problem analysis (see Step E), the proposed solutions or measures can be displayed in clear graphics (see figure 29).

A measures map (with a precise key, drawn to scale, showing the capacities at the exact locations) clearly illustrates the spatial repercussions of bicycle parking.

8.2.1.1 Directive bicycle parking policy in city centre areas

Steps A to F paint a picture of bicycle parking in city centres and station areas, which can be used to formulate a sound, demand-driven policy. However, what the picture does not show is whether cyclists need more secure, better and/or better situated bicycle parking places. Apart from this, a municipal authority may just wish to increase the occupation of supervised storage facilities and so reduce the operating costs. A municipal authority may also want to greatly curtail the number of bicycles that are standing alone or make (narrow and busy) shopping streets bicycle-free.
These kinds of requirements, where bicycle parking policy is more directive or stimulating, need more than a demand-following analysis. This automatically means that the policy offers less certainty about the final effect of the measures to be formulated. After all, it involves measures to which the reaction of the cyclists has not been fully determined. However, a number of guidelines can still be given.

1 Limits to the ambitions for supervised bicycle parking facilities
Whether or not a municipal authority can attract a higher number of cyclists using supervised facilities to the city centre area than the national average of 18 per cent mainly depends on two factors. The first is the size of the city. In cities up to roughly 100,000 inhabitants, it will be hard to rise above this average. Secondly, specific characteristics of cyclists visiting a particular city centre may make it difficult to achieve a higher than average number of people using supervised storage facilities. The length of visit is especially significant. Supervised parking has less chance if cyclists are mainly 'grocery shopping' (≤ 0.5 hour) and not 'shopping' or 'going out' (> 1.5 hours).

2 Free supervised storage is effective
The introduction of free, supervised storage is a very effective means with a significant effect on the parking choices of cyclists; partly due to the price and partly due to the ease of use: paying takes time. If supervised storage is free, the number of short-term parkers in particular will increase. This effect can be reinforced by situating the free storage facilities in the immediate vicinity of ' bicycle magnets'; at this type of facility (for example, a library, town hall or large department store), the number of cyclists using storage facilities for a short period of time is usually high.

The well-documented introduction of free supervised storage facilities in the centre of Apeldoorn shows that this 'simple' measure can lead to an immediate and measurable effect on two of the goals that underlie the parking policy: stimulating the use of bicycles and reducing bicycle theft [43]. Two years after the introduction, the number of people using supervised storage had more than doubled. Of this number, 25% were 'new'; these individuals had never used supervised storage before. Of this 25%, 18% usually did not cycle to the city centre but chose to go by car or bus instead. Since the introduction of free supervised storage, the number of users has continued to grow considerably; now there are five free supervised storage facilities with more than 3,000 bicycle parking spaces [44].

3 Rules of thumb for expanding supervised capacity
If moving a supervised storage facility or building a new (additional) supervised storage facility is considered, then one is faced with the problem of having to make related choices about location, capacity, rate, financing, etcetera, while there is still no clear picture of future use. In that case the following three rules of thumb can help.

- *Rule of thumb 1: Use the rate that applies in the existing storage facilities, if any*
  The rate that is currently applicable is evidently not too high, otherwise the demand would not exceed the capacity. Certainly in the range of 0.50 to 1.00 euro per day the rate is not decisive for use. Substantially higher use is possible by using a zero rate (that is, free) or by introducing a combined (cheap) season ticket system for a number of storage facilities within the municipality. This does indeed reduce incomes, but the advantages appear to be significant: in Apeldoorn an immediate increase in bicycle use and a decrease in bicycle theft could be demonstrated.

- *Rule of thumb 2: Apply the following criteria for a supervised storage facility in city centre areas:*
  - situate the storage facility directly on access cycle routes;
  - situate the storage facility in or right on the edge of the core shopping area;
  - situate the storage facility preferably within a radius of 150 m from the heart of the shopping area (in large cities this distance can be somewhat more generous, in small towns it should preferably be shorter);
  - if the storage facility has to be built in a quieter side street, do not allow the distance to the busy centre area to be more than 30 m;
  - ensure a good 'visual relationship' with the core shopping area and a good, attractive walking route;
  - if possible, situate the storage facility near the entrance (maximum 50 m) to 'bicycle magnets' (the most important destinations for cyclists);
  - situate a new storage facility more than 300 m from an existing storage facility if possible; within this distance a new storage facility services the same market as the existing storage facility to too great a degree.

- *Rule of thumb 3: Estimate the anticipated demand by accurately researching at peak times what the characteristics of those parking bicycles in the immediate sphere of influence (300 m) of the intended new location are and what characteristics apply to all those parking bicycles in the immediate sphere of influence of existing storage facilities (if there are any).*

In the survey required for this research, it is not so much opinions and behaviour expectations that are sought but 'objective characteristics' such as: the quality/price/age of the bicycle, the age of the cyclists, the frequency of visits to the centre by bicycle; the length of the visit to the centre.
If there is an existing storage facility it can be determined for that storage facility what proportion of the cyclists, by characteristic, uses supervised storage. These percentages must then be applied to the new situation, also by characteristic.
If there is no existing storage facility and market research for a first supervised storage facility is involved, the prognosis is automatically less certain. In that case the prognosis can be made by comparing the survey results with the average percentages in table 33.

Table 33. Average percentages of supervised storage users in city centre areas by characteristic

Characteristics	Average percentage of supervised storage users in centre areas: yes	no
good/new/expensive bicycle	18	0
cyclist 40 years of age or older	21	12
visit frequency once per week or more	20	12
length of visit longer than one hour	20	8

8.2.1.2 National approach at NS stations

Thirty to 35 per cent of train passengers in the Netherlands go to the station by bicycle [59]. This means that the bicycle is the most important means of pre-transport. The capacity and quality of the bicycle parking facilities at stations are, however, often wanting. As parking at stations is a ProRail matter and not the responsibility of the local or regional road authority, this Design Manual only touches on bicycle parking at stations.

Bicycle parking at stations should meet a number of conditions. In summary, these are:

- There must be sufficient facilities for regular and occasional passengers to place their bicycle in a supervised or unsupervised bicycle parking facility.
- The walking distance to the station entrance should be no more than 200 metres for a supervised storage facility and 50 metres for an unsupervised bicycle parking facility.
- There are supplementary requirements for the distance between two bicycle racks (minimum of 0.375 m), social safety, preventing vandalism and theft, et cetera.

8.2.2 Older residential areas

Existing residential areas tend to be free of problems with bicycle parking. Where they do exist, they mainly affect older districts with flats and require an area-wide analysis, as it is evident that a solution for each individual dwelling is not feasible.

First it must be determined which districts or areas are worth studying. Three (partly overlapping) criteria are relevant:

- an (older) district or neighbourhood has many flats or dwellings without their own storage;
- in a district or area there is an aesthetic and/or spatial problem with parking bicycles in public areas;
- a district or area has a much higher than average number of bicycle thefts.

Three types of data must be collected for the areas that are involved in the analysis:

- data about the degree to which the dwellings have indoor storage facilities;
- accurate police data about the number of bicycle thefts and the number of burglaries of storerooms/lock-ups per area;
- data about the number of bicycles that are parked overnight in the public space and about the number of bicycles that are kept in the house overnight (so not in a lock-up or storage, but in the hall, the stairwell or even in the living room).

The analysis of this data can lead to the main conclusions and policy directions shown in table 34.

Table 34. Main conclusions and policy directions

Outcome/conclusion...	..and the policy direction arising from it
Many dwellings have storage and at night there are few bicycles parked on the street or in the houses and there is at most an average level of bicycle theft in the residential area.	Action is, in principle, not needed.
Few dwellings have storage and the level of bicycle theft in the residential area is above average.	Developing neighbourhood storage facilities and/or collective lockers is the best remedy for bicycle theft. The fact that large numbers of bicycles are parked outside and/or 'indoors' at night fits within this pattern (much theft, little storage). If this is not the case, the action formulated remains nonetheless necessary, but it is also important to check exactly what is happening: do the occupants have fewer bicycles than average and if so, why?
Many dwellings have storage, but the level of bicycle theft in the residential area is still above average.	The quality of the storage probably leaves something to be desired, as a result of which bicycles are being stolen from storage, while bicycles parked outside are also being stolen. Something will have to be done about this in conjunction with the owners and the police (advisory function).
Although there is little storage and/or many bicycles are parked outside at night, there is little bicycle theft.	Even if the risk of theft is evidently not as high, the situation in which individuals cannot 'normally' put their bicycle into a storeroom is undesirable. This is also a case where the development of neighbourhood storage facilities and/or collective lockers is suitable.

The optimal locations for area storage facilities can be determined by comparing the available locations with locations with high concentrations of buildings (locations with the largest numbers of occupants within 150 m) and bicycle theft.

Bicycle parking solutions in older residential areas often comprise the construction of neighbourhood storage facilities and/or the installation of collective bicycle lockers ('drums'). In practice, it proves difficult to create both types of bicycle parking facilities quickly [53].

For neighbourhood storage facilities quick action is needed when suitable premises appear on the real estate market - but this is often problematic for a municipal authority. And in addition, the costs of a neighbourhood storage facility cannot always be accurately estimated. Also, the process can be delayed by, for instance, the decision of a building aesthetics committee or the need for soundproofing.

Collective lockers are not accepted by all public servants and citizens, particularly as the relationship between the amount involved in the investment and the number of users is found to be disproportionate. There are also aesthetic objections and poor experiences with vandalism. In addition, a bicycle locker takes up space on the street and the location often

requires the surrender of car parking space (with all the associated resistance). Furthermore, a bicycle locker requires planning permission, the granting of which can take up a lot of time.

8.2.3 New housing

Until approximately 2003, sufficient space for storing bicycles in private storerooms in new housing was guaranteed by legislation. The Buildings Decree (article 2.50, section 2) specified that every dwelling must have a lockable storeroom, the surface area of which comprises at least 6.5% of the usable surface area of the dwelling, subject to a minimum of 3.5 m^2. The minimum width was 1.5 m and the height 2.1 m. According to these regulations, a 100 m^2 dwelling should have a storeroom of, for example, 2.50 x 2.60 m (= 6.5 m^2). Assuming the average dwelling occupation, each occupant can in that case keep one bicycle in storage.

Since 2003, however, the Buildings Decree has not contained any stipulation about private storerooms in dwellings. This is to be regretted as, certainly in larger cities, the fear of bicycle theft – and bicycle theft in residential surroundings in particular – strongly inhibits bicycle ownership and hence bicycle use [45]. Even in the old situation, the legal standard was quite low, which was reason to set the recommended storage surface area at 10 per cent of the dwelling's floor area. The Buildings Decree cannot, however, be revoked by municipal (building) regulations.

A municipal authority can now only set requirements for storage when they are directly involved in the development of new construction locations and conclude private law agreements with market parties in this regard. In other cases there are no options for compulsion and the developer will have to be convinced of the importance of good storage facilities by reasoning. Should the latter not be prepared to provide good storage, the municipal authority can try to create communal neighbourhood storage in the public space (see section 8.3).

8.2.4 Companies and institutes

When analysing the bicycle parking situation and developing bicycle parking policy for companies and institutes, a distinction is first made between existing and new situations, and then for each situation between employees and visitors.

Existing situations

In existing situations, there may be various reasons for examining the bicycle parking situation of a company: nuisance from bicycles parked in the public space, complaints about theft from employees or visitors, planned alterations and suchlike. The analysis in existing situations is very simple.

- *Employees*

Count how many employees arrive by bicycle on a normal working day with good cycling weather and then add a margin of 20% for growth and peak times.

- *Visitors*

At peak times on good cycling days, count how many visitors' bicycles are parked and then add a margin of 20% for growth. An unsupervised bicycle parking facility will suffice for visitors. However, a location close to the entrance (maximum 50 metres) is required.

New situations

With respect to the construction of new business accommodation, the Buildings Decree serves as the point of departure for bicycle parking for both employees and visitors. The 2003 Buildings Decree ('Section 4.11, Storage space for bicycles, new construction', article 4.62) stipulates the following standards:

1 A structure that is to be built contains a storage room for bicycles.
2 Insofar as regulations are specified for a functional use shown in table 4.62, the requirement set for that functional use in the first section is met by the application of those regulations.
3 The first section is not applicable to the functional uses for which no regulation is specified in table 4.62.

The Explanatory Memorandum accompanying article 4.62 states: 'The storage space can be implemented as a miscellaneous functional use, being a building, also being an additional use, or as a plot of land, which, like a carport, is either roofed or not. A plot of land, being an outdoor space, can be designated as storage space for bicycles.'

The differentiation in this standard is in the division into classes from B1 to B5. This division is made in two ways. Firstly, certain types of buildings are simply assigned classes in the Buildings Decree. Secondly, there is a

Table 35. Class assignment via level of occupation

	Class assignment via level of occupation: Usable surface area of a building	Class assignment via level of occupation: Residential floor surface area	Standard value (% of total floor surface area of building)	But for certain building functions in any event as a minimum:
B1	< 2 m² p.p.	< 1.3 m² p.p.	12.5%	
B2	2 – 5 m² p.p.	1.3 – 3.3 m² p.p.	5%	
B3	5 – 12 m² p.p.	3.3 – 8 m² p.p.	3%	education building
B4	12 – 30 m² p.p.	8 – 20 m² p.p.	0.8%	conference building; prison building; healthcare building; office building; accommodation building
B5	> 30 m² p.p.	> 20 m² p.p.	0.3%	

Source: Table 4.62, Buildings Decree

calculation method that is not directly linked to the building functions (see table 35) (minimum surface area = 2 m²).

- *Employees*
  The Buildings Decree standards appear useful in determining the space needed insofar as employees are concerned. It is not necessary for bicycle parking facilities for employees to be at minimal distance from the company's entrance; more important is that the bicycle parking facilities are protected. Small companies may well be able to make do with an unsupervised, highly visible bicycle parking facility. However, lockable storage is certainly required for larger companies.

- *Visitors*
  The Buildings Decree standards are also aimed at providing sufficient space for the bicycles of those visiting companies. It is hard to believe that the Buildings Decree

sets a correct rule here for the following two reasons:
- A bicycle parking facility for employees must, in principle, be protected. Visitors will not be able to or allowed to use them. A separation between the bicycle parking facilities for employees and visitors is therefore needed.

- The number of visitors can differ greatly, even for a single type of building: the same type of office building can receive from zero to a hundred visitors each day depending on its tenants. The Buildings Decree standard is therefore insufficiently differentiated for visitors.

The Buildings Decree standards are too low to cover both employees and (larger numbers of) visitors. Accordingly, it is recommended that the application of extra capacity standards for bicycle parking facilities for visitors is agreed in proper consultation and, if possible, in formal agreements. Evidently, municipal authorities often need such guidelines in order to determine the capacity of bicycle parking facilities for 'establishments that attract visitors'. Table 32 shows guidelines for the number of bicycle parking spaces; these *only* relate to:
- visitors (not employees; the standards of the Buildings Decree are sufficient for them);
- new construction ('counting' is appropriate for existing situations);
- facilities (not dwellings);
- solitary functions (otherwise area analyses are appropriate).

In addition to 'sufficient capacity', it is equally important to create good facilities and to provide them at the right locations. For the aforementioned solitary facilities the point of departure must be a maximum walking distance; this is 50 metres for the largest facilities.

An attempt has been made to include all types of functions relevant to policy practice in the table. There is, however, one exception: functions for which the guideline would always stipulate a desired capacity of fewer than 10 bicycle parking spaces have not been included.

Table 36. Guidelines for determining the capacity of bicycle parking facilities for visitors to solitary facilities

Type of facility		Unit	Guideline	Explanation: elect lower limit for
shopping centre	main shopping centre	100 m² gfa	5 - 10	
	large district shopping centre	100 m² gfa	5 - 7	peripheral location and shopping base aimed at bulk purchasing
	local shopping centre	100 m² gfa	6 - 8	
office	without counter function	100 m² gfa	1 - 3	peripheral location and strong PT competition
	with counter function	per counter	2 - 4	
edu-cational institute	day-care centre	10 children	1 - 3	large 'supradistrict' function
	primary school	100 pupils	30 - 40	
	secondary education	100 pupils	60 - 70	large regional function and strong PT competition
	higher education	100 students	40 - 60	strong PT competition
sports complex	sports hall	100-visitor capacity	35 - 45	peripheral location
	sports field with stands	100-visitor capacity	20 - 30	
	sports field without stands	competition field	20 - 30	
	swimming pool	100 m² water-surface area	15 - 20	
places to go out	theatre	100-visitor capacity largest hall	20 - 25	large regional function and strong PT competition
	concert hall	100-visitor capacity largest hall	25 - 35	
	cinema	100-visitor capacity largest hall	25 - 30	
	urban discotheque	100-visitor busiest day	25 - 35	strong PT competition and peripheral location
	non-urban discotheque	100-visitor busiest day	5 - 15	

Table 36. Guidelines for determining the capacity of bicycle parking facilities for visitors to solitary facilities (continued)

Type of facility		Unit	Guideline	Explanation: elect lower limit for
health care institution	urban hospital	100 beds	20 - 40	strong PT competition peripheral location
	regional hospital	100 beds	15 - 30	
	nursing home	100 beds	5 - 15	
recreation	recreation area	100 visitors busiest day	20 - 40	peripheral location
	amusement park	100 visitors busiest day	15 - 30	strong PT competition
sociaal/ cultural institution	church, mosque	10 worshippers	5 - 15	strong PT competition
	museum	100 visitors busiest day	1 - 3	
transfer points	railway stations	location-dependent		
	regular regional transport	stop	3	see section 4.3
	favourable regional transport	stop	10-30	

8.2.5 Public transport stops

Stopping points for buses, trams and the metro are not final destinations, they are 'merely' transfer points. They are, as opposed to station areas, generally not 'areas', but easily pin-pointed locations of a limited size.

Seen nationally, 14 per cent of bus passengers use a bicycle as for pre-transport. This percentage is significantly higher on some routes. There are even bus stops where almost 70 per cent of the boarding passengers arrive by bicycle.

Existing situations

The analysis in existing situations is also simple for PT stops: it begins with 'counting'. The number of bicycles parked at the stop at

approximately 11 a.m. on a weekday when the weather is good can be used as the basis for determining the capacity. This number must then be increased by 10 to 20 per cent to avoid the capacity turning out to be insufficient immediately. With small numbers of bicycles (fewer than 50) an increase of 10 per cent will be too small and the capacity must be increased by an absolute number between 5 and 10.

In practice, stops where large numbers of bicycles are parked (a couple of dozen) are particularly likely to show an increase in bicycle and bus use. Here the upper limit of the increase (20%) should be used.

New situations

The bicycle parking demand is difficult to predict at new stops, which calls for effective monitoring as well as flexible approach: ensure there are sufficient possibilities for expansion. The following guidelines apply to new stops in city and regional transport:

- Bicycle parking facilities are usually not necessary at stops for *city services*. The walking distance remains limited due to the fine-meshed network of stop facilities.
- Bicycle parking facilities are generally required at stops on *regional routes*. Because of the 'extending' of bus routes, residential areas more and more often only have a stop on the edge of the built-up area. Because of this the distances between dwelling and stop are too great to walk, causing bus passengers to use a bicycle. The number of locations requiring facilities depends to a large extent on the number of passengers boarding and the local situation. The most practical solution is the 'standard creation' of three bicycle parking spaces and reserving sufficient space for expansion. After one or two months, the stop must be counted, which will then show whether there are enough places. At regional route stops, it is particularly important that the bicycle parking facilities are situated in such a way that social safety is ensured.

On regional routes there are two cases that call for more extensive bicycle parking facilities, and where account should be taken of a couple of dozen cyclists. These are:

- stops at express and long routes that have no competition from slower buses that stop more frequently. In actual fact this concerns bus routes that compensate for the absence of a railway connection (consider the Interliners here). The use of bicycles for pre-transport is especially high (30 to 40 per cent of passengers) on routes with an average travel speed of approximately 40 km/h and a route distance of more than 25 kilometres [46].
- stops on express routes that are outside of walking distance from a residential centre where no other routes transect the centre. The use of bicycles was highest (more than 60 per cent!) in Noord-Brabant at stops where the bus just does not call at the village itself [47].

In general, it is mainly unsupervised bicycle parking facilities that are created at regional transport stops. These must in any event have good fastening facilities. In terms of service it is, moreover, advisable that the racks are roofed. The facilities should be installed as close to the stop as possible, at a maximum distance of 30 metres.

8.3 Bicycle parking systems and bicycle storage facilities

Bicycle parking systems are structures that are intended for attaching a bicycle in, against or to. Bicycle storage facilities are protected, supervised or unsupervised spaces for parking bicycles, usually in bicycle parking systems.

8.3.1 Bicycle parking systems

There are many basic types of bicycle stands or bicycle racks, which, in turn, come in all kinds of models. Depending on the stability system (the manner in which the bicycle in parked condition achieves most stability), the following classification can be made:

- rack system for the front wheel, front fork, frame or handlebars;
- suspension system for handlebars or wheel;
- system to lean the frame against.

Rack systems into which the front wheel has to be placed are still the most commonly used type in the Netherlands. Cyclists do not like them, however, as they tend to be quite unstable. These racks also involve a greater risk of damage, particularly to the wheel that is clamped in.

There are two types of anti-theft facilities on bicycle parking systems: fastening systems and bolt locking systems. With the fastening system, cyclists have to attach the bicycle using their own chain, cable or U-shackle lock. The preventative effect of the system is therefore partly dependent on the quality of the user's own lock. The best known bolt locking system is the locking pole, into which the frame is locked. There are also systems into which a wheel or the handlebars have to be fastened. Some systems have an integrated lock, others require users to provide their own lock.

The various systems require a different amount of space. In general, it can be said that the wider the range of fastening options, the more room the system requires. Please see section 3.2 for an indication of the space needed for parked bicycles.

Functional quality (Fietsparkeur)

The quality of older bicycle parking systems often leaves a lot to be desired: they are awkward to use, the bicycle is easily damaged and

there is a lack of reliable facilities to prevent bicycle theft. For this reason, TNO developed quality standards for bicycle parking systems at the end of 1998, which are recorded in the *Fietsparkeur* quality mark [48]. The initiators – the Dutch Cyclists' Union and the Fipavo (Dutch Association of Bicycle Parking Facilities Manufacturers and Suppliers) –set up the Fietsparkeur foundation to manage the standard. The Fietsparkeur can be awarded if a bicycle parking system meets the standards and the manufacturer or supplier concludes an agreement with the foundation. Bicycle parking systems bearing the Fietsparkeur can be recognised by the associated logo. It is recommended to use these systems or non-certified) systems that (still) meet the functional requirements of the Fietsparkeur.

Taking account of the various types of bicycles, the Fietsparkeur sets requirements for the following points:

1 ease of inserting a bicycle (for high-low systems, the minimum centre-to-centre distance is 0.375 m; for same-level systems 0.65 m)
2 ease of securing a bicycle
3 risk of injury to the user or passer-by
4 risk of damage to the bicycle
5 burglary resistance/anti-theft quality
6 vandal resistance
7 durability.

8.3.2 Bicycle storage facilities

Bicycle storage facilities comprise individual lockers (best known from railway stations), collective bicycle lockers (such as the bicycle drum) and storage facilities monitored by personnel and/or cameras.

Individual bicycle lockers

Bicycle lockers are used in situations calling for individual protection against bicycle theft, but where the demand is too low to create a supervised storage facility. Information about specific products is available from the various manufacturers and suppliers of individual bicycle lockers. The cost of an individual bicycle locker generally lies somewhere between 500 and 1,000 euros.

Collective bicycle lockers
A collective bicycle locker can contain a number of bicycles. Each user has a key. The most important advantage of the collective locker is that it takes up considerably less space for the same number of bicycles than individual lockers.

Supervised storage
Supervised storage facilities are worthwhile when the following three conditions are met:
- The destinations in question attract large numbers of cyclists.
- A considerable proportion of the cyclists visit these destinations for a somewhat longer period (more than 45 minutes per visit), as long-term parkers are usually more likely to take the trouble to cycle to a supervised storage facility.
- The risk of theft (outside the storage facility) is relatively large.

In actual fact, almost every city centre and station area would meet these conditions.

Supervised storage facilities can be classified as follows:
- *Supervised storage facility inside a building*
  An indoor supervised storage facility can be housed in an existing building that previously had a different function or in a facility specially built for bicycle storage. In the latter case there are many forms conceivable, varying from a simple prefab structure to an attractively designed structure.
- *Supervised storage in a public space*
  Advantages of setting up a supervised storage facility in a public space are that it is cost-effective, that the storage facility is immediately noticed and that it is easily accessible to customers. The bicycles can be parked in the open air or under a roof. There should be a dry waiting room that can be heated for the attendant(s).
- *Mobile storage facility*
  This is a mobile, supervised storage facility in a public space. An area already containing a bicycle parking system or one in which bicycle racks are placed is cordoned off with fencing. A mobile storage facility can be used for one-time events, but also, for example, on the weekly market day.

A well-situated supervised storage facility is favourably situated in relation to the cycle routes and there are sufficient ' bicycle attractive' destinations in the immediate vicinity at a minimal walking distance. The following three location aspects are significant in terms of the actual utilisation of the potential demand:
- *Familiarity*
  It is beneficial if the storage facility is established at a known location, on a central square for instance or near/in an important building. The storage facility then achieves name recognition more easily and cyclists will be quicker to think about parking their bicycles here.
- *Accessibility: ground level or underground*
  A ground-level storage facility is preferred. The technical aspects of an underground storage facility require a great deal of care. Overcoming the height difference can be a problem for the elderly and for people with bicycles that have child-seats or heavy shopping bags. In this case inclines are preferred over stairs with bicycle channels.
- *Social safety*
  Social safety in and around the storage facility is important. The walking route from the storage facility to the destination certainly warrants consideration.

Unmanned storage facility
In many storage facilities (neighbourhood, company and supervised storage) the use of modern technology helps promote security. Examples are camera monitoring and electronic access systems, where modern technology forms a *supplement* to the 'normal' security systems or a *modification* of that 'normal' protection (for example, an electronic instead of a mechanical lock) without this having further consequences.

A different situation arises when modern technology is used to replace security personnel in supervised storage facilities. Personnel in a supervised storage facility initially handle security by means of access control. Creating access control that offers sufficient safety without personnel, while keeping supervised storage truly public in the sense of being accessible to all customers is not a simple matter.

9 Evaluation and management

9 Evaluation and management

Bicycle facilities, more so than facilities for other traffic, require not only good design but also effective management and maintenance. Cyclists are, after all, more 'sensitive' to uneven paving and sand, glass or rubbish on the road surface than other road users.

This chapter examines the following topics successively:

- testing and evaluation;
- inspection of paving;
- temporary measures;
- combating slipperiness;
- management and maintenance of bicycle parking facilities.

9.1 Testing and evaluating bicycle connections

The quality of a bicycle connection is the sum total of the quality of all facilities (road surfaces and junctions) and their continuity. The (aggregate) quality can be determined by means of testing or evaluation. Testing can be undertaken for many reasons. Known examples of this are residents having complaints about a route or specific occasioning events. The testing of a bicycle network can take place during the drafting or updating of a bicycle route network, particularly in the bottleneck phase. Testing can also be useful in working out a priority system within a maintenance programme.

There is a significant difference between testing and setting priorities. Testing involves weighing up criteria that immediately reveal something about the quality of the bicycle facility or, more specifically in relation to the bicycle infrastructure, express the degree to which the five main requirements are met. Other criteria also play a role when setting priorities, such as financial means, political dilemmas, current procedures within the scope of zoning plans and the number of traffic participants that would benefit from any improvements (the effectiveness).

A bicycle facility can be tested at three levels:

- network level;
- connection or route level;
- facility level (road surfaces, junctions, transitions, bicycle parking facilities).

Connections can also be tested on a single aspect, such as the bicycle friendliness of junctions. In addition, a single main requirement can be tested, which is known as thematic testing.

9.1.1 Evaluation of a network

The evaluation of a network involves five different steps (although practice tends to be less systematic than that). The first step is stating the reason for and aim of testing. The second step involves determining a testing method. The third step relates to implementation. The results are processed in the fourth step. The fifth and final step involves marking the quality of the facilities (or connections) and weighting the various criteria; in this way a final conclusion is reached on the facilities or connections that have been tested.

Threshold values

Measurement results are only meaningful if they are compared to standard or threshold values. Sometimes clear standards are available, but this is often not the case. This Design manual provides some footing in setting standards, but in the end the road management authority will have to develop its own policy for what is considered to be standard. If necessary a benchmark can be a solution. The bicycle Balance of the Dutch Cyclists' Union enables the comparison of one's own situation with a value that has been set as standard. This value provides a good reference in terms of a bicycle friendly infrastructure [50].

There are various testing methods. Specific aspects in particular can often be evaluated in different ways. This section specifically examines the Dutch Cyclists' Union's method (Bicycle Balance) as it considers the bicycle climate across the board. Subsequently, another section briefly examines the testing of specific situations and bottlenecks.

Bicycle Balance

As a benchmarking instrument, the bicycle Balance provides a good overview of how various elements that influence the cycling climate can be tested and evaluated. The bicycle Balance comprises four parts [50]:

- Written policy is mapped using a survey that is completed by a traffic officer from the municipal authority.
- Cyclists' satisfaction is gauged by means of a public survey.
- An analysis of Statistics Netherlands figures illustrates bicycle use and safety.
- Finally, a practical measurement follows to objectively establish the experiences of the (daily) cyclist on the street; it is this part of the benchmark in particular that provides handles for testing.

For each municipality a random sample of 12 to 16 journeys is selected. The researchers cycle all journeys with a special measurement bicycle. The same journey is undertaken by car in order to measure the journey time in relation to the car.

Figure 30. bicycle Balance score for Leiden compared to Breda

Scores are recorded for 10 points (see table 37). These are: directness, comfort (nuisance and road surface), attractiveness, competitive position, bicycle use, road safety, urban density, cyclist satisfaction and written policy. The scores (orange) are compared with the standard and with the scores of a city or cities of approximately the same size (green line in figure 30). A well-organised presentation of the results quickly reveals which aspects meet the standard and which do not.

Table 37. bicycle Balance evaluation criteria

Aspect	Description
Directness	Directness is an indication of the time a cyclist needs to reach his/her destination. A bicycle-friendly network has many short and quick cycle routes. Directness is evaluated by measuring the following subaspects: • detour factor (cycling distance/straight-line distance); • delay (number of seconds stationary per kilometre); • average speed (kilometres per hour).
Comfort (nuisance)	Six subaspects that can affect cycling pleasure to a greater or lesser degree are measured for the comfort (nuisance) aspect: • stopping frequency (number of stops per kilometre); • slow cycling (the time that speed falls below 10 km/h); • traffic nuisance (cycling in file due to motorised vehicles, pedestrians or other cyclists); • infra-nuisance (riding in file due to narrow infrastructure or bollards); • no right of way (number of times without right of way per kilometre); • turning off (number of turn-offs per kilometre).
Comfort (road surface)	In order to determine the comfort (smoothness) of the road surface, vibration metres are used to measure the vertical acceleration to which a bicycle is subjected.
Attractiveness	As cyclists are in direct contact with their surroundings, they value an attractive environment. Attractiveness is, however, a subjective term and it is difficult to measure. The bicycle Balance has selected noise nuisance as and indicator of attractiveness. Noise nuisance is relatively easy to measure. Moreover, few cyclists find a noisy environment attractive.

The indicators that are dealt with below are of a different magnitude than the aforementioned. Where directness, comfort and attractiveness relate to the actual situation on the street, the indicators that follow paint more of a picture of the possibilities for the bicycle and policy concern.

Table 37. bicycle Balance Evaluation Criteria (continued)

Aspect	Description
Competitive position bicycle/car	The aspect of competitive position in relation to the car gives an impression of the advantages of the bicycle in relation to the car in a municipality. In order to give an evaluation of the competitive position, all journeys on the routes to be tested are undertaken by both bicycle and car. The competitive position is then determined on basis of the following subaspects: • average journey time ratio (cycling time/driving time); • proportion of journeys where the bicycle is quicker; • parking costs for the car.
bicycle use	The percentage of people who choose the bicycle (instead of another means of transport) is a significant measure of the quality of the cycling climate. It is both an indicator of the degree to which a municipal authority succeeds in removing impediments to the use of the bicycle and of the degree to which a municipal authority succeeds in stimulating use of the bicycle. The bicycle Balance uses the bicycle's share in all journeys up to 7.5 kilometres in the years 1999 to 2001 as a unit for bicycle use. The average is 34 per cent for all municipalities larger than 20,000 inhabitants.
Road safety	Road safety is a significant prerequisite for a good cycling climate. The risk of a cyclist being involved in a serious accident when cycling a distance of 100 million kilometres has been calculated and is used as an indicator for road safety. The calculation in the bicycle Balance is based on accident figures from the years 1997 to 2001 (source: Statistics Netherlands/ Transport Research Centre) and bicycle use in 1999 to 2001. The risk figure has been adjusted for a high or low bicycle use. It also contains a correction for a disproportionate number of the elderly. Moreover, this relates to objective safety, which does not always correspond to cyclists' perception of safety.
Urban density	Cyclists benefit from being able to choose from many destination within cycling distance. Therefore, the bicycle Balance also includes urban density in the evaluation. The density of surrounding addresses has been used as the basis, a Statistics Netherlands figure which is used as a criterion for the degree of urbanisation. The density of surrounding addresses was then adjusted for the number of inhabitants of a municipality. A good score means that the municipality has a high density in relation to other municipalities of the same size and therefore has the basis for a bicycle-friendly structure.

Table 37. bicycle Balance Evaluation Criteria (continued)

Aspect	Description
Cyclist satisfaction	The cyclist's personal opinion cannot, of course, be left out of an investigation into the cycling climate within a municipality. Cyclists can give their own municipality a mark in a survey. They can also express their opinions about: • bicycle parking facilities (supervised and unsupervised); • cycling comfort (traffic nuisance, quality of the road surface); • cyclist road safety; • social safety of cyclists (threat of violence); • tackling bicycle theft (enforcement, detection, engraving).
Written policy	What the cyclist encounters on the street is, to a significant degree, the result of traffic policy that was pursued in the past. Today's cycling policy says something about the cycling climate for the future. The written policy aspect maps how well bicycle is anchored in the policy plans, the budgets and in the municipal organisation. A survey completed by the municipal authority is used for this purpose. It is particularly difficult to evaluate policy in terms of content based on a survey. The evaluation of this aspect is therefore limited to listing the degree to which subjects, aims and aspects form part of policy. The following points are examined: • cycle network (basis, quality requirements, implementation and maintenance); • cycling policy recorded in policy papers and bicycle parking policy documents (basis, quality requirements, implementation and maintenance, subsidies); • budgets; • municipal authority as a model employer.

9.1.2 Route testing

It is not always necessary or worthwhile to evaluate an entire bicycle network. The desire or need can also be limited to testing one or a few specific routes, such as the routes into the city centre, school routes or all routes with a specific use. In that case, the route characteristics can be examined very specifically.

A method used by the Dutch Cyclists' Union is also referred to for route testing. The Dutch Cyclists' Union Route Test is a research method that can be used to give a detailed evaluation of (the layout of) a (main) cycle route, both inside and outside the built-up area.

Instruments used in the field include the measurement bicycle that was developed in 2000 for the Bicycle Balance Test. This measurement bicycle records on a laptop, for every second cycled, the exact location (GPS coordinates), the distance covered, the average and maximum vibration nuisance (vertical acceleration) and noise nuisance (dB(A)); the route is recorded on video at the same time. Apart from this, waiting time data is collected during the rush hour at junctions where right of way has to be given as well as at TCSs. All this data is stored and analysed, and linked to design characteristics.

Aspects that are tested at route level are:
- detour factor
- delay
- stopping frequency
- road surface quality
- dimensioning (width, curve radii, stacking space)
- right of way
- turning off
- noise nuisance
- 'infra-finishing' (bollards, smoothness of the verge, obstacle-free space)
- changes in quality

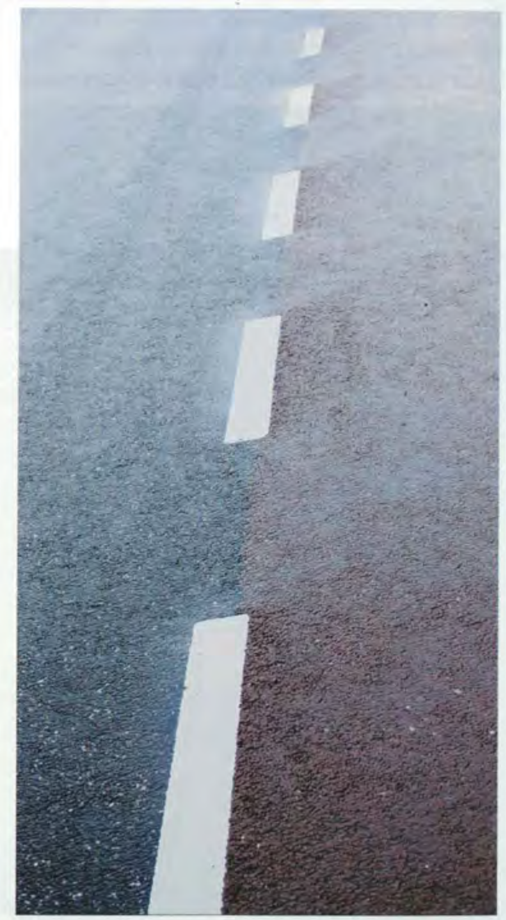
Aspects that are tested at road section/junction level are:
- design in relation to speed regime, motorised traffic speeds and intensities
- delay
- stopping frequency
- right of way
- road surface quality
- dimensioning (width, curve radii, stacking space) in relation to bicycle intensities
- 'infra-finishing' (bollards, smoothness of the verge, obstacle-free space)
- critical reaction lane width at car parking bays
- social safety
- noise nuisance
- clarity of right of way regulations

In addition, the following aspects are examined at detailed level (for both road sections and junctions where stopping is required):
- the length of the halt and the reason for it (a TCS or priority road for example)
- dimensioning
- rights of way
- road surface quality
- noise nuisance
- visibility
- lighting and guiding
- signposting

9.1.3 Analysis of specific bottlenecks

The Bicycle Balance is a labour-intensive method that is not suitable for testing a specific location. If this is required (because there have been large numbers of complaints, for example), it is worth starting with a test using a detailed map (preferred scale 1 : 500). However, a lot of design aspects cannot be evaluated this way. This means that an 'on the street inspection' is also required. Depending on the aim of testing and the problem, tools such as the 'measurement bicycle' or conflict observation techniques can be used.

What is important is that a clear problem description and clear evaluation framework are formulated beforehand to prevent discussions arising about interpretation of the data after the inspection. The standards that are used within the scope of the Bicycle Balance can serve as guidelines for this.



9.2 Inspecting the paving

An example of a specific test is the inspection of damage to the paving. The aim is to evaluate and unequivocally record visible damage to the paving. The road or cycle track is evaluated on technical grounds and damage is evaluated both qualitatively and quantitatively (gravity and scale).

This Design manual pays particular attention to this type of testing, as paving is an essential element of a bicycle-friendly infrastructure. In inspecting the paving, the road management authority must realise that what is regarded as light damage for motorised traffic is very easily moderate or even serious damage for cyclists.

The following types of inspection can be distinguished:

- overall inspection
- minor maintenance inspection
- measures test
- detailed inspection

Each form is briefly explained below.

Overall inspection
An overall inspection is aimed at the quick and efficient gathering of network-level information about the condition of the road network. It is recommended that this inspection is carried out annually. In general, the matters mentioned in table 38 are relevant for an overall inspection.

The 'drainage' and 'setting' damage are no standard part of the overall inspection,

Table 38. Paving characteristics and damage that are relevant to an overall inspection

Paving characteristic	Damage		
	asphalt concrete paving	modular paving	cement concrete paving
texture	ravelling		
smoothness	lateral smoothness irregularities	lateral smoothness irregularities	irregularities
cohesion	cracks		cracks
water tightness			joint filling

although these are of great significance for cyclists. It is therefore recommended that these types of damage are included in the overall inspection. It is also important that the score that is assigned to damage, particularly in the field of smoothness, should be assessed more critically than for motorised traffic. After all, as stated earlier, what can be considered light damage for motorised traffic is very easily serious damage for cyclists.

Minor maintenance inspection
The aim of a minor maintenance inspection is to find and record small defects that have to be repaired in the current budget year. This means that it is not possible to plan this maintenance. The primary aim of minor maintenance is, therefore, to keep the paving in good condition. It is recommended to carry out the minor maintenance inspection of cycle routes, main cycle routes and solitary cycle tracks three times each year, before the winter, after the winter and in the middle of the year (the summer), for example. On other routes the inspection will generally coincide with the inspection of other roads (combined traffic).

Measures test
The aim of a measures test is to accurately determine the nature and location of maintenance measures to be taken at project level and to test the measures that have been selected on the basis of the results of overall inspection

and other observations. The measures test is a compulsory component of road management, but its interpretation depends on the wishes of the road management authority.

Detailed inspection
The aim of a detailed inspection is to accurately determine the condition of the road or the cycle track at project level. In itself, this inspection does not form part of the system of road management, but is carried out for specific purposes (for example, handover of roads, determining a baseline situation or formulating paving recommendations). A detailed examination checks all paving characteristics and damage that has been defined in the catalogue of damage (see table 39).

Table 39. Paving characteristics and damage that are relevant to a detailed visual inspection

	Damage		
Paving characteristic	**asphalt concrete paving**	**modular paving**	**cement concrete paving**
texture	ravelling grease		corrosion
smoothness	lateral smoothness irregularities	lateral smoothness irregularities	irregularities
cohesion	cracks	joint width quality of elements	cracks
water tightness			joint filling
edging strip	edge damage edging	edging	
miscellaneous	drainage verge lateral cracks/lateral welds longitudinal welds setting	drainage verge holes setting	drainage verge joint filling joint damage joint width slab angle defect holes setting
repair			repair

9.3 Measures relating to road works

Cyclists are more affected by work on the infrastructure than other traffic participants. As cyclists depend on their own muscle power, every detour is unwanted. Moreover, the road surface at road works is often temporarily less smooth or is covered in sand or mud. As this can be a significant nuisance to cyclists because of their instability, specific thought should be given to cyclists at these road works.

Many types of work can be taking place on and next to the carriageway. The road works that are meant in this section involve work that is being carried out on or in the road (in the lateral and/or longitudinal direction) and construction work next to the road, to the extent that this can hinder traffic. In many cases it involves (re)laying cables and pipes, often in combination with connecting houses. Chapter 7 therefore already made a case for not laying cables and pipes underneath cycle tracks and cycle lanes.

At road works and temporary measures there are three central concerns for the cyclist:

- cyclists should not be forced to dismount;
- cyclists should not be diverted to the opposite side of the carriageway;
- the management of temporary facilities should be given sufficient attention.

Avoid dismounting and detours
Some hindrance at road works is often unavoidable, but it is important that the main requirements of cohesion, directness, attractiveness, safety and comfort are affected as lit-

tle as possible. When temporary measures are taken, the cyclist's 'obligingness' is often relied upon, without taking clear account of the five main requirements. When taking temporary measures, attempts should be made to ensure that cyclists do not have to dismount and can continue on their way without a lot of detouring.

Do not divert cyclists to the opposite side of the carriageway
Diverting a cycle connection to a cycle track on the other side of the carriageway is discouraged. This leads to additional crossing movements and unexpected manoeuvres on the cycle track. This solution should only be considered if there are opportunities to have the cyclists cross at normal locations and the cycle track is sufficiently wide for two-way traffic. It is better – certainly when the work is going to take a longer time – to build a temporary cycle track in these circumstances, making sure that the requirements regarding smoothness and roughness are duly observed and that the cycle track is sufficiently wide.

Consider management
An important point for attention that is often neglected is management and maintenance of temporary facilities. Especially in the case of large-scale and long-term road works, where works traffic regularly drives over the (temporary) cycle track, there is a considerable risk of subsidence or the formation of ruts and of sand and mud getting onto the carriageway. It is important that such nuisance is resolved as quickly and efficiently as possible. If this is not done, it not only affects the comfort and safety of the bicycle traffic, but there is also a chance that the existing cyclists will look for other routes.

This Design Manual does not deal exhaustively with all possible measures, but places the emphasis on the preparatory process: where work is being carried out, how can the interests of bicycle traffic best be met? For a more detailed discussion, see CROW publication 'Road Works - Measures on cycle tracks and footpaths' [51].

In order to determine which measures should be taken in road works on cycle tracks, account should be taken of:
- the safety of road workers on the road sections;
- the road safety of the cyclists and other road users;
- the flow of the bicycle traffic and other traffic;
- the consequences for quality of life and the environment;
- information and communication.

The preparations for measures comprise the following steps:
- *Preparation and project start-up*
  The duration of the work is particularly important here. For short road works (< half a day), simple measures will suffice. If the work takes longer, more attention should be paid to diversion routes, cordons and suchlike.
- *Formulating a route-signing and diversion plan*
  If the work will last longer than half a day, a route-signing and diversion plan should be formulated in advance, so that what has to be done is clear to the maintenance team or contractor.

In determining the measures, the general point of departure used is that the cyclists must be hindered by the work as little as possible. The measure 'cyclists dismount' is only used as an exception and should only be considered if the reason for dismounting is immediately apparent to the cyclists. If this is not the case, large numbers of cyclists will probably ignore this instruction and find their own way, around the cordon if necessary. This is exactly what should be prevented. Diversions are only acceptable if narrowing or diverting the bicycle facility is impossible (for reasons of space or traffic-engineering).

Measures at cordons

When determining the type of cordon and the associated measures, a great deal of attention will have to be paid to the working space, the safety space and the free space up to the cordon. The following dimensions can be used as the minimum at temporary facilities:
- obstacle distance for cyclists to the cordon: 0.50 m
- free space on work side of cordon: 0.60 m
- safety margin between work space and fence/road-sign vehicle: 5.00 m
- space for a riding cyclist: 0.75 m
- space for a riding cyclist + moped: 1.50 m
- space for cyclists in two directions: 1.75 m
- space for cyclists in two directions, high intensity, mopeds allowed: 2.25 m

Possible situations
Six possible situations can be distinguished with regard to the position of road works in relation to cycle connections. Within these situations, a further distinction can be made between short-term and long-term road works. Short-term road works involve less far-reaching measures and require a less drastic cordon.

The common situations are:

1 *Work carried out a long way from the cycle track*
  In this situation, no measures need to be taken as the bicycle traffic will not be hindered by the road works.

2 *Work carried out a short distance from the cycle track*
  In this situation, too, the cycle track can be kept open. A longitudinal cordon should be installed using guide beacons or traffic cones. At the side of the working space, a free space of at least 0.60 m should be observed; as the work is taking place a short

distance from the cycle track, this will probably make sufficient allowance for the obstacle distance. A safety space of at least 5.00 m should be maintained between the work and the road-sign vehicle or the warning barrier that is to be erected.

3 *Work right next to the cycle track*
The same requirements as described in 2 apply in this situation. Their obstacle distance to the cordon should, however, be specifically looked at in relation to the total available width of the cycle track.

4 *Work carried out right next to the cycle track, with work taking place from the cycle track*
The cycle track can be kept open in this situation, but may have to be narrowed. This is only possible if, in addition to the free space of 0.60 m on the inside of the cordon, there is still at least 1.00 m of cycle track width left. If less than 1.00 m remains, a check must first be made to see whether part of the motorised vehicle carriageway can be cordoned off for the cyclists (see below). If this is not possible, a diversion must be sought. It is also important that the longitudinal cordon is placed on the verge when work is not being carried out. This is perhaps a burden on the contractor, but it gives added quality for the cyclists.

5 *Work on the edge of the cycle track or on the cycle track*
The cycle track may or may not remain in use, depending on the width. See under 4.

6 *Work in the middle of or across the full width of the cycle track*
In this situation, it may be possible to keep the cycle track in use by narrowing it. If this is not possible, a check must be made to see whether part of the main carriageway can be used by cyclists (with cordoning and, if necessary, a local speed reduction for motorised traffic, see also below). If this is not possible either, the cyclists will have to be diverted. If the work is of very short duration (< 2 hours), this may be without a route-signed route; route-signing is required for a longer duration.

Separation between bicycle and motorised traffic when cyclists are on the carriageway
If cyclists are diverted off the cycle track along a section of the carriageway for motorised traffic, motorised and cycle traffic must be separated. This can be done by means of a vehicle retaining barrier, a double row of guide beacons, element marking with cordon signs or fencing. The choice depends on the duration of the work and the characteristics of the adjacent carriageway and traffic flow. The heavier the traffic function and the longer the duration of the work, the more substantial the separation that is required between motorised and bicycle traffic. If substantial separation is not possible, it will be necessary to introduce speed limits for motorised traffic.

9.4 Ice and snow: prevention and clearing

Combating slipperiness is, in principle, even more important to cyclists than to motorised traffic. This aspect of road safety in a general sense plays a role for both groups of traffic participants, but for cyclists there is the additional aspect of (in)stability. The risk of falling and getting injured is, after all, many times greater when it is slippery than at other times.

What is important for cycle tracks is that they are treated simultaneously with the main carriageway, which usually means during the night hours. Determining the gritting routes and the equipment to be used requires special attention here. Obstacles (bollards, tunnels with a limited headroom, raised kerbstones and suchlike), time limits (home-work and home-school traffic) and the limited speed and capacity of cycle track gritters require that gritting routes are planned very carefully.

Gritting is predominantly done using dry salt, although there is a noticeable trend towards wet-salt spreading. But the advantages of this – better adherence to the road surface and a better spread-pattern – are not as significant on cycle tracks as on the main carriageway. After all, cyclists don't grind the salt in as motorised traffic does.

Snowfall also requires additional attention. It is recommended that cycle connections are gritted before snow falls. During snowfall brushing or ploughing can be combined in a single run with dry salt spreading. Here it is best to clear snow from main cycle routes and school routes in any case, even earlier than the motorised traffic routes. After this it is the turn of the cycle routes and the basic network. If the key cycle routes are not cleared and the routes for motorised traffic are, there is a danger that cyclists will use the main carriageway, which, in winter conditions, is especially risky.

Slipperiness: in autumn too!
One aspect that is not given sufficient attention is combating slipperiness as a result of fallen leaves. In autumn, certainly in wet weather conditions, leaves on cycle tracks can lead to hazardous situations. Road management authorities should therefore periodically use sweeper wagons in the autumn to clear important cycle routes under deciduous trees.

9.5 Management and enforcement of bicycle parking facilities

Three groups of bicycles are significant in terms of management of bicycle parking facilities and enforcing the rules relating to bicycle parking: cycles that are inconveniently parked, stray bicycles and unused bicycles.

Inconveniently parked bicycles
In many municipalities bicycles that are parked inconveniently in public spaces form a problem. When it comes to preventing bicycles being parked in random and unwanted places, physical measures are preferred: an attempt can be made to lay out the public space

in such a way that parking bicycles in unwanted locations is made more difficult.

In certain situations, however, measures within the legal sphere are unavoidable in putting matters to right.

Municipal authorities can institute a bicycle parking prohibition on two grounds:
- on the basis of a traffic decree pursuant to the Road Traffic Act (WVW: *Wegenverkeerswet*) a sign can be erected that stipulates a prohibition on the parking of bicycles and mopeds (sign E3, RVV [Traffic Rules and Signs Regulations]) 1990).
- The General Municipal Bye-laws (APV: *Algemene Plaatselijke Verordening*) can stipulate that the Municipal Executive (or the mayor) can designate areas where parking bicycles and mopeds outside the designated bicycle parking facilities is prohibited.

A parking prohibition in accordance with the APV provides the municipal authorities with broader powers to remove inconveniently parked bicycles and the option of using their own warning signs. From the cyclists' perspective, on the other hand, a prohibition based on the Road Traffic Act has a number of advantages: the signposting is uniform and clear, and there are more guarantees of a balanced consideration of interests, as a traffic decree must be enacted with the associated objection and appeal options.

Removal of bicycles that are parked illegally in accordance with an APV is, from a legal perspective, the enforcement of an administrative order. This is also bound by all kinds of due-care requirements that can be tested by the courts. The main ones are:
- *Publishing policy*
  A municipal authority must announce its intention to remove illegally parked bicycles in advance, which can best be done by placing notices at the location.
- *Storage and collection of the bicycles*
  The bicycles that are removed should be stored in a locked and/or supervised space, a short distance from the area where the bicycle parking prohibition is in force.
- *Registration*
  Various details must be recorded: the location where the bicycle was found, characteristics of the bicycle, whether or not the bicycle was locked, reason why the bicycle was designated as being parked illegally, date of removal and storage location.

Stray bicycles
When removing stray bicycles, it appears that municipal authorities are invoking one of the following legal structures:
- The APV incorporates a regulation prohibiting the parking and ownership of a stray bicycle on the public road. The cleaning up of stray bicycles is then understood to be the enforcement of an administrative order.
- Stray bicycles are regarded as domestic waste, or more precisely, as litter or bulk rubbish. The municipal authorities' authority to clear away stray bicycles is, in that case, embodied in environmental legislation (Environmental Management Act [*Wet Milieubeheer*] and the local waste regulations).
- Stray bicycles are regarded as found property, to which the regulations for found property in Book 5 of the Dutch Civil Code are applied.

It appears that all three options suffice for the desired aim. Still, it is recommended that the actions are based on the APV regulation. The reason for this is that this regulation concerns a

prohibition and is therefore clearer, both for the municipal authority and for the owner of the stray bicycle. The other options give more rise to debate.

Regardless of the legal foundation, clean-up actions for stray bicycles will also have to meet due-care requirements. These relate to:

- *timely notification*
- *clear definition of the term 'stray bicycle'*
  The announcements must accurately specify what is understood by the term stray bicycle. The Waste Disposal Police in Amsterdam use the following definition which has proven to be workable:
  'A bicycle is considered to be a stray bicycle if the bicycle (or the remnants of it) meet each of the following conditions:
  - the bicycle is in such bad repair that it cannot be ridden;
  - the bicycle is in an evidently neglected condition (it has not been ridden for a long time, the owner has, apparently, abandoned it);
  - the bicycle has little economic value (the costs of repair clearly exceed the value of the bicycle).'
- *storage period*
  By virtue of the Municipalities Act, stray bicycles must be stored for a minimum of 14 days.

Municipal Authorities often charge 'storage fees' (if the regulation is based on an APV regulation) or a 'fine' (if the regulation is based on the Road Traffic Act). The costs amount to approximately 20 euro per bicycle (wreck). This far from covers costs, but at the same time a higher price would be a strong disincentive to reclaiming, and this is already a major problem: in many cities, at least 60% of bicycles are not collected [69].

Unused bicycles

Unused bicycles form a significant problem for bicycle parking facilities at stations in the sense that scarce capacity is occupied unnecessarily. In 2003, it turned out that at nine large railway stations an average of 15% of all parked bicycles had not been used for at least four weeks [55]. At the nine stations, this involved a total of around 3,300 bicycles that were needlessly occupying capacity.

In order to remove unused bicycles from public bicycle parking facilities, a procedure can be followed that is comparable with that for inconveniently parked bicycles (see above). The APV should then lay down a maximum parking duration for bicycles. The shorter the parking duration, the more manageable the situation will be, but it will require more intensive enforcement. During actions against stray bicycles, the same due-care requirements must be applied as when dealing with inconveniently parked bicycles.

In order to determine whether a bicycle is still being used, bicycles must be marked. This can be done by affixing a coloured sticker to a part of the bicycle that is visible from the street (such as a spoke) using a different coloured sticker each day.

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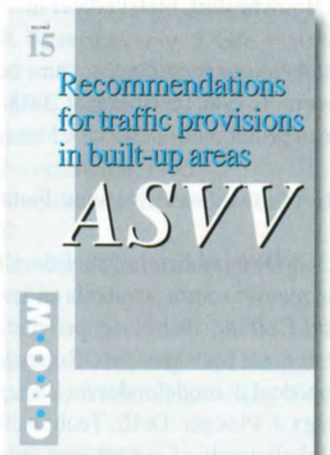

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