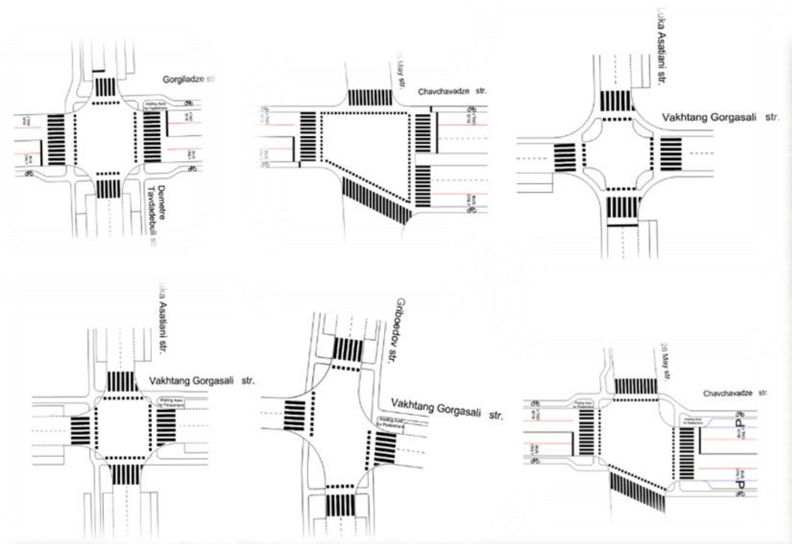
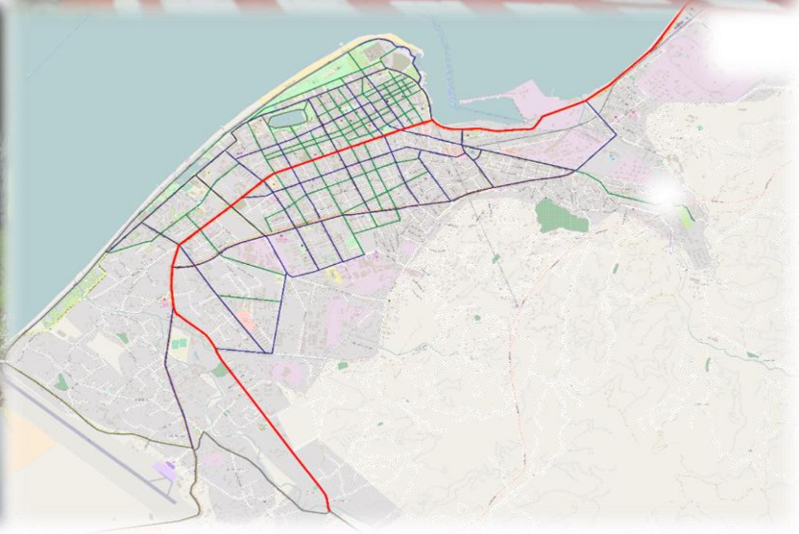
Integrated, Safe and Expanded Bicycle Network

Technical Report #5





The report has been prepared by a team of experts from A+S Consult GmbH

Sub-project: Feasibility Studies for Pilot Low-Carbon Urban Transport Corridor and Integrated Sustainable Urban Mobility Plan for the City of Batumi (ISUMP)

Output 5: Functional Plan for Integrated, Safe and Expanded Bicycled Network in Batumi

The report has been prepared by A+S Consult GmbH

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1 INTRODUCTION

Bicycle policy is on today's agenda in many European cities. In recent years and decades, many local leaders take numerous measures to stimulate the bicycle infrastructure development, as more and more people are convinced that cycling contributes to the development of the city, meeting the transportation needs of residents, positively affecting the environment, quality of life, economic development. First, we need to be aware of the essential user needs of cyclists and the characteristics of bicycles.

It is vital to keep in mind that the bicycle is mainly used for short distances. More than 80% of all bicycle trips are less than 5-7 km long. Figure 1 **Error! Reference source not found.**trips per distance category for the Flemish region in Belgium. In other countries or regions, a similar division of cycle distances will be found. Cycling is essentially a local transport mode similar division of cycle distances will be found. Cycling is essentially a local transport mode.

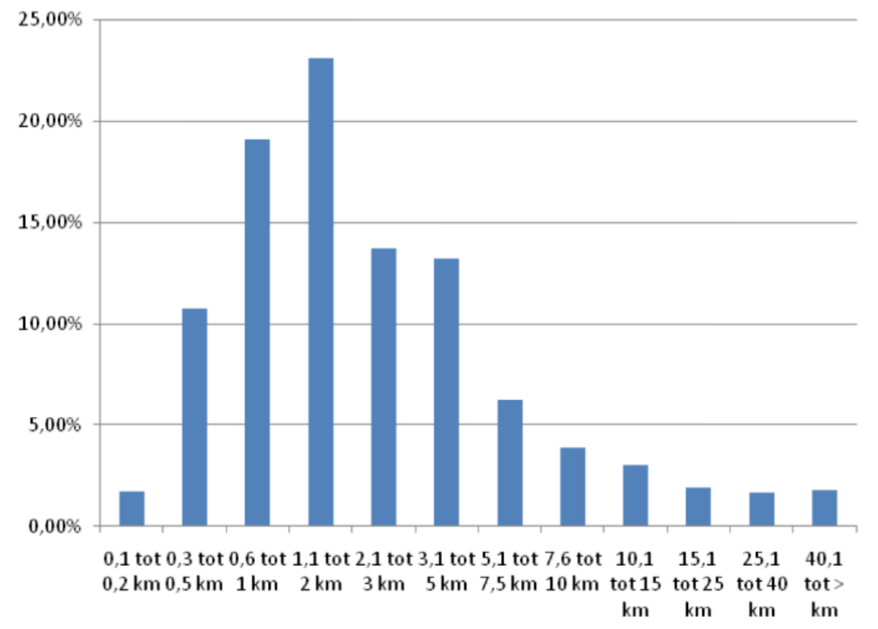


Figure 1 - Distance distribution when travelling by bicycle, according to PRESTO

Considering that the entire territory of the city of Batumi and the nearest towns lies in the 5-km radius (Figure 2), the bike can be used not only for tourism but also for daily trips.

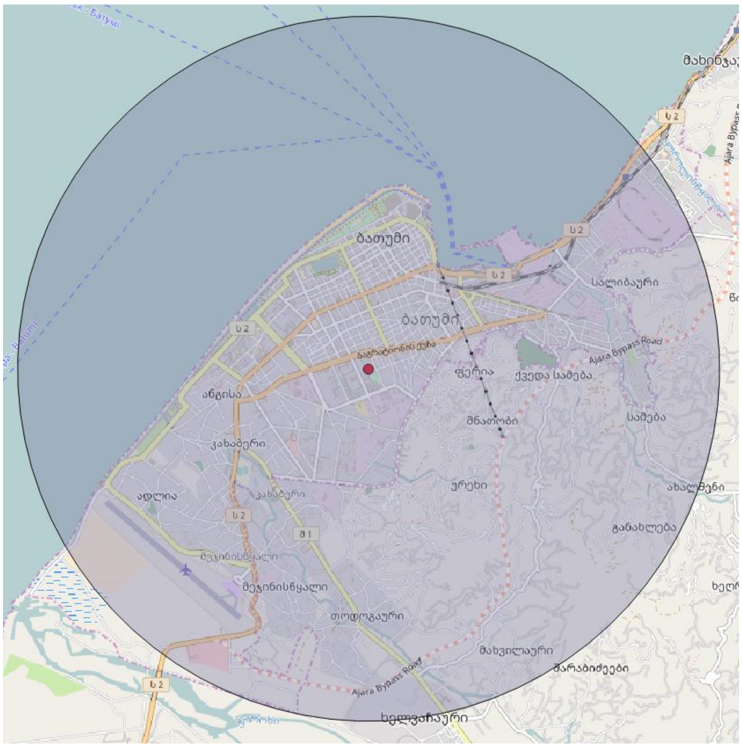


Figure 2 - Batumi fits into 5-km radius around the downtown

According to the survey, in Batumi in 2016, 0.3% of city residents use bicycles for daily commuting. Main reason, from the Consultants point of view, is that people look at bicycle only for leisure and do not have in mind it to use as a common means of transport. The cycling infrastructure, as it is now in Batumi, supports leisure and tourists, but not commuters, coming from the outer city regions. Motorized car users are not aware and do not respect other road users on unsafe means of transport (this also includes pedestrians). There is also a lack of a consistent and cohesive infrastructure for cycling, which does not support the safety for cyclists. The consultant supposes that the weather conditions will not impede people to use bicycle – European examples with similar conditions (Netherlands, Copenhagen) show that it is possible. A more depth analysis of the reasons and proposals how to improve the situation will be elaborated in the next chapters. The further development of bicycle infrastructure can increase the bicycle usage to the typical average values of the European cities.

1.1 Assess the current state of the existing bicycle

The main part of the city is located on the flat territory that promotes the use of bicycles for traveling. Today Batumi has already got a bicycle track network with a total length of over 26 km (Figure 1 and Figure 3).

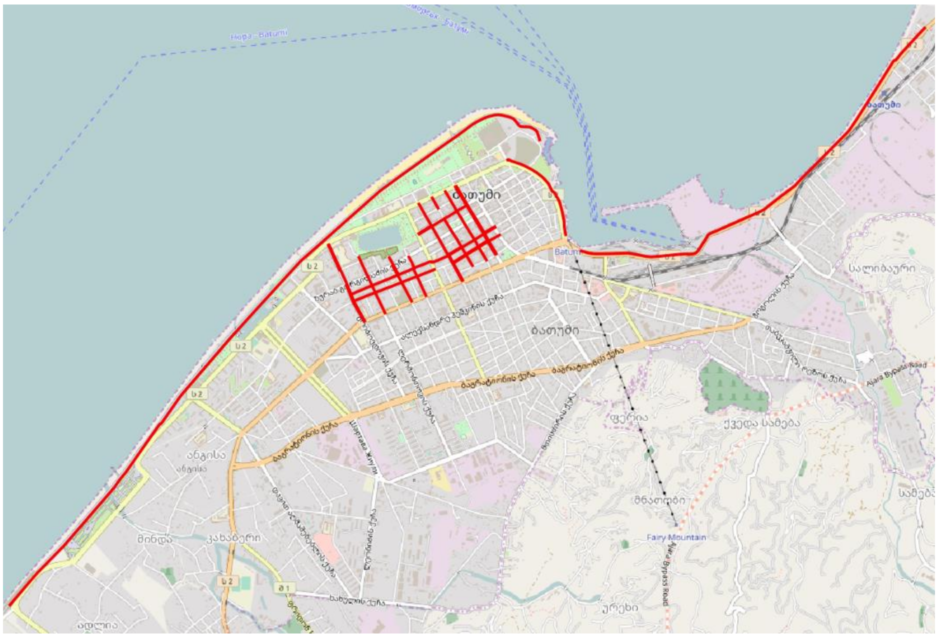


Figure 3 - Batumi bicycle network

The existing bicycle infrastructure characterizes the city, as the one that encourages the use of bicycles both for the purpose of tourism and daily transport. The existing network has its advantages and disadvantages.

To assess the quality of infrastructure the main indicators such as security, connectivity, attractiveness, convenience re used.

Safety

Safety is the basic qualitative requirement to the bicycle infrastructure.

Security is achieved through the separation of cyclists from cars and pedestrians in time and space by reducing the amount of potentially hazardous conflicts. Where it is impossible to avoid the crossings between road traffic, pedestrians and cyclists (such as intersections), potential conflicts should be shown in obvious and understandable way to all traffic members for them to understand the possible risks and, accordingly, adapt their behavior.

Most of the bike paths in Batumi combined with pedestrian sidewalks, leading to non-compliance with the regulatory width of tracks in certain cases. Since the network is developed only in certain parts of the city, speed mode and the volumes of road traffic lead to a significant number of conflicts (pedestrians and vehicles) and the negative impact on the safety of bicycle traffic.

Cohesion

Cohesion is a parameter showing the existence of the possibility to travel by bike from any starting point to any destination without gaps in the network.

Since the cycle paths are formed only in certain parts of the city, it is not possible to get to the certain places in the city using only bicycle paths. This characterizes the lack of infrastructure cohesion.

Attractiveness

Attractiveness means that cycling infrastructure is well integrated into the city. It is a measure of sensation and perception, which can both encourage people to ride bicycles, and vice versa, to repel such a desire.

Basically, only the cycle paths along the waterfront are popular among both tourists and locals due to the good quality of infrastructure, lack of conflicts and scenic environment, (Figure 4).

So, in general, Batumi infrastructure does not look attractive for daily travel, but is well suited for short tourist trips.

Figure 4 - Cycle paths along the waterfront in Batumi

Convenience

Convenient infrastructure allows you to ride without excessive effort and enjoy the ride.

Most of the bicycle routes in Batumi have used red-painted surface, which is visually very well recognized. However, it has a low coefficient of adhesion to the wheel of the bike, especially in rainy weather (which is typical for city, 204 rainy days per year). Bicycle paths feature pits and cracks that lead to shock and force the cyclists to perform maneuvers. There are also different kinds of obstacles that do not allow to ride in comfort, namely: parked cars, tree branches, pedestrians who walk on the bike path and even trade points.

All bike rides start and finish from bicycles storages (both long-term and short-term), and their number is insufficient. What is important, there are ramps and lowered curbs at all intersections with bicycle lanes, (Figure 5).

In case all of the above described notices are corrected and further development is performed, all the bicycle infrastructure may become convenient to use.

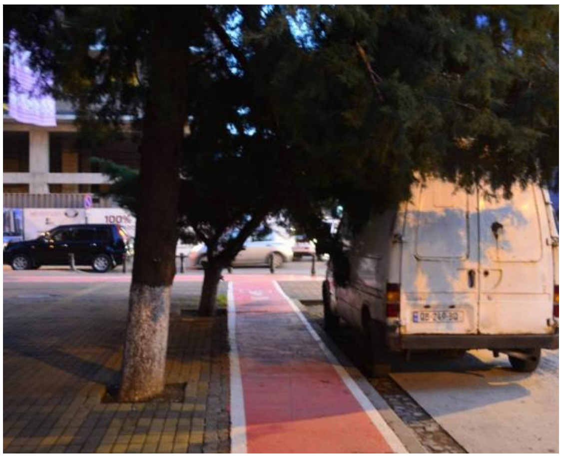
	
	
	

Figure 5 - The current state of bicycle infrastructure in Batumi

1.2 Assess the current state of the bicycle rental

Bicycle rental chain in Batumi consists of 370 bicycles, 23 terminals and more than 600 posts, most of which are concentrated in the coastal and central areas of the city (Figure 6).

The stations operate around the clock. Bicycles have good technical performance and special design.

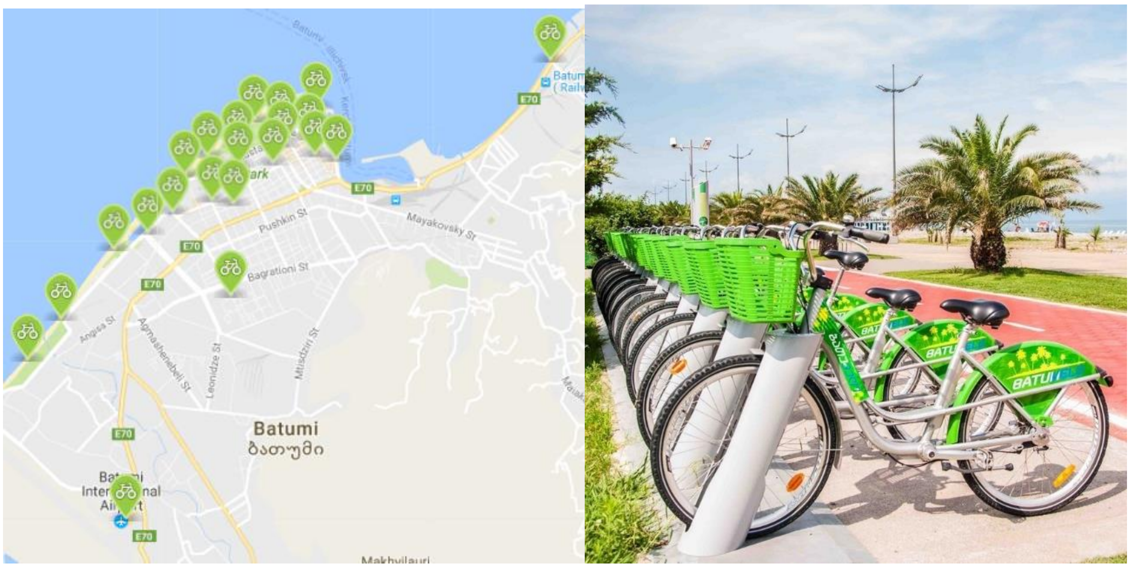


Figure 6 - Bicycle sharing system in Batumi

For the further development of the bike rental and promoting its usage among the majority of local residents the following steps are needed:

- Expand the network of points for the user registration (currently one can only register in a single Information Center on Ninoshvili St.)
- Expand the network of bike rental stations to cover the whole territory of the city (ITDP

recommends to cover a minimum of 10 square km with a station density of 10-16 stations per square km, which results in approximately 300 metres walking distance between stations and any point between) (more detailed see chapter 2.2.1)

- Develop and install of navigation labels and signs
- Develop resources to monitor the number of bicycles at stations and free columns (to provide the data to mobile app and web site, so users get an overview of the station occupancy and availability)
- Provide more ways for travel payment (for example, banking cards, mobile phone – mobile application is provided e.g. by company NextBike)

The recreational route Batumi – Mivreti (Figure 7), enables tourists and residents to explore the countryside and enjoy the environment.

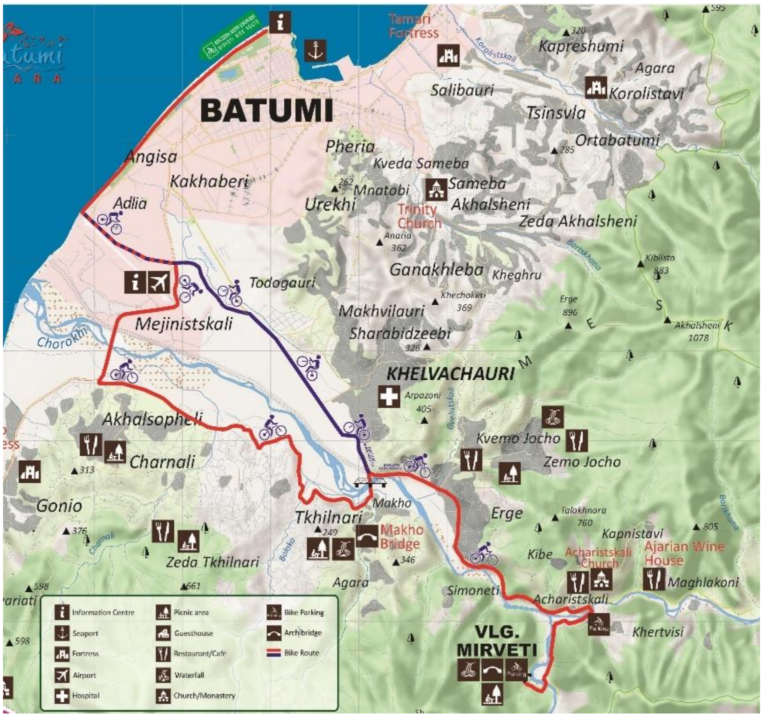


Figure 7 - Recreational route Batumi – Mivreti

2 RECOMMENDATIONS

2.1 Bicycle Network

2.1.1 Planning bicycle network

The development of bicycle network must start from the cyclists' travel needs (safety, cohesion, attractiveness, convenience – see chapter 1.1), independent from other transport modes. A correctly developed bicycle network starts from this principle and targets cycle facilities on these locations where high cycle flows are present or expected.

A cycle network is an interconnected set of safe and direct cycling routes covering a given area or city. It is worth stressing once again that a network consists of **routes, not tracks or lanes**. The quality of a route or a network does not depend on one particular type of infrastructure, such as segregated tracks.

A good cycling route is **an uninterrupted route** fitting the criteria outlined above (safe, direct, cohesive, comfortable and attractive) as closely as possible. The actual form of the infrastructure may vary from route to route and even within one route. A route may start in a residential 30km/h area mixed with light traffic, move onto a cycle lane where traffic is slightly heavier, run through a dedicated cycling tunnel under a ring road, continue as a segregated track along a main road, cut through a park as a short-cut and through a pedestrianized shopping area reach to the railway station.

The quality of the network depends on its structure: how well does it fit together; how easily does it make urban destinations accessible; how well does it avoid or manage risky situations?

Three main requirements described above are essential for the bicycle network: safety, directness and cohesion.

The basic network requirement is **network cohesion**. Without cohesion, there is no network, only a bunch of single routes. This is a matter of scale: the more routes interconnect and allow cyclists to freely choose their itinerary, the stronger the network is. cohesion is a very important feature for the cyclists: it is the extent to which they can reach their destination via the route of their choice.

Apart from major connections, the mesh width and density are important factors of cohesion: the smaller is the distance between routes, the more the cyclist has the choice, for instance between a fast route along a busy road or a slower but quieter one, or between a direct uphill route and a longer one avoiding steep hills.

Mesh width. A mesh is the smallest, closed element in a network. The mesh width is the distance between parallel routes, (Figure 8). The larger is the mesh width, the lower is the network density (the total link length per surface unit) and the lower is the level of cohesion. In Batumi the existing bicycle routes have a mesh from 80 to 180m.

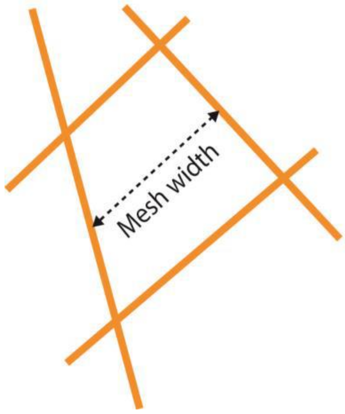


Figure 8 - Mesh width

The mesh width is only relevant in built-up areas, where there is a demand for cycle trips. Maximum mesh width of 250 meters is recommended for the cycle networks. Outside the built-up area, it is only relevant that there are bicycle connections between villages, centers and amenities that attract cyclist.

The **network directness** concerns the distance or time you need to cycle between points of origin and destination. In terms of policy, the bicycle should have more direct routes than the car in the built-up area. This way cycling is quicker than taking the car. Directness in distance can be determined by calculating the detour factor. The more a route from A to B approaches a straight line, the better for the cyclist.

Detour factor. The detour factor is the relationship between the shortest distance over the network and the distance as the crow flies. The lower the detour factor the higher the directness of the network. The detour factor must of course be related to distance: the same detour factor over a longer distance implies a longer absolute detour. For a dense cycle network, a maximum detour factor of 1.4 applies as a guide value. To make cycling attractive over short distances (in the built-up area) the detour factor of the cycle network should be less than the detour factor for cars.

The basic requirement of safety is more than a matter of physical design. Much can be done to ensure safety on the network level. Here are some guidelines to ensure **network safety**.

- Avoid conflicts with crossing traffic. It is not obvious to accomplish without reducing the quality of traffic flows, especially in the built-up area. In theory grade-separated crossings (bridge, tunnel) with car roads would be perfect with regard to safety, but in practice traffic lights and traffic calming facilities (street narrowing, chicanes, roundabouts, curbs, road humbs, median islands) are often more appropriate to avoid conflicts with crossing traffic. The NACTO "Urban Bikeway Design Guide" gives recommendations regarding traffic lights signals for bicycles.

Figure 9 - Bicycle Traffic Signal in Denmark

Figure 10 - Traffic Calming chicane

Figure 11 - Traffic Calming street narrowing

- Separate different types of road users. When speed differences between motorized traffic and cyclists are too high these road users should be separated from each other and have their 'own' network of connections. A basic rule of thumb is always to separate (best is always to completely separate with a segregated bicycle lane) cyclists from motorized traffic at speeds over 50 km/h.

- Reduce speed at points of conflict. When separating vehicle, types is not possible, the speed differences between motorized traffic and cyclists should be minimized. The speed of the slowest means of transport (the bicycle) is used as the basis. The maximum recommended speed for mixing is 50 km/h but 30 km/h is much more preferable, if only because injuries in case of accidents are significantly less severe.

- Ensure recognizable road categories. Creating recognizable and comprehensible traffic situations is essential for safety. Consistent design solutions on roads with similar functions (in terms of road hierarchy) makes potential conflict situations more predictable for cyclists and other users, while also inciting everyone to behave more predictably. Consistent design means in this case that intersections and road sections look similar to the road user in the whole area. So that the user does not need to study and understand the road and intersection geometry on every new facility. In a consistent environment the road user does not lose any time not being concentrated on the traffic itself and by this wins on safety. This similarity is an essential advantage in terms of road safety. In Germany, for example, are allowed only four types of highway intersections, to make the traffic management and road user behavior predictable.

Developing a **utility cycle network**. If we focus on cycling as a daily transport mode, we need to set up a utility network, as opposed to a recreational network. The goal of a utility or functional cycle network is to connect destinations for functional trip purposes such as shopping, working, education, socio-cultural visits etc. The connections should be as direct as possible.

Developing a utility cycle network for a city or a wider area usually takes three main steps:

Step 1: determining major origin and destination areas and links

Origins and destinations depend on the size of the study area. At the level of the urban region, a city center can be regarded as a single point of origin, while for the network inside the center of the various neighborhoods and districts will be regarded as separate points of origin. Origin-Destination analysis are typically made from mobility surveys and transport models.

Typical cycling destinations are:

- residential neighborhoods and districts;

- schools and universities;

- shopping areas;

- sports amenities;

- employment concentrations, such as large companies and business parks;

- major public transport hubs and interchanges (railway, bus, tram, metro).

All these destinations can now be connected on a map with simple straight lines. The result is called the preferential (theoretical) network, a set of high-potential links that the network must contain.

Step 2: detailing preference lines into routes

Next, the origin-destination links should be detailed into preferential routes. This means they should be drawn in on a map, along existing roads and cycle infrastructure, possibly indicating missing links and cycling shortcuts to be created. The shortest most direct route should be considered first and checked against the other criteria.

Step 3: Creating a hierarchy in the network

An extensive cycling network is most effective when it has a clear hierarchy. We are all familiar with this from the road network, from motorways to district roads and local roads. Similarly, across an urban area cycle network users have different priorities at different times: short trips or long trips, utility or recreational purposes, speed or safety.

To respond to these different needs, cycle routes can be classified into three levels (Figure 12). This is a logical differentiation and is not necessarily related to the design characteristics (there exists no regulation):

- **MAIN ROUTES** have a connecting function at city or intercity level. They connect

centers, villages, towns and cities with each other, outside the built-up area.

- **PRIMARY LOCAL ROUTES** have a distributor function at the district level of the built-up

area. They provide the main cycling connections between urban districts and major urban areas.

- **SECONDARY LOCAL ROUTES** have an access function at the neighborhood level. They include basically every street or track that can be used by cyclists, connecting all buildings and other origins and destinations to higher level routes.

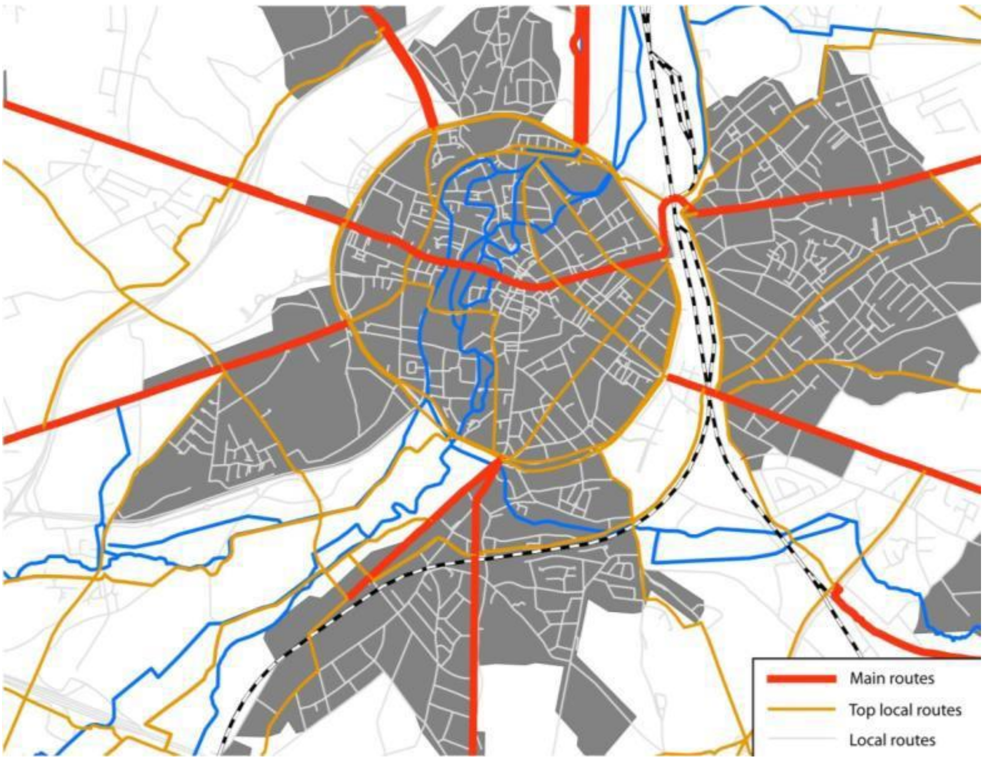


Figure 12 - An example of the hierarchic bicycle network

In and around urban areas there is growing user demand for **recreational networks**. For these, the attractiveness and experience offered by the cycle route and its surroundings is more important than direct connections.

The traditional concepts are designated (signaled by information tables and routing signs) long distance routes and touristic theme route, which are still attractive. But more recently, **recreational cycle networks** have been developing. They are structured as a number of nodes connected with links, offering cyclists the freedom to determine their own trip on a network. Exploring a region by bicycle is the goal of these networks. Many of these recreational routes pass through urban areas and centers.

2.1.2 Bicycle parking

For all cycling trips, it is necessary to provide for parking and storage of bicycles.

Depending on the purpose of the trip and duration, there are two types of bicycle parking:

Short-term parking

Short-term bike parking is defined as unsheltered, unenclosed bike racks with an intended parking duration of less than two hours. The majority of public bike racks are considered short-term parking that include buildings, constructions or just an area with bicycle racks and stands, that provide safe bicycle parking during the short period of time, (Figure 13).

Short-term bike parking’s can be with or without shelters (to protect bicycles from rain).

Figure 13 – An example of the short-term bike parking

Long-term parking

In the case, long-term parking is considered, the facility needs the additional protection of an enclosure (shelters, bike rooms, lockers) or active surveillance, (Figure 14).

Figure 14 - An example of the long-term bike parking (on the left individual bicycle locker, on the right collective bicycle locker eventually supervised)

There are three main types of long-term parking:

Individual bicycle lockers are used in situations calling for individual protection against bicycle theft and vandalism, but where the demand is too low to create a supervised storage facility (e.g. small railway stations, park & bikes near city centers).

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. A specific type is the bicycle drum used in urban neighborhoods (mentioned above).

Supervised storage is worthwhile at destinations with large number of cyclists (e.g. main railway stations), a high rate of long-term parking and a high risk of bicycle theft. Railway stations are typical examples, but also large events, which may require temporary or mobile supervised storage.

Type of parking provision needed, as summed up in the Table 1.

Table 1 - Function, duration and type of bicycle parking

			PARKING DURATION			
			Short / daytime (<1 hour)	Between short and long	Long / daytime (> 6 hours)	Long overnight
Type of parking provision			**reserved space in public area**	**stands or racks in public area**	**sheltered secured or supervised storage**	**indoor secured or guarded storage**
ORIGIN – DESTINATION	Residence					
	Public transport hub (railway, bus)	Pre-trip				
		After trip				
	School	Students and teachers				
		Visitors				
	Companies	Employees				
		Visitors				
	Shopping	Employees				
		Visitors				
	Entertainment / leisure	Employees				
		Visitors				
	Visits (at home)					

The number of parking spaces is recommended to be set depending on the type of institution, the number of visitors or employees, the area of the institution and other characteristics (Table 2).

Table 2 – Recommended number of bicycle parking spaces

Type of institution	Recommended standard *
Residential buildings (guest parking)	at least one place for five households / apartments
Offices, administrative, medical institutions, museums, exhibition centers, etc.	at least one parking place per 25 visitors (including permanent employees)
Schools, universities, etc. educational institutions	at least one place for five people - students and staff
Theaters, concert halls, cinemas (Not included in shopping and entertainment centers)	at least one seat for 15-20 place and one place for five people staff
Shops (up to 200 square meters)	1-3 place / shop
Shopping centers (up to 3 000 sq. m)	at least one place to 150 sq. m retail space
Shopping centers (up to 10 000 sq. m)	at least one place to 300 sq. m retail space
Mollies and other large shopping centers (area more than 10,000 square meters)	at least one place to 500 sq. m retail space
Catering establishments, hotels	at least one place for 15 visitors and one place on the five-person staff
Major stops	not less than 0.5% of the total passenger traffic in the morning rush hour
Stadiums, sports arenas	at least one place for 15 seats
* Note: These standards may be revised with an increase in the modal share of bicycle transport.	

At a minimum, a good bike rack will allow both the frame and at least one wheel of the bike to be secured with a u-style lock. For orderly parking, the rack should make at least two points of contact with the bike (Figure 15).

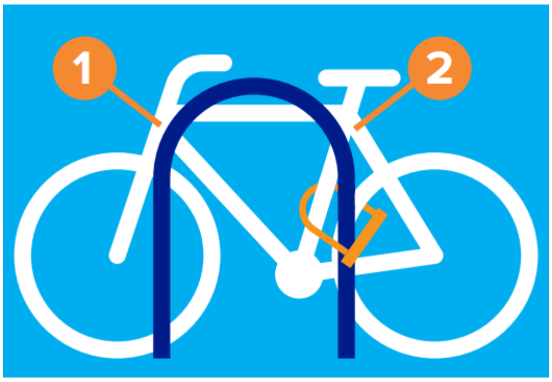


Figure 15 - An example concept of a good bike rack

The easiest type of the bicycle stand is a so-called Sheffield stand (typically steel is used as material). Recommended dimensions for this type of bicycle parking are: pipe diameter - 40 mm, overground height > 750 mm, length- 300-1000 mm, curve radius – 100 - 250 mm, (Figure 16).

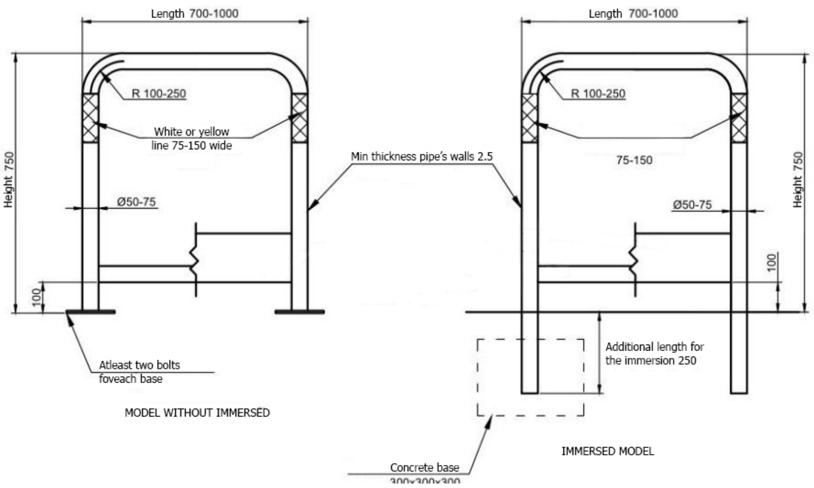
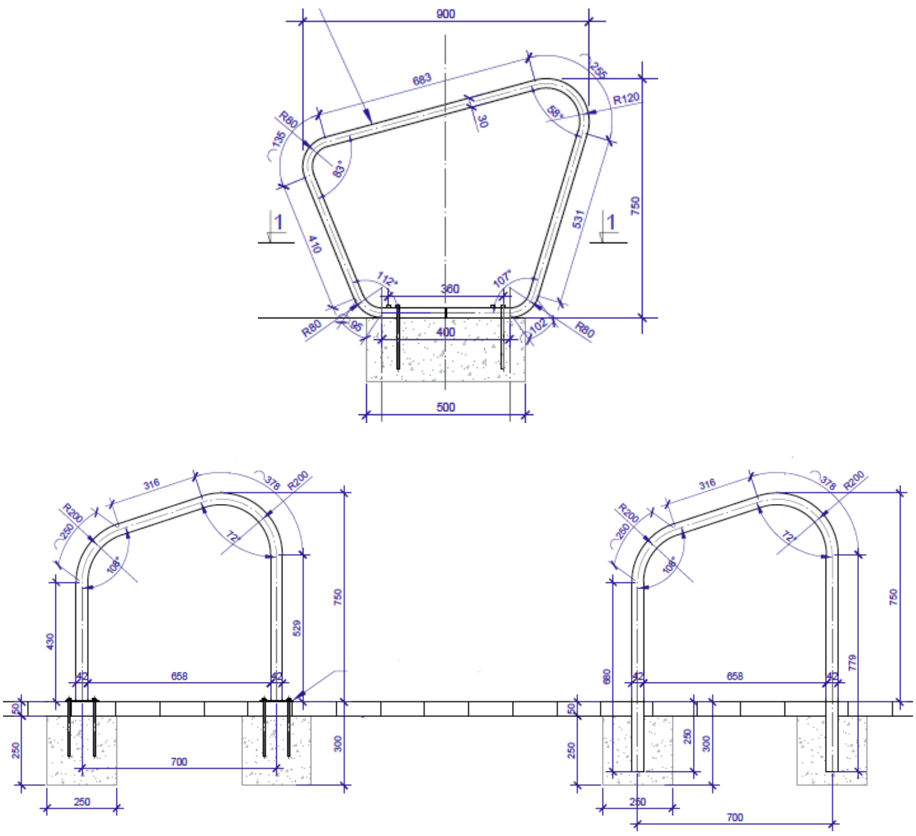


Figure 16 - Recommended dimensions for Sheffield stand

There are several analogues of the Sheffield stand that are widely used. They usually respect the recommended dimensions, described above, (Figure 17).



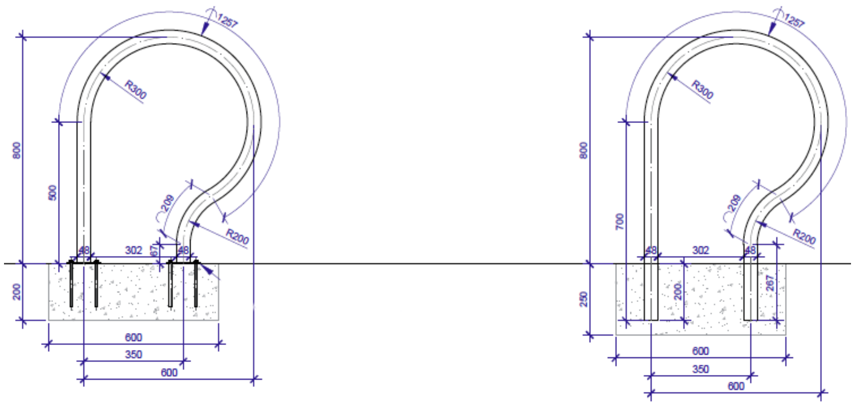


Figure 17 - Trapezoid and P-style stands

Parking rack is a complex of several parking stands, connected with each other by the common base, or mounted to the same surface within the same interval. Bicycle rack has to give easy independent access to each bike. To comply with this requirement, standard stands should be located with the interval at least 750 mm. This allows mounting the bicycles to each stand, one from each side.

Bike rack installation scheme, (Figure 18 - Figure 22).

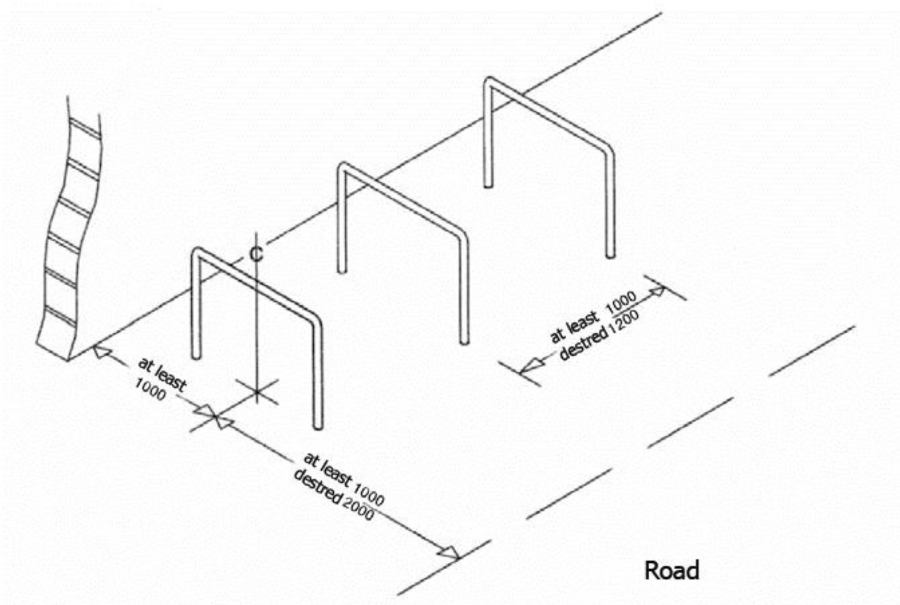


Figure 18 - U-shaped rack located at 90 degrees to the wall and the road

Note: Recommended distance to the traffic is 2 m. It can be reduced to 1.75 m, if there if a kerb that separates the bicycle rack from the traffic.

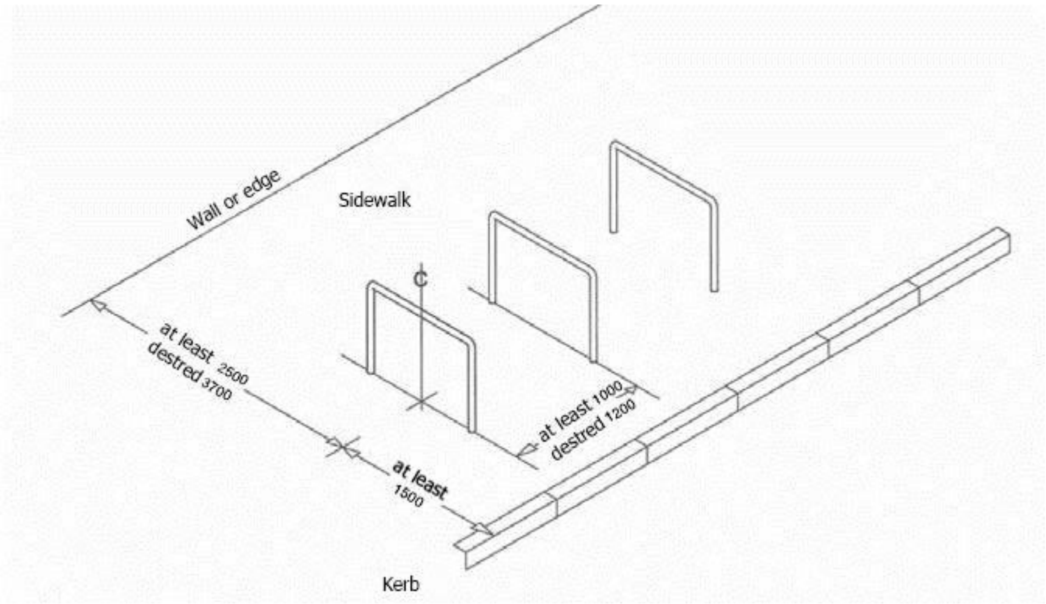


Figure 19 - U-shaped rack located at 90 degrees to sidewalk and road

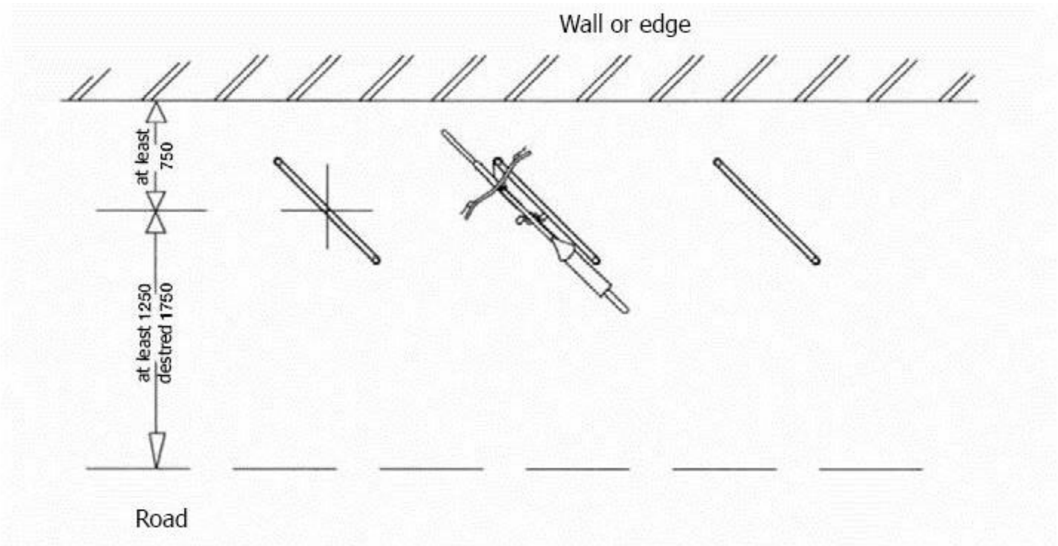


Figure 20 - U-shaped rack located at 45 degrees to the wall and flow of motorized traffic

Note: recommended distance to the car traffic is 1.75 m (if there is no kerb) and 1.5 m if there is a kerb between the bicycle parking and car traffic.

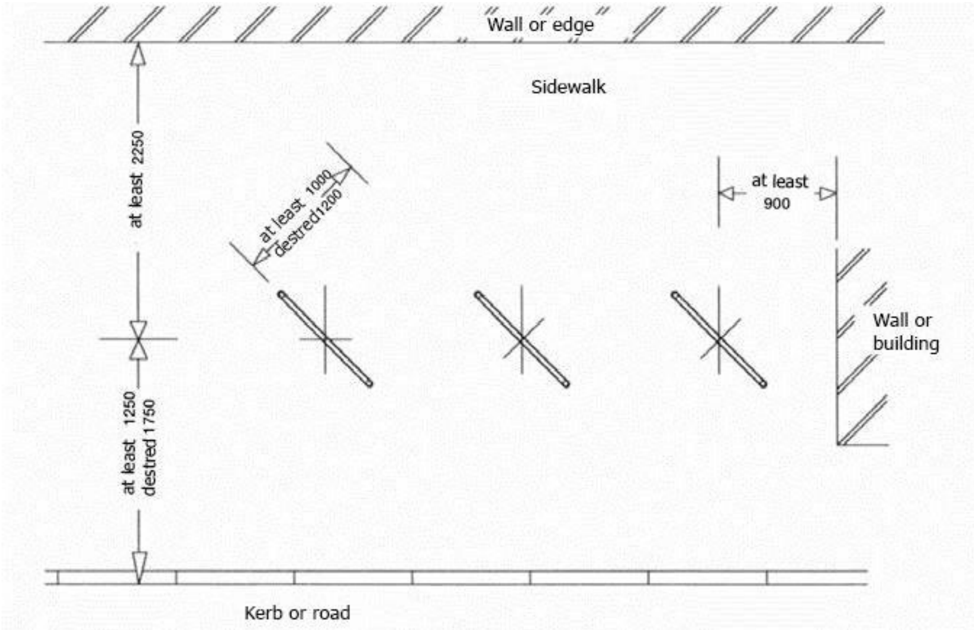


Figure 21 - U-shaped rack located at 45 degrees to the curb and the sidewalk

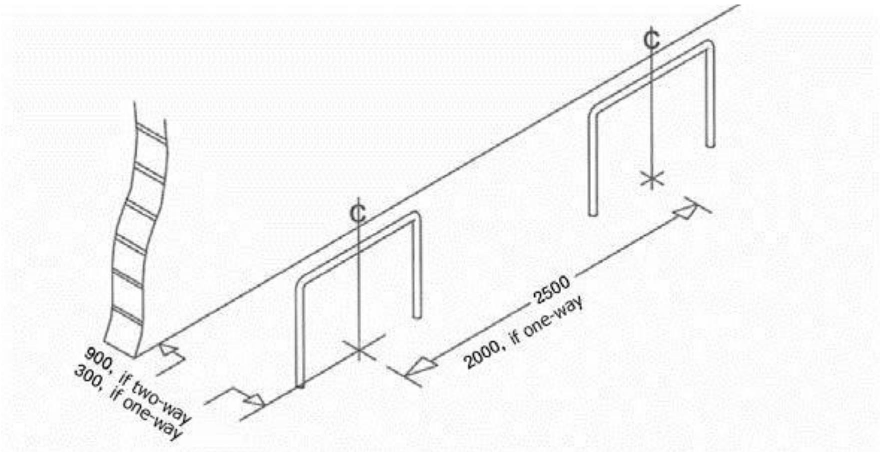


Figure 22 - U-shaped rack parallel walls

Note: this distance allows the cyclists to comfortably park their bicycles from the both sides of the stand. In the case, when single-side parking is considered, a handler, or a ring mounted into the wall is a more efficient solution.

2.1.3 Storing bicycle in residential areas

Providing secure and comfortable residential storage in these areas is vital to develop the cycling potential. Data on available storage facilities or surveys can help to determine latent demand. An alternative is a demand-led approach: make an offer available to neighborhoods and invite residents to claim provision in their area.

Here are two common solutions, (Figure 23).

Neighborhood storage facilities. Space can be found inside buildings or enclosed areas the residents can store their bicycles collectively. Generally, they will be attractive within a 150m radius, and access should be restricted to users.

On-street bicycle drums. Small collective lockers for 5 to 8 bicycles can be provided in various places. Bicycle drums are the size of a car, so they can simply be installed on a car-parking space.

For both, users generally pay a yearly rent, but local authorities can decide on the level of public funding. The facility can be run on a community basis, by the authorities, the public parking agency, or a commercial service provider or a mix of those.

Figure 23 - Example neighborhood storage facilities and on-street bicycle drums.

2.1.4 Navigation

Information posters.

Information board aimed to help the cyclists navigating through the city, including the bicycle lanes, (Figure 24).

Figure 24 - An example information posters

These posters illustrate the overall system of cycle routes with the selection of the route on which the person and show the point of her stay.

Information signs

For information sign boards, designated direction and distance to key destinations for cyclists, (Figure 25).

Figure 25 – An example information sign boards

2.1.5 Other elements of bicycle infrastructure

Bicycle self-service stations

The self-service stations include all the tools necessary to perform basic bike repairs and maintenance, from changing a flat to adjusting brakes and derailleurs. The tools and air pump are securely attached to the stand with stainless steel cables and tamper-proof fasteners, (Figure 26). Hanging the bike from the hanger arms allows the pedals and wheels to spin freely while making adjustments.

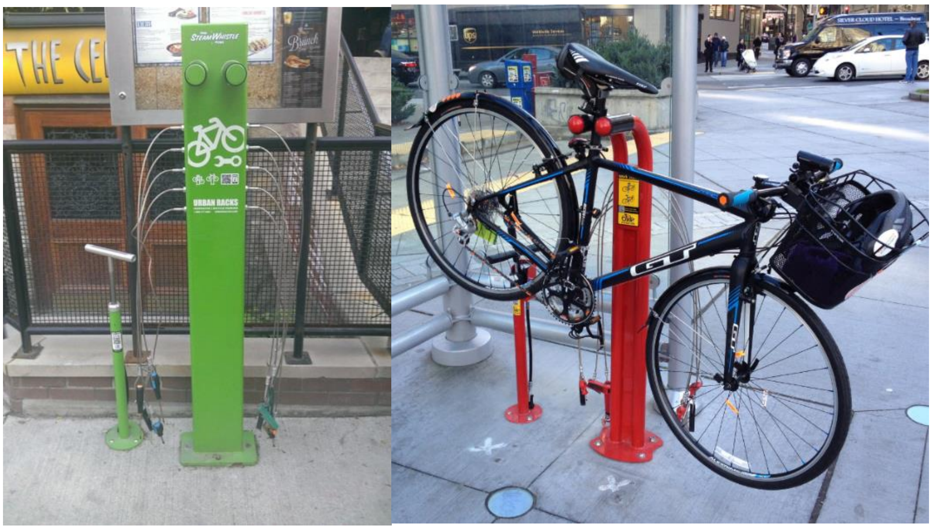


Figure 26 – An example bicycle self-service stations

Cycling traffic volume detectors

Visually demonstrates the effectiveness of bicycle paths.

Detectors are usually used to monitor the bicycle traffic, (Figure 27). Each detector that lies in the pavement on the bicycle lane reacts on the bicycle passing over in and generates a signal. Then, the computer that transfers this data to the main traffic information center processes this signal and shows is on the screen.

It is recommended to install the detectors on the main intersections that are usually intersections of the main and local routes. The density of detectors is defined by the aims of the monitoring.

Figure 27 -An example cycling traffic volume detectors

Bicycle facilities

Development of bicycle facilities in the offices is an investment into business. Businesses will definitely benefit from more productive, punctual, healthy employees; more comfortable conditions for the visitors and good bicycle-friendly reputation of the company.

The city of Batumi has to work on the implementation of the bicycle-friendly facilities that include shower, dressing room, places for clothes storage and drying to develop Bicycle Friendly Business, (Figure 28).

Figure 28 - An Example Bicycle Friendly Business

2.2 Bike Sharing

2.2.1 Rental stations

Registration

It is necessary to expand the network of points for registering users (now only in one Information Center at Ninoshvili St.). For example, to provide registration in all information centers, post offices, banks, hotels.

Station network

Increase the number of bicycle rental stations, covering the entire city and promoting the use of rental bicycles for daily trips by local residents. ITDP (Institute for Transportation and Development Policy) recommends covering a minimum of 10 square km with a station density of 10-16 stations per square km, which results in approximately 300 metres walking distance between stations and any point in between. For Batumi we propose to develop the station network in the more dense regions of the city. Figure 29 shows a map of the regions of Batumi in which the bike sharing station network should be developed with priority. These are populated regions with more than 2.500 inhabitants/km2. The area of these regions is about 16km2, which results in a recommended number of bike sharing stations of 160 to 256.

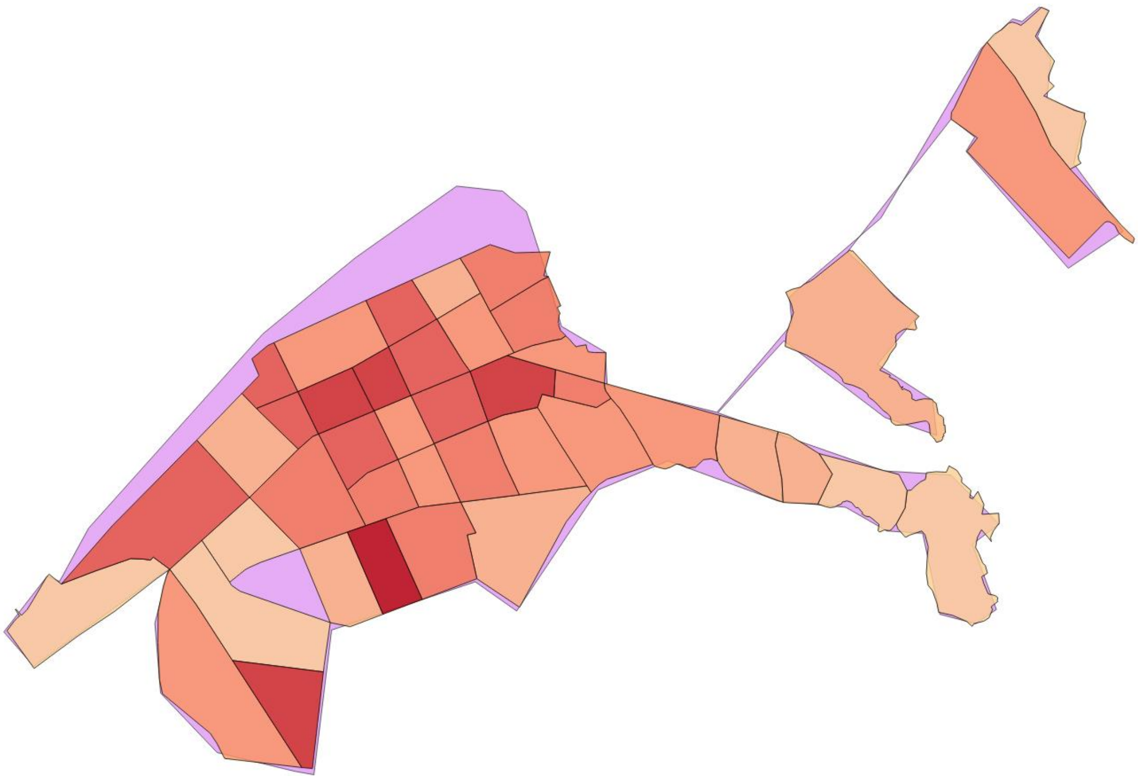


Figure 29 - Regions of Batumi to primary develop Bike Sharing Station network

Integration rental stations with public transport (Figure 30). Integration on bus terminal and central bus stops is a must-have. The integration on minor bus stops can be considered if demand is high enough to argue on this.

Figure 30 - Bike sharing stations on bus stop

Navigation

Rental stations need navigation posters, that display the current location on the general map of the city, show the sights and possible routes.

Monitoring of demand for bicycles

To be satisfied, users should have regular access to the bikes and avoid empty rental stations. Therefore, the bicycle turnover is essential to ensure system functionality and customer satisfaction, (Figure 31).

Monitoring the technical condition of bicycles: operational repair, planned repairs, gradual replacement bicycles park.

Multifunctional terminals: BSS (Bike Sharing System) can perform a variety of additional functions: sale of public transport tickets, concert tickets, offer parking tickets or mobile phone charging. Solar panels for power supply of rental terminals (Figure 31).

To reduce the cost of operating the stations and ensuring their energy independence, the installation of solar panels is recommended.

Figure 31 – An example solar panels in terminals (left) and monitoring of demand for bicycles (right)

Web and Mobile App

Development of the Internet and mobile applications to improve the quality of services, namely: rental stations locations, monitoring the number of available bikes and racks for rental stations, (Figure 32).

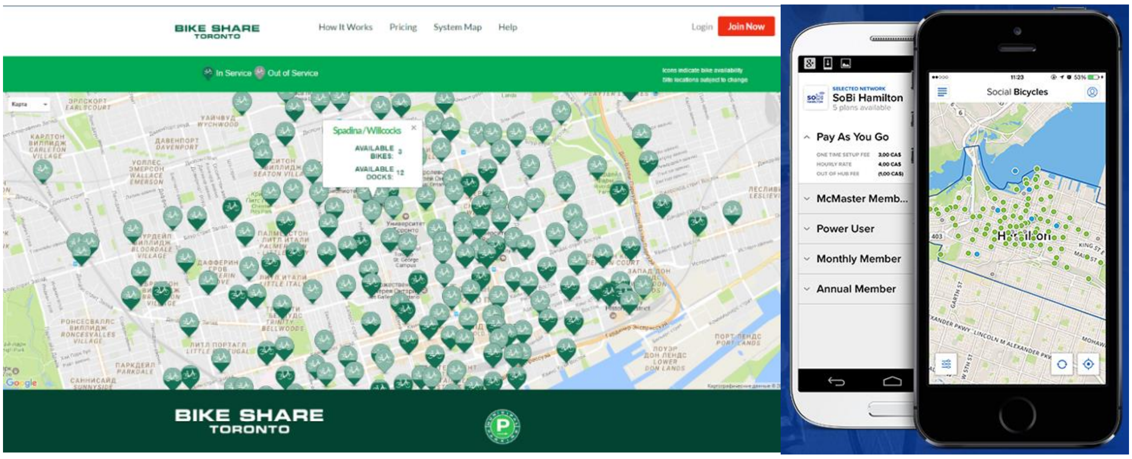


Figure 32 – An example web and mobile app

2.2.2 Rental bicycle

The bicycle should be attractive and durable. The overall appearance of the cycle is a key element in the overall branding of a cycle sharing system and should project a sleek, modern image. The design can differentiate the cycle sharing fleet from regular cycles in the city through distinctive design, colors, and graphics.

Bicycles must meet the following specifications:

- Robust parts: to reduce wear and damage from vandalism to a minimum the bicycles need strong and easily replaceable parts (planetary hub, brake drum, plastic mud guards, etc.). To protect rental bikes from dismantling for parts, it is important that they have specific standards that are not suitable for typical of private bicycles.

- Distinctive design: To avoid thefts, rental bicycles must stand out among private bicycles. Bicycles rental unified system usually have the same frame, and color. They can be recognized even repainted.

- One size fits all: Some settings such as seat height or stem allow to adapt the bike to your personal settings. The disadvantage is that some people, such as people with children, older or disabled, low or very high people cannot use such a rental.

Some characteristics may vary depending on the type of bicycle rental:

- Advertising: bike can be fitted to place advertising on it without compromising its performance. Third party as well as bicycle rental system itself can be advertised.

- Bicycle locks: Usually the bikes are locked with special fixing points with solenoids or mechanically. The operator can provide separate bicycle locks to attach the bike outside of the stations during use (short-term parking).

2.2.3 Payment and registration

User registration is required to prevent theft of bicycles by the anonymous users and maintain proper payment. Registration should be available via the Internet or in person. There are several payment opportunities of the rental services: card, key or deposit, (Figure 33).

- Card is the most common method of payment for the rental. For this purpose, stations themselves or the bikes are equipped bid the card readers. Different types of cards can be used: magnetic, microchipped, credit and so on.
- Key: the user receives the key of the bike in the machine or kiosk. The uses need to certify his/her identity.
- Deposit: To unlock the bike, the user must make a cash deposit to the machine or kiosk (used only in cities with low crime statistics or high mutual trust among citizens).

Figure 33 - An example payment on rental station

Fare system should be flexible enough to be competitive in comparison to other modes of transport and should provide free of charge service during first 15 minutes.

2.2.4 Safety

The helmet performs a protective function. Head injuries associated with cycling, are often quite serious. They can be prevented if the protective helmets are used. There should be an option to rent or buy o bicycle helmet at the rental stations, (Figure 34).

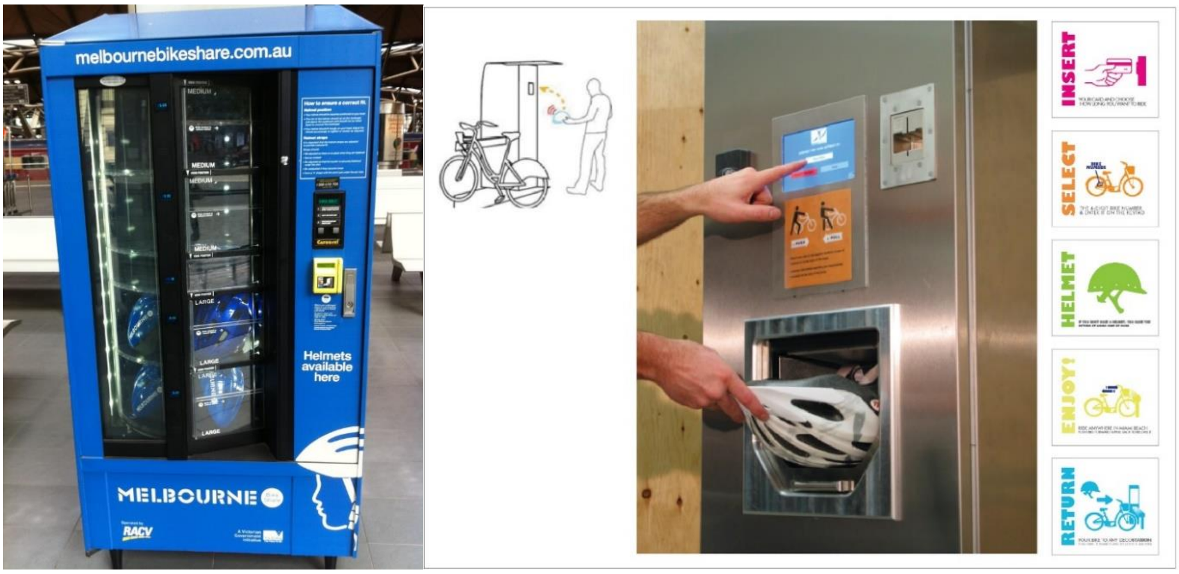


Figure 34 - An example of selling, renting a bicycle helmet at the rental stations

2.3 Policies

2.3.1 Common Bike Road Rules

- Bicycle helmets
- Bicycle equipment
  - at least 1 working brake
  - a working bell, horn or a similar warning device
- Bicycle equipment for night time and unsafe weather
  - a white light (flashing or steady) that can be clearly seen at least 200m from the front of the bicycle
  - a red light (flashing or steady) that can be clearly seen at least 200m from the back of the bicycle
  - a red reflector that can be clearly seen at least 50m from behind the bicycle—when a vehicle's headlights shine on it
- Carrying a load on a bicycle
  - attach the load to your bicycle in a way that does not make the bicycle unstable
  - make sure the load is unlikely to fall from the bicycle
- Bicycle Lane
  - A bicycle lane is a marked lane with either a bicycle lane signs or a road marking of a bicycle symbol and the words 'Bike Lane' painted in white. It is recommended to use the bicycle lane where available.

3 DESIGNS AND SPECIFICATIONS

3.1 Network concept sketch

Bicycle network is a set of interrelated, safe and straight routes covering the entire city. Four types of routes were identified for Batumi: main, primary local, secondary local, recreation (Figure 35) according to the classification indicated in 2.1.1. The design of the network is based on the analysis of the origin-destination matrices from the transport model. The lengths of the routes are expected to be:

- Main routes - approximately 19 km long, connecting Batumi to Khelvachauri and Makhinjauri and passing through the train station and the central part of the city (Figure 37);
- Primary local routes (approx. 52 km long), have a distributon function at the district level of the built-up area.
  They provide the main cycling connections between major urban areas, such as bagrationis, javaxiSvilis, aRmaSeneblis, boni-gorodokis ubani, aRmaSeneblis ubani with Zveli baTumis, rusTavelis, ximSiaSvilis ubani, (Figure 38);
- Secondary local routes length ≈ 38 km long, providing access to the final destination (housing,

work, education, leisure), (Figure 39).

The implementation of the planned scheme should be done selectively, starting with the primary local routes in the areas with the highest bicycle potential, where people already ride bikes. These primary local routes should be put together and connected into the main routes. Then the network can consistently connect other areas, developing and gradually compacting.

Also, **bicycle infrastructure development** should be included into the **major repairs** and **constructions of new road sections,** regardless of the route types.

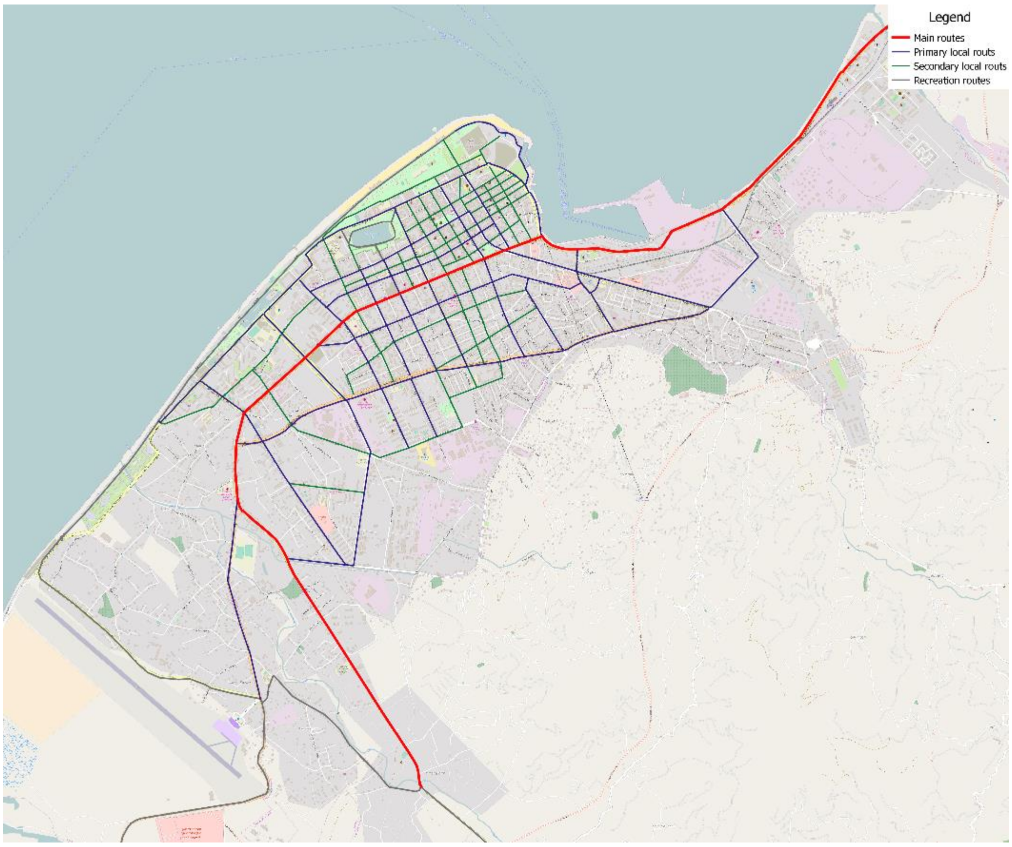


Figure 35 - Network concept sketch for Batumi

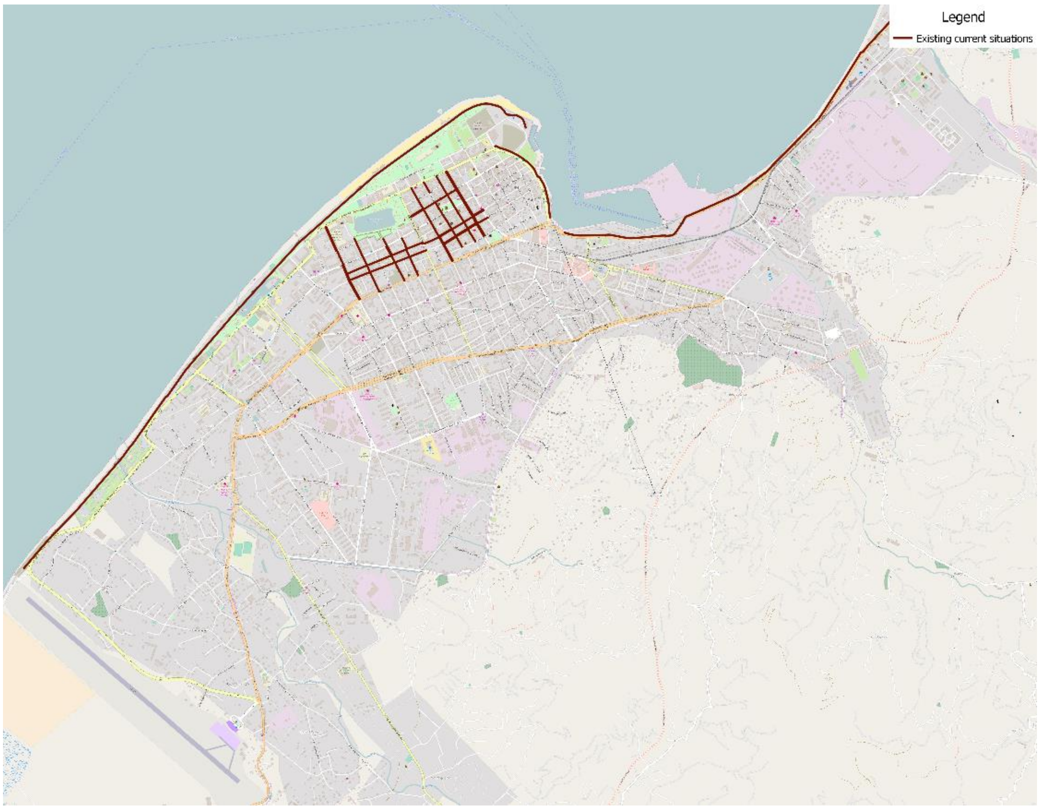


Figure 36 – Batumi bicycle network (Existing current situations)

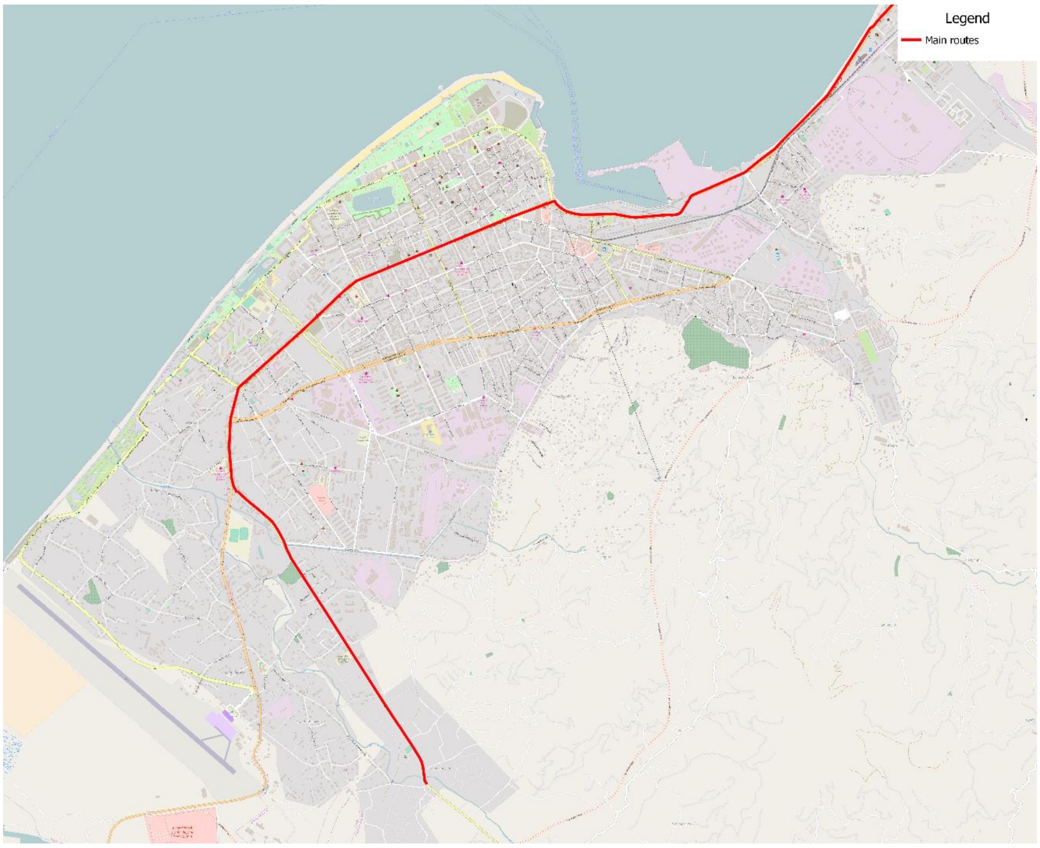


Figure 37 – Main routes concept sketch

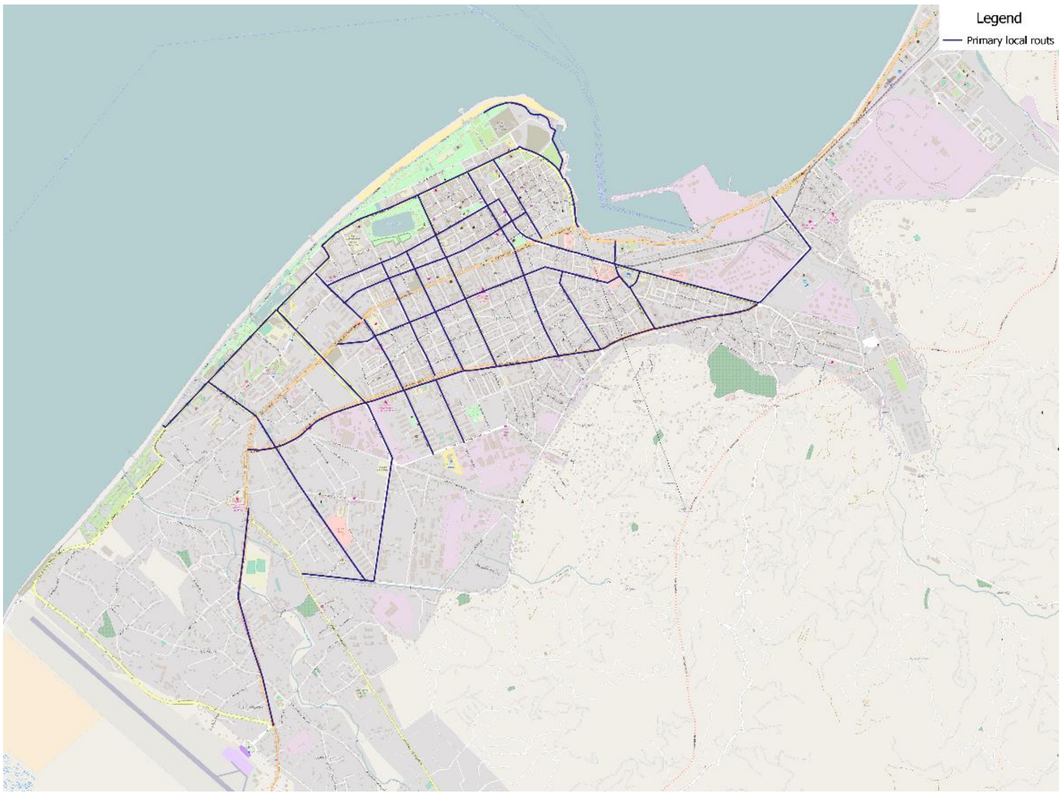


Figure 38 - Primary local routes concept sketch

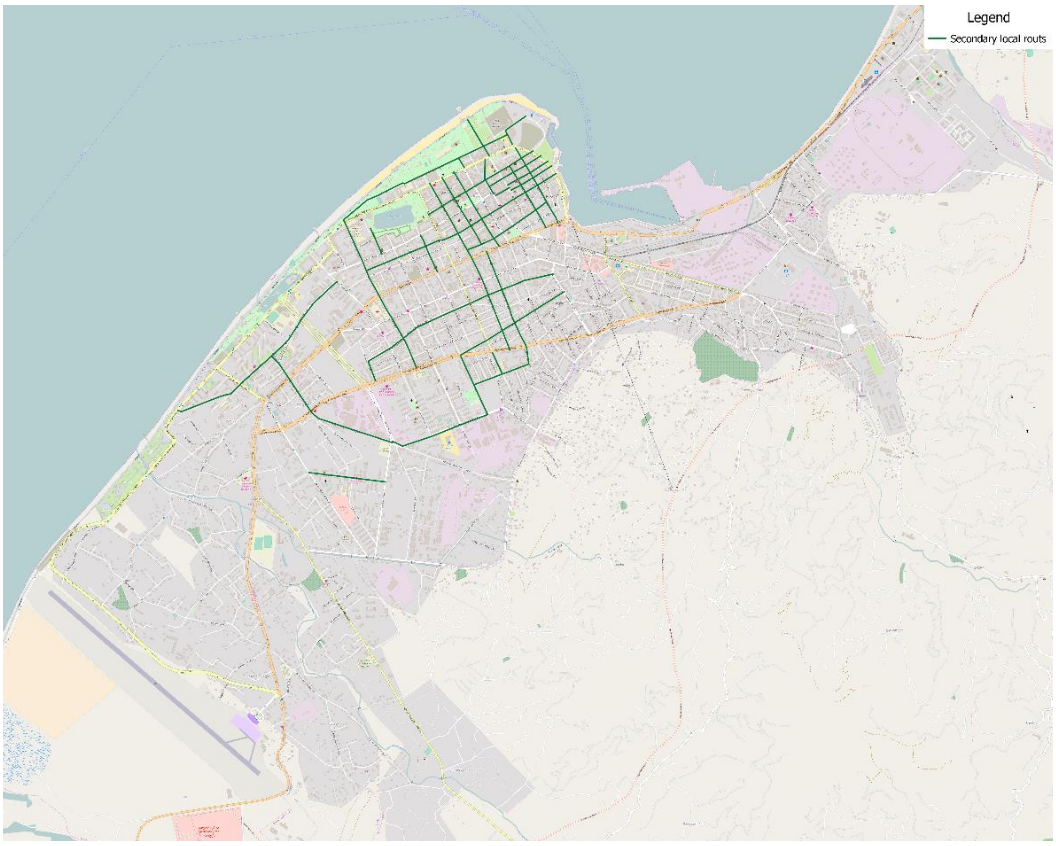


Figure 39 - Secondary local routes concept sketch

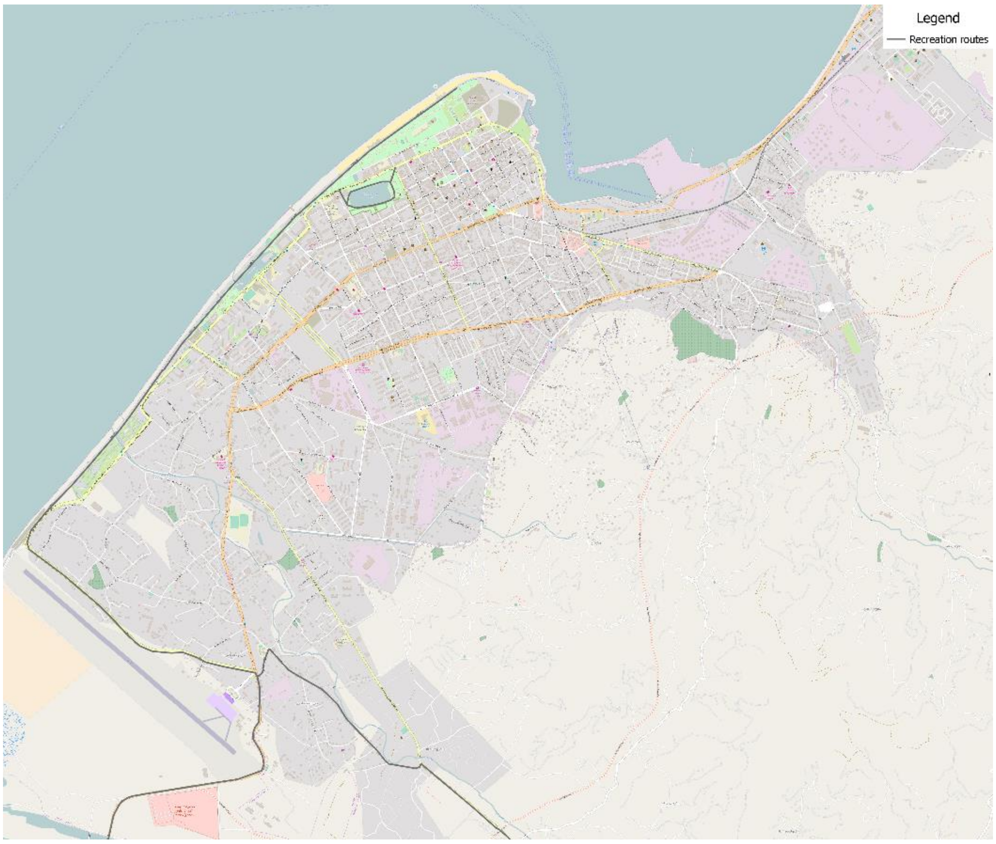


Figure 40 - Recreation routes

3.2 Road Sections

3.2.1 Bike Lane

A Bike Lane is defined as a portion of the roadway that has been designated by striping, signage, and pavement markings for the preferential or exclusive use of bicyclists.

Bike lanes enable bicyclists to ride at their preferred speed without interference from prevailing traffic conditions and facilitate predictable behavior and movements between bicyclists and motorists. A bike lane is distinguished from a cycle track in that it has no physical barrier (bollards, medians, raised curbs, etc.) that restricts the encroachment of motorized traffic. Conventional bike lanes run curbside when no parking is present, adjacent to parked cars on the right-hand side of the street or on the left-hand side of the street in specific situations. Bike lanes typically run in the same direction of traffic, though they may be configured in the contra-flow direction on low-traffic corridors necessary for the connectivity of a particular bicycle route.

3.2.1.1 Conventional Bike Lanes

Bike lanes designate an exclusive space for bicyclists through the use of pavement markings and signage. The bike lane is located adjacent to motor vehicle lanes and flows in the same direction as motor vehicle traffic. Bike lanes are typically on the right side of the street, between the adjacent travel lane and curb, road edge, or parking lane. This facility type may be located on the left side when installed on one-way streets, or may be buffered if space permits, (Figure 41).

Bike lanes enable bicyclists to ride at their preferred speed without interference from prevailing traffic conditions. Bike lanes also facilitate predictable behavior and movements between bicyclists and motorists. Bicyclists may leave the bike lane to pass other bicyclists, make left turns, avoid obstacles or debris, and avoid other conflicts with other users of the street.

Typical Applications

- Bike lanes are most helpful on streets with ≥ 3,000 motor vehicle average daily traffic.
- Bike lanes are most helpful on streets with a posted speed ≥ 40 km/h.
- On streets with high transit vehicle volume.
- On streets with high traffic volume, regular truck traffic, high parking turnover, or speed limit > 60 km/h

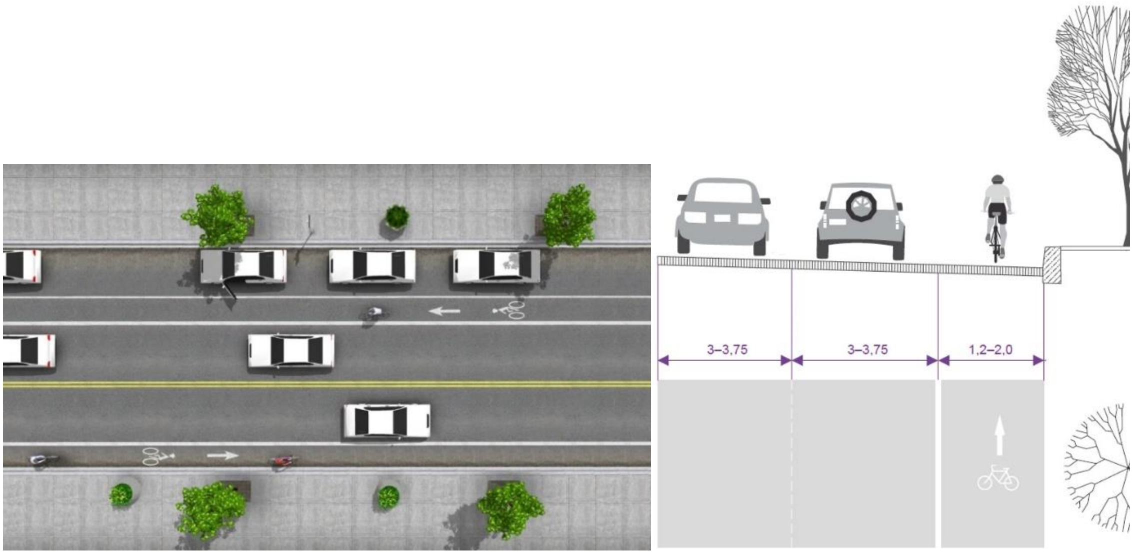


Figure 41 - Conventional bike lanes

Recommended dimensions of the bicycle lane, depending on the space available are shown in Table 3

Table 3 – Standard width of bike lanes

Bike lanes width, m		
Minimum	**Standard**	**Best practice**
1,20	1,50	2,00

3.2.1.2 Buffered Bike Lanes

Buffered bike lanes are conventional bicycle lanes paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane, (Figure 42).

Typical Applications

-Anywhere a standard bike lane is being considered.

- On streets with high travel speeds, high travel volumes, and/or high amounts of truck traffic.

- On streets with extra lanes or extra lane width.

- Special consideration should be given at transit stops to manage bicycle and pedestrian interactions.

Recommended width of the buffer zone is at least 0,75m (0,5m in cramped conditions).

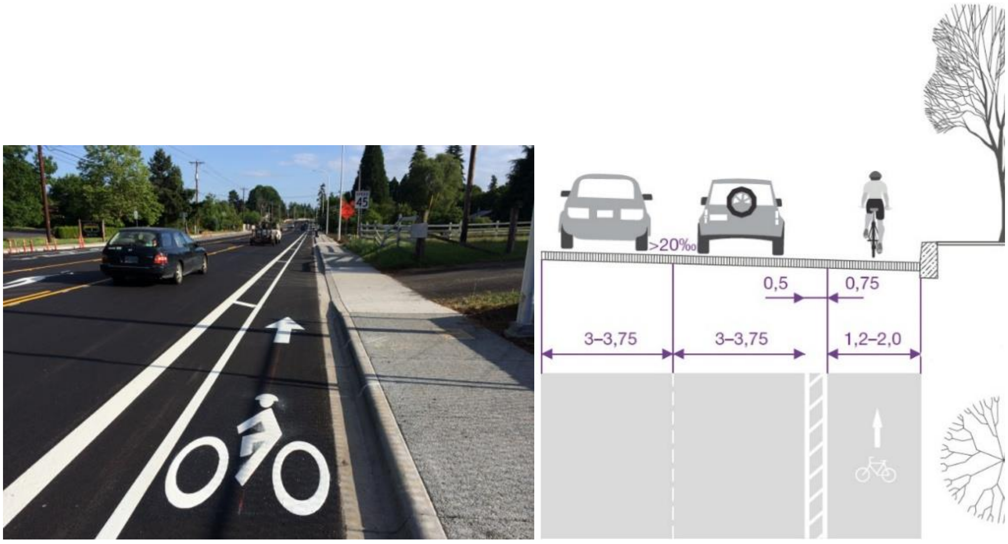


Figure 42 - An example buffered bike lanes

3.2.1.3 Contra-Flow Bike Lanes

Contra-flow bicycle lanes are bicycle lanes designed to allow bicyclists to ride in the opposite direction of motor vehicle traffic, (Figure 43). They convert one-way traffic street into a two-way street: one direction for motor vehicles and bikes, and the other for bikes only. Contra-flow lanes are separated with yellow center lane striping. Combining both direction bicycle travel on one side of the street to accommodate contra-flow movement results in a two-way cycle track.

The contra-flow design introduces new design challenges and may introduce additional conflict points as motorists may not expect oncoming bicyclists.

Typical Applications

- On streets where large numbers of bicyclists are already riding the wrong way.

- On corridors where alternate routes require excessive out-of-direction travel.

- On corridors where alternate routes include unsafe or uncomfortable streets with high traffic volumes and/or no bicycle facilities.

- On corridors where the contra-flow lane provides direct access to destinations on the street under consideration.

- Where two-way connections between bicycle facilities are needed along one way streets.

- Works best on low-speed, low volume streets to minimize the risk of dangerous crashes.

The recommended values for the width of the bicycle lane, depending on the available street space, are given in Table 3.

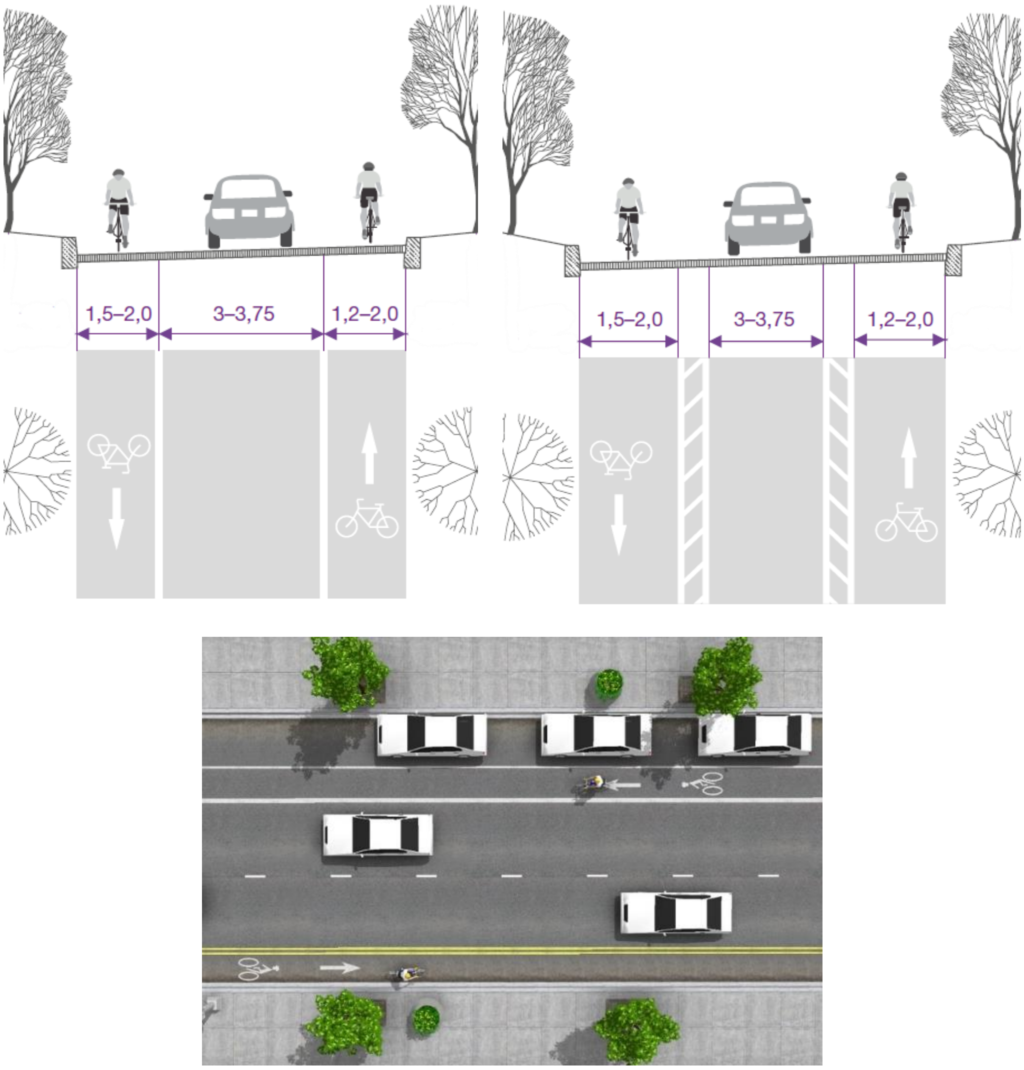


Figure 43 - Contra-Flow bike lanes

3.2.1.4 Left-Side Bike Lanes

Left-side bike lanes are conventional bike lanes placed on the left side of one-way streets or two-way median divided streets, (Figure 44). Left-side bike lanes offer advantages along streets with heavy delivery or transit use, frequent parking turnover on the right side, or other potential conflicts that could be associated with right-side bicycle lanes.

Typical Applications

- On one-way streets or median divided streets with frequent bus stops or truck loading zones on the right side of the street.

- On streets with high parking turnover.

- On streets with rush hour parking restrictions.

- On streets with high volumes of right turn movements by motor vehicles.

- On streets with a significant number of left-turning bicyclists.

- On streets where traffic enters into an add lane on the right-hand side, as from a freeway off-ramp.

- For favorable alignment to connect to a path, two-way cycle track, or other bicycle facility.

The recommended values for the width of the bicycle lane, depending on the available street space, are given in Table 3.

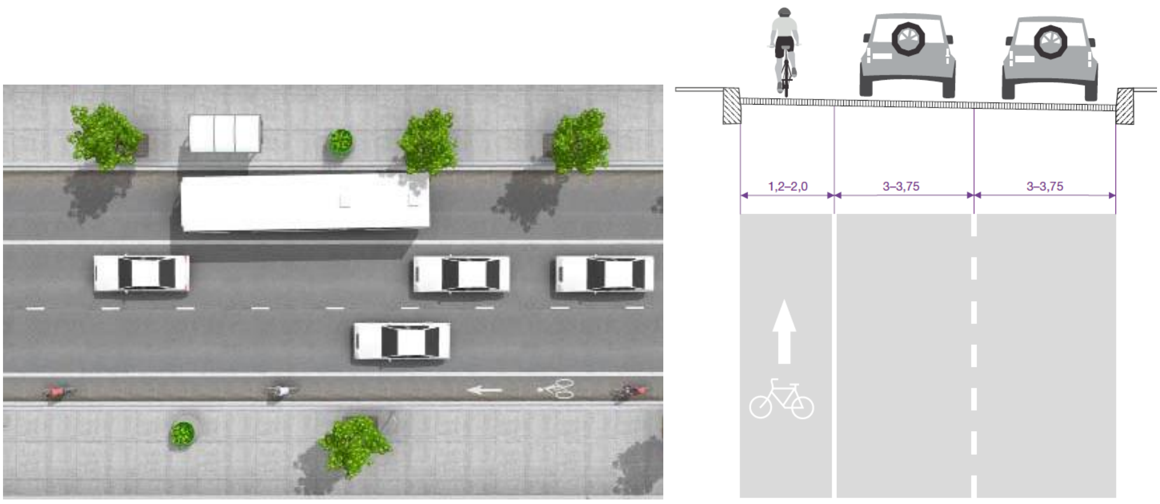


Figure 44 - Left-side bike lanes

3.2.1.5 Shared Bus-Bike Lane

Shared bus-bike lanes are most commonly applied on two-way streets with curbside or offset bus lanes, and no existing or planned bicycle facility, (Figure 45). Contraflow bus lanes with high bicycle demand and no other bicycle facilities in the contraflow direction may be regulated as shared bus-bike lanes. Shared bus-bike lanes can be applied where parking is in place at off-peak times. Applications should generally be limited to bus lanes with operating speeds of 30 km/h or less, and transit headways of 4 minutes or longer.

Lanes may be placed directly adjacent to the curb or offset from the curb by a parking lane.

The width of a full-time bus-bike lane is 3–3,5 m for offset lanes, and up to 4,75m for curbside lanes.

Bicycle shared lane markings should be placed in the center or left side of the lane. At stops, place markings at the left side of the lane.

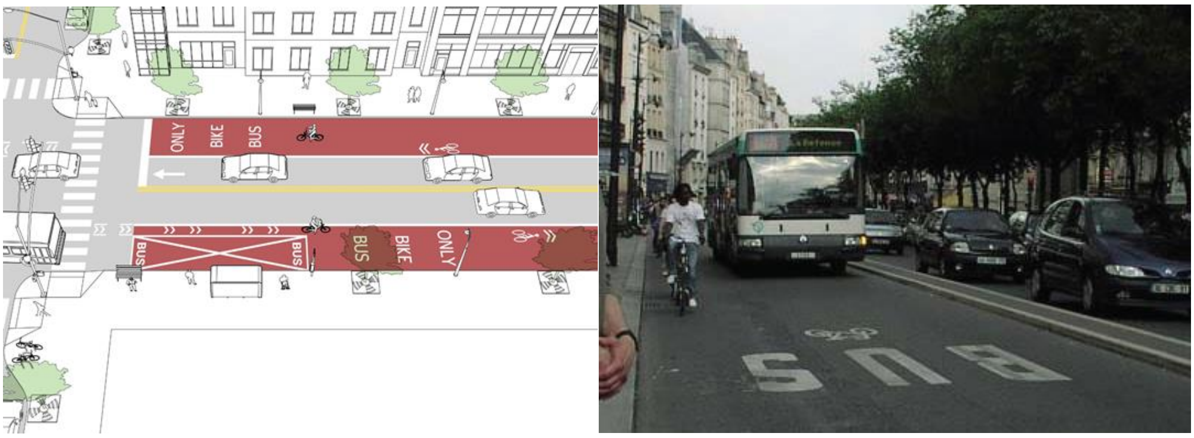


Figure 45 – An example shared bus-bike lane (Paris, France)

3.2.2 **Cycle Tracks**

A cycle track is an exclusive bike facility that combines the user experience of a separated path with the on-street infrastructure of a conventional bike lane.

A cycle track is physically separated from motor traffic and distinct from the sidewalk. Cycle tracks have different forms but all share common elements—they provide space that is intended to be exclusively or primarily used for bicycles, and are separated from motor vehicle travel lanes, parking lanes, and sidewalks. In situations where on-street parking is allowed cycle tracks are located to the curb-side of the parking (in contrast to bike lanes).

3.2.2.1 One-Way Cycle Tracks

One-way protected cycle tracks are bikeways that are at street level and use a variety of methods for physical protection from passing traffic, (Figure 46). A one-way protected cycle track may be combined with a parking lane or other barrier between the cycle track and the motor vehicle travel lane. When a cycle track is elevated above street level it is called a raised cycle track and different design considerations may apply.

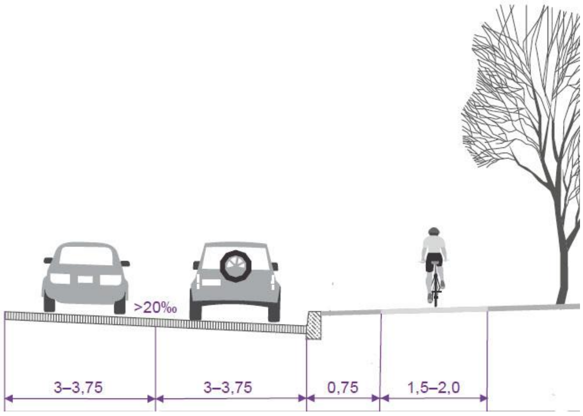


Figure 46 - An example one-way cycle tracks

Typical Applications

- Streets with parking lanes.
- Streets on which bike lanes would cause many bicyclists to feel stress because of factors such as multiple lanes, high traffic volumes, high speed traffic, high demand for double parking, and high parking turnover. While there are no US standards for the bicyclist and motor vehicle volumes that warrant cycle tracks, several international documents provide basic guidance (see references below).
- Streets for which conflicts at intersections can be effectively mitigated using parking lane setbacks, bicycle markings through the intersection, and other signalized intersection treatments.
- Along streets with high bicycle volumes.
- Along streets with high motor vehicle volumes and/or speeds.
- Special consideration should be given at transit stops to manage bicycle & pedestrian interactions.

One-way one-lane bicycle lanes should be 1.2-2.0 m wide, depending on the conditions. Possible width of such bicycle lanes can be seen in Table 4.

Table 4 - Standard width one-way cycle tracks

One-way cycle tracks width		
Minimum	**Standard**	**Best practice**
1.20–1.50	1.50–1.75	2,00 and more

Bicycle lane edge curvature radiuses on the intersections with another bicycle lanes or roads with bicycle traffic are recommended to be at least: 5,0 m – on the main bicycle routes; 2,5 m – on the local bicycle routes.

3.2.2.2 Raised Cycle Tracks

Raised cycle tracks are bicycle facilities that are vertically separated from motor vehicle traffic. Many are paired with a furnishing zone between the cycle track and motor vehicle travel lane and/or pedestrian area. A raised cycle track may allow for one-way or two-way travel by bicyclists.

Raised cycle tracks may be at the level of the adjacent sidewalk, or set at an intermediate level between the roadway and sidewalk to segregate the cycle track from the pedestrian area. A raised cycle track may be combined with a parking lane or other barrier between the cycle track and the motor vehicle travel lane. At intersections, the raised cycle track can be dropped and merged onto the street, or it can be maintained at sidewalk level, where bicyclists cross with pedestrians, possibly with a dedicated bicycle signal.

When placed adjacent to a travel lane, one-way raised cycle tracks may be configured with a mountable curb to allow entry and exit from the bicycle lane for passing other bicyclists or to access vehicular turn lanes. This configuration has also been known as a 'raised bike lane.'

Typical Applications

- Raised cycle tracks can be considered wherever a bicycle lane would be the standard recommendation. They may be most beneficial:
- Along higher speed streets with few driveways and cross streets.
- Along streets on which bike lanes would cause many bicyclists to feel stress because of factors such as multiple lanes, high traffic volumes, high speed traffic, high demand for double parking, and high parking turnover.
- On streets for which conflicts at intersections can be effectively mitigated using parking lane setbacks, bicycle markings through the intersection, and other signalized intersection treatments.
- On streets with numerous curves where vehicle encroachment into bike lanes may be a concern.
- Along streets with high bicycle volumes.

3.2.2.3 Two-Way Cycle Tracks

Two-way cycle tracks (also known as protected bike lanes, separated bikeways, and on-street bike paths) are physically separated cycle tracks that allow bicycle movement in both directions on one side of the road, (Figure 47). Two-way cycle tracks share some of the same design characteristics as one-way tracks, but may require additional considerations at driveway and side-street crossings.

A two-way cycle track may be configured as a protected cycle track - at street level with a parking lane or other barrier between the cycle track and the motor vehicle travel lane and/or as a raised cycle track to provide vertical separation from the adjacent motor vehicle lane.

Typical Applications

- On streets with few conflicts such as driveways or cross-streets on one side of the street.

- On streets where there is not enough room for a one-way cycle track on both sides of the street.
- On one-way streets where contra-flow bicycle travel is desired.
- On streets where more destinations are on one side thereby reducing the need to cross the street.
- On streets with extra right-of-way on one side.
- To connect with another bicycle facility, such as a second cycle track on one side of the street.
- Along streets on which bike lanes would cause many bicyclists to feel stress because of factors such as multiple lanes, high traffic volumes, high speed traffic, high incidence of double parking, and high parking turnover.
- On streets for which conflicts at intersections can be effectively mitigated using parking lane setbacks, bicycle markings through the intersection, and other signalized intersection treatments.
- Along streets with high bicycle volumes.
- Along streets with high motor vehicle volumes and/or speeds.
- Special consideration should be given at transit stops to manage bicycle and pedestrian interactions.

Overall width of the two-way two-lane bicycle track is set in accordance to the space available, as in Table 5.

Table 5 - Standard width two-way cycle tracks

Two-way cycle tracks width		
Minimum	**Standard**	**Best practice**
2,50	3,50	4,00

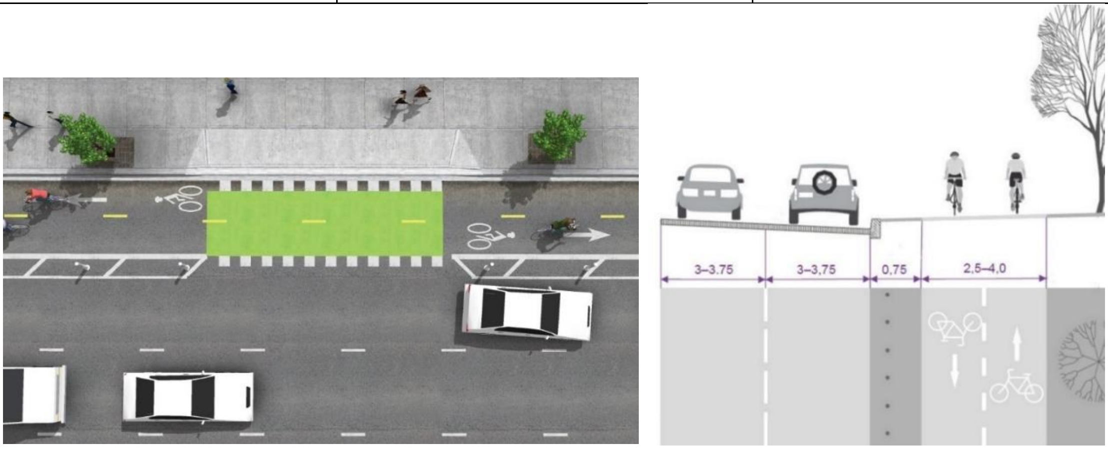


Figure 47 - Two-Way Cycle Tracks

3.2.2.4 Mixed-use cycle tracks

The dimensions of mixed-use pedestrian cycle tracks depend on their purpose and usage (traffic volumes), (Figure 48). Recommended widths for the mixed-use tracks are in the Table 6.

Table 6 - Standard width mixed-use cycle tracks

Mixed use cycle tracks width		
Minimum	**Standard**	**Best practice**
2,50 (2,00*) *in cramped conditions, with traffic flow up to 30 bicycles/hour and 50 pedestrians/hour	3,00	4,00

Typical Applications

- in the cases when pedestrian infrastructure is wide enough, or can be widened;
- in case local routes are created on the sidewalks with the traffic less than 100 pedestrians per 1m width.

Figure 48 - An example mixed-use cycle tracks

3.3 Choosing design solutions

The decision depends on the following key factors:

- The function of the route, from main cycling route to local route;

- The spatial environment, basically inside or outside the built-up area;

- The overall traffic situation, essentially the volume and speed of motorized traffic, related to the road function (connector road, distributor road, access road) and physical characteristics (available width, number of lanes etc.).

Basic principles. The following generally recognized basic guiding principles should be used a rule of thumb, (Table 7).

Table 7 - Choosing design solutions

OUTSIDE THE BUILT-UP AREA	**INSIDE THE BUILT-UP AREA**

ALWAYS strict **separation** of cyclists and motorized traffic.	**Mixing** as the default option **Separation** where necessary, because of high speed (> 50 km/h) and high intensity of motorized traffic
CONFLICT AVOIDANCE	**CONFLICT PRESENTATION**

Outside the built-up area

Because of the speed differences between cyclists and motorized traffic the risk of conflicts and serious injury is too high for allowing them to share the same space. The starting point is then **conflict avoidance through separation**. Separated cycling facilities are always necessary to ensure safety. The specific type of cycling facility is closely linked to the road's function in the hierarchy and the speed restrictions.

More detailed recommendations are given in Table 8

Table 8 - Choosing design solutions in Outside the built-up area

				Cycle route function	
		Speed (km/h)	**Intensity (cars/day)**	**Basic network**	**Main cycle route (I_{cycle} > 2000 bikes/day)**
		n/a	0	Solitary track	
Road function	**Distributor road**	60	1-2.500	Mixed traffic or cycle suggestion lane	Cycle street, if I_{car} < 500 cars/day
			2.000 – 3.500	Advisory cycle lane or cycle lane	Cycle track
			> 3.000	Cycle track	
	Connector road	80	irrelevant	Separated cycle track	

Inside the built-up area

Inside the more complex built-up area, it is clearly impossible to always separate users and to avoid conflict situations. Therefore, the starting point in the built-up area is **conflict presentation**. The road and cycling facilities should be designed in such a way that all road users are visually alerted to potential conflict situations between different types of users. In practice this starting point means that cycling facilities are mixed where possible and separated where necessary.

Most links on the basic cycle network should run through quiet streets with a 30km/h speed limit. This is the safest situation all-round and requires no cycle-specific infrastructure. Mixing should be the default option. On busier roads and complex intersections, especially at high speeds and intensities separation must be preferred.

More detailed recommendations are given in Table 9.

Table 9 - Choosing design solutions in Inside the built-up area

<table>
<tr><td colspan="5"></td><td colspan="3">Cycle route function</td></tr>
<tr><td colspan="2" rowspan="3"></td><td colspan="2" rowspan="2">Speed (km/h)</td><td rowspan="2">intensity (cars/day)</td><td colspan="2">Basic network</td><td>Main cycle route</td></tr>
<tr><td>($I_{bicycle}$ < 750/day)</td><td>($I_{bicycle}$ 500-2500/day)</td><td>($I_{bicycle}$> 2000/day)</td></tr>
<tr><td colspan="2">Not applicable</td><td>0</td><td colspan="3">Solitary track</td></tr>
<tr><td rowspan="6">Function traffic road</td><td rowspan="3">Local access road</td><td colspan="2" rowspan="3">Walking space or 30 km/h</td><td>1 – 2.500</td><td colspan="2" rowspan="2">Mixed traffic (with or without advisory cycle lane)</td><td rowspan="3">Cycle street or cycle lane (with right of way)</td></tr>
<tr><td>2.000 - 5.000</td></tr>
<tr><td>> 4.000</td><td colspan="2">Cycle track or cycle lane</td></tr>
<tr><td rowspan="3">Distributor road</td><td rowspan="2">50 km/h</td><td>2x1 lanes</td><td rowspan="3">not applicable</td><td></td><td colspan="2" rowspan="3">Cycle track (adjacent or separated)</td></tr>
<tr><td>2x2 lanes</td><td rowspan="2"></td></tr>
<tr><td colspan="2">70 km/h</td></tr>
</table>

3.4 Design around bus stops

If the bus stop is located at the edge of the roadway, the choice of bus stop type depends on many factors. The possible variants of the bicycle traffic near the different bus stops are shown Table 10.

In general, bus stops make bicycle traffic less comfortable because of the traffic conflicts. The most attention should be paid to the following conflict situations:

- Between the bicycles and passengers boarding or alighting the bus, in case bicycles move along the roadside
- Between the buses that return to the lane and the bicycles moving forward (in case bus stops are located in the turnout or at the roadside)
- Between the buses that stop on the bus lane or a narrow road and a bicyclist that has to stop also.

Table 10 - Variants of the bicycle traffic near the different bus stops

	Bus stop type		
Bicycle traffic type	**Cape-stop**	**Roadway edge stop**	**Turnout stop**
Mixed traffic using roadway, bicycle lanes and safety lines	Well-suited	Well-suited	Well-suited
Traffic in the side space	Well-suited	Conditionally suited (depending on the side space width)	Conditionally suited (depending on the side space width)
Mixed bus-bicycle lanes	Conditionally suited (in case of narrow bus lanes, stopping time should be restricted)	Conditionally suited (in case of narrow bus lanes, stopping time should be restricted)	

Bus dedicated lanes with bicycle traffic allowed go through the stop at the edge of the roadway without a turnout. When cycling the mixed-use bus and bicycle lanes more than 4,75 m wide, cyclists can pass by the bus at the stop. If the dedicated bus lanes width is less than 3,5 m and combined with the bicycle traffic, cyclists have to wait behind the bus when it stops, (Figure 50). If the buses stop for a long time (for example, at the last stop), a detour for the cyclists should be provided.

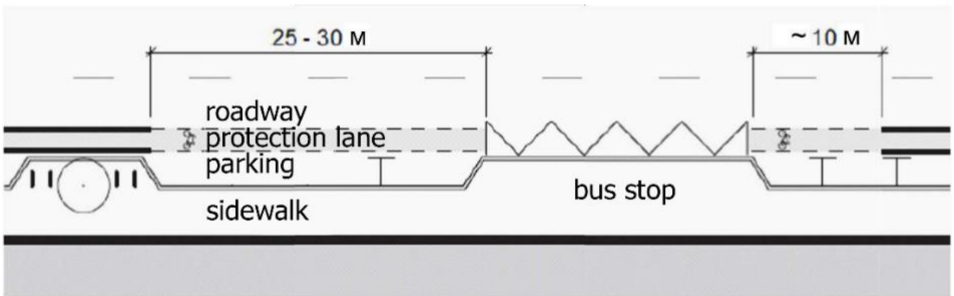


Figure 49 - Bicycle lane that transforms into the protection line

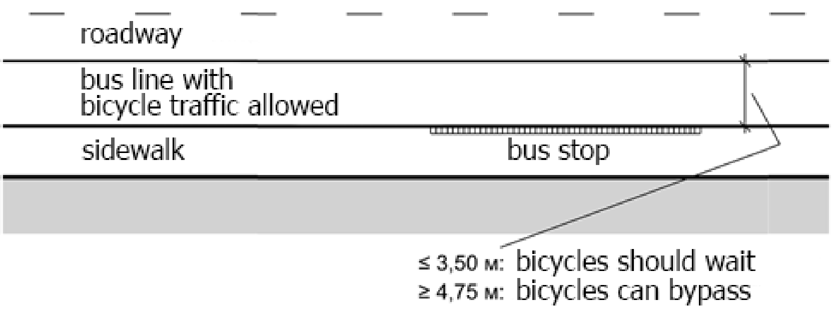


Figure 50 - Bicycle lane that transforms into a protection line

In case there is a bicycle lane, it interrupts near the stops that have turnouts (Figure 51). Cyclists can pass by the stopped bus.

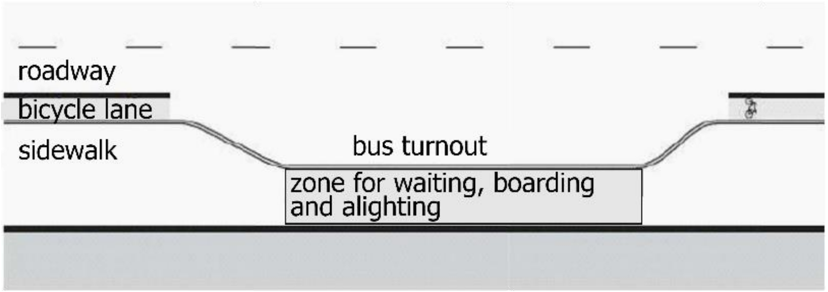


Figure 51 - The gap of the bicycles line near the bus stop turnout

In the other layout, the road space is widened outside the stops, so it is located one closet to the traffic. In this case, the track must pass behind the waiting areas for passengers (Figure 52).

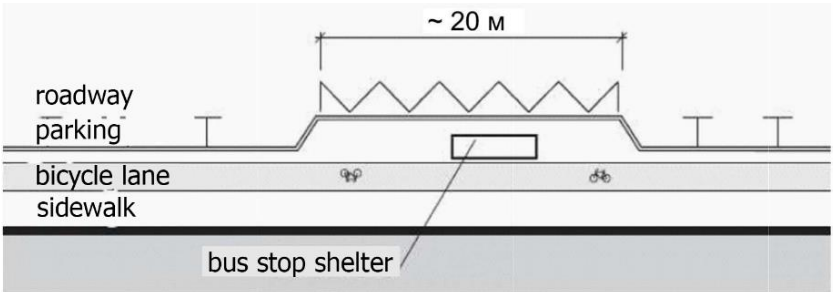


Figure 52 - A cycle track in the area of the bus stop boarding ledge

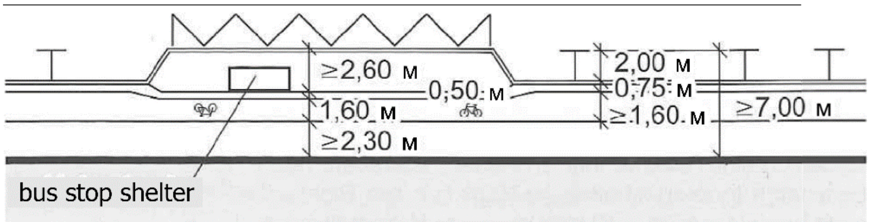


Figure 53 - Bicycle track layout in the area of the stop with sufficient lateral space width (≥ 7,00 m)

In the case of small lateral space cycle tracks in a narrow area can be converted into a mixed-use bicycle-pedestrian track (Figure 54). In this case, the common segment should be allocated noticeable change of surface or other symbols, and freed from obstacles. For this case a total width of lateral space ≥ 4,60 m is needed. In the case of heavy pedestrian and passenger traffic it should be checked if it is the feasible to construct the bicycle track outside the road (at least in the vicinity of stops, Figure 55).

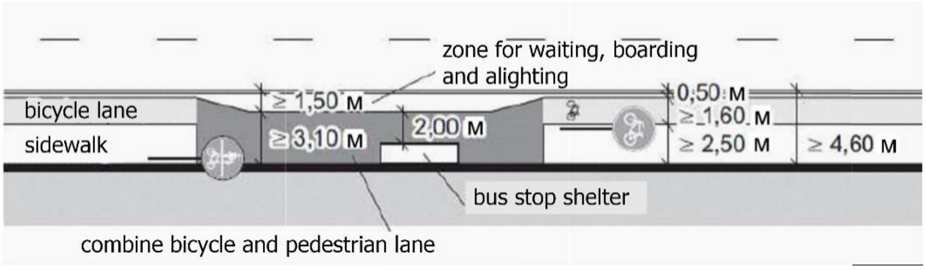


Figure 54 - Bicycle track layout in the stop area in case of less lateral space (≥ 4,60m)

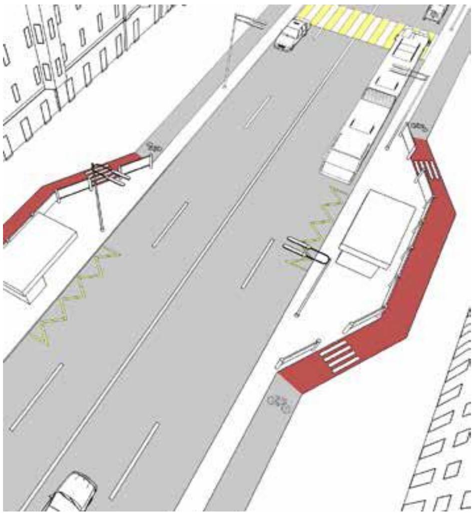


Figure 55 - Outside of the bus stop bicycle track layout

In the case of extremely restricted lateral space (<4.60 m) the only possible way is to create common cycling footpaths (Figure 56). In this case, the stops should also be highlighted by the changed surface. If the use of the roadway for bicycle traffic is appropriate, a zone of mixed traffic can be designated.

In this case, a space of at least 1.00 m should be provided for the boarding and alighting of passengers should be provided. The mixed-use bike-pedestrian track should be 2.00 m. and free of obstacles. However, this layout is possible only in the case of small flow of passengers at bus stops.

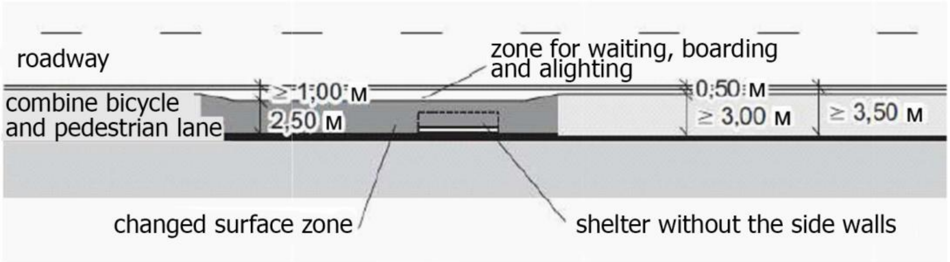


Figure 56 - Mixed-use pedestrian-bike path layout in the area stop with very small lateral space width (≥ 3,50)

3.5 Intersections

Intersections are junctions at which different modes of transportation meet and facilities overlap.

An intersection facilitates the interchange between bicyclists, motorists, pedestrians, and other competing modes in order to advance traffic flow in a safe and efficient manner. Designs for intersections with bicycle facilities should reduce conflict between bicyclists (and other vulnerable road users) and vehicles by heightening the level of visibility, denoting a clear right-of way, and facilitating eye contact and awareness with competing modes. Intersection treatments can resolve both queuing and merging maneuvers for bicyclists, and are often coordinated with timed or specialized signals.

The configuration of a safe intersection for bicyclists may include elements such as color, signage, medians, signal detection, and pavement markings. Intersection design should take into consideration existing and anticipated bicyclist, pedestrian and motorist movements. In all cases, the degree of mixing or separation between bicyclists and other modes is intended to reduce the risk of crashes and increase bicyclist comfort. The level of treatment required for bicyclists at an intersection will depend on the bicycle facility type used, whether bicycle facilities are intersecting, the adjacent street function and land use.

3.5.1 Typical unregulated intersection

Important elements of the intersection are shown in Table 11. Usually no special measures.is required to provide cyclists with the right turn.

Table 11 Elements of bicycle traffic planning at the unregulated intersections (traffic is regulated by the road signs)

	Through traffic	**Left turn**
Traffic along the main road	• On the secondary road abutment to the main one, mark the bicycle lanes as bicycle crossings. • apply safety lines at the intersections and exits from the main road to a secondary • common cycling footpaths, • take the bike route to the	• waiting area for the two-stage left turns • cycle lane to turn left • (divided) central island as a waiting place for bicycles, that turn left

	roadway, ensure the cyclists are always in the area of drivers' visibility ● mark the intersection crossings ● if necessary, raised the bicycle or bicycle-pedestrian tracks ● transform the bicycle tracks into protective lines or bicycle lanes.	
Traffic along the minor road	● usually turning left in one stage ● central dividing line (dividing safety island) as a secondary factor when crossing the main road ● no bicycle crossing marking (no priority in the movement for cycling)	

One must distinguish between left turn in one and two takes that can also be implemented in different ways:

- turn left in one take: the left-turning cyclists rearrange to the left-most lane for general traffic and perform the left turn;

- turn left in two takes: at the intersection cyclists move straight and slightly to the right, along with the through traffic and place themselves at the crossing street. Then they turn left, crossing the street in the right direction;

Organization of the one-stage left turn.

If there is no left-turning lane, the auxiliary thing is the central dividing line with a gap (safety island), (Figure 57).

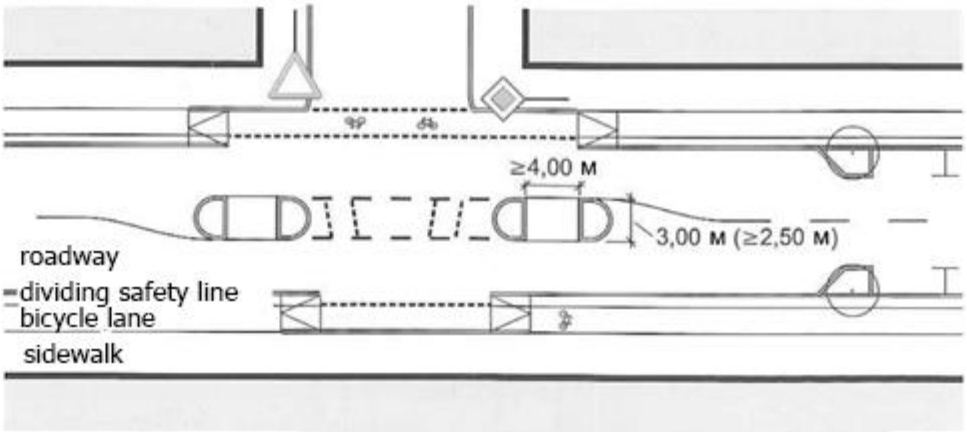


Figure 57 - Divided island with seating expectations safety for cyclists turning left

Exclusive left turn for the cyclists can be done even more safe by using a dividing safety line (see Figure 58). This turning bicycle should have a width of at least 1.5 m.

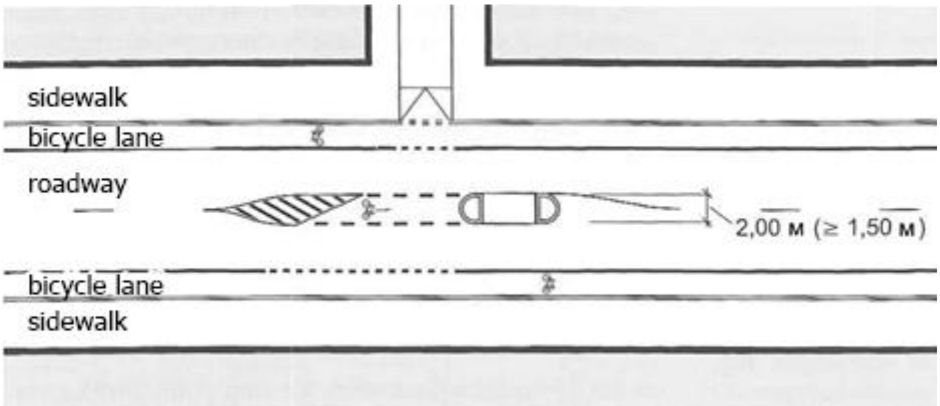


Figure 58 - Exclusive left turn for the cyclists

The width of the island of safety in 2.00 m allows to organize a crosswalk through it. If the left-turning lane is required, then left turn lane for bicycles can be demarked alongside, if there is sufficient space (Figure 59).

The bicycle track thus should have a width of at least 1.5 m. The left-turn lanes for the car traffic should be at least 2.75 m wide.

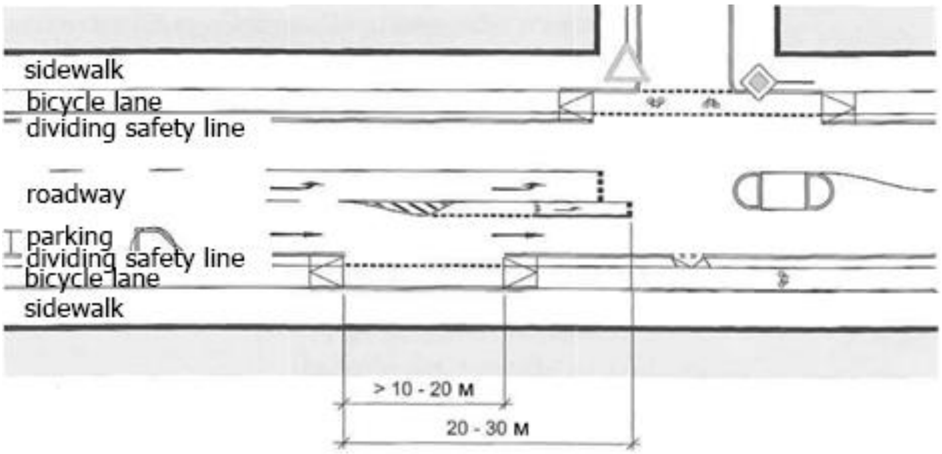


Figure 59 - Example of combined lane for the left turn in front of the intersection

In a limited space alternative is safety line that transforms into a left-turn lane. Such solutions are used when turning lanes for vehicles are 3.5 to 3.75 m wide, and can be divided into a general lane 2.25 m for vehicles and 1.25 m (1.5 m) for bicycles.

Organization of the two-stage left turn in case the two-stage left turn is organized, the trajectory of bike traffic is slightly changed at the intersection (Figure 60). The waiting zone is marked on the left of bike pass. If the secondary entrances to the intersection feature bicycle infrastructure, waiting areas will be located along it.

If there is enough space, more safe left turn in two steps can be organized by establishing, for example, an island of safety.

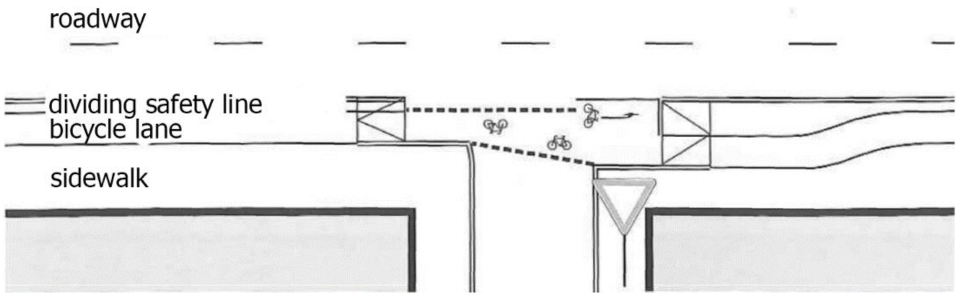


Figure 60 - Example of left turn in two stages at the intersection where the priority directions determined using

3.5.2 Typical traffic light intersection

Bicyclists' rights cannot be ignored while facilitating the needs of the car traffic. Bicycle traffic organization can be improved by giving enough space for waiting and avoiding redundant stops. Bicycle infrastructure planning and control (with traffic light devices) should always be considered as a whole, to ensure clarity of the principles of the traffic.

Left-turning bicycle traffic

Left-turning options for the bicyclists are shown in Table 12. One and two-stage left turns may be combined.

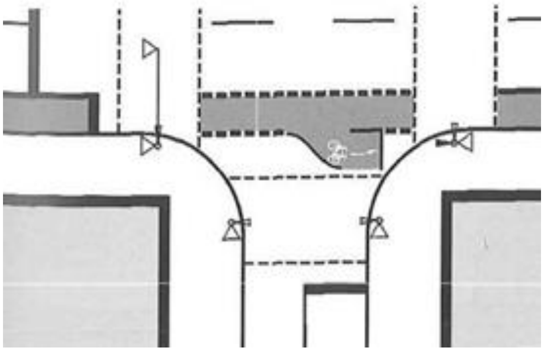
Table 12 - Bicycle directions at intersections with traffic light control

Type of traffic	Used in case	Bicycle traffic forms	Regulation of traffic lights
One-stage left turn with an ability to rearrange before the intersection, with, or without the corresponding road markings.	- not more than 2 lanes are crossed during the rearrangement - $V_{85} \leq 50$ km / h	- mixed movement, safety lines or bicycle lanes, in some cases mixed with the general traffic for the left turn or with the extended bicycle lanes with waiting zones.	Traffic light regulation is common for all the traffic
One-stage left turn with protected rearrangement using a bicycle lock	- high motor vehicle traffic volume - a significant number of bicycles that turns left	bicycle paths, bicycle lanes	separate traffic light regulation for the cyclists that are directed from the adjacent bicycle path to roadway
Turn left in two stages within the intersection	- high motor vehicle traffic volume - a smaller proportion of cyclists that turn	possible all forms of bicycle tracks	traffic light regulation for the first stage - checking-in the waiting area; for the second stage - crossing intersections together with pedestrian lights, or the individual traffic light regulation specifically for cyclists

turn left in two stages	always possible	no special forms of bicycle tracks: cyclists must return and cross the road at a pedestrian crossing	Bicycle traffic mives in accordance with the signals of pedestrian traffic lights
Diagonal crossing intersection	is especially suitable for conversion with two-way traffic on	bicycle paths with two-way traffic, and any other forms of two-way traffic	for cyclists crossing the intersection required its own traffic light phase ("all cyclists green")

Left turn in one stage with the protected rearrangement using a bicycle lock.

When the left turn is performed in two stages, at the first one cyclists cross the street adjacent to the right and then rearrange as shown in Figure 61, Figure 62 to cross the street, they want to turn left, with the flow of other vehicles.



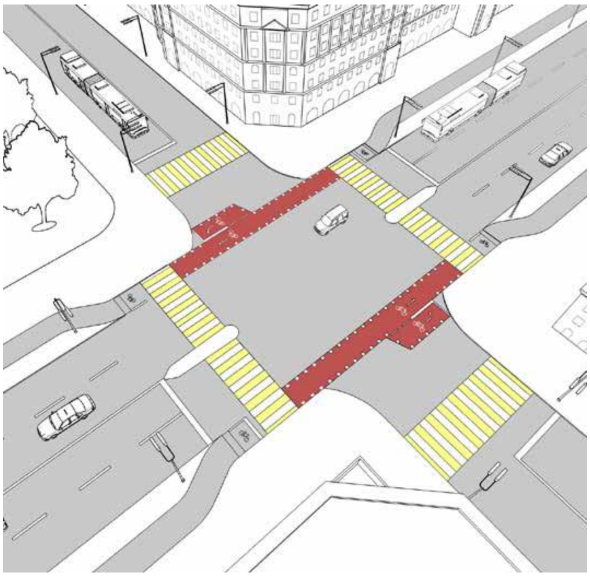


Figure 61 - Turn left in two stages within the intersection

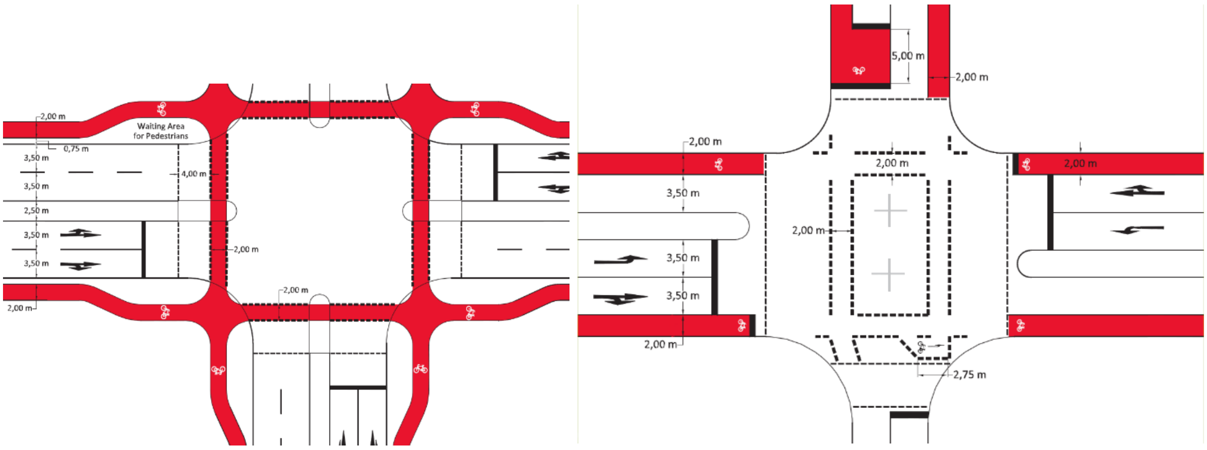


Figure 62 - Turn left in two stages within the intersection

Turn left in two stages within the intersection requires:

- the possibility to safely stop while waiting

-a special approach to lighting device design to comply the requirements and alternating phase

- for the major intersections - timely and clearly visible instructions on the two-stage left turn.

Turn left after the intersection

Turn left after intersection is always possible. In this case the cyclists turning left, should not rearrange, they just cross the roadway after the intersection. Cyclists have to go with the bike and cross the street as pedestrians, (Figure 63).

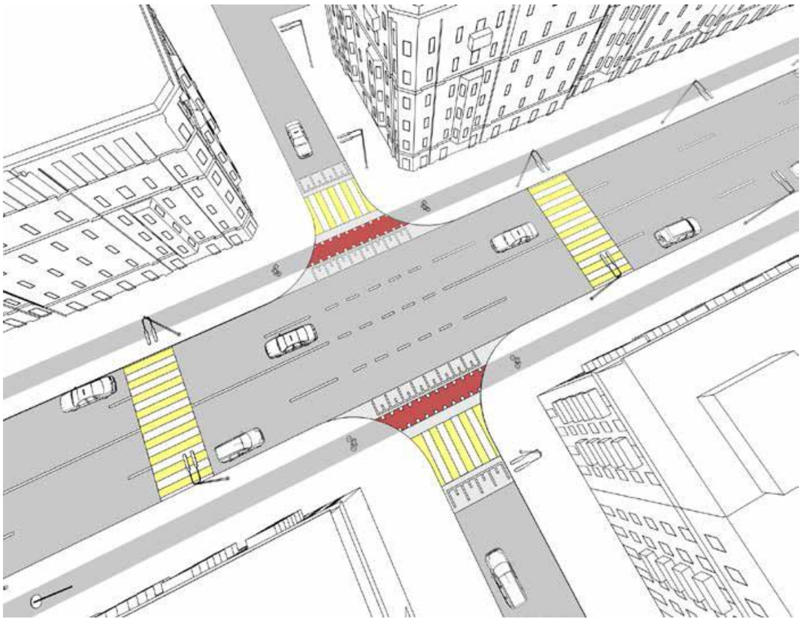


Figure 63 - Turn left after the intersection

Combined Bike Lane / Turn Lane

A combined bicycle lane/turn lane places a suggested bike lane within the inside portion of a dedicated motor vehicle turn lane, (Figure 64). A dashed line can either delineate the space for bicyclists and motorists within the shared lane or indicate the intended path for through bicyclists. This treatment includes signage advising motorists and bicyclists of proper positioning within the lane.

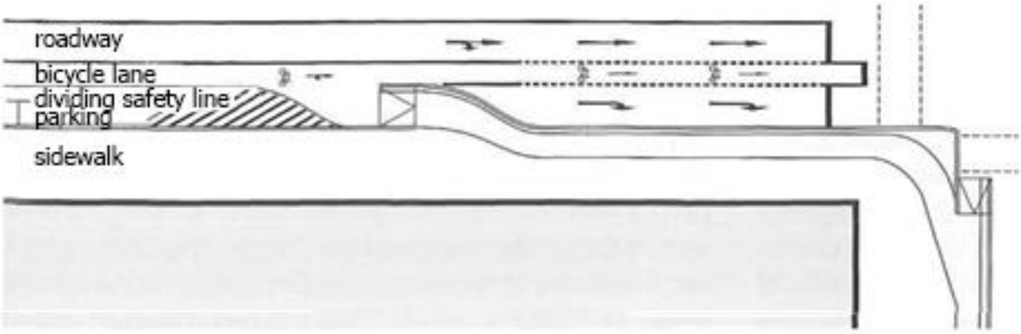


Figure 64 - Bicycle fork at the beginning of the right-turning lane

3.5.3 Roundabout intersection

In the case of unregulated roundabout, it is recommended to organize constructive separation of the general and bicycle traffic. Bicycle traffic is organized on the bicycle tracks around the roundabout (Figure 65). Bicycle crossing of the adjacent streets is combined with the pedestrian crossings and highlighted by the road markings before and after the crossing.

Bicycle paths should lay at a distance of 4.00 m from the edge of the roundabout carriageway directly next to the pedestrian crossing over the dividing safety islands.

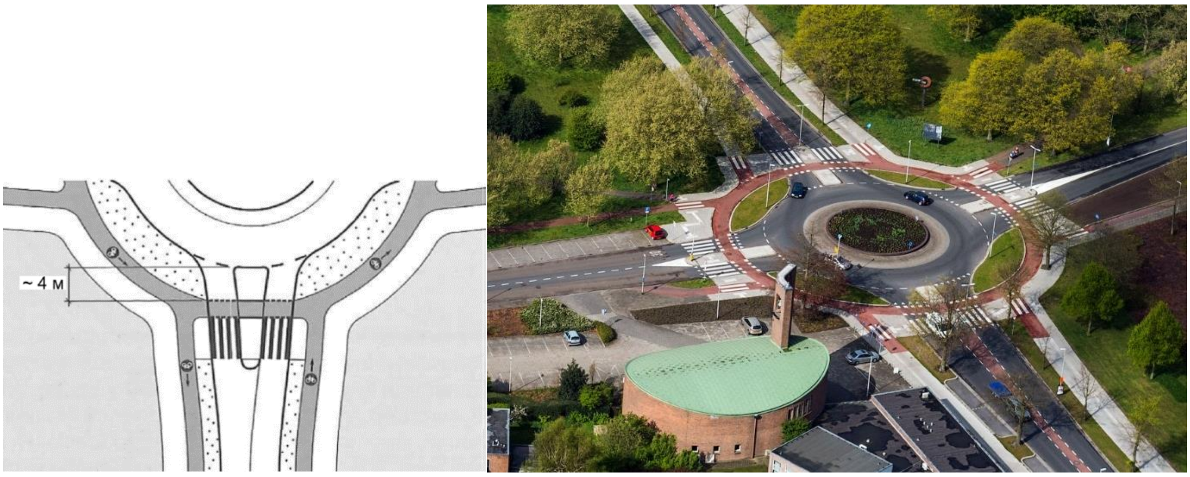


Figure 65 - The layout of the two-lane roundabout with the priority to the ring traffic

In the case of one-lane roundabout, mixed traffic is allowed without bicycle traffic segregation. (Figure 66)

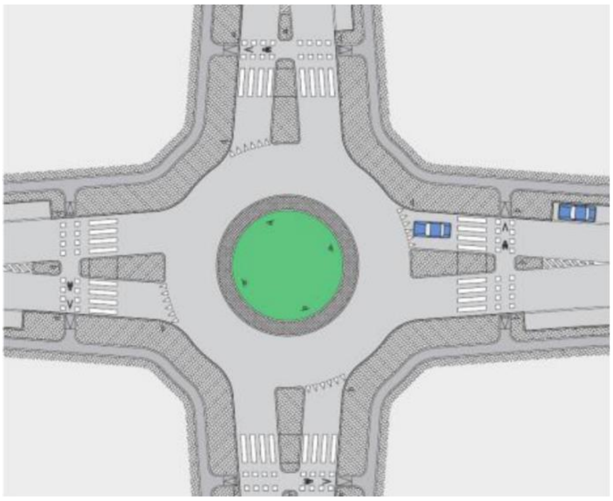


Figure 66 - The layout of the one-lane roundabout with the priority to the ring traffic

Cycle lanes at the entrance to the roundabout must end at least 20 meters before the traffic ring and continue in the form of protective lines down to dividing safety island. Away from the roundabout these protection lines transform into cycle lanes after about 10 meters after the dividing safety island.

Bicycle traffic on the lanes adjacent to the carriageway, that should transform into the mixed traffic in the roundabout, should be moved to the general traffic on the approach to the roundabout. To do this, a safe bicycle lane ending in the form of the safety line has to be constructed (Figure 67). Away from the roundabout cycle track begins right after the ring, if there are enough space or After the dividing safety island in accordance with the bicycle lane planning.

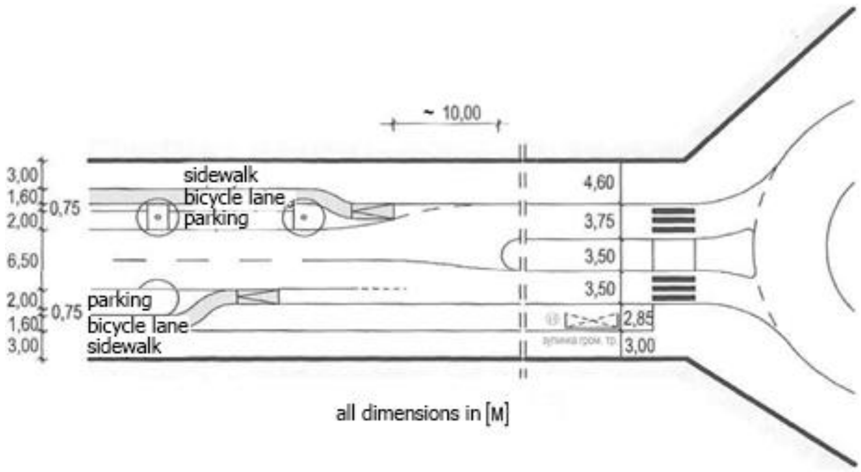


Figure 67 - Roundabout intersection

3.5.4 Typical intersections in Batumi

Basing on the recommendations described in 3.2 - 3.5 were developed options for model bicycle intersections in Batumi. Each intersection was considered in two versions: with a bicycle lane on the roadway and a bike path along the pedestrian sidewalk.

Examples of some intersections are indicated in the figures (Figure 68, Figure 69). Images of all considered typical intersections are indicated in the Appendix.

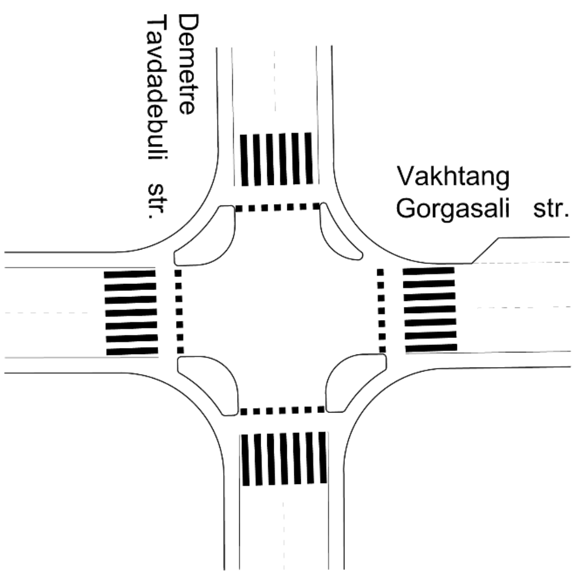


Figure 68 – An examples Demetre Tavdadebuli - Vakhtang Gorgasali intersection

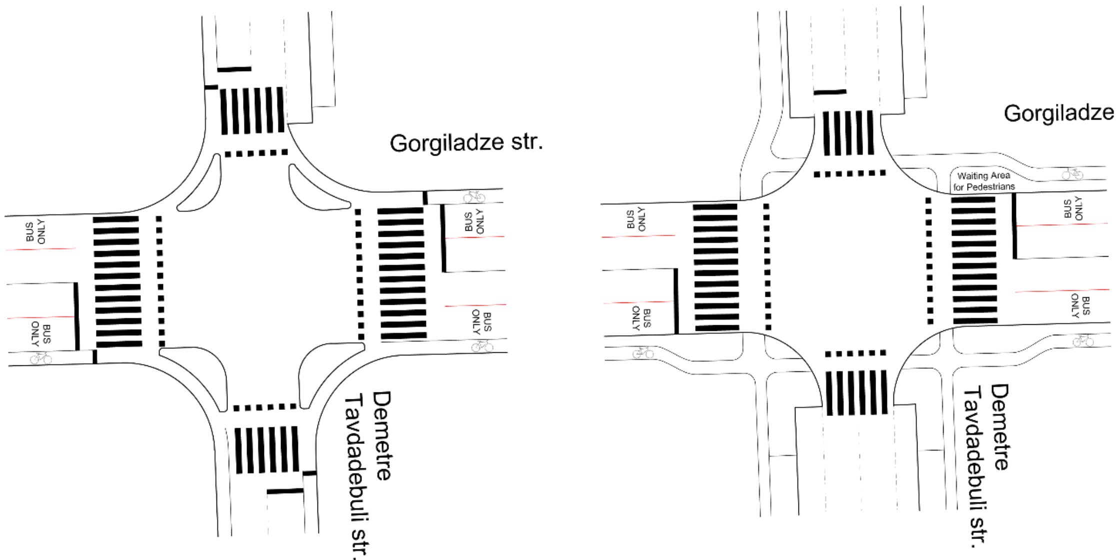


Figure 69 - An examples Gorgiladze - Demetre Tavdadebuli intersection

3.5.5 Crossing the roadway outside intersections

Crossing the road with no traffic lights, bicycles must pass another vehicle. No traffic light road crossings are arranged only if the roadway to be crossed, is no more than two lanes. For safe road crossing the safety island can be organized, especially if the intersection is in the built-up area or there is high pedestrian and bicycle traffic, crossing the road (Figure 70).

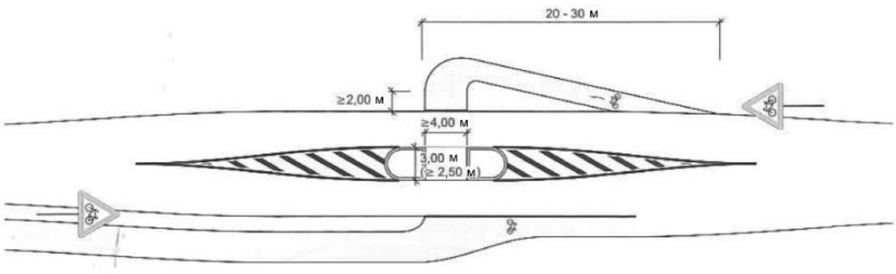


Figure 70 - Crossing the road with no traffic lights

The roadway crossing with traffic light regulation may be necessary if the high traffic volumes are observed (daily volume > 5000 cars / day).

Traffic lights may be appropriate and on roads with less traffic when crossing the road is regularly crossed by inexperienced persons, such as children that cross the road on their way to school.

If the roadway is more than two lanes, roadway crossing must always be equipped with traffic lights.

Depending on the traffic of cyclists, traffic lights object can be equipped with automatic sensors switch or button lights on demand (Figure 71).

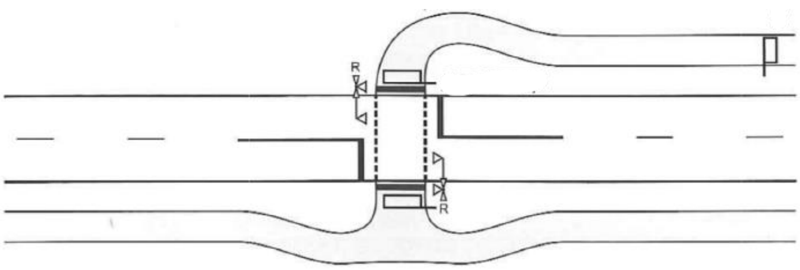


Figure 71 - Crossing the road with traffic lights

3.5.6 Intersection Crossing Markings

Bicycle pavement markings through intersections indicate the intended path of bicyclists through an intersection or across a driveway or ramp. They guide bicyclists on a safe and direct path through the intersection, and provide a clear boundary between the paths of through bicyclists and either through or crossing motor vehicles in the adjacent lane, (Figure 72).

Typical Applications

- Across signalized intersections, particularly through wide or complex intersections where the bicycle path may be unclear.

- Along roadways with bike lanes or cycle tracks.

- Across driveways and Stop or Yield controlled cross-streets.

- Where typical vehicle movements frequently encroach into bicycle space, such as across ramp-style exits and entries where the prevailing speed of ramp traffic at the conflict point is low enough that motorist yielding behavior can be expected.

- May not be applicable for crossings in which bicycles are expected to yield priority, such as when the street with the bicycle route has Stop or Yield control at an intersection.

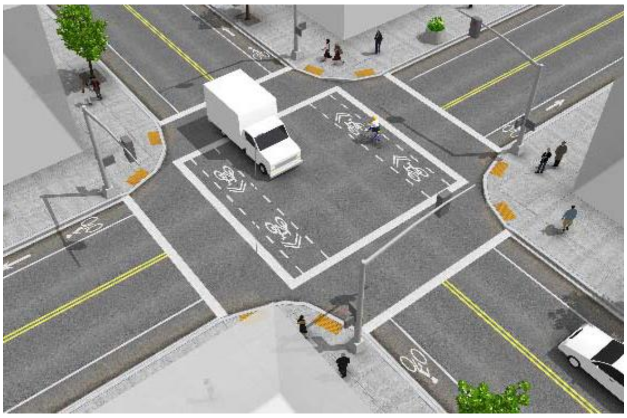


Figure 72 – An example intersection crossing markings bicycle track

If because of the wide boulevard or road dividing line additional traffic light is installed and the stop-bars are duplicated, for safety reasons, bicycle track should be shifted closer to the one side of the boulevard, near the stop bar.

Two approaches can be used at the regulated boulevard intersections, depending on the traffic volumes, type of roads and other conditions: direct crossing (Figure 73).

Bicycle track rearrangement from the center of the boulevard or splitting line to the one (or both) side of the boulevard. In this case bicycle crossing is located along the pedestrian one.

If the intersection has a complex layout, it is desired that the bicycle track detours this intersection.

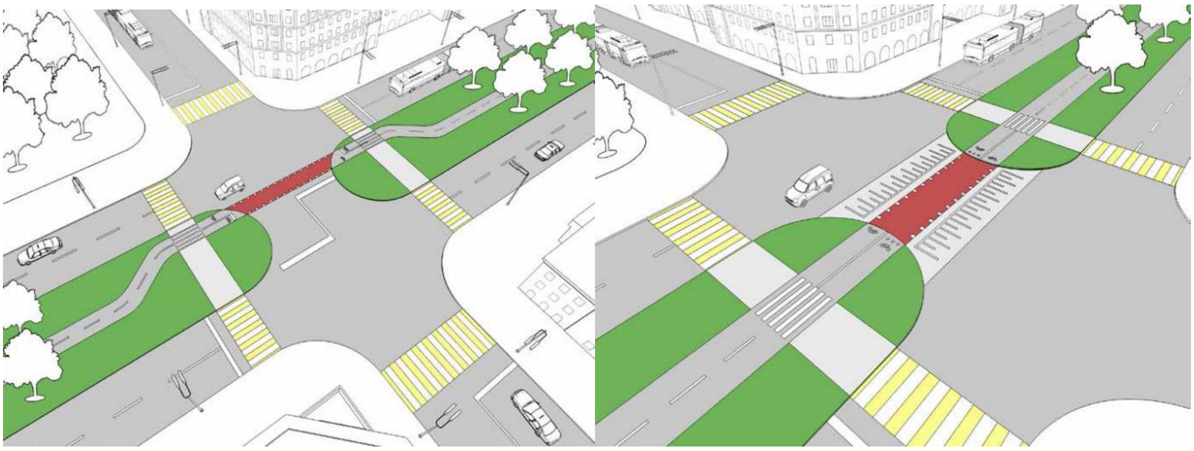


Figure 73 – Examples boulevard intersections

3.6 Bike Boxes

A bike box is a designated area at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible way to get ahead of queuing traffic during the red signal phase, (Figure 74).

Typical Applications

- At signalized intersections with high volumes of bicycles and/or motor vehicles, especially those with frequent bicyclist left-turns and/or motorist right-turns.

- Where there may be, right or left-turning conflicts between bicyclists and motorists.

- Where there is a desire to better accommodate left turning bicycle traffic.

- Where a left turn is required to follow a designated bike route, access a shared use path, or when the bicycle lane moves to the left side of the street.

- When the dominant motor vehicle traffic flows right and bicycle traffic continues through (such as a Y intersection or access ramp).

A box formed by transverse lines shall be used to hold queuing bicyclists, typically 3-5 m deep.

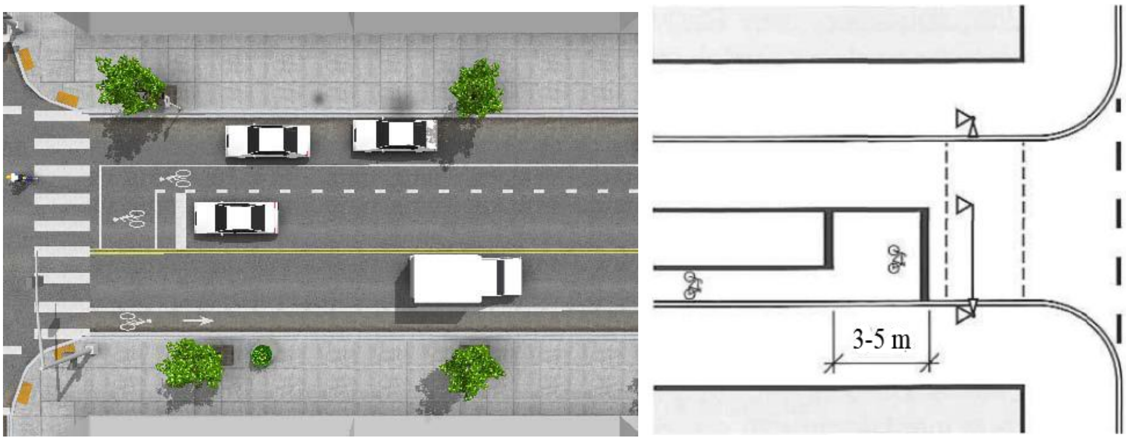


Figure 74 – An example bike boxes

3.7 Bicycle Signals

Bicycle signals and beacons facilitate bicyclist crossings of roadways. Bicycle signals make crossing intersections safer for bicyclists by clarifying when to enter an intersection and by restricting conflicting vehicle movements. Bicycle signals are traditional three lens signal heads with green-yellow and red bicycle stenciled lenses that can be employed at standard signalized intersections and Hybrid Signal crossings. Flashing amber warning beacons are used at unsignalized intersection crossings. Push buttons, signage, and pavement markings may be used to highlight these facilities for both bicyclists and motorists.

Bicycle signals are typically used to provide guidance for bicyclists at intersections where they may have different needs from other road users (e.g., bicycle-only movements, leading bicycle intervals).

Two type of traffic lights can be applied, (Figure 75).

To regulate the movement of bicyclists at the intersection of the bicycle path with the carriageway or a controlled pedestrian crossing, traffic lights of type 1 are used, but if the sign indicating the type of vehicle to which the traffic light applies is used, the use of a traffic light of type 2 is appropriate.

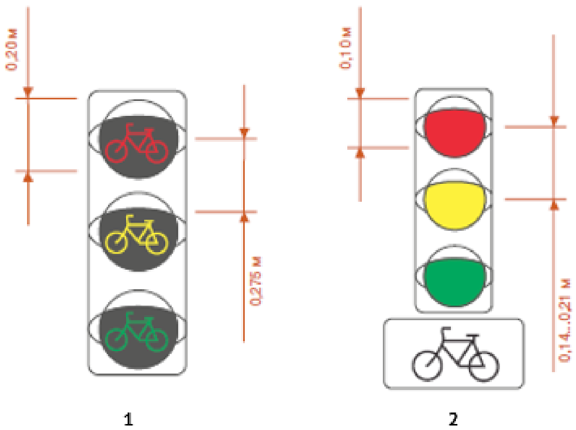


Figure 75 – An example bicycle signals

Traffic lights should be recognizable on the distance at least 50 m.

Traffic light vertical position should lie between 1.5 m to 2.0 m to the pavement, (Figure 76).

Typical Applications

- Where a stand-alone bike path or multi-use path crosses a street, especially where the needed bicycle clearance time differs substantially from the needed pedestrian clearance time.

- To split signal phases at intersections where a predominant bicycle movement conflicts with a main motor vehicle movement during the same green phase.

- At intersections where a bicycle facility transitions from a cycle track to a bicycle lane, if turning movements are significant.

- At intersections with contra-flow bicycle movements that otherwise would have no signal indication and where a normal traffic signal head may encourage wrong-way driving by motorists.

- To give bicyclists an advanced green (like a leading pedestrian interval), or to indicate an "all-bike" phase where bicyclist turning movements are high.

- To make it legal for bicyclists to enter an intersection during an all-pedestrian phase (may not be appropriate in some cities).

- At complex intersections that may otherwise be difficult for bicyclists to navigate.

- At intersections with high numbers of bicycle and motor vehicle crashes.

- At intersections near schools (primary, secondary, and university).

Figure 76 – Bicycle traffic light

3.8 Bike lane specifications

Dimensions bicycle traffic spaces

Basic dimensions bicycle traffic spaces can be derived from a basic width (0.75 m), height of the cyclist (1.9 m) and lateral vibrations when driving (0.25 m), (Figure 77).

An inclusive space consists of space for movement and space security.

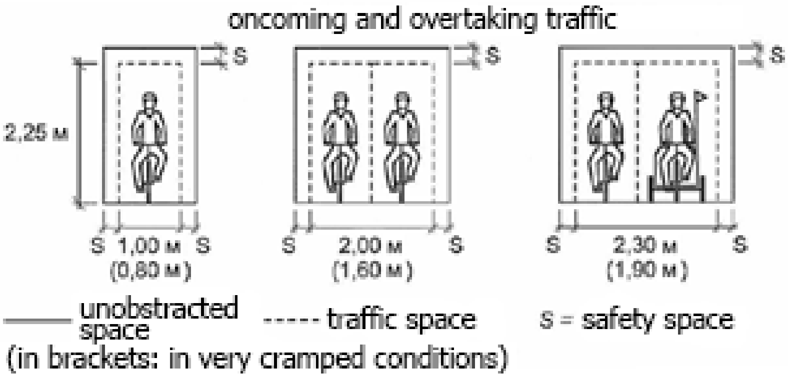


Figure 77 - Spaces for movement and unobstructed spaces for bicyclists

Materials

Basic requirements

Quality of the constructive solutions is important for the safety and comfort of the propel driving on bicycle paths. In general, bicycle paths must be constructed within the same quality required for the roadway. This applies to horizontal and vertical layout, surface coating and lighting, speed limits. Also, when administrative control over construction is performed it should be ensured that all special requirements concerning bicycles were met.

Technical regulations and standards

"Directive on the Standardization of Pavement Surfaces for Traffic Areas» RStO have recommended ways of building pedestrian and bicycle paths with asphalt, concrete, and cobblestone surface. Methods of construction and layer's thickness is chosen in the way to be able to carry road maintenance car traffic. The occasional passage of heavy vehicles is not considered for the bike paths

When choosing a cheaper method of construction (for example, protective layers of pavement) one should take into account that the cost savings in the construction will lead to higher costs of operation and to premature repairs. In addition, the choice of another method of construction can therefore provide less comfort during the bicycle travel, and therefore decline the feasibility of bicycle paths.

The basis for the design, procurement and construction is a regulatory mechanism with appropriate acceptable formulation, which should be developed by the appropriate research institution on construction of roads and traffic or other authority responsible for the construction, which will have the appropriate competence (Directives, notes, standards, additional technical and contractual terms, etc.).

Pavement layers

The following basic requirements to the bike tracks are put forward:

- top coat layer should provide small rolling resistance for quite a long time

- the surface should remain non-slip in wet conditions, the bike track should be suitable for movement in any weather (good drainage to avoid the formation of puddles and mud spray, avoiding accumulation of dust, the possibility of cleaning the area from snow).

All major mentioned requirements can be fulfilled in the best way if pavement is laid with asphalt and mechanized way. Laying the asphalt manually should be limited even in small areas.

Colored pavement can be utilized either as a corridor treatment along the length of a bike lane or cycle track, or in limited locations as a spot treatment, such as a bike box, conflict area, or intersection crossing marking. Colored pavement for use within bikeways treatments may take the form of an overlay, when the colored material is placed on top of the pavement or embedded, when the colored material is mixed into the pavement.

Paint, sometimes with additives such as reflective glass beads for retro reflectivity and sand for skid resistance, is the most widely used method to mark road surfaces. Paint is considered a non-durable pavement marking, is easily worn by vehicle tires and the elements in snowy winter climates, and often requires annual reapplication. Paint is the least expensive of the overlay materials.

Durable Liquid Pavement Markings (DLPM) include epoxy and Methyl Methacrylate (MMA). Epoxies are adhesive, waterborne acrylics that are typically applied as a paint or spray. MMA are 2-part liquids comprised of a resin and activator. While both coatings can be skid resistant, retro reflective and can adhere to concrete or asphalt surfaces, epoxies are sensitive to moisture and temperature and may require long dry times. MMA may be installed at any temperature, is durable and dries quickly, but is more expensive than epoxy.

Thermoplastic, another type of durable pavement marking, is a type of plastic made from polymer resins that becomes a homogenized liquid when heated and hard when cooled. Thermoplastic can be pre-formed in specific shapes; such as tiles that can be assembled like a puzzle to color bicycle facilities. Thermoplastic can also be used for bicycle lane symbols, arrows, pavement legends and shared lane markings. Thermoplastic tends to last longer than epoxy and is easier to apply then MMA. Retro reflective and anti-skid materials can be applied or mixed throughout the plastic.

Colored asphalt is composed of the same material as standard asphalt, but has a colored pigment added. The colored asphalt may be installed as a thin layer over conventional asphalt to reduce cost. One well-known use of colored asphalt is Bend, Oregon's red bike lanes, which utilize a localized red pigment in the colored asphalt. The tinted asphalt was applied over fresh black asphalt before the year 2000 and has worn well with regular street sweeping and maintenance, but has faded over time. Green pigment options are available.

4 EMISSIONS CALCULATIONS

Three scenarios: pessimistic, balanced and optimistic where considered over the base model to calculate the emission level. These scenarios imply the raise of bicycle modal share by 1%, 3% or 5%, respectively.

The results of the calculation, overall modal split change and the individual transport mileage are in Table 13.

Table 13 – Scenario calculation results

	Base model	Pessimistic scenario	Balanced scenario	Optimistic scenario
Modal split, %	Car = 31,8 PuT = 35,3 Ped = 32,6 Bike = 0,3	Car = -0,3 PuT = -0,2 Ped = -0,1 Bike = +0,7	Car = -1,1 PuT = -0,9 Ped = -0,6 Bike = +2,7	Car = -1,6 PuT = -1,7 Ped = -1,3 Bike = +4,7
Mileage PrT, km	743068,5	738257,9	722574,4	717712,3
Over-mileage, PrT, km	0	4810,6	20494,1	25356,2

To calculate the CO_2 emissions, the data of the EU countries will be taken. In average, modern passenger car emits about 130 grams of CO_2 per 1 km. Environmental impact can be estimated as daily amount of CO_2 that does not get into the air of the city in each scenario.

Pessimistic scenario - 4810.6 * 0.13 = 625.4 kg;

Balanced scenario - 20494.1 * 0.13 = 2664.2 kg;

Optimistic scenario - 25356.2 * 0.13 = 3296.3 kg.

5 CONCLUSION

In this report, we analyze the existing bicycle infrastructure in the city, its advantages, disadvantages and their possible solutions. We have also developed bicycle network sketch for the city and surrounding areas, provided examples of the main types of intersections and road sections to be used in the further bicycle infrastructure development.

This report considers the development of a bicycle rental network, parking's, bike storage facilities and bicycle navigation in the city.

Further development of bicycle infrastructure and increase of bicycle modal share can reduce daily CO_2 emissions by 625 - 3296 kg.