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Technical Guideline

FOR BICYCLE INFRASTRUCTURE DESIGN IN URBAN AREA

CONSTRUCTION PUBLISHING HOUSE

Implemented by

Technical Guideline

FOR BICYCLE INFRASTRUCTURE DESIGN IN URBAN AREA

HANOI - 2023

Acknowledgments

The development of the Technical Guideline for Bicycle Infrastructure Design in Urban Area was led by the Administration of Technical Infrastructure (ATI), Ministry of Construction (MOC) in collaboration with Department of Science and Technology (DOST), the Ministry of Transportation (MOT) with technical support from GIZ, WRI, and HealthBridge.

The development of the Guideline would not have been possible without the commitment of Administration of Technical Infrastructure and the support and collaborative effort of the following organizations, professional experts, and individuals: Mr. Nguyen Anh Dung (MOT), Mr. Tran Huu Minh (National Traffic Safety Committee), Mr. Phan Le Binh (Vietnam-Japan University transportation expert), Mr. Jan Rickmeyer (GIZ Leading Technical Advisor for Mobility4Cities), Mr. Lennart Nout (Mobycon), and Mrs. Retno Wihanesta (WRI). Special thanks to experts of many professional associations and organizations, and urban transportation officials of many cities nationwide for their valuable technical comments on the Guideline.

The development, design and printing of the Technical Guideline for Bicycle Infrastructure Design in Urban Area are supported by Federal Ministry for Economic Cooperation and Development (BMZ) and under the framework of the DeveloPPP Project "Promote and Pilot a Public Bike-Sharing (PBS) Scheme in Viet Nam towards Sustainable Urban Mobility and Smart Cities", Bloomberg Initiative for Global Road Safety (BIGRS) Project, and HealthBridge Livable Cities Programme.

Foreword

In the memory of many Vietnamese people, bicycles were a primary mode of transport and could be easily spotted in every city of the country. In recent decades, however, with the rapid increase in ownership of private motorised vehicles, bicycles have become less commonly used, and thus receiving little attention in urban transport policies.

The transport sector is responsible for more than 20% of global emissions, of which road transport and urban transport account for more than 70% and around 40% of the total emissions in transport sector, respectively. Bicycles, on the other hand, are an accessible, safe, healthy, and environmentally friendly means of transport. Prioritising bicycles as a daily means of transport is an effective, low-cost strategy that helps cities achieve their green growth goals and contribute to national net-zero emission commitments.

The urban population in Vietnam is growing fast and is projected to reach 50% of the total population by 2025. Rapid urbanisation puts pressure on the management of urban public services and results in several concerns on urban transportation and environment. One of these concerns is the fact that the urban road network poses a high risk of collision for vulnerable road users including bicycle users, while other small streets have little space and are not equipped with proper facilities for bicycle users and pedestrians.

To develop cities that are livable, safe, and sustainable, the development of support infrastructures for bicycles should become a fundamental component of urban development. Planning and implementing bicycle infrastructure in coordination with other public transport projects will improve the overall efficiency of the transportation system and maximise the benefits of its investment.

The Technical Guideline for Bicycle Infrastructure Design in Urban Area is the first of its kind in Vietnam. This Guideline is developed upon lessons learnt from recent bicycle infrastructure and road safety projects in Vietnamese cities, as well as insights from international case studies. The guidance and strategies outlined in this document will help riding a bicycle become a daily, safe, convenient, and attractive travel option for people of all ages and abilities and for a wide variety of trip purposes in Vietnam. We encourage urban planners, urban designers, road *engineers, and city managers to use this Guideline as a reference in their works. The Guideline can provide both theoretical and technical solutions to problems related to bicycle facilities that have not been fully mentioned in the current regulations and standards in Viet Nam.*

The Administration of Technical Infrastructure, MOC

Ta Quang Vinh
Director General

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Daniel Herrmann
Chief Technical Advisor, "Support to Viet Nam for the Implementation of the Paris Agreement II"

World Resources Institute (WRI)

Claudia Adriazola - Steil
Deputy Director, Urban Mobility, and Director, Health & Road Safety, WRI Ross Center for Sustainable Cities

HealthBridge Canada

Kristie Daniel
Director, HealthBridge Livable Cities Program

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Key Terms Defined

Bicycle infrastructure	Bicycle infrastructure is the works and facilities for bicycle traffic, including the bicycle networks, bicycle lanes, neighborhood bikeways, intersection designs, roadside traffic safety equipment, bicycle parking area, lighting system, information system, and other utilities for bicycle traffic.
Frontage Road	Frontage road is a roadway running parallel and adjacent to the main street, separated from the main street by a rigid divider, or a stretch of greenery. A frontage road provides local access along the street.
Roundabout	Roundabout is an at-grade intersection with a special traffic organization, where the traffic goes around the central traffic island in a circular and counter-clockwise order. Some other names are traffic-circle and rotary, although rarely used.
Intersection approaches	Intersection approaches are the branches leading to the at-grade intersection.
Signal head	A signal head is a module of one or more signal compartments. It contains green, red, and yellow bulbs.
Signal phase	A traffic signal phase is defined as the green, change, and clearance intervals in a cycle assigned to the specified movement(s) of traffic.
Signal cycle	The traffic signal cycle is defined as the total time to complete one sequence of signalization for all movements at an intersection.
Green wave	A green wave is a way of linking signals at successive intersections so that in a certain direction, the traffic flow continuously receives green signals when traveling at a certain recommended speed.

Design speed	Design speed is the speed chosen for the design of bicycle infrastructure components. It is also the maximum safe speed that can be maintained over a specified section of the bicycle path.
Operating speed	Operating speed is the observed speed of the vehicle in favorable conditions of the traffic flow and control where only the road geometry conditions have a major influence on that speed.
Dimension of clearance	Dimensions that define a space on the cross-section of the lane/road where bicycles must pass, such as underpasses, under bridges, or locations where street equipment is installed over the bicycle lanes/roads... Clearance needs to be of sufficient size for bicyclists to pass without being hit by obstacles, causing unsafety. According to the TCVN 13592-2022 standard, the minimum clearance of the bicycle path is a rectangle 2.5m high and 1.5m wide.
Connectivity	Connectivity refers to how a bicycle network connects all points of departure and arrival. For the bicycle network, connectivity is the ability to connect one point to another easily and safely through designated bike infrastructures. Connectivity depicts the coherence of the bicycle infrastructure through the seamless connection of all points of departure and arrival to improve its accessibility.
Directness	Directness is an evaluation of how efficient a route is or an assessment of the connectivity of infrastructure in its ability to connect one location to another with the shortest distance possible. With bicycles, due to the use of human power, the directness of the bicycle path is very important to assist and attract people to ride a bicycle for daily trips.
Continuity	Continuity is the seamlessness of bike infrastructures on a route and/or from one location to another. Bike infrastructures that allow for continuity are designed and constructed to produce an uninterrupted end-to-end journey for bike users.

Attractiveness	The attractiveness of a bicycle infrastructure refers to the aesthetics of its design and construction. This can be heavily affected by convenience and safety for users. Also, the landscape around the infrastructure is a factor that can increase its attractiveness.
Neighborhood Unit	The basic functional cluster of urban areas is mainly designed to serve the daily residential needs including housing groups, public service buildings, and public greenspaces; traffic roads (from the collector road to the local road) and bicycle parking areas for neighborhood units. *Source: National Technical Regulation on Construction Planning, Circular No. 01/TT-BXD issued by Ministry of Construction dated 19 July 2021.*
Traffic Calming	Traffic calming refers to measures in either physical or other forms to "manage traffic speed and flow", to ensure safety for more vulnerable participants such as pedestrians and cyclists. These measures aim to reduce the speed of motorized vehicles or prohibit them and are usually applied in residential areas. Common measures include the use of roundabouts, street width reduction, chicanes, textured road surfaces, greenery, speed humps, speed bumps, fences, and bollards. Traffic calming measures also include surveillance to conduct traffic control.
Bollard	Bollards are cylindrical or cone-shaped posts used in traffic to separate different traffic movements or to prohibit other vehicles from entering a vehicle-designated lane.
Complete Street	Complete streets are streets with design features that contribute to a safe, convenient, and comfortable travel experience for all users, especially for the more vulnerable traffic participants such as bicyclists, pedestrians, and wheelchair users.

Overview

The "Technical Guideline for Bicycle Infrastructure Design in Urban Area" provides fundamentals and advanced technical knowledge to support the planning, design, implementation as well as policy establishment for bicycle infrastructure development in cities of Vietnam. This Guideline aims to assist architects, urban planners, and the authorities to develop bicycle infrastructure in Vietnamese cities, which are consistent with local and international standards.

The contents of this Guideline were developed with references to the current Vietnamese standards, policies, and guidelines in conjunction with international standards, guidelines, and relevant studies. Technical features and measures in this Guideline are in accordance with the infrastructural conditions, as well as the potential capacity of Vietnamese cities.

This Guideline is not only for professional traffic engineers and planners, but also for policy makers and experts on urban architecture, public health, urban development, and socio-economic development. The readers can refer to this Guideline in parts or whole.

The overall structure of the Guideline is as follows:

Section 1:	Scope of application of the Guideline, including: Where can the Guideline be applied, for what, when, and who can utilize it.
Section 2:	Principles of bicycle infrastructure planning and design, including the characteristics of cyclists, and principles for implementing a biking network that provides safe, multi-modal, user-friendly transportation.
Section 3:	Guidance selecting the appropriate types of bicycle lanes in a variety of urban settings. This section also includes fundamental technical design parameters to ensure the infrastructure meets the technical requirements of operation as well as safety for bicycles.
Section 4:	Guidance for principles and epitomes for the design of bicycle traffic organization at intersections, including safe routes into intersections, bike boxes, bike signals, and complex at-grade intersection cases.
Section 5:	Principles and reference designs of traffic calming to reduce conflicts between cyclists and other vehicles and manage motor vehicle speeds to guarantee bicycle safety.

Section 6:	Principles for arranging facilities according to legal regulations, including pavement markings, signs, and bicycle traffic signals.
Section 7:	Essential facilities for bicycle infrastructure, including a system of stops, parking, and other utility works such as road signs, trees, lighting, and wheelchair support.
Section 8:	Notable points to consider when designing and planning bicycle infrastructure for adaptable designs based on the street scene.
Appendices:	Appendix A. Introduces additional guidelines for infrastructure development projects for bicycles
	Appendix B. Introduces research tools for design and decision-making purposes

1 Scope of This Guideline

1.1. What is this Guideline for and where to apply

This Guideline provides the design solutions for bicycle transport infrastructure in urban areas, including the principles for bicycle infrastructure development and the required technical design specifications for bicycle safety. These principles, specifications and good practices are referenced from multiple studies, and projects, as well as international standards and requirements.

1.2. Who is the intended audience

This Guideline is for urban traffic engineers and planners, technical infrastructure and urban traffic experts, urban designers, architects, policymakers, as well as individuals and organizations working in related development fields. The contents of the Guideline aim to assist in solving issues that may arise from planning urban bicycle infrastructures, designing bike lanes, and bike-assisting utilities.

1.3. When to utilize this Guideline

Readers can refer to the contents of this Guideline in different stages of a bicycle infrastructure development project, namely (1) Preparation, (2) Execution, and (3) Operation. Additionally, the technical contents can be applied to (1) examine road safety – for planning and designing bike infrastructures, and (2) evaluate road safety – for projects in operation or development to ensure the safety and quality of bike infrastructures.


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2 Planning and Design Principles

2.1. Characteristics of bicycle users

Certain bicycle users have particular characteristics that require special design considerations:

Children: Children tend to bike in line or in groups when they ride bicycles to school. They often have limited experience and are not fully aware of traffic safety issues. Moreover, it may pose a safety issue when children ride bicycles that are not suitable for their physical abilities.

1)

Elderly: Elderly bicycle riders are affected by age-related functional limitations such as physical health, cognitive ability, and reaction time, which could increase the likelihood of crashes. Older people often have to make an effort to balance their bicycles during cycling. Evidence shows that the elderly is more likely to fall, lose control, and have difficulty keeping the straight trajectory of a bike upright than young people (Nghiem et al., 2017).


2)

Women: To encourage women to ride bicycles daily, they should be involved in planning, designing and decision-making process as they may have different preferences and views on safe and comfortable bicycle infrastructure.

Shared-bike users: Shared-bike requires direct and continuous routes to connect to destinations to facilitate commuting trips. Shared bikes have many potential users with different physical and health conditions, genders, and travel requirement, such as carrying luggage. Therefore, the shared bicycle infrastructure should consider the principle of "for all users, all ages and abilities". Infrastructure that is easy to be recognized, convenient to use, return, and transfer will be featured to attract bicycle users.

Low-income residents: Low-income residents often rely on bicycles for their daily transport. Bicycle infrastructures in lower-income neighborhoods are often limited with safety and security conditions. Bicycle infrastructure planning should take into account safety and security issues to ensure that everyone has safe access to traffic.


3)


4)

5)

People with disabilities: People who require a wheelchair often find difficulties navigating through obstacles. Uneven roads and high curbs might discourage them from utilizing the bicycle infrastructures, which leads to wrong direction traveling, or traveling by shortcuts that endanger themselves and others. The moving and turning movements of wheelchair users require wide, flat, and gentle slope bicycle infrastructures.

Cargo bike users: People in Vietnam use bicycles to transport freights or goods due to their low cost and suitability for narrow streets and alleys in urban areas of Vietnam. Therefore, the design of bicycle infrastructure should, to the possibility, consider the needs of this group to ensure the usability of these infrastructures for them.

Figure 2.1. Diversified groups of users

(Source: 1,2,3,5,6 ©GIZ/Vu Hoai Nam; 4 TUMI/GIZ; 7 Fred Young)

2.2. Principles of bicycle network planning

2.2.1. Multi-modal and multi-destination bicycle network

A multimodal bicycle network allows bicyclists to travel across an entire transportation system that connects pedestrian traffic, public transport, and means of individual transport. At its most fundamental level, a multi-modal and multi-destination network addresses the question: "Can I get to where I want to go easily and safely?". From the bicyclists' perspectives, a successful bicycle route network should be connected, direct, safe and continuous.

- Connectivity: A continuity bicycle network connects popular destinations within the city such as schools, public transit hubs, recreational facilities, community centers, hospitals, local markets, supermarkets, and other essential services.
- Directness: A bicycle network prioritizes the shortest possible routes to connect destinations. Studies show that directness is an important criterion that makes people decide to choose bicycles as their daily means of transportation. Network planning needs to avoid designing indirect bike routes.
- Continuity: A continuous bicycle network integrates a variety of high-quality bicycle infrastructure facilities (low-speed zones, bike lanes, bike paths, intersections, and other infrastructure) to provide seamless and intuitive travel for people of all ages and abilities. The design and construction of a continuous bikeway network should ensure consistency in design standards to create infrastructures that are easy to use and understand for all.

Figure 2.2. A multimodal and safe bicycle network

(Source: WRI, 2021)

The bicycle network plan needs to be considered an integral component of the urban road network in urban planning. Transport planning and land use planning should support each other to promote the development of bicycle transportation, including the following:

- Major cities should encourage the use of compact land-use planning, transit-oriented development (T.O.D), and bicycle-oriented development (B.O.D) to encourage people to travel by environmentally friendly transport modes, such as walking, bicycling for short trips combined with public transit for longer trips. Public transport should be the backbone of the transport network, with bicycle and pedestrian networks providing first and last miles connectivity, as well as individual short trips.
- Small cities should encourage compact land use and people-friendly streets. For example, the development of streets or areas dedicated to pedestrians and non-motorized traffic should be implemented in several areas within the city.
- Comprehensively implement a sustainable mobility system.
- Consider implementing a 15-minute city where housing, retails, recreational facilities, educational facilities, and other public amenities are conveniently connected within 15-minutes of active mobilities.
- Cities should prioritize small block sizes and dense street networks, which benefit walking and bicycling.
- Planning bicycle network connections to important public buildings and public spaces of the city such as administrative buildings, markets, cultural facilities, sports facilities, public squares, etc.

2.2.2. Bicycle network density and land-use planning

As bicycle infrastructure is part of the urban transport infrastructure, the bicycle network density is related to the current road network and cycling demand. It is recommended that the bicycle network density should be between 15 km – 20 km/km^2 when the distance between internal roads in residential areas ranges from 100 m – 200 m (Luu Duc Hai, 1993). According to a study in 2021 by Transformative Urban Mobilities Initiative (TUMI), cities should build 2 km of dedicated bike lanes for every 1,000 inhabitants. Determining bicycle network density is a complex socio-economic issue. Therefore, it would be helpful to reference the best practices from other countries.

1. China: China has developed a national standard for bicycle network density that corresponds with traffic zones. Class I Zones refer to the city center: core functional areas, densely populated areas, concentrated areas around public transport hubs, and railway stations, while Class II Zones refer to urban areas outside the core areas.

2. Netherlands: The "CROW Design Manual for Bicycle Traffic" recommends a network density from 200 m to 250 m between bikeways in urban areas.

3. United States: The US Federal Highway Administration has developed guidelines for evaluating bicycle network connectivity and density. These tools can be used to establish a bicycle network most suitable for the local context and are defined in detail in the publication "FHWA Guidebook for Measuring Multimodal Network Connectivity" published in 2018.

2.3. Design principles

A bicycle infrastructure should be designed based on the main principles: (1) bicycle for transport, (2) suitability for all, (3) road safety, (4) efficient transportation system, and (5) complete network.

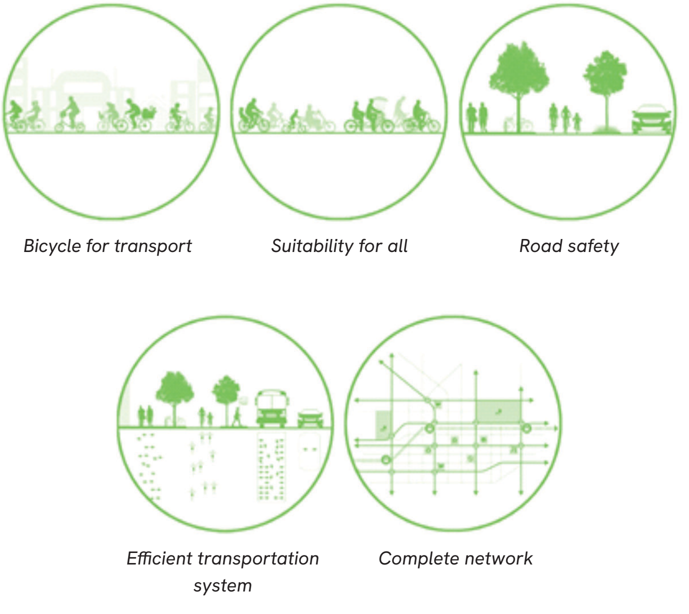


Figure 2.3. General principles for designing bicycle infrastructures

(Source: WRI, 2021)

2.3.1. Principle 1: Bicycle for transport

Using bicycles daily helps to reduce environmental pollution. They are used not only for exercise but also as a means of transport that covers short-distance trips and improves connectivity and accessibility to the public transport system contributing to the attractiveness and the effectiveness, especially in the context of recent significant investments in mass rapid transit (MRT) and bus rapid transit (BRT).

Additionally, bicycles are considered an important feature to promote tourism in Viet Nam's tourist cities. Bicycles are the most popular choice among students, the elderly, and low-income residents due to their accessibility and low operation and maintenance costs. With the characteristics of the urban street network in Vietnam with many small alleys, bicycles provide the first and last miles means of connection, expanding the service range of public transport, contributing to increasing the attractiveness and efficiency of public transport systems.

a) Protected bicycle lanes with physical separators Bicyclists feel confident

b) Bicycle lanes are separated by painted lines. Bicyclists are much less confident than the case in the photo a

c) Bicycle lanes are protected when approaching the intersection, bicyclists feel confident

d) Unprotected bicycle lanes at the intersection. Bicyclists feel much less confident in comparison with the case in photo c

Figure 2.4. Bicycle for transport

(Source: ©GIZ/Vu Hoai Nam)

2.3.2. Principle 2: Suitability for all

Building and developing a bicycle network that is convenient and accessible to everyone, including the elderly, children, and people with disabilities, is a requirement that should be incorporated into the design and construction of bicycle infrastructure. The suitability for all should be implemented in the bicycle network throughout the city to promote bicycles as a safe, convenient mode of transport as part of the transport system.

2.3.3. Principle 3: Road safety

Bicycles are considered lightweight and a simple form of transportation, which makes it hard to be visible at night. Similar to pedestrians, cyclists do not have external protections that the car drivers do, and, therefore, are highly vulnerable in traffic crashes. Consequently, when designing transport infrastructures, possible conflicts between motorized vehicles and cyclists/ pedestrians are considered high risks and need to be prioritized. Road safety for vulnerable participants is one of the most important principles.

2.3.4. Principle 4: Efficient transportation system

A principle that should be considered is to manage traffic demand through effective utilization of the existing street space. The lanes for motor vehicles can be adjusted and reduced, which not only helps achieve the goals of traffic speed management, traffic safety enhancement, and traffic congestion reduction but also creates more land area for other sustainable means of transport such as walking, cycling, and public transport.

2.3.5. Principal 5: Complete networks

A complete bicycle network is one that caters to every desired journey of cyclists by providing end-to-end connections throughout the city. Developing a complete bicycle infrastructure network will help increase the number of bicycle users who take daily work trips on bicycles. A complete bicycle infrastructure network offers seamless connections and transfers to other means of transport at transit points of the existing traffic network.

3 Bicycle Infrastructure Design

3.1. Dimensions of bicycle used for design

Within the scope of this Guideline, the types of bicycles that are mentioned herein are based on the vehicle classification in the Standard QCVN41-2019, which describes bicycles as "Vehicles having two or three wheels that can be moved by pedaling or by hand-turning power, including specialized vehicles of people with disabilities with similar features"[(1)].

Bicycles' design dimensions determine the necessary space for people and vehicles to operate safely and conveniently based on the traffic organization. The length, width, and height of bicycles affect the design of turning radius, shy distance when bicyclists have to dodge obstacles, and/or vertical clearance allowing them to go under tunnels, overpasses, or other types of elevated roads. Figures 3.1 to 3.4 demonstrate the standard dimensions of a bicycle when taken into consideration for design.

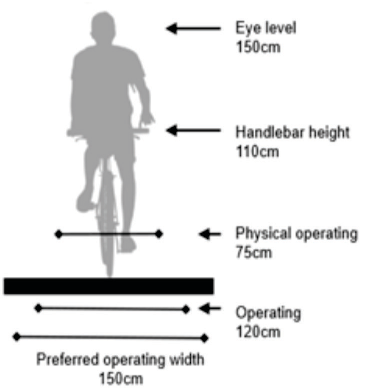


Figure 3.1. Typical dimensions of a bicycle rider

(Source: ©GIZ/Le Son)

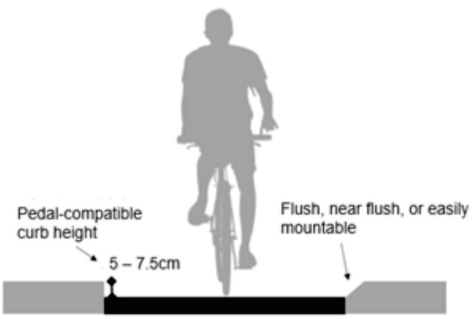


Figure 3.2. Reinforced curbs compatible with bicycle paths

(Source: ©GIZ/Le Son)

[1)] *Source: Article 3.34, National Standard No. 41: National Technical Regulation on Traffic Signs and Signals, 2019.*

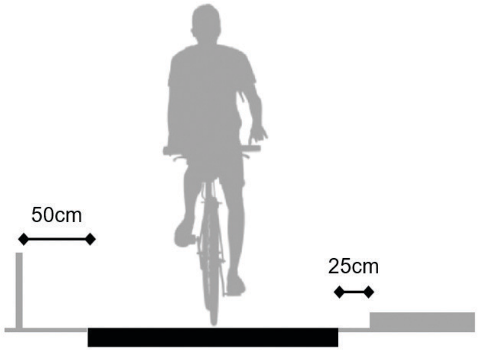


Figure 3.3. Distance from reinforced curbs

(Source: ©GIZ/Le Son)

Figure 3.4. Typical dimensions of a bicycle

(Source: ©GIZ/Le Son)

3.2. Design specifications for bicycle infrastructure

3.2.1. Design speed

Selecting a safe design speed for bicycle infrastructure depends on the traffic organizations, and it will affect the technical measurements of the infrastructure, such as the vertical slope, the horizontal curve radius, curb radii of intersections, width of bicycle lanes, materials and flatness of road surface, or duration of bicycle signal phases at intersections.

Table 3.1 presents the design speeds for bicycles in different conditions.

Table 3.1. Safe design speed for bicycles

Bicycle type	Feature	Safe design speeds
Standard adult bicycle	Asphalt road surface	20 km/h
	Paved level surfacing	9 km/h
	Crossing intersections	6 km/h
	Downhill	18 km/h
	Uphill	3-8 km/h

Note: *Tandem bicycles and cargo bicycles have design speeds equal to or less than the standard adult bicycles*

3.2.2. Width of bicycle lane

Table 3.2. Width and measures to protect bicycle lanes in correspondence with vehicles' speed

Motorized vehicles speed V85% (highest actual speed)	Type	Width	Note
≤ 30km/h (Traffic flow is less than 2,000 vehicles/day)	Shared bicycle roads.	Use the full width of the street/alley.	Use traffic calming measures to reduce vehicles' speed. Use signages and road markings for bicycle priority.
Up to 40km/h (Traffic flow is less than 6,000 vehicles/day)	Conventional bicycle lane.	At least 1.5m with a 0.5m buffer zone; Or At least 2.0m, no buffer zone.	One-way lane located on the right side of the road, using Lines 3.1 (continuous lines) and 4.1 (chevron lines) in line with the QCVN41: 2019/BGTVT for lane and buffer zone.
Up to 50km/h (Traffic flow is more than 6,000 vehicles/day)	Bicycle lane with physical protection.	At least 2.0m with a 1.0m buffer zone.	One-way lane located on the right side of the road, using Line 4.1 (chevron lines) in line with the QCVN41:2019/ BGTVT for a buffer zone. Using barriers, concrete curbs, flower beds, etc., or other equivalent physical dividers.
> 50km/h	Bicycle path.	At least 2.0m for a one-way bicycle path; At least 3.0m for two-way bicycle lanes.	Suitable for bicycle highway; tourist and recreational bicycle routes; traffic routes with vehicles traveling at high speed and high demand for bicycle use; and along lakes and rivers, etc.

The design width of bicycle lanes on urban roads is selected depending on various factors such as: design speed of traffic, volume of bicycle and other modes, vertical slope, and bicycle lanes arrangements.

The width of the bicycle lane affects the level of conflict among bicycles itself and between bicycles and other motor vehicles such as cars and motorbikes if they share the same lane. Bicyclists riding closely to the right-side curb without rigid medians tend to keep a distance approx. 0.5 m from the motorized vehicle lanes on their left.

The minimum width of a one-way bicycle lane is 1.5 m. However, this only applies to standard bicycles, therefore if the design includes other non-motorised vehicles, such as cargo bikes which have a larger width; or for heavy-duty bikes or downhill bike lanes, the lane will have to be wider.

3.2.3. Vertical slope and its length

The vertical slope and its length significantly influence the comfort level of the bicycle infrastructure due to its dependence on physical strength for operation. The maximum slope verticality of the road and the bicycle lane should not be greater than 3.5%.

A long and steep slope may be dangerous for cyclists as this could cause slipping and falling. Therefore, the slope and its length should be restricted as shown in Table 3.3 to ensure that the bicycle speeds at the end of the slope do not exceed 20 km/h.

Table 3.3. The uphill slope and the length of the designed slope for bicycle lanes

The uphill slope (%)	Length of slope (m)
3.5	100
3	140
2.5	200
<2	Unlimited

(Source: Nguyen Khai, 1982)

3.2.4. The radius of the horizontal curve of the bicycle lane

The horizontal curve of bicycle lanes depends on the designed speed and the frictional force between bicycle wheels and the road surface. The higher the design speed is, the larger the horizontal curve is. The minimum radius of horizontal curves for the bicycle lane should be 4.0 m or it can be calculated as an equation as below[(2)]:

[(2)] *Source: Nguyen Khai, 1982. Urban Road Design Volume 1. Professional College and University Publishing House.*

$$R = 0.238.V + 0.41$$

In which:

R = radius of the horizontal curve (m);

V = designed speed (km/h).

When designing separated bicycle lanes, the National Standard TCVN 13592-2022 recommends using the geometrical parameters of the bicycle lane equivalent to a road grade of 20 of urban roads. At this time, the minimum radius of the horizontal curve is 15 m.

3.2.5. Bicycle lane capacity

Studies and standards over the world on bicycle lane capacity vary greatly. Research conducted in Beijing, China, recommends that the capacity value of a bicycle lane is about 1,800-2,100 bicycles/ hour with a lane of width 1.0m average (Liu et al., 1993), (DanZhou et al., 2015), (Wei.H. et al., 1997) while the recommendation capacity from the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD, 2012) for bicycle lane separated by fixed dividers is 1,600-1,800 bicycles/h, and 1,400-1,600 bicycles/h with soft dividers.

This Guideline recommends referencing the current National Standard TCVN 13592-2022 for bicycle lane capacity of 1,500 bicycles/lane for a 1.5m wide lane.

3.3. Shared bicycle roads

3.3.1. Regularly shared bicycle roads

Shared streets where traffic volume is less than 2,000 vehicles/day and motor vehicle speeds are below 30 km/h are the type of roads most used by bicycles. These streets can be internal roads of sub-districts, roadways connecting sub-zones, streets in retail areas, or old quarters. Regularly shared bicycle lanes may be used on frontage roads or urban areas with a motor vehicle speed control at 30 km/h or less.

3.3.2. Bicycle boulevard

Bicycle boulevards, also known as neighborhood greenways or neighborhood bikeways, are special shared bicycle streets. Bicycle boulevard should be a linear route that either restricts motor vehicles' access or controls their speed to be less than 30 km/h with an average vehicle traffic of fewer than 2,000 vehicles/day, to improve the safety and comfort for bicyclists. Bicycle boulevards are suitable to combine with landscape and roadside space to create a comfortable and quiet environment and public space, not only for bicycle users, but also for other road users and locals as well.

Figure 3.5. Bicycle Boulevard

(Source: WRI, 2021)

Because of the shared nature of the streets, bicyclists can use the entire designed street. These streets have a width of 3.5 m to 7.0 m, so if parking lanes are arranged, the size of the parking lane could be as wide as 2.1m. It also means, however, that it is necessary to have traffic calming measures to control the speed of motor vehicles when entering these roads.

Bicycle boulevards are streets prioritized for bicycles, but motorized vehicles can still enter when there are no bicycles in use and/or must give the right of way to bicycles when they are on the streets. The bicycle boulevard solution can be used on internal streets with limited road space that cannot arrange separate bicycle lanes. The main function of bicycle boulevards is to ensure accessibility, so the speed is limited to 30 km/h. In cycling network planning, bicycle boulevards can be used to ensure directivity, shorten travel distances, and facilitate bicyclists.

Due to the limited space insufficient to arrange a separated bicycle lane, roadways will only display bicycle symbols (line 9.6 in QCVN41-2019) or the word “bicycle” (line 9.5e) at intervals of 50 m. In the Vietnam context, the bicycle sign named R.412h should be used along with the supplemental sign with the words "Bicycle priority” on bicycle-priority streets.

3.3.3. Bicycles in Alleys and Hems

In the urban areas in Viet Nam, alleys have the same characteristics as a street with business, service activities, and motorbike parking. It provides convenient shortcuts to pedestrians and cyclists, increasing the overall accessibility of the city. Using these alleyways to organize bicycle traffic is beneficial in multiple ways. To ensure traffic safety, painted markings, traffic signs, and waypoints for bicycle users are essential infrastructures that need to be implemented. It is also important to consider enhancing the road surface, drainage, cleanliness, and nighttime illumination when designing bicycle-friendly alleys.

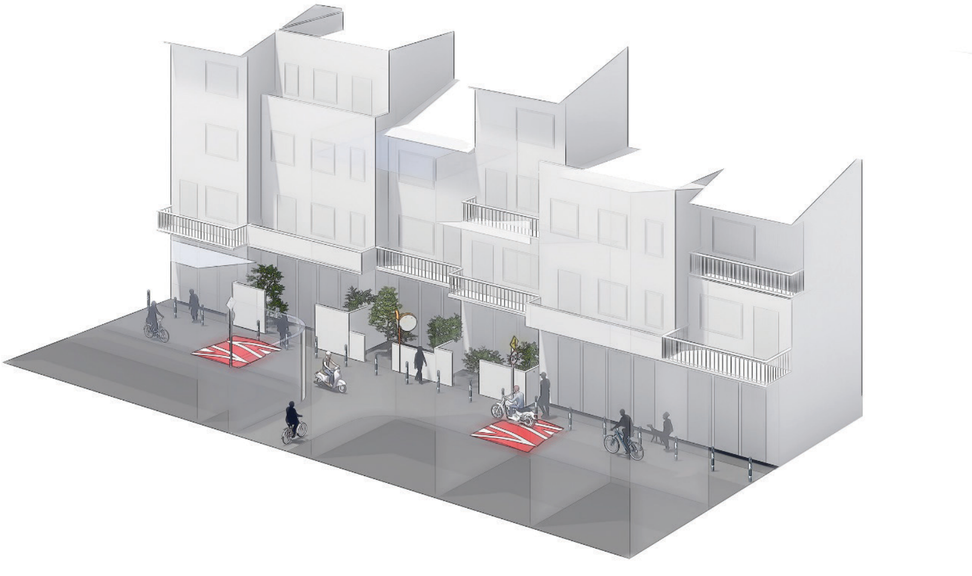


Figure 3.6. Bicycle priority in alleys

(Source: WRI, 2021)

The application of bicycle lanes in alleys may follow the principles below:

- Applying traffic calming measures to limit the speed of motor vehicles in alleys, such as speed bumps to limit vehicle speed to 30 km/h maximum, preferably 20 km/h combined with speed signals.
- Installing convex mirrors to improve visibility.
- Creating walking paths inside the alleys by pavement markings; especially for children who walk to schools through alleys.
- Increasing lighting at night as well as security and safety in alleyways.

3.4. Conventional bicycle lane

When bicycle volume increases to over 2,000 bicycles/day but below 6,000 bicycles/day, or the speeds of motorized traffic are from 30 km/h to 40 km/h, it is necessary to arrange conventional bicycle lanes through pavement markings to improve safety and convenience for bicyclists. Bicycle lanes are one-way lanes arranged parallel in the same direction as motorised vehicle lanes.

Conventional bicycle lanes include 2 common types: (1) dedicated bicycle lanes separated by road marking (1a) solid line marking (line number 3.1, QCVN41-2019), and (1b) channelizing line marking (line number 4.1, QCVN41-2019) and (2) dedicated bike lanes protected by physical measures.

3.4.1. Conventional bicycle lane separated by solid lines

A conventional bicycle lane is arranged parallel and in the same direction as that of motor vehicles, separated by a solid line (Line 3.1, QCVN41). This type of lane is applicable when the motorway has a vehicle speed of ≤40 km/h and an average traffic of 2,000 to 6,000 vehicles/day, and the number of large trucks and coaches, buses account for less than 10% of the vehicle volume.

Figure 3.7. Conventional bicycle lane separated by solid lines

(Source: WRI, 2021)

To improve visibility and attention towards motor vehicle drivers, bicycle lanes can be painted or paved with materials whose colors are different from motor vehicle roadways. Various international guidelines recommend green, blue, or reddish brown. This Guideline advises the use of reddish brown for bicycle lanes in urban areas of Vietnam. If colored lanes are implemented, the color needs to be uniform throughout the city's whole bicycle infrastructure system to ensure awareness for road users.

The lane marking by bicycle icon can also be applied (line 9.6 or 9.5e) at intervals of 50 meters along the lane. The design width of bicycle lane is the shortest horizontal clearances, excluding the width of the painted lines for marking on both sides of the lane and without physical obstacles on the lane surface such as drainage and curbs, etc.

3.4.2. Buffered bicycle lane

When the motor vehicle lane is designed with the same speed and traffic volume as mentioned in 3.4.1 and the width of the roadway is enough. It is recommended to install an additional buffer zone for the bicycle lane to avoid collisions with motor vehicles, improving bicycle safety. Channelisation (Line 4.1, QCVN41 - 2019) should be applied to create a safe buffer zone.

Figure 3.8. Conventional bicycle lane with a buffer

(Source: WRI, 2021)

A parking strip between the motor vehicle lane and the bicycle lane with a buffer zone helps to improve the visibility of road users and safety for cyclists. This buffer also helps to avoid collisions between the bicycle and the car door when the occupants open the door to get off the vehicle.

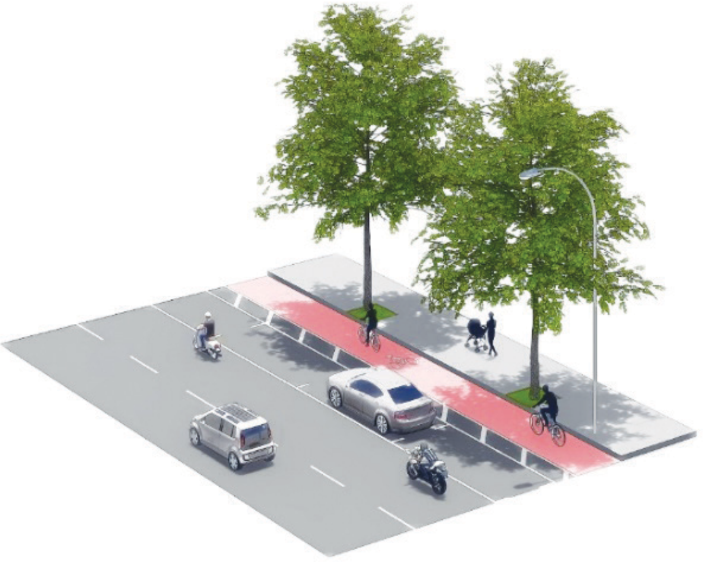


Figure 3.9. Conventional bicycle lane with a parking strip and buffer zone
(Source: WRI, 2021)

3.4.3. Bicycle lane protected by physical dividers

Another solution to protect bicycle lanes is a physical divider when the motor vehicle speed on the road is over 40 km/h and below 50 km/h or the traffic volume is more than 6,000 motor vehicles/day. The advantage of these solutions is to create a fully protected and clear bike lane. However, this solution faces many challenges when applied to streets requiring high curb access such as commercial streets. To solve this problem, it is necessary to limit the motor vehicle speed to ≤40 km/h to apply conventional bicycle lanes or ≤30 km/h to apply shared bicycle road solutions as mentioned above.

Physical barriers for protected bike lanes can be fences, green strips, and concrete curbs. It is also possible to create a difference in the levels of the pavement between the motorized lane and the protected bicycle lane. If physical separation solutions are applied, it should be noted that no dividers are built, and daylighting is provided 20 m before the intersection to ensure visibility for all road users.

Figures 3.10 to 3.14 show different physical separation solutions for different bicycle lanes.

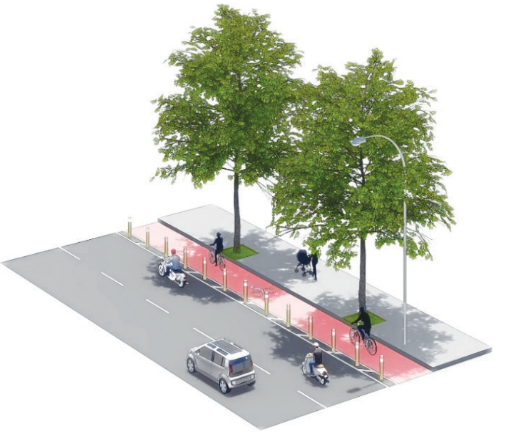


Figure 3.10. Bicycle lane is protected by bollards

(Source: WRI, 2021)

Figure 3.11. Bicycle lane is protected by greenery strips and streetscapes

(Source: WRI, 2021)

Figure 3.12. Bicycle lane is protected by fences

(Source: WRI, 2021)

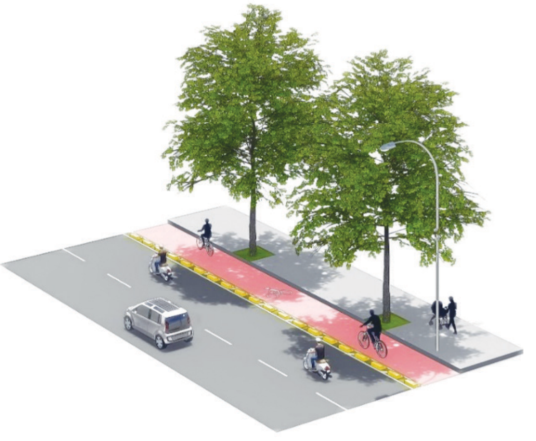


Figure 3.13. Bicycle lane is protected by a barrier type of curb

(Source: WRI, 2021)

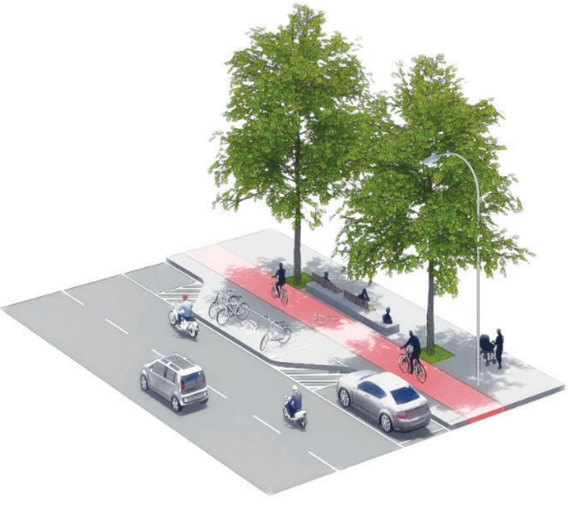


Figure 3.14. Bicycle lane is protected by elevating it to the sidewalk level

(Source: WRI, 2021)

In special cases, bicycle lane can be organized in two directions on one side of the street. A two-way protected bike lane has similar technical features to a one-way protected bike lane. In general, this alternative is not recommended due to the complexity of traffic organization, especially at intersections. This alternative is also considered unsafe for bicycle traffic if not carefully designed. Two-way protected bike lanes are appropriate when the other traffic direction either has nothing interesting in its opposite side, or it is too dangerous for them to approach the other side such as bike lanes bordering large parks and long walls of industrial parks.

3.5. Bicycle path

A bicycle path or a cycle path is a bikeway completely separated from motorized traffic and dedicated for cyclists or shared with pedestrians or other non-motorized users. In some cases, a bicycle path encompasses shared use path and multi-use path. It is a paved path that has been designated for bicyclists to use outside the right of way of a high-speed vehicle road.

In addition to different types of conventional bicycle lanes which are separated from traffic by painted markings, buffered zones and physically separated devices in adjacent to high-speed travel lanes, bicycle paths can be a solution to improve safety and protect bicyclists from the risk of being impacted by vehicles with high speed and volume.

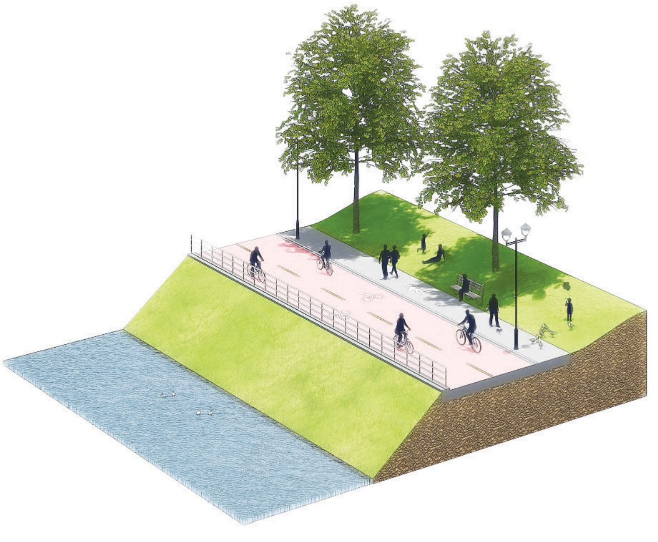


Figure 3.15. The off-street path along a river

(Source: WRI, 2021)

4 Intersection Design

4.1. Design principles for intersections

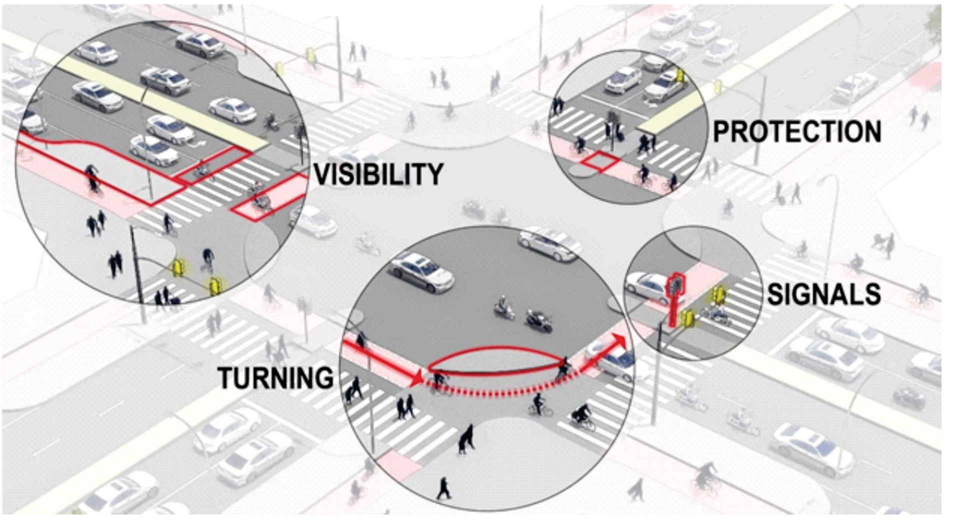


Figure 4.1. Key design principles of intersection for bicycle users

(Source: WRI 2021)

There are 4 principles when designing to ensure the safety for bicycles at the intersections:

- Ensuring visibility,
- Enhancing protection with traffic islands, painted markings, and signs,
- Providing protection with traffic signals,
- Creating safe turnings.

4.1.1. Ensuring visibility

A key principle is to maintain clear visibility for bicycles and motor vehicle drivers to ensure safe handling. In addition to that, bicycle lane designs should be properly evaluated to avoid cyclists falling into motor vehicle drivers' blind spots. The following aspects need to be carefully considered:

- Drawing turning paths at intersections to check the entire space when large vehicles make a turn. Based on the turning path of vehicles, the designed lane for bicycles through the intersection must ensure to (1) always maintain a distance equal to the length of the buffer zone between the turning path of vehicles and the bike/ motorcycle lane and (2) avoid designing a bicycle lane that falls into the blind spots of trucks and buses.
- While there are numerous trucks on the street with a high driver's seat position and a long hood, the design of stop lines for motor vehicles needs to be at least 3m from that of bicycles, such as bicycle boxes or lanes for crossing.
- If needed, it is recommended to prohibit heavy trucks with wide blind spots from turning right when the traffic signal light is red, separate the straight bicycle traffic from the right turning trucks through signal phasing, or install convex mirrors to remove blind spots for drivers.

4.1.2. Enhancing protection with traffic islands, painted markings, and signs

- Refuge islands serve as a protected area for pedestrians and bicyclists to wait safely when they cannot finish crossing the roads, which are essential at large intersections. It is recommended to use the traffic islands design with a minimum width of 2m, enough to protect at least one bicycle. Even at signalized intersections, traffic islands are essential for cyclists when their green phase to pass through is insufficient.
- Mid-block crossings for pedestrians and bicycles can be designed where people want to cross the street but that are not well served by the existing traffic network. These crossings, which commonly occur at schools, parks, waterfronts, and the distance between two adjacent crossings at intersections is too far.
- The signal phase call buttons for pedestrians or cyclists should be arranged so that when pressing the button, they will always face the traffic flow in front of them.
- Combination of solutions that enhance cyclist safety, such as motor vehicle speed restrictions or highlighting bicycle lanes with colors at intersections.
- When the intersection is large and controlled by signal lights, to save traffic signal phase time, improve traffic capacity, and enhance the safety of cyclists, it is possible to organize a two-stage left turn box for bicycles (see section 4.2.2.3).

- When the width allows, the right-turn lane should be arranged separately from the straight bike lane, which not only reduces stress on the drivers but also protects cyclists (see Figure 4.5).
- At intersections where have a large curb radius and traffic flow is mainly cars and motorbikes, rubber bollards and moveable barriers can be installed to reduce the radius of curbstone, forcing the vehicles turning right to slow down.

Figure 4.2. Protection islands for bicycles at the intersection
(Source: WRI 2021)

4.1.3. Providing protection with traffic signals

General principles:

- The minimum green phase time for bicyclists should provide enough time for cyclists or pedestrians to reach the nearest refuge island or cross through intersections safely within their green phase.
- It is recommended to separate signal lights for bicyclists. The signal lights display the bike image and should be located in the sightline of the cyclists.
- An "early" green phase for bicycles can be applied with the aim of helping bicyclists enter the intersection earlier than other vehicles within the same green phase, improving the visibility of motor vehicle users for bicycles, and increasing the green phase period for bicyclists.

- When necessary, a dedicated signal phase for bicycles can be provided to help them cross the intersection.
- When the signal lights at adjacent and consecutive intersections are connected to form a "green wave", it is important to adjust the wave speed to help bicyclists maintain their momentum. When considering bicycles, the recommended wave speed should be 20 km/h (TUMI, December 2020).
- Countdown lights at intersections have a positive effect on the psychology of bicyclists. When designing, consider using only green countdown lights for bicycle users.
- Using traffic camera systems to collect information on bicycle usage. The above information can be a good input for the design and operation of a more efficient bicycle signals system.

4.1.4. Creating safe turnings

It is necessary to limit the speed of motor vehicles and prioritize the protection of bicycle users at intersections. Apply the solutions for organizing turning paths described in Section 4.2 below in a flexible manner to ensure the safety of cyclists when turning left or when bicycles heading straight in order to avoid collision with motorised vehicles from different directions.

4.2. Specific design solutions

4.2.1. Design bicycle lanes at typical intersections

Design solutions for bicycles crossing the intersection depend on the geometry, control method, and complexity of the intersection. In this document, the typical intersections with 4 approaches, perpendicular to each other, controlled by traffic signals with different configurations are as follows:

- Small intersections: intersections with two to four traffic lanes on all intersection approaches.
- Large intersections without channelization: Intersections with more than four traffic lanes on one approach; there are no buffer zones separated by traffic islands or dedicated slip lanes.
- Large intersections with channelization: Intersections with more than four traffic lanes on one intersection approach; there are channelization separated by traffic islands and slip lanes at the corners of intersections.

Elements for safe intersection designs:

- For small intersections:
  - Narrow right turn radius, reduce motor vehicle speed when turning, enhance safety for cyclists.
  - Ensure visibility for traffic users, especially motorists and cyclists.
  - Reduce turning radius: this measure can slow down turning vehicles, therefore ensuring safety for bicycles.
  - Use bicycle boxes in front of motorised vehicles: It is recommended to use an area of the road in front of motorised vehicles to create space for bicycles to wait for a left turn. The width of the bicycle box should be equal to the width of the pathway leading to the intersection with a length of 4 m - 5 m. Arrange painted arrows in bicycle boxes to instruct bicyclists.
  - Use colored pavement on bicycle lanes crossing intersections to create an area of attention for motorcycle users when crossing bicycle lanes.

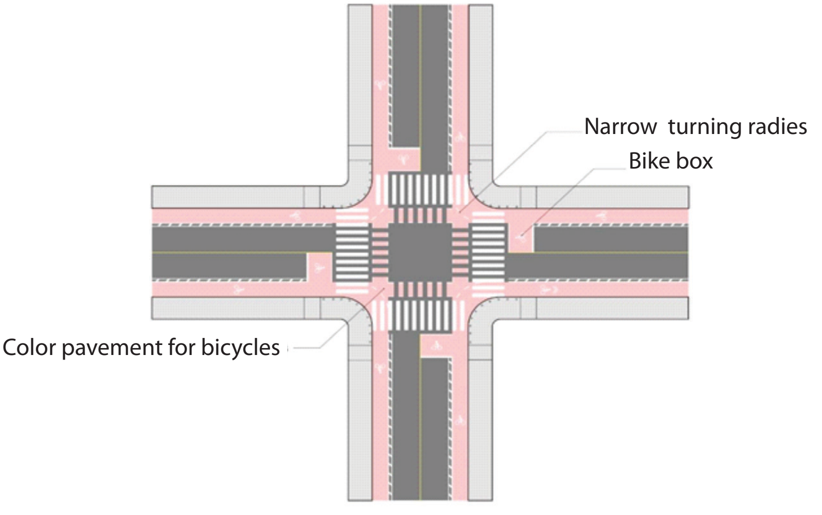


Figure 4.3. Design elements for small intersection with bicycles

(Source: WRI 2021)

For large intersections without channelization islands:

- Large intersections are prone to encourage high vehicle speed, long crossing time, and quick right-turn movement of vehicles. It is dangerous for left-turning cyclists because they cut through many lanes of motor vehicles. Therefore, to ensure bicycle safety, attention should be paid to motor vehicle speed control, visibility, reducing conflict with turning motor vehicles, and implementing other bicycle protection solutions. Bicycle safety signals should also be considered.

- Reducing turning radius can slow down turning vehicles, therefore ensuring safety for bicycles.
- Install refuge islands: Provide refuge islands for pedestrians and bicycle users to reduce crossing distances and increase safety and comfort. Protective devices should be installed on the islands to prevent motor vehicles from entering.
- Reverse the motor vehicle stop line behind the bicycle stop line to help drivers see the bicycle at the intersection corners.
- Use two-stage left turns: For details, see Section 4.2.2.3.

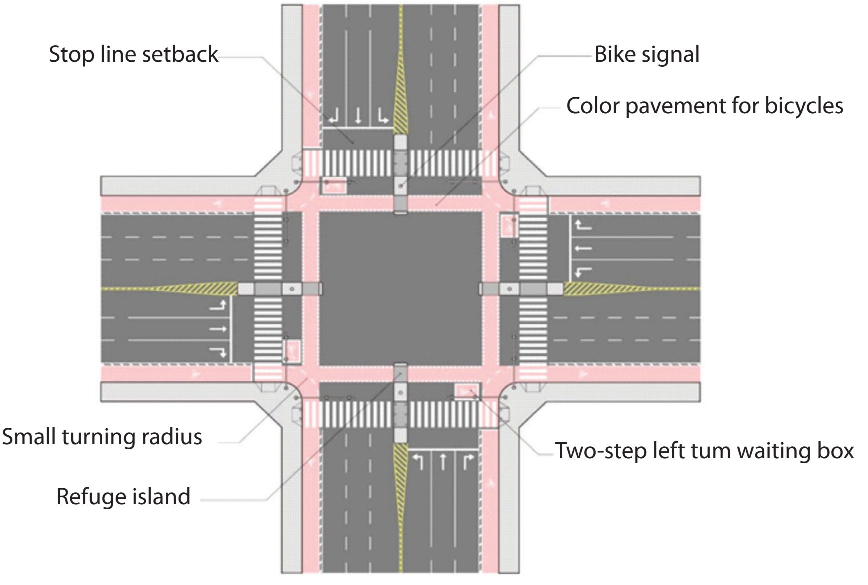


Figure 4.4. Design elements for bicycles at large intersections without channelization islands
(Source: WRI 2021)

For large intersections with channelization islands:

- Large intersections with channelization islands usually have more lanes entering the intersection. The risks for bicycle users are in slip lanes. However, large intersections with channelization islands usually have more lanes entering the intersection than regular large intersections. Crossing this intersection is also more difficult because bicycles are required to stop several times on refuge islands.
- Using traffic regulation devices such as speed bumps, and pedestrian crossings in combination with raising the road surface level for pedestrians and bicycle users, using colored surfaces of road to draw the attention of the motorised vehicle drivers and bicyclists to the potential conflict.

- Install refuge islands with protection for bicyclists and pedestrians.
- Install bicycle signals for the protection of pedestrians and bicyclists.
- Provide access to refuge islands for bicycles by adding ramps. See 4.5.

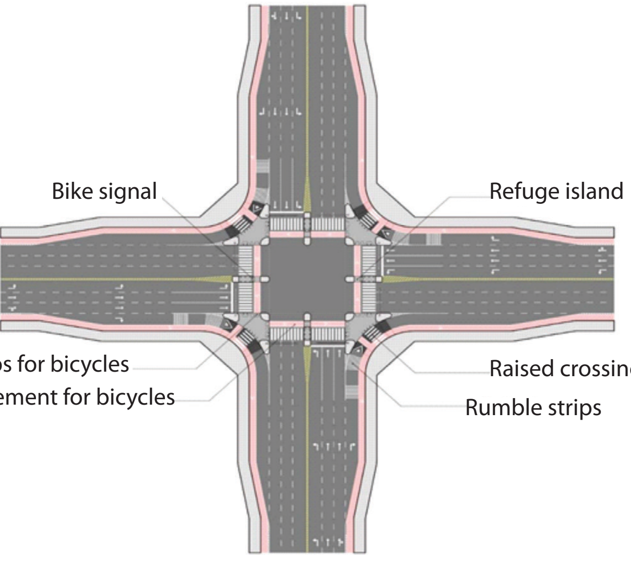


Figure 4.5. Design elements for bicycles at large intersections with channelization islands for the right turn lane

(Source: WRI 2021)

4.2.2. Design solutions for bicycle lanes on the intersection approach

In this section, more solutions for bicycles crossing intersections based on the principles outlined above are presented. The solutions include bend-out, bend-in, and bicycle boxes.

4.2.2.1. Bend-in bicycle lane

This method is used on road leading to intersections with separated bicycle lanes and non-channelized right-turning lanes of motorised vehicles. Motor vehicles must make a right turn according to the curb radius. It should be applied in places where large trucks are not allowed on streets with moderate and high traffic volume. The "bend-in" bicycle lane parallel to the motor vehicle lane is mainly for the driver to see the bicycle lane when entering the intersection and see the bicycles in their rear mirrors when they make a right turn at the intersection, and to actively yield to bicycles to minimize collisions.

When applying the bend-in solution to design a bicycle lane, it is necessary to ensure the following requirements:

- "Bend-in" length: From 6 m - 12 m.
- Curbs extension: Relocate space of parking strips at the approaches of intersection to extend the curbs. This design could help to protect bicyclists at the intersections as well as shortening the crossing distance for pedestrians. If the curb cannot be extended, road markings can be used to create a buffer area for bicycles and pedestrians.
- Length of bike lanes approaching the intersection: the minimum length is 6.0 m; the minimum width is 1.5 m.
- Priority signs for bicycles: Use the sign "Yielding to bicycles when turning right".
- Painted markings in the parking space: Use painted markings (Line 4.1, QCVN41-2019) to create a buffer zone.
- Painted markings on the road surface: Use painted markings (Line 9.6, QCVN41-2019) with the arrow lines to mark the bicycle lanes approaching the intersection.

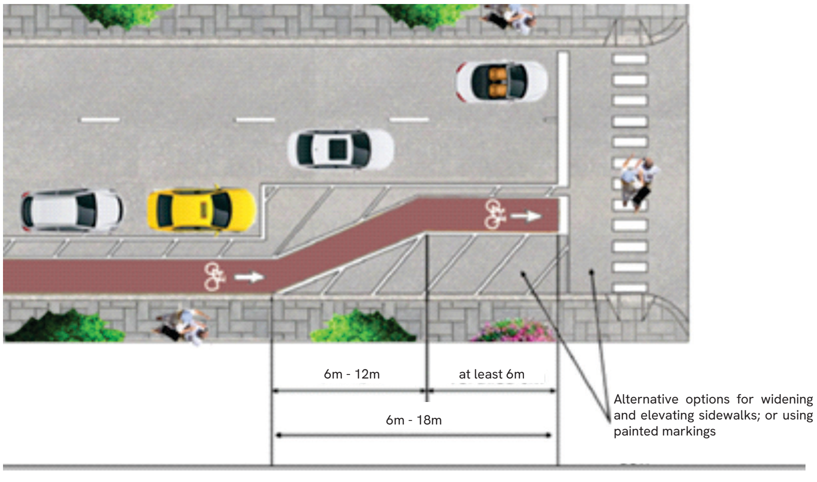


Figure 4.6. Solution to bend bicycle lanes in motorised vehicle lanes
(Source: ©GIZ/Nguyen Viet Phuong)

4.2.2.2. Bend-out bicycle lane

Shift the bicycle lane away from the motor vehicle lanes at the intersection, which results in turning motorised vehicles having exited the through-travel lane prior to crossing the bike lane. This design can help slow down vehicles' speed and approach the crossing at closer to a 90-degree angle. The option of bend-out bicycle lanes at intersection is commonly considered as a "protected intersection". It also provides motorcycle users with sufficient visibility for bicycles. As bicycle lanes separated from motor vehicle lanes become much safer, bicycle users have a waiting space to go through the node or make a left turn according to the signal light.

This solution is frequently applied at the intersections where large vehicles are presented. With this solution, the sidewalk space should be wide enough for bicycle lanes to bend out. The technical condition is a disadvantage of this solution as you do not always find a wide sidewalk to apply. In addition, when designing bend-out bicycle lanes, it is necessary to ensure that crossing areas should be in the drivers' sightlines on all approaches.

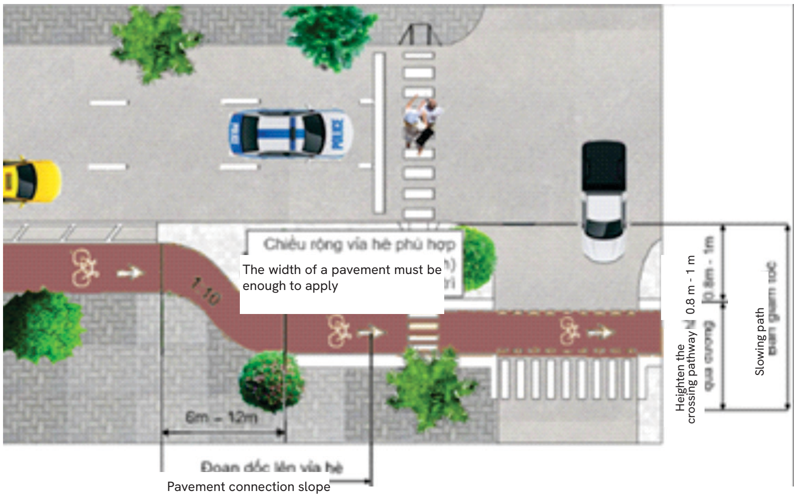


Figure 4.7. Solution to bend bicycle lanes out of motorised vehicle lanes

(Source: ©GIZ/Nguyen Viet Phuong)

When applying the bend-out solution to design a bicycle lane, it is necessary to ensure the following requirements:

- "Bend-out" length: From 6 m to 12 m.
- Stop lines and signals: Additional stop lines and signals for bicycles are needed to improve bicycle traffic safety.
- Raised bicycle lane: In order to give more attention to cyclists when crossing pedestrian areas, the raised section of bicycle lane can be applied. Raised bicycle lane can be at the level of the adjacent sidewalk, or set at an intermediate level between the roadway and sidewalk to segregate the cycle lane from the pedestrian area. The ramps at both ends of raised bicycle lane slope should be less than 10%.
- Buffer zone: The width of the buffer zone separating bicycle lanes and motor vehicle lanes by painted marking ranges from 0.8 m - 1.0 m (Line 4.2, QCVN41-2019).
- Priority signs for bicycles: Use the sign "Yielding to bicycles when turning right" on motor vehicle lanes.
- Place painted markings on the road surface: Painted markings on the road surface with a bicycle shape (Line 9.6, QCVN41-2019) in combination with the arrow line.

4.2.2.3. Bike boxes

Bike box

A bike box is a rectangular area defined by painted markings, which is located at the head of a traffic lane at a signalized intersection. It provides bicyclists with a safe and visible space to get in front of the queuing motorized traffic during the red signal, increasing the visibility for motor vehicle drivers. The box allows bicycles to cross intersections before motor vehicles and thus becomes suitable when there is high volume of bicycles turning left or bicycles having to turn left through multiple lanes of motor vehicles. The use of a bike box may not be appropriate at intersections on arterials with heavy trucks or on intersections located at the end of the slope.

Bike boxes are suitable for use at intersections that have the following features:

- Intersections with high bicycle volume, especially places where a lot of bicycles make left turns.
- 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.
- On compacted streets or small roads with restricted green signal phase.
- Other intersections with low traffic volumes can also receive this solution; but needs detailed technical analysis.

Figure 4.8. Construction of bike boxes
(Source: ©GIZ/Nguyen Huu Dung)

When designing a bike box, it is necessary to ensure the following design principles:

- A bike box:
  - A box formed by horizontal lines (line 7.1, QCVN41-2019) and vertical lines (line 3.1) to create a space for bicyclists to wait during red lights, the length of the bicycle box is 3-5 m, equivalent to 1-2 rows of bicycles.
  - Use of colored pavement to increase motor vehicle drivers' recognition of bicycles.
  - The bicycle box must be placed in sight and highlighted with colored backgrounds and reflective nails so that motorists can easily recognize it when entering the intersection.
- Stop lines: It is used to indicate the line behind the bicycle box, at which motor vehicles are required to stop according to traffic lights (line 7.1, QCVN41-2019). There should be a certain distance between the stop line and the bicycle box to ensure that drivers, including truck drivers with a high sightline behind a long hood, can still see.
- Bicycle-icon road markings: Place at the center of the bike box to designate the space for bikes only (line 9.6).
- Sign of R122 "STOP" combined with the sub-sign "Motor vehicles stop here: When there is no separated signal light pole for motor vehicle control (i.e., it is arranged on a common light pole with a boom), there should be a "STOP" sign below the sub-sign "Motor vehicles stop here" right at the position of the motor vehicle stop line. The sub-sign has a red background and white letters to prevent vehicles from entering the bicycle box.
- Ingress lane: using marking 3.1b (dotted line), the separated line between lanes for motorised vehicles and non-motorised transport modes. Painted marking with bicycle symbol or the obvious word "Bicycles only" should be applied on the roads approaching bicycle boxes. In case of necessity, lane separation markings R.415 can be used.
- Warning signs or sub-signs: Used to remind right-turning motorists to yield to pedestrians and bicyclists.

2-stage turn queue boxes

This arrangement is applied when a low volume of bicycles turns left to cross high-volume streets with multiple lanes in the same and opposite directions. When the bicycle lane is arranged close to the right side of the road, or the signal timing is not enough to ensure a safe one-stage left turn for bicyclists.

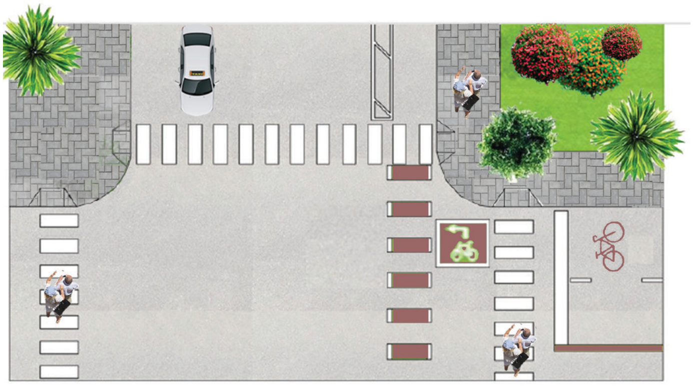


Figure 4.9. Arrange the bike box for the left turn in 2 stages

(Source: ©GIZ/Nguyen Viet Phuong)

To ensure that bicycle users can arrive and stay safely in the 2-stage turns box, the placement of the box should be arranged appropriately in terms of location and distance.

When designing a 2-stage turn queue box, the following requirements must be ensured:

- Turn queue box size: The minimum queue box size is 1 m x 2 m, which can accommodate at least one cyclist. Depending on the number of bicycles, the queue box size can be increased. It must be located outside of a straight bike path, usually between bicycle paths and pedestrian paths.
- The drawing figure in the queue box: The background of the queue box should use prominent colors to draw the attention of motorcycle users. The queue box is bordered by white-painted line 3.1. Reflective nails should be used on the painted lines. Bicycle pavement markings (line 9.6) and turning arrows must be used to signify the proper direction and waiting position of the bicycles.

4.2.3. Traffic organization for bicycle lanes at complex intersections

In addition to the typical intersections described above, in reality, there are also complex intersections in cities such as roundabouts, large intersections, complex intersections, and off-set intersections.

4.2.3.1. Roundabout

At the roundabout, bicycles are at a disadvantage because of the long distance through the intersection, and they are easy to be at the blind spots of motor vehicles. The wider the roundabout, with multi-rotating lanes, the more dangerous it is, and it makes bicyclists insecure when entering this type of intersection.

Here are some considerations when designing a roundabout:

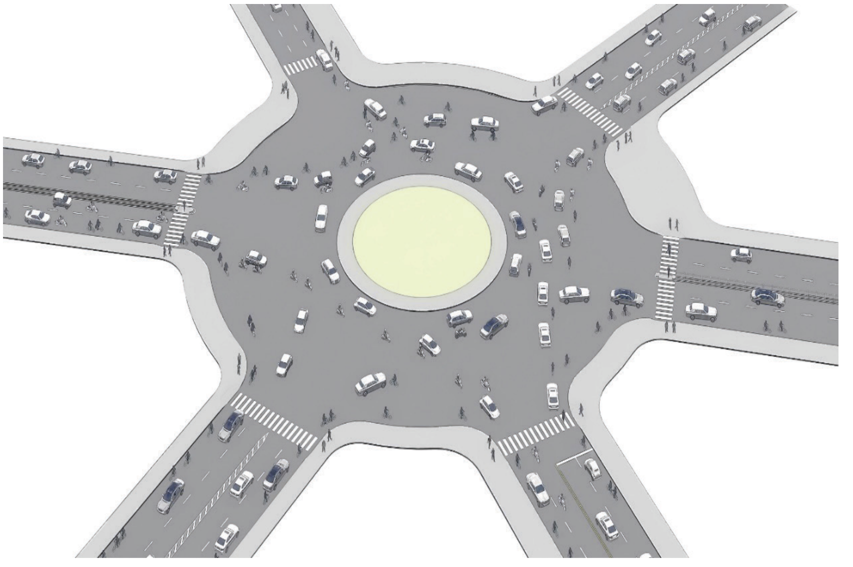
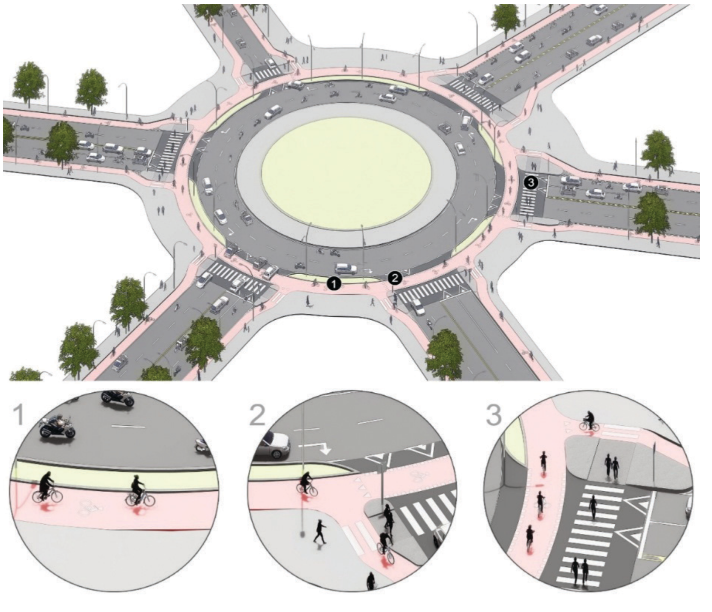


Figure 4.10. Roundabout without bicycle and pedestrian infrastructure before improvement

(Source: WRI, 2021)



Note:

(1) Bicycle path on the outside of the roundabout protected by guard islands;

(2) Speed calming measures and yield symbols;

(3) Bicycle lanes and pedestrian crossings are marked to help motorists recognize and slow down before entering an intersection.

Figure 4.11. Roundabout with bicycle and pedestrian infrastructure after improvement

(Source: WRI, 2021)

- Small roundabout: a single-lane roundabout with a smaller entry radius, narrower lane width, is considered safer for bicyclists. Small roundabouts help to slow down vehicle speeds and allow drivers to have more time to recognize and yield to bicyclists. More space for large motor vehicles to turn when maintaining a narrow lane can be created by creating a low curb area where large wheels can pass around the central island.
- Reducing speed: Vehicle speed in the roundabout should be less than 40 km/h. The small roundabouts on streets where bicycles use mixed lanes with motor vehicles should be limited the speed to less than 20 km/h.
- Enhancing visibility: Improving mutual visibility between approaching motor vehicle drivers and bicyclists as well as pedestrian crossings should always be considered. Reducing the speed of motor vehicles is a useful solution to improve visibility.
- Bicycle mixed traffic: Only at a single-lane roundabout with low traffic and vehicle speeds, bicyclists can safely share the lane with cars. When a roundabout has multiple lanes in and out, it is necessary to design a separate lane for bicyclists.
- Clear road signs and pavement markings: In case bicycles share the mixed lane at a roundabout intersection with cars, signs and pavement markings must be designed and installed on the road surface, signaling bicycles to help motorcycle users pay more attention to bicyclists. In case a dedicated bike lane is installed, clear visible signs and pavement markings should be installed to guide the bicyclists.
- Notes: When it is not possible to organize safe bicycle traffic through the roundabout (due to its large size, multiple lanes, several branch paths leading into and out of it, and the large volume of heavy vehicles traveling at high-speed), consideration should be given to replacing the signal lights, or organizing an alternative route or lane for bicycles to cross the intersection safely, if possible.

4.2.3.2. Large intersection

Large intersections in urban areas are often combined with multi-lane roads, making the journey of bicycles and pedestrians passing through the intersection extraordinarily inconvenient and dangerous because they have to pass through many motor vehicle lanes.

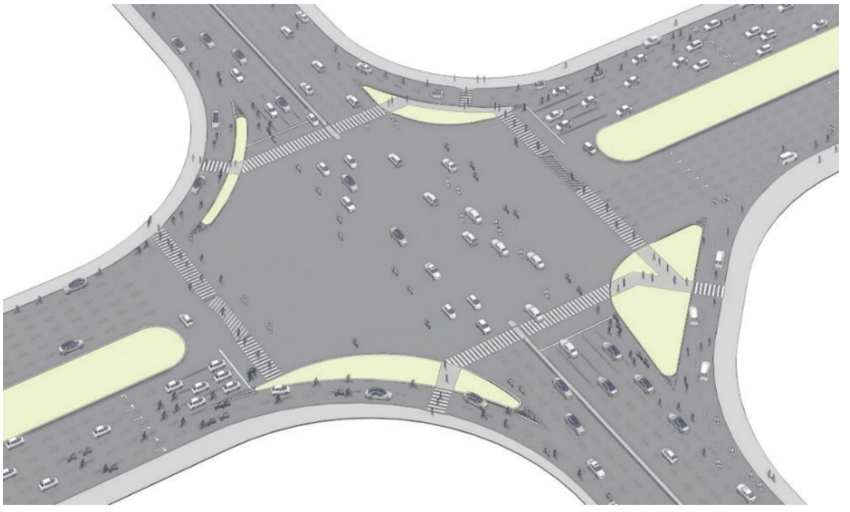
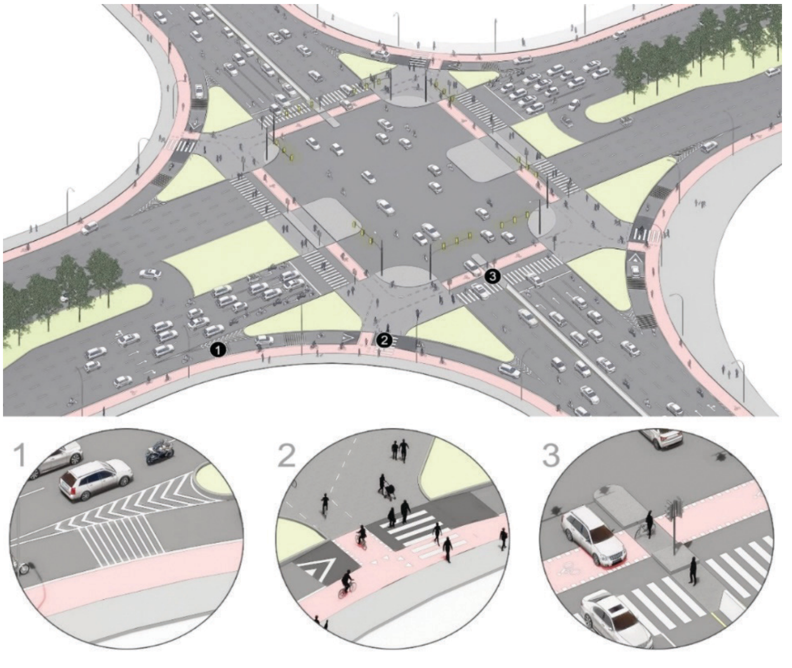


Figure 4.12. A large intersection before improvement without bicycle and pedestrian infrastructure

(Source: WRI, 2021)



Note:
(1) Slow down traffic by using rumble strip;
(2) Elevated crossings for both pedestrians and bicycles;
3) Refuge Island.

Figure 4.13. A large intersection after improvement with bicycle and pedestrian infrastructure

(Source: WRI, 2021)

To improve safety for bicyclists and pedestrians at large intersections, the following points should be kept in mind:

- Redesigning the intersection in the direction of compaction, channelization, and clear delineation of lanes for all vehicles and priority order often creates a safer node.
- Pedestrian overpasses are not always appreciated, especially where there is a high volume of pedestrians carrying a lot of luggage or pedestrians and bicyclists having age and physical limitations. Organization of bicycles and walk-in traffic in an equal and protective approach to create the shortest way to cross the street. Create more space on sidewalks and shelters that are large enough for all pedestrians when waiting to cross the street.
- Reduce the turning radius of motor vehicles at intersections.
- Reduce the number of lanes and lane widths for motor vehicles to reduce motor vehicle speeds and provide more space for bike lanes and protected islands for bicyclists.
- Install pedestrian and bicyclist refuge islands at the median or between lanes to create a protected waiting space when a green light is not long enough for bicycles and pedestrians to pass entire lanes safely from one side of the road to the other.
- Extend the pavement markings for bicycle lanes across the conflict zones at intersections to bring attention and give way to motorists and provide more space for bicyclists when facing with conflicts.
- At channelized turning pathways: Use speed bumps and elevate bicycle and pedestrian crossings. Use painted markings and signs to warn or instruct motor vehicles to give way to bicycles at the crosswalks.

4.2.3.3. Complex intersection

A complex intersection is a collection of intersections that are very close to each other and have overlapping intersection areas. In addition, diagonal intersections, and multi-branch intersections are also complex intersections. These intersections cause difficulties in organizing traffic. Without appropriate traffic designs and organization measures at complex intersections, localized traffic congestion will happen easily.

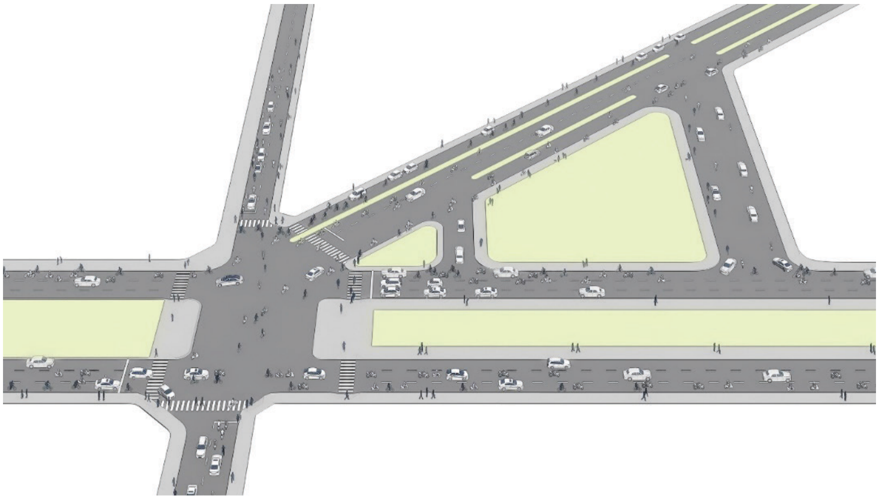
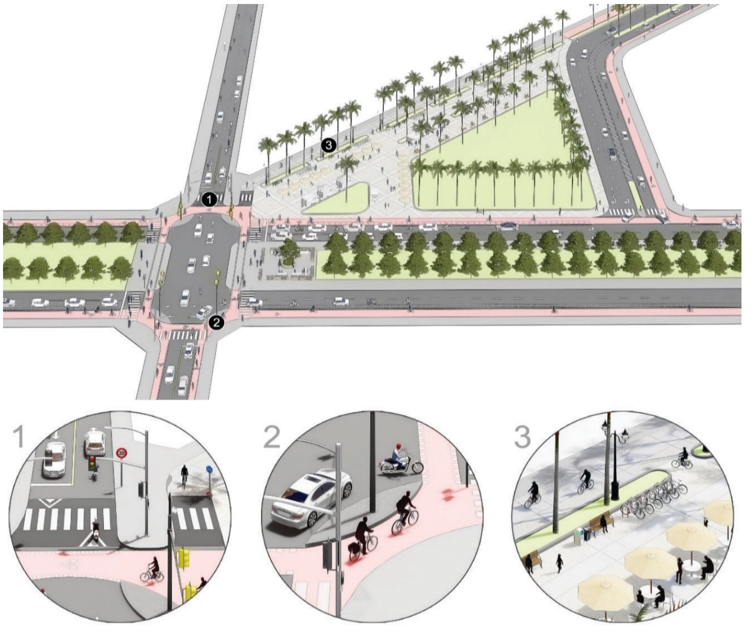


Figure 4.14. The complex intersection before improvement

(Source: WRI, 2021)



Note:

(1) Elevated crossings for both pedestrians and bicyclists.

(2) Protection bay for bicyclists.

(3) A branch into the converted node is reserved for bicycle users and pedestrians

Figure 4.15. Complex intersection after improvement with bicycle and pedestrian infrastructure

(Source: WRI, 2021)

- Consider designing adjacent intersections as a regional traffic system instead of treating each node separately.
- Bicycle users are prone to crashes at hidden and indistinct intersections. Therefore, it is necessary to have design solutions to simplify the complex intersections to make them clearer and more coherent.
- Apply traffic calming measures appropriately on shared streets to control the speeds of motor vehicles.
- Improve the design of diagonal intersections to be as close to the right angle as possible. Look for alternative solutions to reduce the number of lanes entering the intersection and limit left turnings. In addition, sidewalks should not be narrowed, and dividers should not be removed/cut to widen the roadway.
- Try to avoid use of multi-phase traffic signal heads; two-phase signals should be used at first and increase the number of signal phases if needed.
- Re-organize parking areas along streets by the intersection to improve visibility and local congestion.
- Consider converting some of the narrow streets of intersection into a street plaza in order to create pedestrian or public spaces and to simplify the intersection as well as to improve diversity around the intersection area.
- Provide crosswalks and refuge islands for pedestrians and bicyclists to create safer crossings and approaches directly to the streets.
- Highlight conflict zones for bicycles through the intersection. Create bicycle stop bars in front of motor vehicle stop bars.
- Incorporate more public space with shared bike/bike parking.

4.2.3.4. Off-set intersection

Off-set intersections are crossing sections where two misaligned bike lanes intersect with a main road or can be understood as two junctions intersecting with a main road, which are opposite and adjacent to each other. Such intersections can make it difficult and unsafe for a bicyclist on the secondary road to take a short ride along a crowded main road before turning onto the exit of the opposite side street to continue the desired journey through the intersection.

There are several factors to keep in mind when organizing bicycle traffic at offset intersections:

- Create the safest, shortest, and most convenient bicycle crossing.
- Use bike boxes, and guide markings (line 7.4, QCVN41-2019) in combination with colored pavement and bike signals (if any).
- If the offset intersections are close to each other, they might be treated as one intersection when organizing bicycle traffic. If the two side roads are far apart, they can be treated as two T-junctions. However, the design considerations mention before still applied.

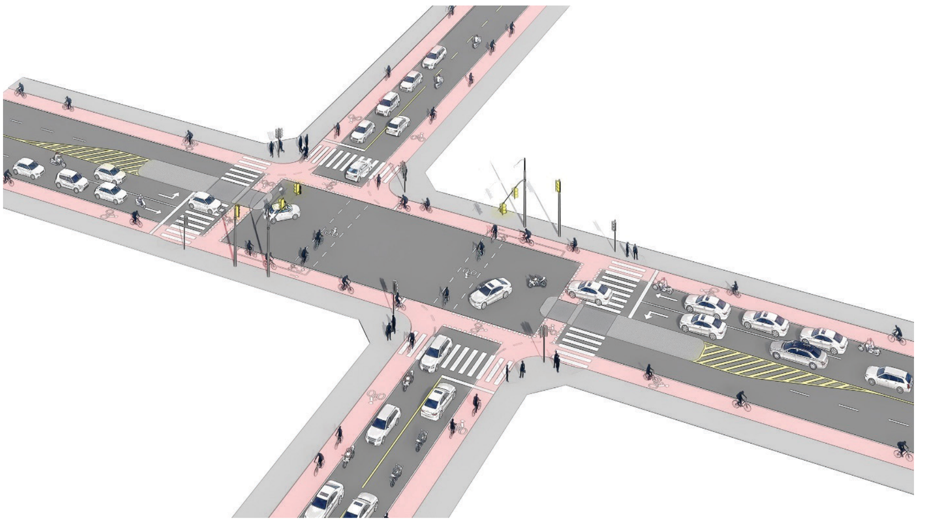


Figure 4.16. Off-set intersection improvement with bicycle infrastructure
(Source: WRI, 2021)

5 Design to Minimize Conflicts

5.1. Traffic calming strategies

5.1.1. Motor Vehicles Speed and Fatality Risk

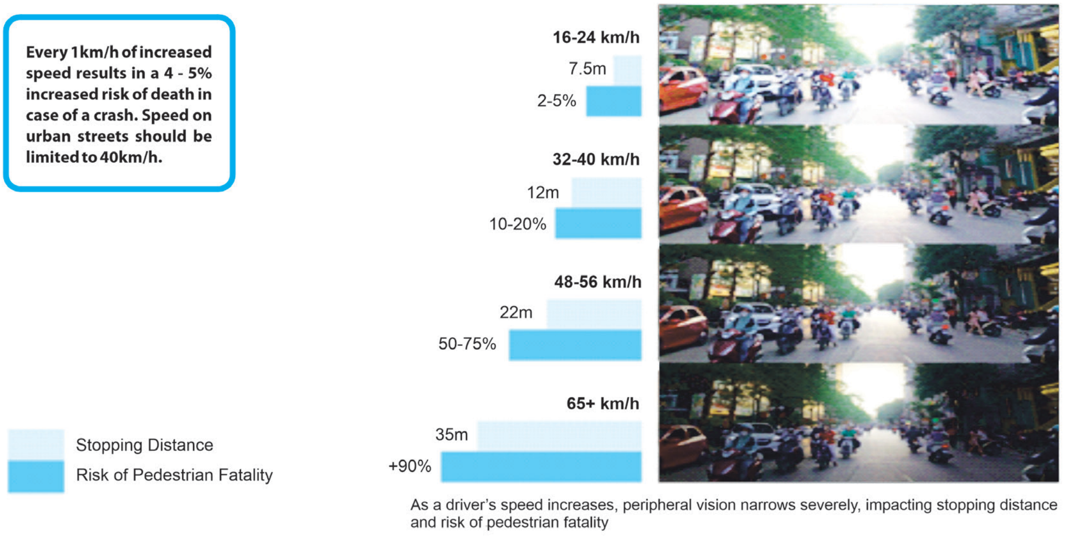


Figure 5.1. The relationship between motor vehicle speeds and the fatal risk of pedestrian

(Source: ©GIZ/Nguyen Huu Dung)

Vehicular speed is inversely proportional to vehicular volume. The lower the vehicular volume on the street, for example, late at night or early in the morning, the higher the tendency to drive at high speed, increasing the severity level of the traffic crashes. While the vehicular volume is high, the vehicular speed is low, and the severity of the traffic crashes may decrease. However, due to the large traffic volume, the risks of collisions and traffic crashes also increase.

Experience has shown that the trend of high vehicular speed will increase when the designed distance between each intersection is far or on the wide streets. The risk of traffic crashes for bicycles are higher if the bicycle is in a shared lane with vehicles or is not protected separately by physical measures such as rigid medians.

The large speed differences between bicycles and motor vehicles, heavy trucks, has psychologically negative effect on bicyclists. Most of them find it uncomfortable to travel next to motor vehicles, even in parallel lanes adjacent to motor vehicles, traveling at speeds above 40 km/h. Reducing the traffic speed of motor vehicles also reduces the speed differences between bicycles and motor vehicles, thereby improving safety and reducing conflicts.

5.1.2. Design speed and operating speed

On the same street, traffic organization and motor vehicle operating speed control are impactful in reducing traffic accidents. The more the design speed deviates from the actual operating speed vehicle, the higher the risk of traffic crashes. On the same route, the frequency of abrupt changes in operating speeds, the greater the risk of conflicts.

5.2. General principles of traffic calming

The management of motor vehicle speeds and volumes helps to ensure safe conditions for bicycles. Several principles are presented as follows:

- Physical calming measures should not be applied on bike lanes, such as speed bumps. The facilities for separating motorbikes should preferably have a structure that motorcycle users immediately perceive as unable to enter and give up their intentions at first sight. For example, instead of using low bumpers separating bicycle and motorcycle lanes, fences, or blocking structures that do not pose a danger to motorcyclists should be used.
- The use of simple speed rumble strips or traffic fines by surveillance cameras are examples of recommended “soft” traffic calming measures.
- Speed calming measures such as lane narrowing, and other physical measures can be taken to achieve the goal of safe speed. However, if the traffic volume of the streets is still more than 1,500 vehicles/day, it should not be designed to mix traffic for bicycles on these streets.
- It is possible to use a combination of traffic calming measures and traffic flow and volume management at large intersections.

- When traffic calming measures and designs fail to reduce traffic to the desired limits or cause traffic congestion, installation of bicycle lanes should be considered.

5.3. Traffic calming measures

Lane narrowing:

In the USA *(Source: Dan Burden, 2021)*

In Singapore *(Source: Larry Schaeffe, 2021)*

In the USA
(Source: New York Department of Transport, 2021)

Figure 5.2. The examples of traffic regulation solutions in the USA and Singapore

- **Narrowing of motor vehicle lanes:** Narrowing of motor vehicle lanes to reduce motor vehicle speeds on streets that require traffic calming. Low-speed streets encourage cycling and improve pedestrian safety by shortening the crossing distances for pedestrians.
- **Rumble strips, speed bumps and speed cushion:** These are measures to elevate the heights of road surface to reduce the speeds of motor vehicles. These deceleration measures can be combined with bicycle and pedestrian crosswalks.

- **Lane shift:** The lanes on both directions are shifted diagonally to the right-hand side by using traffic islands at the center of the road in combination with curb extensions on straight streets to slow down motor vehicles.
- **Chicanes:** Slow down motor vehicles by making the roadway chicane-shape, combined with curb extension for parking along the road. The chicanes are a form of lane transitions repeated many times on the same street.
- **Restricted Movement:** Traffic diverters with barriers or other physical measures can be used to manage vehicle movements while maintaining accessibility for pedestrians and bicyclists.
- **Restricted access:** Use fixed dividers, such as fences, solid bollards, and barriers, to reduce motor vehicle volumes and speeds, to prioritize bicyclists and pedestrians.

Figure 5.3. An example of a land shift solution

(Source: Kristen Brookshire, 2021)

Figure 5.4. An example of chicane measure in Florida, USA

(Source: Dan Burden, 2021)

- **Mini roundabout:** Mini roundabouts reduce traffic speed of motorised vehicle when going through intersections.

In Vancouver, Canada
(Source: Dan Burden, 2021)

In the USA
(Source: Dan Burden, 2021)

Figure 5.5. An example of the mini roundabout in the USA and Canada

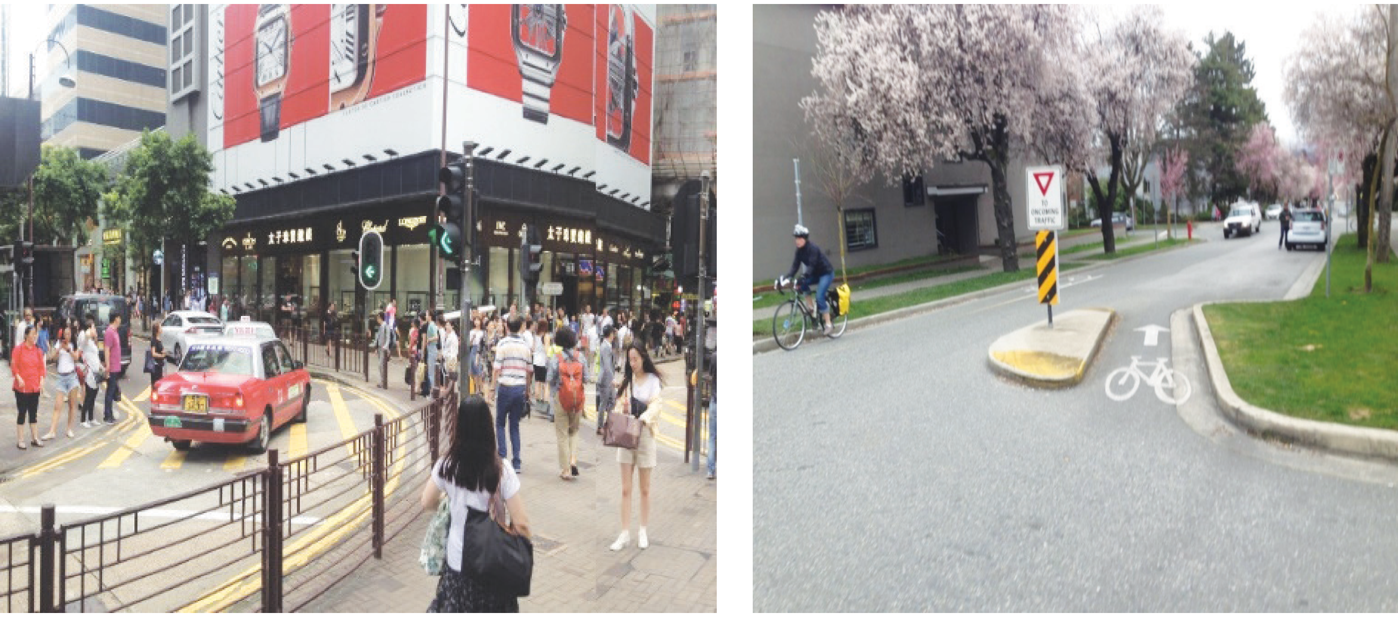
- **Restricted Movement:** Traffic diverters with barriers or other physical measures can be used to manage vehicle movements while maintaining accessibility for pedestrians and bicyclists.
- **Restricted access:** Use fixed dividers, such as fences, solid bollards, and barriers, to reduce motor vehicle volumes and speeds, to prioritize bicyclists and pedestrians.

Other solutions:

- **Create green waves:** A green wave occurs when a series of traffic lights are coordinated to allow continuous traffic flow over several intersections in one main direction. Green waves could be applied to manage the traffic speed of the corridor at a designated speed limit.

Figure 5.6. An example of hard separation in Vancouver, Canada

(Source: Fred Young, 2021)



Fence diverter in Hong Kong, China

Traffic Island dividers in Vancouver, Canada

Figure 5.7. An example of dividers in Hong Kong (China) and Canada

(Source: Fred Young, 2021)

5.4. Conflicts with motorcycles

For streets with speeds higher than 30 km/h, it is ideal to establish dedicated bike lanes. However, in some cases, a lane for both bicycles and motorcycles can be designed since motorcyclists are also vulnerable road users and need to be considered.

When designing a lane for mix-use between motorcycles and bicycles, the speed limit should be managed at 30km/h by traffic calming measures. Figure 5.8 and Figure 5.9 show two design solutions for motorbikes and bicycles. Figure 5.8 shows a solution to create a motorcycle lane outside the protected bicycle lane. The lanes of motorbikes and bicycles are separated from each other by solid painted lines. The advanced solution shown in Figure 5.9 is to apply additional speed calming measures such as rumble strips, speed humps for motorbike lanes. However, when motorbikes and bicycles share the same lane, enforcement are critical to ensure a safe speed for bicycles.

Figure 5.8. Motorcycle lane and bicycle lane are separated by a physical median
(Source: WRI, 2021)

Figure 5.9. Motorcycles and bicycles share the same lane, bicycles use the curb
(Source: WRI, 2021)

5.5. Conflicts with parked vehicles

Parking strips can obscure the view of road users and pose a risk of an accident. Any car parking area adjacent to a bike lane requires careful design. Ideally, do not design parking strips when there is a bike lane. When a parking strip is required, it should be located outside the bicycle lane. An example in Figure 5.10, the parking strip is designed to form a protective strip for the bicycle lane.

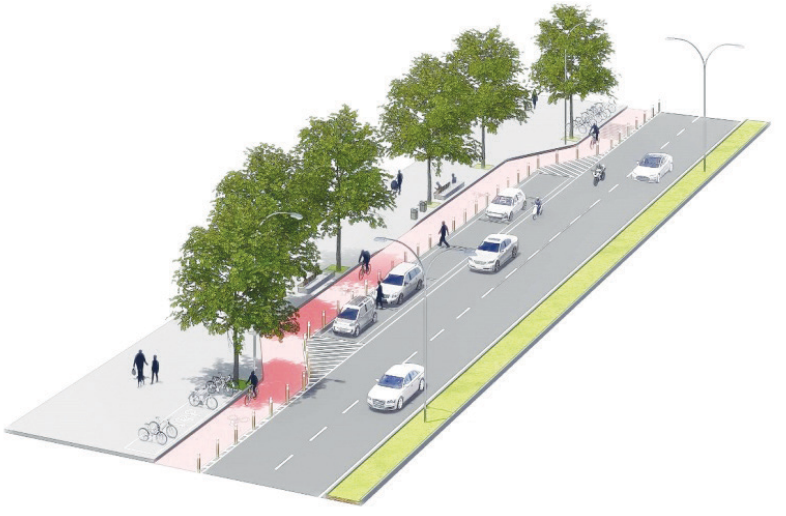


Figure 5.10. Design solution for bicycle lanes to avoid parking strip

(Source: WRI, 2021)

5.6. Conflicts at bus stops

When a bicycle passes a bus stop, it may collide with buses and embarking, disembarking, or crossing passengers. To reduce conflicts at bus stops, the following points should be kept in mind:

- **Avoid combining buses and bicycles in one lane:** Buses stop at their stops while bicyclists keep moving, increasing the risk of collisions.
- **Reduce conflict between buses and bicycle users:** This can be achieved by making bicycle lanes bypass behind bus stops (Figure 5.11) and/or raising the bicycle path bicycle to make it higher than bus lanes (Figure 5.12).
- **Reduce conflict between bicyclists and bus passengers:** The safety of passengers crossing a bicycle lane when approaching or leaving buses can be enhanced by installing yield markings or warning strips to notify bicyclists to

yield to passengers. It is also possible to paint a buffer zone or a refuge area between the bicycle lane and the bus stop area. The refuge should be more than 2 meters wide, enough for a caregiver with a stroller or a wheelchair user. If the bicycle lane is not elevated and there is not enough space to arrange a refuge area between the bicycle lane and the buses, it is necessary to design a buffer zone with enough area for passengers to stand when getting on and off the bus between the two lanes. Using the painting line (Line 7.3, QCVN41-2019) to designate the crossings for passengers to crosses bicycle lanes (Figure 5.13).

- **Highlight bicycle lanes** by applying markings and colors to increase the visibility of bicycle lanes and buffer zones as well as parking areas and bicycle lanes (Figure 5.13).

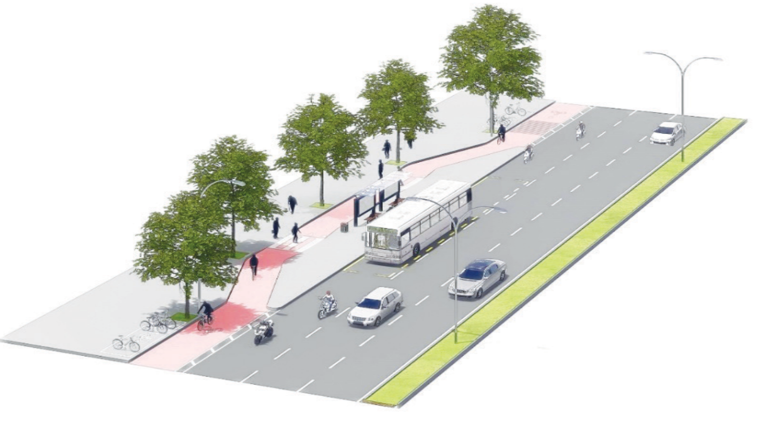


Figure 5.11. Floating bus stop where bicycles pass a bus stop from behind

(Source: WRI, 2021)

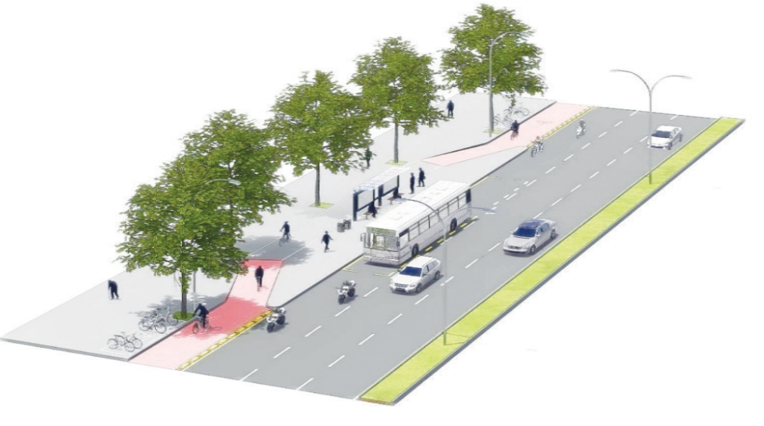


Figure 5.12. Floating bus stop where bicycles pass a bus stop from behind (bicycle lane is elevated at the bus stop)

(Source: WRI, 2021)

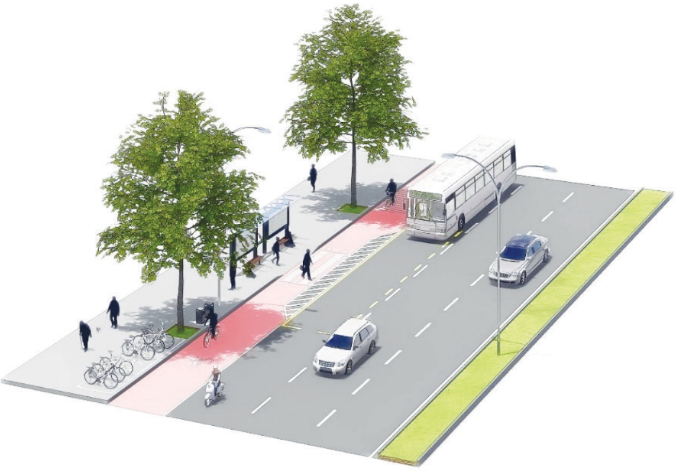


Figure 5.13. The pedestrian crossing and the buffer zone are highlighted by painted markings between the bicycle lane and the bus lane

(Source: WRI, 2021)

5.7. Conflict at intersections with alleys and entrances to the building

The design of bicycle lanes at low or very low volumes intersections, such as alleyways and entrances to buildings, entrances to parking lots, and other public facilities, should be considered. Painted markings and signs should be applied at potential conflict locations to increase hazard awareness for bicyclists and motorcycle users. At the intersecting points between bicycles and building entrances, the following requirements should be ensured as below.

- Ensure visibility for drivers when entering/exiting:
  - All drivers should be able to see the bicyclists when entering/exiting the building at a safe distance. Do not arrange medians to protect the bicycle lanes and/or parking strips to block the view of road users entering or exiting the building or garages. The median and parking strip needs to be installed at least 2m after the intersection, similar to other common intersections.
- Ensure that bicyclists and motorists can clearly see the entrances and exits of the building: Signs and colored warning signs should be installed on the street at the intersection to identify the entrances and exits.
  - Small turning radius in combination with speed bumps and/or deceleration markings at building entrances to regulate and reduce the vehicle speeds in and out of buildings.

- Elevate the bicycle path when crossing the motor vehicle lane to act as a speed reducer and identify bicycle priority.
- Where bicycle lanes intersect with entrances and exits with a high volume of vehicles (concentrated parking lots, commercial centers, etc.), if possible, it is recommended to separate left turn and right turn traffic at different gates to reduce the number of vehicles at each entrance to avoid congestion.

- Arrange traffic signal lights with push buttons for bicyclists and pedestrians to cross streets at the entrances and exits of large buildings and large volume of motor vehicle traffic, such as entrances to apartment complexes, offices, industrial areas, etc.

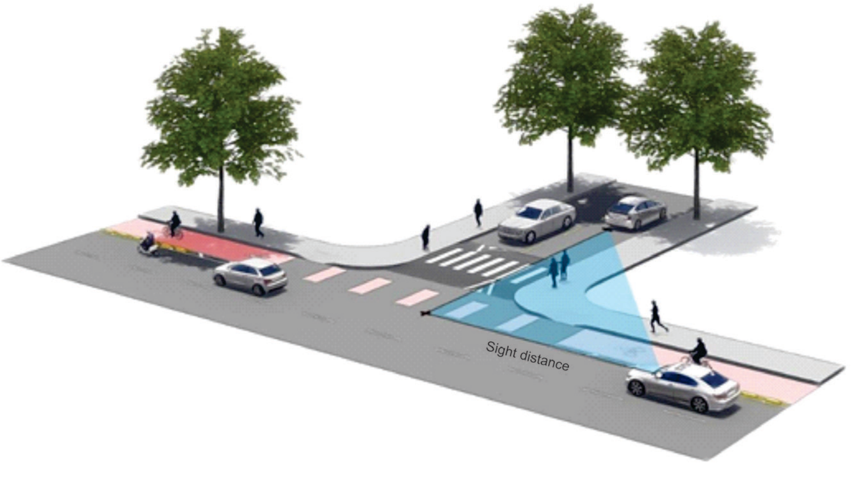


Figure 5.14. Ensure sight distance for vehicles when crossing the bicycle lane

(Source: WRI, 2021)

6 Traffic Signals, Road Markings, and Traffic Signs

6.1. Bicycle signals

6.1.1. Operation of bicycle signals

When designing for bicyclists to cross at intersections or at mid-block crossings with signals, it can be designed with dedicated signal phases or in combination with the other traffic signals for motor vehicles and pedestrians. Table 6.1 presents an analysis of the signal phase usage for the bicycle crossing the intersection for different cases.

Table 6.1. Organization of signal phase for bicycle through the intersection

Phase diagram	Description	Advantages	Disadvantages
Simultaneous control signal.	The bicycle signal phase is the same as motor vehicle signal phase.	Simple, easy to organize.	Not suitable for intersections with a large amount of left- turning motor vehicles or large trucks.
Green phase for bicycles to travel early. Green phase for motor vehicles to travel after the green phase for bicycles.	Create a green signal phase for bicycles in front of the phases for motor vehicles.	Bicycles can enter intersections before motor vehicles. Improved cyclist visibility to other traffic participants.	Increased vehicle waiting time for motor vehicles.
Two-stage left-turn bicycle signal phases.	Same as above, but bicycles are not allowed to turn left directly. They have to make a two-stage left turn.	Maximum protection for bicycles on all journeys. Motor vehicles do not require to yield to bicycles.	Increasing the number of signal phases to increase the total time a light cycle takes to cross an intersection.
Specific signal phase for bicycle.	Create a separate protective signal phase for bicycles so that all motorised vehicles must stop. This can be combined with control signals for pedestrians crossing the street.	Maximum protection for cyclists and pedestrians. Allow bicycles to turn left directly through the intersections.	Increase the number of phases and increase the total signal cycle time.

6.1.2. Bicycle signal design and location

Traffic signal heads must be located within the line of sight of cyclists. On busy streets with many large vehicles, the view of cyclists can be obscured, thus requiring reasonable placement for bicycle signal heads. The solutions are as follows:

- Install on mast arm poles.
- Place a supplemental signal head at the position close to the bicyclists.
- Use bigger signal heads with bicycle symbols.
- Increase the number of signal heads and/or combine additional signs.

6.1.2.1. Adding bicycle signals at existing signalized intersections

At existing signalized intersections, bicycle signals can be added to help cyclists cross or make turns more safely.

In most cases, using bicycle stenciled lens for bicycle signals is preferred. However, when bicycle stenciled lens are not available, the standard signal lens can be used in combination with additional panels of “bicycle signal” (type S, QCVN41-2019).

Ideally, the equipped bicycle signal heads should be designed consistently throughout the traffic signal system of cities to ensure the same understanding for cyclists and all road users.

Figure 6.1. Signal heads for each traffic lane

(Source: ©GIZ/Vu Hoai Nam)

Bicycle signal countdown: Above the signal heads, arrange a countdown lens to inform remaining time to cyclists and let them get ready to follow the signals.

Figure 6.2 Traffic signal countdown timer
(Source: ©GIZ/Le Son)

Figure 6.3. Green signal call button for pedestrians crossing the road
(Source: ©GIZ/Le Son)

6.1.2.2. Bicycle signal at large intersections

Large intersections always pose risks for cyclists, especially when they make left turns or cross over those intersections. Therefore, bicycle signals should be installed at the intersections to improve safety for cyclists. At the large intersections on major streets, where the conventional poles for traffic signals may not be sufficient to install bicycle signals, the mast arm poles can be used to ensure visibility for cyclists and all other road users.

6.1.2.3. Additional signal heads for bicycles

Figure 6.4. Near-sided bicycle signals improve the sight distance of bicycle users at intersections
(Source: ©GIZ/Le Son)

Near-sided bicycle signals are especially appropriate for large intersections where drivers have difficulty recognizing the traffic signal. It is preferred to provide a separate lane for bicycles entering the intersection at a curve, approaching in the opposite direction of sunlight, or waiting in bicycle boxes.

According to QCVN41-2019, it is possible to use the bicycle symbol on the bicycle control signals. This provision helps to reduce confusion. Bicycle-symbol lights can also be applied when organizing separate phases for bicycles. However, if the bicycle symbol is small because of the size of the signal, motorcyclists may misinterpret it as motorcycles. It may create confusion for motorcyclists. The size of the signal heads should be determined by the positions and distance from the bicycles' waiting positions.

In addition, it is recommended to use the size of a light face with a diameter of 300 mm or more in the following cases:

- The signal heads are placed at a distance of at least 45 m from the stop line.
- The signal heads are located from 35 m to 45 m from the stop line and no supplemental traffic lights on upright poles.
- The signal heads are arranged in the opposite direction of the sunlight, which can cause glare for drivers.
- The signal heads with a bicycle symbol on the light.

Figure 6.5. The light surface shows the bicycles symbol

(Source: ©GIZ/Le Son)

6.1.2.4. Placement for installation of bicycle signal heads

When necessary, it is possible to design a push-button that can be used for both bicyclists and pedestrians. The buttons need to be located conveniently for the bicyclists to operate without dismounting while continuing their travel forward.

6.1.3. Push button for bicycle crossing

- The bicycle signal head shall face the direction of the bicyclists. In the case where the straight and turning phases are separated, it is necessary to use the arrow-shaped light to indicate the direction of travel.
- When a signal head is arranged on a pole placed on the roadside, the installation height should be in the range of 1.7 m to 2.8 m, and the distance from the light head to the edge of the roadway is from 0.5 m to 2 m.
- When the bicycle signal head is arranged on the mast arm pole, the installation height should be in the range of 5.2 m to 7.8 m.

6.1.4. Warning lights

The warning signal light is a yellow light that flashes continuously, activated by the user or automatically through its motion sensor system when a bicyclist crosses the intersection. Warning signals help to raise the attention of motorcyclists with the presence of bicyclists at unlit intersections and/or crosswalks.

Locations required to install warning lights:

- Intersections with no traffic signals.
- Crosswalks is the place, where bicyclists and pedestrians cross streets, such as the mid-block crossings.
- Dangerous intersections with frequent traffic collisions among bicycles, pedestrians, and motor vehicles.
- Warning lights are placed on the side of the roads or islands for bicyclists and pedestrians.

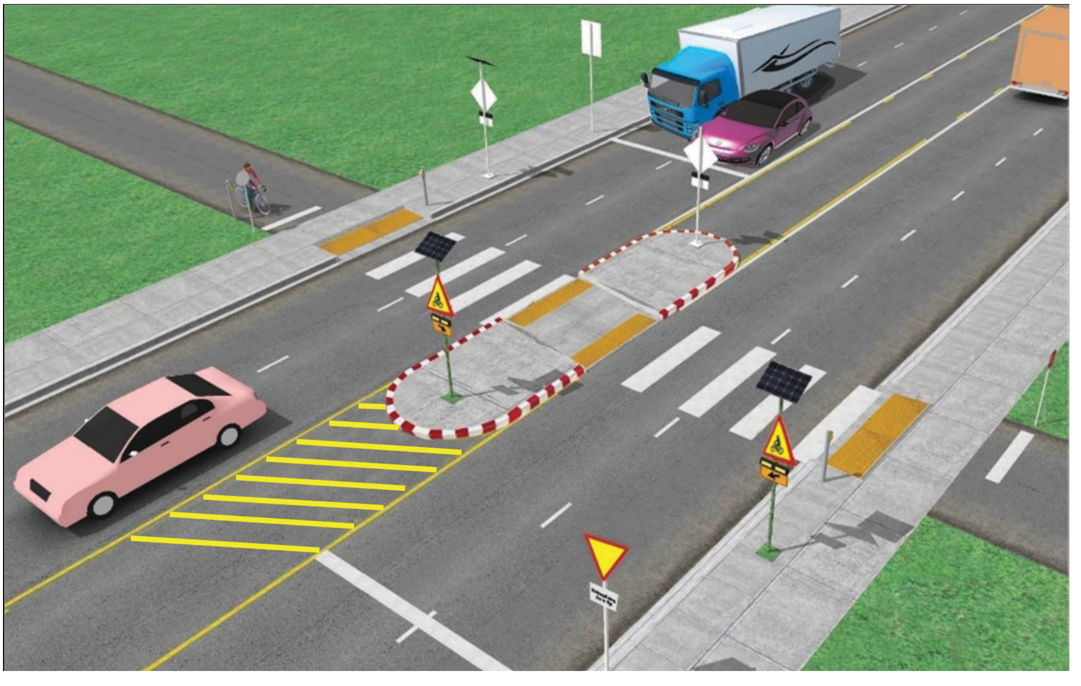


Figure 6.6. Warning signal lights using solar energy

(Source: ©GIZ/Le Son)

6.2. Traffic signs

6.2.1. Prohibition signs

The QCVN41-2019 regulation has provided adequate guidance on prohibition signs applied in traffic in general. In Table 6.2 below, some prohibition signs in QCVN41-2019 are applied when designing and building infrastructure for bicycles to improve traffic safety.

Table 6.2. Some prohibition signs are often used for bicycle traffic on the street

Name	Prohibition Signs	Code according to QCVN41-2019	Description
No parking.		P.131	Prohibit motor vehicle parking, combined with supplemental signs. The paint color on the curb can be used to identify no parking.
No motor vehicle.		P.105	Placed at the beginning of a separate bicycle lane to prevent motor vehicles from entering. It can be combined with the supplemental sign "Dedicated Road for non-motorised transportation means" The sign " bicycles only", and sign R.412h can also be used to replace this.
No bicycle or wrong way warning for bicycles.		P.110a	Placed on the roads where bicycles are prohibited, including e-bikes.
Speed limit signs by zone.		R.E.9D	This sign displays the maximum speed that motorised vehicles can travel. *(Note: the value 30 in the picture is for reference only).*

6.2.2. Danger and warning signs

The warning sign system specified in QCVN41-2019 is relatively adequate. Table 6.3 below will detail the application of warning signs in the design and construction of bicycle infrastructure.

Table 6.3. Types of warning signs to pay attention to

No	Warning signs	Application notes
1	W.203. Narrow road warning sign with bicycles 	Sign W.203 is placed in front of narrow bicycle paths to warn bicyclists to slow down. It should be combined with a supplemental sign that displays "narrow bicycle path". This sign should not be used on dedicated bicycle lanes next to motor vehicle lanes as it can be misleading. If a separate warning for bicyclists is required, a sub-sign with words only could be installed.
2	W.219. Dangerous downhill sign for cycling 	Sign W.219 warns of dangerous slopes for cycling combined with the side sign "dangerous steep bicycle paths”. Because bicycles are much lighter than motor vehicles, bicycle wheels are not designed to adapt to high speeds. As a result, some ramps may be safe for motor vehicles but dangerous for bicyclists. At the same time, this sign can also be placed on downhill bicycle trails. Bikeways with a slope of more than 5% need to place this sign at the beginning of the ramp.
3	W.266. Bicycle users crossing 	Use this sign on motorways to warn where bicycle paths cross them. When visibility is sufficient, the sign is placed right at the intersection. When there is not enough visibility, it is necessary to put a sign in front of the intersection at least 50m in advance to warn.
4	W.221. Hump or ramp 	W.221 This sign warns that the upcoming road section with uneven road surface such as speed bumps, speed humps, raised crossings...

Table 6.3. Types of warning signs to pay attention to *(cont.)*

No	Warning signs	Application notes
5	W.233. Warning 	To warn road users about the present of bicycles/ bicyclists. It is required to use this sign to warn the present of bicycles/bicyclists or inform road users on shared streets. It can be used in combination with an additional sign "Attention to bicyclists".
6	W.208. Give way 	Placed on bicycle paths when crossing other roads to warn bicyclists to give way to vehicles on the main road crossing.

6.2.3. Regulatory signs

The effective command signs for bicycles regulated by QCVN41-2019 include the following signs:

Table 6.4. Regulatory signs

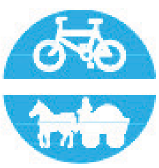
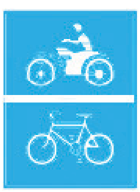
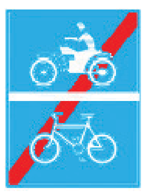
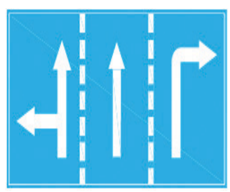
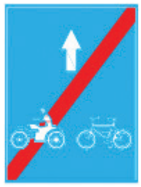
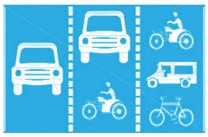
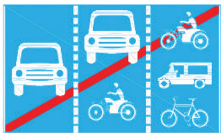
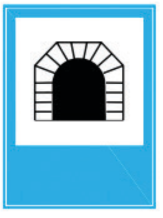
 R.122 STOP	 R.301 (a,b,c,d,e,f,g,h) Straight ahead	 R.302 (a,b,c) Keep right	 R.303 Roundabout
 R.304. Mix-use lane for non-motorised transportation means	 R.403f Bicycles and motorcycles only	 R.404f End of bicycles and motorcycles only	 R.411 Direction in each lane must follow

Table 6.4. Regulatory signs *(cont.)*

			
R.412g Bicycle and motorcycle lane	R.412h Bicycle lane	R.412o End of bicycle and motorcycle lane	R.412p End of bicycle lane
			
R.415a Separated lanes by vehicle types	R.415b End of a separated lane by vehicle types	R.420 Start of a residential area	R.421 End of a residential area
			
	R.E,11a; R.E,11b Start and end of the tunnel		

6.2.4. Informational signs

Informational signs are used to indicate directions to ensure safety. Sign boards are square and rectangular in shape. The signs have a blue background, white drawings, and texts. The drawings and texts are black if the background is white, except for some signposts different from this regulation as stated in QCVN41-2019. In addition to general signs, bicycle paths can use small-sized "wayfinding" signs of their specific design and are often placed in separate bicycle lanes or internal roads in residential areas, tourist areas, etc. Bicycle-specific signs are covered in Section 6.3.

6.3. Wayfinding

Wayfinding is one of the utilities that help bicyclists make their journey easier. In the current regulation QCVN41-2019 on traffic signs, there are no specific regulations on this type of sign. This Guideline, which recommends the application of three types of road signs, is detailed in the following sections. The symbols on these signs align with the regulations in QCVN41-2019; however, their colors, sizes, and materials of them can be adjusted to the characteristics of their surroundings.

6.3.1. Bicycle lane's name signs

Purpose: To help road users (pedestrians, bicyclists, motorcyclists, car drivers) to be aware of the existence of the bicycle routes they are traveling on or nearby.

Content: The names of the routes, destinations, distances, and traveling time (and route maps, occasionally) are generally included, while arrows are not included.

The bicycle lane name signs should be installed with intervals of 400 m to 800 m or 2 to 3 blocks.

Figure 6.7. Name of lane signs
(Source: Nguyen Thanh Tu)

6.3.2. Direction signs

Figure 6.8. Direction signs
(Source: Nguyen Thanh Tu)

Purpose: To indicate directions to destinations for bicyclists. Signs are placed at turns when bicycles change directions from one direction/street to the other.

Content: Directional signs include the following information: (1) An Arrow indicating the direction, (2) A bicycle pictures, (3) A destination name, (4) Distance from the location of the sign to the destination.

Specifications: Color: Green background, white border, white text, and drawings; Position: On roadside poles, the surface of which is perpendicular to the direction of the bicycle.

Location: In front of junctions and intersections where the direction of bicycle lanes change.

6.3.3. Multi direction signs

Purpose: To mark a turning point where there are two or more bicycle routes ahead; To inform the directions of destinations.

Content: Destinations, arrows, and travel distances are generally included. Estimated travel times can be added.

Destinations on decision signpost are:

Figure 6.9. Multi direction signs

(Source: Nguyen Thanh Tu)

- Dedicated bicycle routes, railway stations, intercity bus stations, urban public transport stations, pedestrian bridges, pedestrian tunnels, etc.
- Markets, shopping malls, commercial streets, etc.

- Schools, hospitals/ medical clinics, community houses, civic/administrative buildings, etc.
- Squares, parks, gardens, pedestrian streets, etc., and other public places.
- Popular spiritual and religious sites.
- Parking areas for public and shared bicycles.

A sign should not be displayed over three destinations. If the travel distance to a destination is long, it is necessary to put up repeating signposts along the bicycle route; the destination names listed on these signs must be consistent. Names of the nearest destinations need to place be at the top row(s) while further destinations are placed in the subsequent row(s) on the sign. Signs located on long bicycle routes should include names of intermediate destinations only. It is not required to list all the destinations on the same sign.

It is recommended to classify destinations by service levels and to put their names on signs following this principle: names of destinations display on a sign at a distance of 2-3 km ahead if these places are public buildings at the city level; at a distance of 0.5-1 km ahead if these places are at local district level; at a distance of 0.5 km ahead if these places are at the neighborhood level.

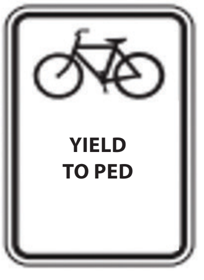
Location: In front of junctions and intersections where bicycle lanes must cross each other.

Figure 6.10. Illustrations on how to place bicycle wayfinding signpost
(Source: Nguyen Thanh Tu)

6.4. Additional panels or supplemental plate

Additional panels in QCVN41 – 2019 are often combined with the main signs for explanation, except for sign S.507 "Turn direction" which is used independently. Supplemental plate or additional panels are rectangular or square in shape. Signs colored with a white background, black drawings, and texts, or with a blue background, white texts. With the signs used for bicycle control, because QCVN41-2019 does not have a full sign for bicycles, it can be combined a S.509 supplemental plate with the main sign.

Table 6.5. Examples for additional panels S.509

S.509: Use the walk signal	S.509: Bicyclists give way to pedestrians	S.509: Separated bicycle and pedestrian lanes
Supplemental signs that say "Bicyclists push the crosswalk button" are used when bicycles cross the road with pedestrian lights. This sign should be placed at the position of the button. It can be combined with the bicycle image above the text.	S.509 is used when bicyclists are required to cross streets or share infrastructure with pedestrians but must yield to pedestrians. Additional signs with the words "give way to pedestrians" combined with the image of a bicycle above the text.	S.509 “bicycles on the left” may be placed in sections of the road shared by both pedestrians and bicyclists. The logos on the sign are subject to change.
		

6.5. Placement of signs

In case the sign is placed on poles (can be placed on lighting poles or electricity poles), the distance from the outer edge of a sign in the horizontal direction from the edge of the roadway or bicycle lane should be between 0.5 and 1.7 m. If there is no curb or pavement, or obstructed visibility, or in particular cases, horizontal adjustment is allowed, but the sign edge on the side of the road must not overlap the edge of the roadway and away from the edge of the roadway no more than 3.5 m.

The height of a sign from the bottom edge of the sign to the road surface is 1.8 m for roads outside densely populated areas and 2.0 m for roads in densely populated areas. If design to install a sign above a bicycle lane, should ensure a minimum vertical clearance of 2.2 m–2.5 m.

6.6. Road markings

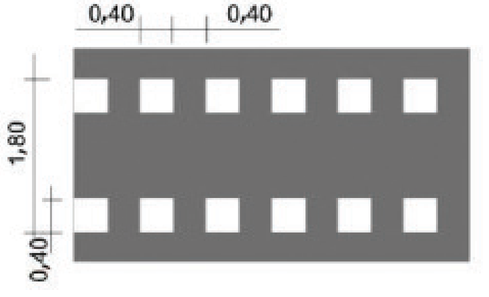
Table 6.6. Classification of road markings used in bicycle traffic organization according to QCVN41-2019

Marking 7.4. Crossing marking for bicycles

Meaning: To identify places for cyclists crossing motor vehicle lanes. At intersections without traffic controllers and traffic signals, bicyclists must give way to motorized vehicles crossing bicycle lanes.

The markings are as follows:

Two white parallel dotted lines of the same width of 40 cm, the length of the broken line is 40 cm, and the interval is 40 cm. Two external edges of two lines are 1.8 m from each other. This marking specifies a place for cyclists crossing at intersections. Where there are no traffic lights, bicyclists must give way to motorized vehicles.



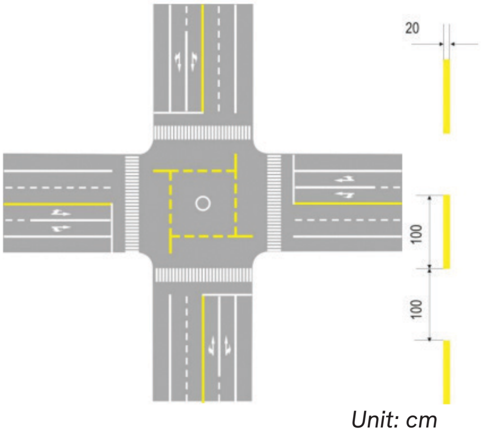
Unit: m

Marking 7.5: Non-motorized vehicle, and bicycles prohibition marking at the intersection

Meaning: The marking indicates the prohibited areas for non-motorized vehicles and bicycles when entering the intersection with traffic signals.

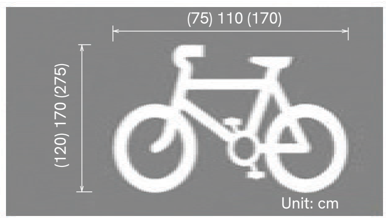
The markings are as follows:

Marking 7.5 consists of yellow single dash lines, width of 20 cm. The area where non-motorised transport modes cannot enter at the intersection is identified by yellow dashed lines. The end of each line is a solid yellow line of the same width of 20 cm as the dashed part.



Unit: cm

Table 6.6. Classification of road markings used in bicycle traffic organization according to QCVN41-2019 *(cont.)*

Marking 9.5: Indicated words, numbers, or colors on road surface Meaning: Used in combination with other types of indicators to improve the clarity for road users. *The markings are as follows:* Letters in white; height of 3.0 m applies to highways; 2.5 m applies to other types of roads; in urban areas with low-speed roads, the letter height of 1.6m can be used; distance between lines of letters or numbers along the road is 1.0 m - 1.5 m; lines width is 12 cm - 18 cm.	Dedicated bicycle lane 
Marking 9.6: Bicycle marking on the road surface Meaning: use for dedicated bicycle lanes. *The markings are as follows:* The white symbol illustrates a bicycle drawing. The sizes of drawings are determined by the width of bicycle lanes. The drawing width and height values include 75 cm x 120 cm; 110 cm x 170 cm, and 170 cm x 275 cm.	

This Guideline recommends using sepia color for all bicycle lanes in Viet Nam. If colored bicycle lanes are applied, it is necessary to use a consistent color throughout the bicycle infrastructure of the whole city to avoid confusion.

7 Supporting Facilities

7.1. Bicycle parking

Bicycle parking is the place equipped with suitable facilities to meet the needs of stopping, parking, and keeping bicycles. Bicycle parking areas should be combined with multi-transfer stations or multi-purpose public spaces.

7.1.1. Design guidelines

General requirements for location of bicycle parking areas include:

- Easily access from the street and separated from motor vehicle traffic.
- High visibility to ensure efficiency and security.
- Do not obstruct the traffic, block the sidewalks and negatively impact to the landscape.
- Do not impede access to bus stops and other public transport, building entrances, or service entries.
- When arranging a bicycle parking area on sidewalks, parking should not interfere or conflict with the parking operation of the curbside parking strip, if any. It is necessary to design a space of at least 60cm wide between the curbside parking strip and the bicycle parking area to prevent bicycles from colliding with opening car doors.
- When bicycles are parked in several rows, the space between two rows needs to be wide enough for bicyclists and the ease of taking out bicycles. The minimum distance is 1.0m.

7.1.2. Dimensions of the bicycle parking area

Sidewalks are a preferred space for bike parking, which increases access to services on either side of the street. However, when designing a bicycle parking area on the sidewalk, it should be noted: do not arrange a bicycle parking space to obstruct and cause unsafe conditions for pedestrians. Depending on the specific context, it is possible to design a bicycle parking space close to the curb or the walls of buildings along the street. Please refer to the dimensions of a sidewalk parking area in Figure 7.1 below.

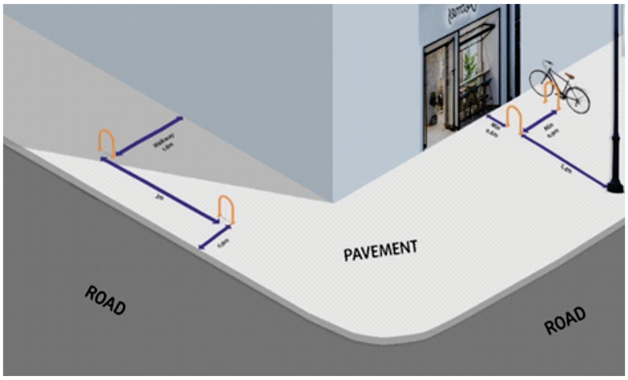


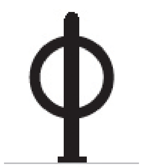
Figure 7.1. Illustrations of the minimum distance among bicycle racks and between the bicycle rack and the edge of the construction road

(Source: Nguyen Thanh Tu)

7.1.3. Rack design

A parking rack is one of the basic utilities to have when designing a bicycle parking area. Table 7.1 describes some common types of parking racks that can be applied in many cases.

Table 7.1. Typical types of racks

Types	Description
Type A 	- 02 pedestals. - Can be installed in a row. - Material: Steel pipe, diameter 5 cm. - Size: Height 80 cm - 90 cm, length 75 cm -100 cm, base width 15 cm - 20 cm, diameter 5 cm.
Type B 	- 1 pedestal. - Can be installed in a row. - Material: steel pipe, diameter 5 cm. - Size: Height 80 cm - 90 cm, width 45 cm.

To help increase the appeal of bicycle infrastructure, innovative designs can also be applied. Figures 7.2 and 7.3 below provide some references to parking rack designs that incorporate various urban amenities and street arts.

Figure 7.2. Bicycle racks with built-in seat utility
(Source: Nguyen Thanh Tu and authors – Hanoi University of Civil Engineering, 2021)

(Source: Thomas Quine, 2006)

(Source: Don O'Brien, 2012)

Figure 7.3. Bicycle racks designed to incorporate public works of art

7.2. Pavement design and drainage

When designing bicycle lanes and paths, surface material should be selected carefully to ensure safety, convenience for bicyclists, as well as long-lasting.

Bicycle pavement must comply with national standards on urban roads. In addition, when designing and constructing bicycle lanes and roads, it is necessary to ensure the quality of the surface. The surface should have anti-slip friction and quality materials to limit cracking and fading.

Colored asphalt or cement concrete may be used for bicycle lanes.

The road surface drainage systems help to drain rainwater and prevent it from settling on the surface after rain. In rainy cities, more attention should be paid to the designs of surface water drainage systems, ensuring sufficient drainage capacity.

When designing drainage systems for bicycle lanes and roads, the following points should be kept in mind:

- For a bicycle route: The designs of drainage systems for bicycle lanes should ensure the same requirements as the designs of urban roads, equivalent to grade 20 internal roads according to TCXDVN 104-2007. The water falling on the bicycle lanes surface would flow to the drainage ditches on both sides of the roads and in the direction of the drainage ditches or stormwater sluice gates if it is a culvert system. Bicycle lane pavements should have a horizontal slope to ensure that rainwater can quickly drain to the collection ditch. In some areas with low annual precipitation and light precipitation during rain and topographic and soil conditions permitting, it is possible to design a surface water drainage system with natural infiltration. Rainwater can be collected to the sides of the road and seeped into the groundwater system through grass, tree planting, or natural soil on both sides of the road. Figure 7.5 shows the channel system and surface water inlets for a bicycle route.
- For bicycle lanes close to both sides of a road: When bicycle lanes are arranged close to both sides of a road, the bicycle lanes and the road share the surface water drainage. It should be noted that when arranging bicycle lanes close to both sides of the road, the rainwater collectors can cause obstacles and dangers for bicyclists.

Figure 7.4. Drain and rainwater inlets for bicycle routes

(Source: Alta Planning + Design)

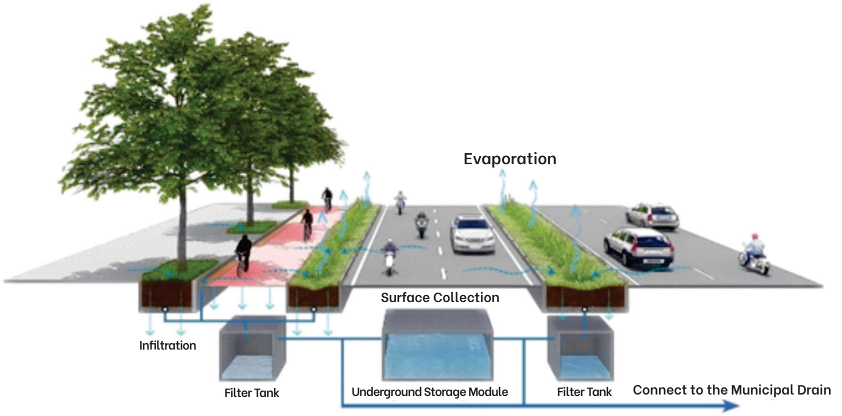


Figure 7.5. Illustration of green infrastructure solutions to support street drainage
(Source: WRI, 2021)

7.3. Lighting system design

Lighting systems improve visibility along roads, at intersections at night or in poorly lit conditions, such as in tunnels. The lighting system helps road users increase their visibility and thus helps them join the traffic more safely. In addition to safety issues, the good lighting system aims to enhance security and urban landscape. Lighting design should take into account energy consumption, light pollution, enhancing the sense of streets.

Installation requirements of lighting

Safe lighting standards for bicycle routes and lanes:

- Select and arrange lights in accordance with the regulation of street lighting in QCVN 07-7-2016.
- Illuminance: In compliance with regulations on the lighting of traffic works for pedestrians and bicycle paths according to QCVN 07-7-2016: for cycling paths in the central urban area, the average horizontal illuminance 20 lux, the minimum illuminance is 10 lux; for bicycle paths in other areas: the average horizontal illuminance 10 lux, the minimum illuminance 5 lux.
- Heights of lamps: The lighting system for bicycle lanes uses light poles with a height of 4.5 to 6 meters [3].
- Colors: It is recommended to use white light to provide better visibility at night.

(3) *Taking reference to (Lighting Design Guidance).*

- Additional notes: Lightning equipment that is energy efficient or uses renewable energy sources should be selected.

7.4. Tree shading design

Tree planting along the bicycle path is necessary as it provides the following benefits:

- Providing shade for bicyclists.
- Guiding and protecting bicycle lanes/paths.
- Preventing noise and dust caused by motor vehicles.
- Creating a landscape for the urban road network in general and bicycle lanes/paths in particular.

Trees planted in urban traffic infrastructure are classified into 3 main types: shaded trees, landscape trees, and shrubs (complying with Decree No. 64/2010/ND-CP). When designing tree planting, it is necessary to choose the types of trees that complies with the provisions of Circular 20/2005[4] of the Ministry of Construction and TCVN 9257:2012[5] on urban greenery and traffic.

Figure 7.6. Planting staggered green trees on both sides to create shade for bicycle lanes
(Source: WRI, 2021)

[4] *Circular 20/2005 of Ministry of Construction regarding Guidelines for Urban Forestry.*
[5] *National Standard TCVN 9257:2012 on Tree Planting in Urban Area - Design Standard.*

In order not to obstruct the visibility of road users, when planting trees for shading, it is necessary to choose the type of trees with a canopy height greater than 2.5 m from the road surface. When planting vegetations for landscape on the sidewalks and/or the central median at the approaches to intersections, ensure that not obstruct the line of sight. The total height of landscape vegetations should not be higher than 1.0 m.

Shade trees can be planted in two staggered rows on either side of a bicycle lane/ path to create shade for the bicycle lane throughout the day.

It is encouraged to use green trees to create a distinctive look to routes: trees need to be consistent throughout the routes, incorporating natural characteristics of the site to further improve the aesthetic of the landscape. In riverside or coastal areas, it is recommended that the trees' height exceeds 2.5 m to avoid obstructing the views.

7.5. Rest areas design

Rest areas are designed and planned along bicycle paths. The density and spacing of rest areas on the bicycle infrastructure network should ensure that bicyclists have a comfortable place to rest. The distance between two rest areas on a bicycle route is recommended between 3 and 5 km, which equates to 10 to 15 minutes of cycling.

Necessary facilities at the rest areas include seating and parking areas. In addition, other facilities can be added to increase the attractiveness and landscape, such as playgrounds for children, shaded trees, drinking fountains, walking paths, etc. Part of the parking strips along the road can be converted into temporary rest areas for bicycles, especially at high-density malls.

Figure 7.7. A rest area converted from part of the parking strip

(Source: Duong Quynh Nga and authors - Hanoi University of Civil Engineering, 2021)

7.6. Design to mitigate extreme weather conditions

Vietnam is a tropical monsoon country, with extreme climatic conditions affecting the safety and comfort of bicyclists such as heat, heavy rain, and frost. When designing and planning bicycle transport infrastructure, it is necessary to take supportive measures to overcome these climatic conditions to ensure a safe and comfortable infrastructure for users. The solutions to planning and building rest stops, planting trees to create shade, and building surface water drainage systems mentioned above are the solutions to overcome adverse climatic conditions to provide a quality, safe, and comfortable bicycle infrastructure for bicyclists.

7.7. Design with attention to bicycles of various sizes

Design bicycle infrastructure with attention to all user groups, especially bicycles equipped with kids' seats or cargos, wheelchairs for users with diverse abilities, the elderly and two or three wheels non-motorized transport modes are important requirements. A bicycle infrastructure that accommodates access to different types of non-motorized transport modes will appeal to users and help them get from the point of origin to their destination safely and conveniently. From there, encourage more people to choose bicycles as a means of transportation for daily trips and ensure equity in access to transport.

7.7.1. Design dimensions for bicycles with various sizes

Although the types of non-motorized transport modes for users with different abilities are diverse, the design of bicycle infrastructure should consider wheelchair users at the minimum. According to the existing regulations, QCVN 10:2014 BXD, the minimum horizontal distance of the entrances for wheelchair access to the bicycle infrastructure should not be less than 900 mm and the turning spaces should not be less than 1.4 m x 1.4 m.

7.7.2. Fixed bollards

In the case of using bollards to prevent motor vehicles, cars, and motorcycles from entering the bicycle infrastructure, attention should be paid to the design so that bicycles of different sizes, and wheelchairs for people with different abilities and the elderly are still accessible. The distance between bollards at the accessway is not less than 900 mm. In addition, based on the context, it is possible to study and apply different geometrical design solutions for barriers to achieve the goal of preventing motor vehicles while ensuring access and use of standard and non-standard bicycles.

7.7.3. Traffic signals

At intersections, traffic signals should be organized to support people with disabilities and the elderly. Solutions to improve safety include 5 to 10 seconds advance turning on the green signal for cyclists and disability people to give them leading intervals and help them enter the intersections earlier than other means of traffic.

Figure 7.8. Low-height stand
(Source: ©GIZ/Le Quynh Chi)

7.7.4. Bike parking area for bicycle with various sizes

Parking spaces for bicycles of various sizes must be prioritized and designed for easy access, sufficient parking space, and performing maneuvers. Some conveniences such as handrails, and low cargo lock racks can be added.

8 Other Considerations

Bicycles are always considered an important means of transport, so spatial planning and bicycle lane designs must be at the forefront of the design task. Designing bicycle infrastructure in new urban areas and around new buildings makes it easier to achieve the goals that urban transport brings to the communities: mobility, accessibility, safety, equality, environmental, health, economic, and livable. When designing, it is important to pay attention to the design criteria for bicycle infrastructure: (1) multi-purpose street designs and (2) contextual designs.

8.1. Multi-purpose streets

Multi-purpose street design, or complete street design, is a design in which a street performs multiple functions simultaneously to ensure multiple community goals. The benefits of designing a complete street are great because it is not only for traffic but also an important public space, a meeting point, and a point of attraction for many people, and creates jobs for everyone. There are some design principles presented below.

8.1.1. Ensure the full function of the street

The benefits of a street are expressed through the components that make up the street, such as carriageways, curbs, median, sidewalks, parking, landscaping, etc. Therefore, each specific street (street context) must determine the main function to design and arrange the components on the cross-section completely and scientifically to promote all functions and meet the traffic demand. In addition to the traffic function, the benefits of the street also come from spatial functions, creating a harmonious environmental space, creating a comfortable feeling for vehicle drivers, and reducing the level of monotony and dullness with a beautiful and orderly view, and increasing traffic safety. When the street project comes into operation, it will create conditions for connection inside and outside the area, creating space on both sides of the street for business, cultural, and social activities; thus, the benefits gained from the street for society are significant.

8.1.2. Ensure benefits of communities – people on both sides of the street

The street is different from the roadways outside the city where people inhabit both sides of the roadways. So how the people on both sides enjoy those benefits is an important objective. The complete streets are designed with multiple functions to create more jobs and promote business activities, daily activities, cultural exchanges, and community cohesion, thereby promoting economic and social development.

8.1.3. Maximize functions

Streets need "an appropriate dimension" for convenient way for everyone to use. Therefore, when planning, designing, constructing, and operating a street, it is necessary to consider the different usages of road users. Therefore, it is necessary to have a unified design idea suitable for all people who will use the street. On the other hand, in order to create streets with more functions, it is necessary to determine the economic-technical conditions of a street, the demand for use, consideration of local context, etc. to arrange the components. A complete street for all will create more travel options for people, especially bicyclists.

8.2. Contextual design

Depending on the function and type of urban road, bicycle infrastructures need to be designed accordingly.

On urban main streets, where motor vehicle speed is high, multiple vehicle lanes, and the roadbed is large, it is necessary to arrange bicycle lanes protected by physical separation, such as barriers, parking strips, vegetations green strip... Figure 8.1a presents a typical configuration for bicycle infrastructure on urban main streets where motor vehicle speeds are up to 50 km/h.

On congested streets, fewer vehicle lanes, slower speeds, smaller roadbed widths, a solution for creating dedicated bike lanes protected by physical barriers, and other similar physical dividers to save space while ensuring safe lanes for bicycles. Figure 8.1b presents a typical configuration for bicycle infrastructure on collector streets where motor vehicle speeds are up to 40 km/h.

In the inner streets, with low traffic and speed are below 30 km/h. Bicycle infrastructure solutions that share the road with motor vehicles such as mixed traffic roads, or dedicated bike lanes separated by painted lines can be applied. In this case, measures to reduce traffic speed, and enforcement of driving and parking on bicycle lanes should be taken to ensure that the bicycle lanes are always clear will be the key. Figure 8.1c shows a typical configuration for bicycle lanes on internal streets.

a)

b)

c)

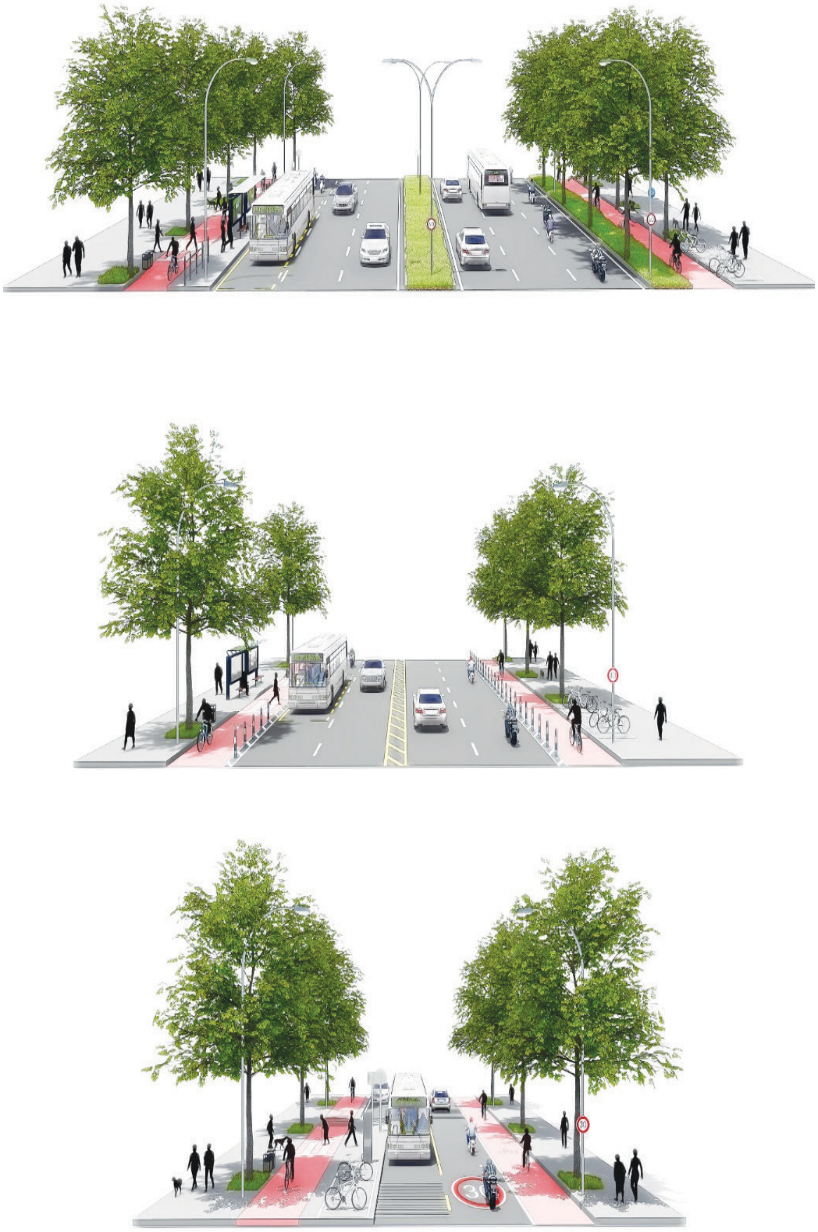


Figure 8.1. Typical Cross-sections with bicycle infrastructure

(a) Urban main streets, (b) Collector streets, (c) Internal streets

(Source: WRI, 2021)

A. Appendix

Development of Bicycle Infrastructure Project

A.1. Project phases

In essence, the order of implementation of an investment project to build bicycle infrastructure consists of 3 main phases as follows:

1. Phase 1 – Preparation: Engineering design and safety appraisal.

2. Phase 2 – Implementation: Infrastructure construction and equipment installation.

3. Phase 3 – Operation: Put to use; safety assessment and further adjustment.

Table A.1 below provides several indicators including, but not limited to, the measurement and management of the project as follows:

Table A.1. Indicators for measuring the efficiency and progress of bicycle infrastructure projects

No	Measure	Indicator
1	Number of bicycles.	Percentage of bicycles mode share at locations with bicycle infrastructure increased.
2	Using bicycles/walking on daily trips.	Percentage of bicyclists and pedestrians in comparison to other modes of transport on daily trips.
3	Using bicycles/walking on all trips.	Percentage of bicyclists and pedestrians in comparison to other modes of transport on all trips.
4	Amount of bicycle infrastructure for pedestrians and bicyclists.	Number of kilometers of bicycle lanes and other infrastructure for bicycle increased.
5	Amount of traffic accidents related to pedestrians and bicyclists.	The ratio of pedestrian / bicycle-related accidents on all trips.
6	Traffic network.	Project completion in phasing plan to establish a connective bicycle network.

A.2. Quick response strategies

A.2.1. Trial project

Testing solutions in the short term is a quick way to help urban traffic managers improve road safety for bicycles, pedestrians, and other non-motorized vehicles. For example, close a street in the short term to create a pedestrian and bicycle area. This strategy uses available standard materials such as bollards, installable speed bumps, traffic paints, signs, etc. to create short-term trial-use bicycle and pedestrian infrastructures. The goal of trial projects is to get feedback from the public and collect metrics that improve design quality. Trial projects can last hours or days.

A.2.2. Pilot project

A pilot project is a solution to apply design in the field to assess the impact and public reaction in order to help policymakers with more information to make decisions. Pilot projects are medium-term projects, which can be implemented in weeks, months to years. After piloting, projects can be adjusted and upgraded to long-term infrastructure construction projects. When implementing pilot projects, it is possible to use low-cost and movable materials such as bollards, traffic paint, and signs.

Pilot project for bicycle lanes in Hoi An City

Hoi An is a popular destination for Vietnamese and foreign tourists. It is an ideal location to develop bicycles as a mode of transportation due to its relatively small area, short travel distance, and easy access to many other locations.

In 2019, the Hoi An People's Committee approved the Hoi An Comprehensive Bicycle Transportation Development Plan. The plan was developed in collaboration with a team of project partners: GIZ, HealthBridge, WRI, and TUMI. Strategies for improving the safety and convenience of travel by bicycle for residents and visitors included four main components: identification of a bicycle network; establishment of a bicycle share scheme; bicycle lane implementation from the city center to An Bang beach; and training, communication, and capacity building.

The bicycle lanes connecting the city center and An Bang Beach were implemented along 2.5 km of Hai Ba Trung. This alignment was selected because it connects central Hoi An with An Bang Beach – two well-known areas in Hoi An and is a highly traveled route by residents and visitors.

Successes: The bicycle lane on Hai Ba Trung route, Hoi An is the first dedicated bicycle lane in the City and is a good example for other cities to refer to. These bicycle lanes are separated by painted road markings that combine traffic control solutions and signs to limit motor vehicle speeds to a level that is safe for bicycles. The five interchanges on the route are designed to improve bicycle safety with physical solutions such as deceleration paint lines, speed buffers, and elevated crosswalks for pedestrians and bicyclists.

Challenges: The project is implemented in the context that Vietnam and Hoi An do not have technical guidelines, technical standards, or national standards for bicycle infrastructure. With the technical support of national and international experts, the project has applied current standards and regulations, combined with successful practices of cities around the world to develop short-term use bicycle lanes. Even though the lanes are separated by painted markings, they are still often blocked by motor vehicles; in some cases, motor vehicles even parked in the lane, causing risks to bicyclists.

Lessons Learned: The application of bicycle lanes separated by painted markings is an option that requires a lot of effort in enforcement, when motor vehicles enter the bicycle lane or encroach on the bicycle lane to park. The involvement of all stakeholders, especially the traffic police officers in this case, is extremely important to ensure that bicycle lanes are respected at all times and that bicyclists have a safe infrastructure to move around.

Policy recommendations for the development of bicycle infrastructure in the context of Vietnam:

- The Ministry of Construction and the Ministry of Transport should develop policies at the national level to orient and encourage cities to have a comprehensive and long-term plan for sustainable transport development, especially bicycles.

Figure A.2. Enforcement measures to target bicycle lane compliance in Hoi An
(Source: GIZ TUMI Project Hoi An)

Figure A.1. Dedicated bicycle lanes separated by markings on the Hai Ba Trung route, Hoi An
(Source: GIZ TUMI Project Hoi An)

- The Ministry of Construction should make bicycle traffic development an important assessment target for urban development shortly.
- The Ministry of Construction should prepare technical documentation, standards, and national regulations on bicycle infrastructure, to support localities in implementing the development of bicycle infrastructure synchronously and consistently nationwide soon.
- Urban governments should proactively propose projects and implement overall strategies from capacity building, design, participation, communication, etc., according to pilot project models, short-term or long-term, in accordance with the current conditions and capacity of the locality to gradually improve bicycle safety, towards the development of a quality bicycle infrastructure system.

B. Appendix
Project Evaluation Tools

B.1. User surveys

User surveys are surveys with the objective of gathering information about the needs and expectations of road users with existing bicycle infrastructure, helping designers, policymakers, and other stakeholders make appropriate improvement decisions.

Quantitative data collection methods with large sample sizes should be employed. The survey questions were prepared in a multiple-choice response format. Table B.1 presents some reference research questions.

Table B.1. Research questions for surveying users

Criteria	Definition
Coherence/Connectivity	Depicted by the continuity of the route, the destinations are connected logically and navigated clearly and seamlessly.
Directness	Bicycle routes that connect desired destinations in the shortest or fastest time possible while taking into account cost and travel time.
Attractiveness	Bicycle infrastructure is designed, equipped, and illuminated to be attractive, aesthetically pleasing, clean, and safe for bicyclists.
Road Safety	Bicycle infrastructure ensures traffic safety for all road users.
Comfort/Convenience	Bicycle infrastructure that allows bicycles to travel smoothly (i.e. flat road surface, favorable geometry for human strength).
Spatial Integration	Bicycle infrastructure is integrated with other types of transport and is suitable for contexts such as connections to public transport, urban centers, sightseeing, and scenic spots.
Experience	Are users excited or stressed when using bicycle infrastructure.
Social Economic Value	Bicycle infrastructure is considered to bring economic benefits to the community such as commercial areas, residential areas, and industrial zones.

B.2. Behavior surveys

Observations on infrastructure conditions, road users' activity, and responses are also important. This study aims to show the problems that road users are facing when using bicycle infrastructure. Activity observations include:

- Locations where motor vehicles accelerate their speed;
- Points of conflict between bicycles and other means of transport;
- Points of violation of road traffic laws such as running red lights, going in the opposite direction, entering the bicycle lane, parking in the bicycle lane, and using dangerous shortcuts.

The above observations help to point out the inadequacies in infrastructure, which are the causes of unsafe traffic behaviors for vehicles, especially pedestrians and bicycles so that design measures can be taken to improve.

B.3. Bicycle counts

Bicycle traffic counting can be done manually or automatically with the assistance of traffic cameras and artificial intelligence applications. To understand the demand and status of bicycle use in the city, bicycle traffic should be counted at least once a year for a period of several days. If possible, counting bicycle traffic continuously over a long period of time will help in planning and developing bicycle networks for cities.

B.4. Using collected data to improve bicycle infrastructures

The above studies will provide useful information to help designers find the causes and propose solutions to improve the bicycle infrastructure promptly. Table B.2 below suggests corresponding considerations.

Table B.2. Recommendations for improving the quality of bicycle infrastructure

Observable bicyclist behaviors	Questions about the cause	Possible improvement solutions
Frequently ride/drive in the opposite direction on the street or on the sidewalk to take shortcuts.	Can go in the opposite direction, taking shortcuts to help to reduce the desired journey length for bicycle riders?	Check the directness of the route.
	Can such cycling help bicyclists save energy uphill?	Add more lanes to help shorten the bicycle's journey.

Table B.2. Recommendations for improving the quality of bicycle infrastructure *(cont.)*

Observable bicyclist behaviors	Questions about the cause	Possible improvement solutions
Running a red light.	Are red light bulbs difficult to see because of visibility, glare from sunlight, or because of mixing in advertising headlights?	- Increase the brightness or size of bulbs. - Replace old bulbs with new ones. - Relocate electronic advertising billboards.
	Do cars ahead obstruct the view of bicyclists?	- Add repeating light nearby.
	Are you confused by motorcycle and bicycle signal lights?	- Dedicated bicycle signal lights. - Make the bicycle signal light face more distinguishable.
	Misunderstanding or not observing the supplemental signs?	- Check the location of the additional sign. - Check the content of the sign.
	Does the red-light signal last too long?	- Adjusted accordingly.
	Is the weather too hot?	- Solutions for shading.
Not using bicycle lane/ section.	Are you not aware of the bicycle lane/section?	- Check the system of signs and painted markings. - Use colored road surfaces for bicycle lanes.
	Are there any bicycle lanes or road sections that are not appropriate for bicyclists?	- Check the road surface's level, as well as any curbs or obstructions that make the bicycle difficult to handle or become unsafe.
	Is the bicycle lane occupied by other vehicles or used for other purposes?	- Strengthening penalties and enforcement for acts of encroaching on bicycle lanes.
	Are the bicycle lanes hazardous for traffic, unclean, polluting, or dangerous?	- Ensure the clean, well-ventilated environment.
The situation of bicyclists using motorized lanes to ride.	Are there no lanes, dedicated lanes, or prioritized bicycle lanes?	- Additional bicycle lanes/ routes.
	Is there a lane that is a part of the bicycle path but is not continuous?	- Check the continuity of the bicycle infrastructure.

Table B.2. Recommendations for improving the quality of bicycle infrastructure *(cont.)*

Observable bicyclist behaviors	Questions about the cause	Possible improvement solutions
Do not use bicycle facilities such as overpasses, underpasses, walkways, and signal buttons for pedestrians crossing the street.	Is the design inappropriate for the location? Is the slope of the overpass too steep? No bike ramps? No crossing buttons for walkers and bicyclists? Are the buttons broken? Are bicyclists not aware of the button's existence?	- Check, repair, or supplement missing or damaged equipment. - Additional signs or instructions for use (if necessary).
	Do the infrastructure lack aesthetics and hygiene?	- Ensure hygiene, embellishment, and aesthetics.
Going downhill at high speed or walking the bicycle.	Large vertical slope and long slope?	- Improve suitable vertical slope.
Having to walk the bicycle uphill.	Large vertical slope and long slope?	- Improve suitable vertical slope.
Bad pavement affects bicyclists.	Is the road surface concave and slippery? Or are there tree roots on the road surface?	- Rework the road surface by increasing the roughness and cleaning it.
Status of manhole cover, a water collection station.	Is it dangerous for bicycle users? Is there an appropriate design?	- Rearrange, or replace broken, damaged, or lost manhole covers.
Do bicyclists have encroached into motorized lanes due to the road's poor drainage?	Is there water stagnation on the road surface as a result of a lack of drainage, or is the drainage system blocked?	- Improve drainage system. - Supplement drainage system.
	Is the road surface riddled with deep potholes and prone to water stagnation?	- Maintain pavement.
The situation of collision when the car door opens.	Is the bicycle lane width not enough? Parking lanes do not have a buffer zone.	- Create a buffer zone, widen the bicycle path. - Create a buffer zone large enough.
Status of bicyclist passing through a major roundabout.	Is there no bicycle path across the shorter node?	- Protection of bicyclists and pedestrians by controlled signal light crossing large roundabouts with multiple lanes. - Restrict motorized vehicle speed. - Arrange bicycles to avoid passing through large roundabouts, guiding them through the nodes more safely.

Table B.2. Recommendations for improving the quality of bicycle infrastructure *(cont.)*

Observable bicyclist behaviors	Questions about the cause	Possible improvement solutions
	Are there no dedicated bicycle lanes surrounding the node?	- Conduct traffic safety inspections and make bicycle lanes more visible to bicyclists traveling across the nodes.
Feeling unsafe on the road due to heavy/high-speed traffic.	Are the bicycle lanes not well-protected or separated? Is the bicycle lane too small?	- Limit the speed of motor vehicles close to the bicycle lane. - Separation of bicycle lanes combined with a hard divider. - Widen the bicycle lane when the speed of the adjacent motor vehicle is high.
	Are drivers unable to perceive bicycle lanes or distinguish the prioritized bicycle lanes?	- Clarifying bicycle lanes with marking signs, symbols, and colored pavement.
Not daring to ride a bicycle at night.	Is the road too vacant and too dark because there is no night lighting system?	- Supplement lighting, reflective or luminescent systems.
	Are there many hidden corners?	- Supplement lighting, security cameras, clearing bushes.
	The security condition of the bicycle route is not good.	- Strengthen police patrols. - Create a safer bicycle route. - Recommendations for bicyclists.
Feeling disoriented when reaching a particular place.	Lack of proper direction system.	- Supplement a unified sign system, with easy-to-observe direction signs.
	Does the bicycle route lose its continuity?	- Addition to ensuring continuity of bicycle route.
Feeling unsafe when there is no place to park the bicycle or lock the bicycle.	Is there no secured bicycle parking?	- Building a rest and parking area for bicycles.
	Are there any devices for bicyclist to lock their bikes?	- Supplement a device to help bicyclists lock the bikes. - Supplement security cameras in the bicycle parking area.
	Is there no bicycle paid parking?	- Provide automatically or manually bicycle paid parking services.

References

US Department of Transportation. (2004). Signalized Intersections: Informational Guide. Federal Highway Administration.

AASHTO. (1993). Guide for the Development of Bicycle Facilities. U.S. Department of Transportation.

APBP. (2015). Essentials of Bike Parking. Association of Pedestrian and Bicycle Professionals. Retrieved from https://www.apbp.org/assets/docs/EssentialsofBikeParking_FINA.pdf

Bikeway Selection Guide. (February 2019). Federal Highway Administration.

Complete Streets Design Guide. (2017). State of New Jersey.

Congiu et al. (2008). Child Pedestrian Factors associated with the ability to cross roads safely and development of a training package. Monash University Accident Research Centre.

Contra Costa County. (June 2020). Iron Horse Regional Trail: Active Transportation Corridor Study. California, USA. Retrieved from https://www.contracosta.ca.gov/DocumentCenter/View/67559/200609IHT-ATStudy-Final?bidId=

Cycling Embassy of Denmark. (2018). Cycling – Danish Solutions. Retrieved from https://cyclingsolutions.info/

(December 2014). Cycling Safety Panel Final Report and Recommendations: Safer Journeys for People Who Cycle . Cycling Safety Panel.

DanZhou et al. (2015). Estimating Capacity of Bicycle Path on Urban Roads in Hangzhou, China. 94th Annual Meeting of The Transportation Research Board of New Jersey. Washington D.C.: National Research Council.

DanZhou et al. (2015). Estimating Capacity of Bicycle Path on Urban Roads in Hangzhou, China. 94th Annual Meeting of The Transportation Research Board of New Jersey. Washington D.C.: National Research Council.

David L.Harkey et al. (2006). Observation Analysis of Pedestrian, Bicyclist, and Motorist behaviors at Roundabouts in the United States. Transportation Research Records No. 1982 (pp. 155-165). Washington, D.C.: Transportation Research Board of the National Academies.

Dean Taylor and W.Jeffrey Davis. (1999). Review of Basic Research in Bicycle Traffic Science, Traffic Operations, and Facility Design. Journal of Transportation Research Board, 1674, 102-110.

Denver Bikeway Design Guidelines. (n.d.).

Department of Planning, Transport and Infrastructure Safety and Service Division. (2015).

Guide to Bikeway Pavement Design - Construction & Maintenance for South Australia. South Australia, Australia: Government of South Australia.

Dutch Bicycling Council. (2006). Continuous and integral: The Cycling Policies of Groningen and other European Cities. The Netherlands: Fietsberaad.

Electrotechnics Corporation. (2021). https://elteccorp.com/. (a.k.a.) "HAWK" = High Intensity Activated Crosswalk. Retrieved from https://elteccorp.com/products/pedestrian-crossing-systems/hawk-hybrid-pedestrian-crosswalk/

ETSC. (1999). Safety of pedestrians and cyclists in urban areas . Brussel, Belgium: European Transport Safety Council.

FHWA. (2012). Bicycle Road Safety Audit Guidelines and Prompt Lists. Washington, D.C, USA: Office of Safety, Federal Highway Administration.

FHWA. (2015). Separated Bike Lane Planning and Design Guide. Federal Highway Administration.

Fitzpatrick et al. (2001). Design Factors That Affect Driver Speed in Suburban Streets. Journal of the Transportation Research Board, 1751 (1), 18-25. doi:https://doi.org/10.3141/1751-03

Geertman, S. (2007). The Self-Organizing City in Vietnam - Processes of Change and Transformation in Housing in Hanoi. Bouwstenen Publicatieburo.

Global Design Cities Initiative. (n.d.). Lighting Design Guidance. Retrieved from http://globaldesigningcities.org/publication/global-street-design-guide/utilities-and-infrastructure/lighting-and-technology/lighting-design-guidance/

Gourou, P. (1936). Người nông dân Châu thổ Bắc kỳ: Nghiên cứu địa lý nhân văn. (N. K. Đạm, Trans.). Nhà xuất bản Trẻ, xuất bản năm 2015.

Guideline: Selection and Design of Cycle Tracks. (October, 2019). Queensland, Australia: Queensland Government.

Hai, L. D. (1993). Bicycle traffic in Vietnamese cities. Hanoi: Thesis of Associate Doctor of Science and Technology - National University of Civil Engineering.

Isaksson-Hellman. (2012). A study of bicycle and passenger car collisions based on insurance claims data. Ann Adv Automot Med, 3-12.

Jensen, S. (1999). Pedestrian safety in Denmark. Transportation Research Record, 1674, 61-9.

Lê Huy Trí. (2019). Tình hình, đặc điểm và nguyên nhân tai nạn giao thông đường bộ tại Việt Nam. Tạp chí GTVT số đặc biệt.

Leccese, F., & Tuoni, G. (2005). Lighting Requirements and other Energy and Safety Aspects in Urban Areas. 10th European Lighting Conference on Lighting for humans. Berlin, Germany. Retrieved from http://www.researchgate.net/publication/259260880_Lighting_Requirements_and_other_Energy_and_Safety_Aspects_in_Urban_Areas

(n.d.). Lighting Design Guidance. New York, USA: Global Designing Cities Initiative.

Liu et al. (1993). Operational Analysis of Bicycle Interchanges in Beijing, China. Transportation Research Board (pp. 18-21). Washington. D.C.: National Research Council.

Liu et al. (1993). Operational Analysis of Bicycle Interchanges in Beijing, China. Transportation Research Board (pp. 18-21). Washington. D.C.: National Research Council.

Lưu Đức Hải. (1993). Giao thông xe đạp trong các thành phố của Việt Nam. Hà Nội: Luận án Phó Tiến sỹ Khoa học Kỹ thuật - Trường Đại học Xây dựng.

Medina, L., & Hernández, S. (2008). Manual for the design of cyclepaths in Catalonia. Generalitat de Catalunya.

Mikhail et al. (2016). Transport Systems of Russian Cities - Ongoing Transformation. Springer.

MOHURD. (2012). Code for design of urban road engineering. China: Ministry of Housing and Urban-Rural Development of China.

NACTO. (2011). Urban Bikeway Design Guide - First Edition. National Association of City Transportation Officials .

NACTO. (2014). Urban Bikeway Design Guide - Second Edition. National Association of City Transportation Officials .

National Association of City Transportation Officials (NACTO). (2014). Interim Design Strategies: Urban Street Design Guide (3rd ed). Washington D.C: Island Press.

National Association of City Transportation Officials (NACTO). (2019). Don't Give Up at the Intersection. Retrieved from https://nacto.org/publication/dont-give-up-at-the-intersection/

Nghiêm et al. (2017). Effect of surface roughness on cyclist's handlebar controllability: an insight into bicycle safety. Advances in Transportation Studies, 75-92.

Nguyễn Khải. (1982). Thiết kế đường đô thị tập 1. Nhà xuất bản Đại học và Trung học chuyên nghiệp.

Nguyen, K. (1982). Thiết kế đường đô thị tập 1. Nhà xuất bản Đại học và Trung học chuyên nghiệp.

Pierre Clement, Emmanuel Cerise, Dominique Delaunay, Ines Gaulis, Lisa Ros. (2005). Hanoi - the cycle of metamorphoses. (N. Lancret, Ed.) Science and Technics Publishing House.

Schramm, AmyJ and Rakotonirainy, Andry. (2010). The effect of traffic lane widths on the safety of cyclists in urban areas. Journal of the Australasian College of Road Safety, 12 (2), 43-49. Retrieved from https://www.cyclingresourcecentre.org.au/images/uploads/post/attachment/RS094046.pdf

Sign Up for the Bike: Design Manual for a Cycle-Friendly Infrastructure . (1993). The Netherlands: Centre for Research and Contract Standardization in Civil and Traffic Engineering.

Special Report 2009: Highway Capacity Manual. (1995). 3rd Transportation Research Board (pp. 38-44). Washington. D.C.: National Research Council.

Thomas R and Janina. (2016). Turning accidents between cars and trucks and cyclists driving straight ahead. Transportation Research Procedia, 1946-1954.

Thuc, T., Neefjes, K., Huong, T. T., & Tuong, L. N. (2015). Summary for Policymakers: Vietnam

Special Report on Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation (1st ed). Vietnam Publishing house of natural resource, environment and cartography.

TUMI. (December 2020). CUENCA 2020 Bicycle Intersection PEER review. TUMI and the Federal Ministry for Economic Cooperation and Development.

US Department of Transportation. (2016). Guidebook for Developing Pedestrian and Bicycle Performance measures. Federal Highway Administration.

US Department ofTransportation. (2010). Roundabouts: An Informational Guide. NCHRP Report 672, Federal Highway Administration.

Vis, A. (1994). Design and implementation of safe cycle provision. Leidschendam, SWOV.

Vũ Anh Tuấn. (2018). Vai trò của xe máy trong hiện tại và tương lai ở Việt Nam.

Wei.H. et al. (1997). Models for Estimating Traffic Capacity on Urban Bicycle Lanes. Annual Meeting of the Transportation Research Board. Washington, D.C.: National Research Council.

Wei.H. et al. (1997). Models for Estimating Traffic Capacity on Urban Bicycle Lanes. Annual Meeting of the Transportation Research Board. Washington, D.C.: National Research Council.

Wellbeing, W. f. (n.d.). A guide to Inclusive Cycling - 4th Edition/ 2020. Retrieved August 2021, from http://wheelsforwellbeing.org.uk/campaigning/guide

WHO. (2018). Báo cáo hiện trạng toàn cầu về an toàn giao thông đường bộ.

Winttink et al. (1994). Stimulation of cycling in a safeway. Annual Meeting Transportation Research Board. Washington D.C: National Research Council.

Xingchen Yan et al. (2018). Recommended Widths for Separated Bicycle Lane Considering Abreast Riding and Overtaking. Journal of Sustainability, Vol.10, 3127; doi:10.3390/su10093127.

Technical Guideline
FOR BICYCLE INFRASTRUCTURE DESIGN IN URBAN AREA

Responsible for publication
Director, Editor-in-chief
NGO DUC VINH

Editor:	TRAN THI HANG THU
	NGUYEN MINH HANG
Designer:	TRAN MINH ANH
Cover designer:	TRAN MINH ANH

Publication registration number: 3144-2023/CXBIPH/1-476/XD day 19/9/2023. Code ISBN: 978-604-82-7487-0. Decided to publish: 99-2023/QĐ-XBSĐT-NXBXD day 21/9/2023.

PUBLICATION INFORMATION

Organized and coordinated by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH,
Project Office in Viet Nam, 14 Thuy Khue, Hanoi, Viet Nam.
World Resources Institutes (WRI),
10 G Street NE, Suite 800, Washington DC 20002.
HealthBridge Canada, Office in Viet Nam,
#202 - 203, Lot E4, Trung Tu Diplomatic Area, Dong Da District, Hanoi, Viet Nam.

Chaired by
Technical Infrastructure Administration (ATI), Ministry of Construction (MOC)

Authors
Assoc.Prof. Vu Hoai Nam - Team Leader - Highway and Bridge Faculty - Hanoi University of Civil Engineering.
Assoc.Prof. Nguyen Viet Phuong - Highway and Bridge Faculty - Hanoi University of Civil Engineering.
Dr. Le Quynh Chi - Architecture and Urban Planning Faculty - Hanoi University of Civil Engineering.
Dr. Nguyen Duc Nghiem - Highway and Bridge Faculty - Hanoi University of Civil Engineering.
MSc. Le Hoang Son - Technical Designer
MSc. Nguyen Huu Dung - Team Assistant

Advisory team:
Fred Young - Alta Consultancy Company - International Technical Advisor.
Wei Li - WRI - International Technical Advisor

Content editing and supervising team:
GIZ represented by Truong Thi Quynh Trang - Senior Project Officer
HealthBridge represented by Dinh Dang Hai - Senior Project Officer

English edition:
Fred Young (Alta), Wei Li (WRI), Retno Wihanesta (WRI), Dinh Dang Hai (HB),
Truong Thi Quynh Trang (GIZ), Nguyen Thi Ngoc Anh (GIZ), Luu Hoang Son (GIZ),
Nguyen Anh Tung (GIZ), Nguyen Thanh Xuan (GIZ), Kim Beng Lua (GRSP)

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GIZ/ Nguyen Thanh Tu, GIZ/ Vu Hoai Nam, Dan Burden, Larry Schaeffe, Fred Young, Don O'Brien,
Thomas Quine, Alta Planning + Design, Department of Transport - New York City, WRI, Authors.

Design:
Tran Minh Anh

Publication date:
May 2023

Download the Vietnamese version

ISBN: 978-604-82-7487-0