WORLD RESOURCES INSTITUTE

SAFE BICYCLE LANE DESIGN PRINCIPLES

Responding to Cycling Needs in Cities during COVID and Beyond

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Cycling Embassy of Denmark

THE LEAGUE OF AMERICAN BICYCLISTS since 1880

DUTCH CYCLING EMBASSY

Urban Cycle Planning
Lotte Bech, Architect

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EXECUTIVE SUMMARY

The global COVID-19 pandemic has created a seismic change on how we move around in cities. The need for physical distancing generated massive and immediate demand for new infrastructure for pedestrians and cyclists.

This shift to cycling comes at a perfect time when cities have been making efforts to meet greenhouse gas emissions reduction targets.

The purpose of this guide is to help cities make good and quick decisions and take swift actions to make cycling a safe and appealing mobility option during and beyond the current global health emergency.

HIGHLIGHTS

- The COVID-19 pandemic has motivated a rapid surge in bicycling in urban areas around the world.
- Cycling has become an appealing option due to reduced public transport capacity and ridesharing options under physical distancing requirements, lower vehicle traffic volumes during various forms of "lockdown," increased awareness of the link between physical activity and mental health, and increased comfort provided by temporary bike lanes.
- Cities need to consider two public health issues when planning for immediate and future cyclist needs: road safety and physical distancing.
- Temporary, or "emergent," cycling lanes are an excellent way to address the increased demand for safe cycling and support increased cycling volumes even as traffic levels increase or the necessity for physical distancing is reduced.
- Cycling is one the cleanest and healthiest modes of transportation. This surge in cycling is here to stay.
- Temporary bike lanes must meet safe design standards, be linked with speed management, and fit within the city's cycling and mobility network and strategies.
- The purpose of this guide is to help cities make **quick, effective, and safe decisions and actions** to make cycling a safe and appealing transport option during and beyond the current global health emergency.

WHY "RAPID RESPONSE" BICYCLE LANES ARE NEEDED

The global pandemic has added urgency to an existing need for safe bicycle infrastructure. Research has found that in most cities, more people would like to use a bike for transport if it is perceived as safe and convenient (Noland and Kunreuther 1995; Dill and Carr 2003; Heinen et al. 2009; Willis et al. 2015). In response, many cities have slowly been establishing policies, plans, and infrastructure to support biking. The global COVID-19 pandemic has created an urgent need for physical distancing that has reduced the capacity of public transport and generated massive and immediate demand for walking and biking routes that offer both space for physical distancing and protection from road safety risks.

ABOUT THIS GUIDE

This guide presents key considerations for cities working to rapidly create a safe bike network. Based on existing resources on road safety and bicycle infrastructure design, it outlines key strategies, requirements, and principles that city designers and decision-makers should take into account in order to maximize the long-term benefits of short-term action and investment. The guide then dives deeper into bike lane design principles and makes recommendations on bike lane dimensions and layout, route network planning, material selection, and managing the most common risks to cyclists. The guidance provided here is based on the broad experience of the global team of authors, led by the WRI Ross Center for Sustainable Cities in collaboration with the Dutch Cycling Embassy, the League of American Bicyclists, Urban Cycle Planning (Denmark), and Asplan Viak (Norway).

FINDINGS AND RECOMMENDATIONS

Temporary and quickly designed bike lanes should not compromise on safety. Bike lanes that are deployed now may have a significant impact on travel patterns and safety in cities for years to come, especially as the broad range of temporary materials available can be rapidly installed yet offer a semipermanent solution. For this reason, it is important to get the design and planning right. And right means safe. The guidance provided here is based on the strong link between road safety and vehicle speed. This guide outlines the appropriate design and materials for bicycle infrastructure according to the operating speed of motor vehicles present. It makes the point that on streets where sufficient space for separate bike infrastructure is not available, other tools, such as traffic circulation design, speed bumps, or enforcement, should be used to lower vehicle operating speeds to safe levels for sharing the roadway with people on bikes.

The success of a bike lane and bike lane network, is based on how many women and children use the lanes. When a considerable number of women, children, and families use bike lanes, its a clear sign that the infrastructure is safe and comfortable to use.

Figure ES-1 | Bicyclist design user profiles

Interested but concerned: 51-56%

Often not comfortable with bike lanes, may bike on sidewalks even if bike lanes are provided; prefer off-street or separated bicycle facilities or quiet or traffic-calmed residential roads. May not bike at all if bicycle facilities do not meet needs for perceived comfort.

Somewhat confident: 5-9%

Generally prefer more separated facilities, but are comfortable riding in bicycle lanes or on paved shoulders if need be.

Highly confident: 4-7%

Comfortable riding with traffic; will use roads without bike lanes.

Note: The percentages of total population above reflect only adults who have stated an interest in bicycling.
Source: ***Bikeway Selection Guide***, Federal Highway Administration (February 2019).

Families among other individuals would fall into the ‘interested but concerned group’ (Figure ES-1) . It is this particular group that is the ‘untapped’ potential for cities who want to promote cycling.

KEY REQUIREMENTS OF SAFE BIKE INFRASTRUCTURE

There are typically five interconnected requirements for a successful bicycle network: safety, directness, coherence, comfort, and attractiveness (Figure ES-2). In response to health emergencies such as the COVID-19 crisis, cycling infrastructure must now also provide for physical distancing and space for a broader range of users.

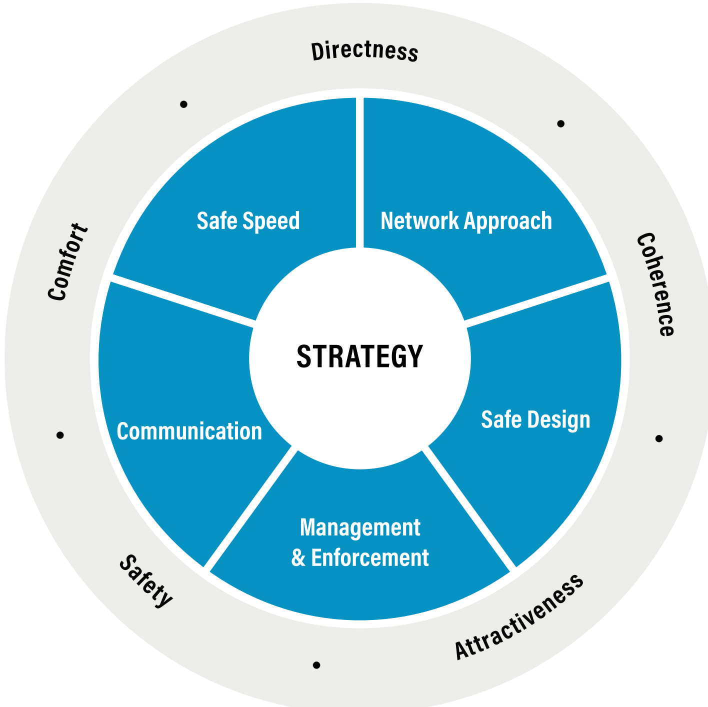
KEY PRINCIPLES OF SAFE BIKE LANE DESIGN

To meet the requirements for safe bicycle lanes, cities should consider the following set of guiding principles:

- **Establish safe operational vehicle speeds for all urban streets**, according to the infrastructure and types of road users present.
- **Maintain a coherent network approach** by integrating new bike lanes with any existing bicycle network or infra-structure as well as significant origins and destinations, both during and after the public health crisis.

- **Design bike lanes to prioritize safety for cyclists and pedestrians**, considering lane setup and protection, managing common conflict zones, and selecting appropriate materials.
- **Provide ongoing communication and engagement** at all stages of the design and implementation of safe bike lanes.

Figure ES-2 | Strategies, principles, and key requirements for new cycling infrastructure



Source: Authors.

- **Manage and enforce regulations to protect bike lanes** from common types of infringement such as parking, delivery, and freight loading.

KEY STRATEGIES FOR SAFE BIKE LANE DESIGN

- **Integrate cycling in broader city planning:** To gain long-term value from the short-term investment in planning and design, cities that already have a bicycle network plan should consider accelerated implementation, facilitated by the use of temporary materials. If a long-term cycle network plan does not exist, then temporary lanes can form the foundation of a future plan and help integrate cycling with public transport modes as part of less car-intensive urban transportation systems.
- **Consider the duration of the measures:** The duration of a nonpermanent bike lane can range from a few days to a few years. Clarity about the intended duration is important for both planning and communications.
- **Build the case for permanent changes:** Temporary measures can actively engage the public in cycling infrastructure and provide the opportunity for new cyclists to try it out and drivers to experience adapted spaces. Evidence has shown that once people experience the safety and comfort provided by temporary bike lanes, demand will be generated for more permanent measures, creating momentum for the prioritization of investment in good-quality, permanent bicycle infrastructure.
- **Allow for adaptation:** Temporary infrastructure has the advantage of being adjustable. Adjusting or changing designs to address issues that emerge after implementation is a normal and expected part of the process. Some cities were not planned, many other cities have been more planned for using cars, and plenty of city center areas were originally conceived for walking only. In situ monitoring is a key to measure the results of the implementation of the preliminary bike lanes and preparing to adapt and make changes to bike lanes if problems become apparent.
- **Safety should be prioritized in every aspect of cycling infrastructure design both during the immediate pandemic response and as a foundation for any future transition to permanent cycling infrastructure.**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INTRODUCTION

Cycling has surged in popularity as a resilient and reliable travel option during the pandemic, and consequently, many cities have swiftly been establishing policies, schemes, plans, and infrastructure to support it. Cycling as a mode of commuting could reduce carbon emissions by a substantial amount and improve overall public health.

The COVID-19 pandemic has dramatically changed the way we move in cities, adding urgency to an already existing need for safe bicycle infrastructure. As long as the virus is a threat, some level of physical distancing will be required, which demands that more attention, resources, and physical space be dedicated to making walking and cycling as safe as possible (Visontay 2020; WHO 2020). Evidence suggests that cycling has surged in popularity as a resilient and reliable travel option during the pandemic (Bryant 2020; UN News 2020), and as a consequence many cities have slowly been establishing policies, plans, and infrastructure to support biking. Most cities were already full of potential cyclists, people who were interested in taking up cycling but concerned about safety risks (Winters and Teschke 2010; Lois et al. 2016; Dill and McNeil 2016; Félix et al. 2017). Now, people around the world have taken to bikes in order to reduce their risk of exposure to the virus when they need to travel. As pandemic health concerns have outweighed road safety concerns and public transport options have contracted, people have taken advantage of quieter streets, and/or been motivated to try biking to maintain their physical or mental health under lockdown conditions.

This rapid shift in behavior and travel demand has synced with many cities' preexisting goals to increase cycling and walking and foster more multimodal, sustainable travel choices. Physical distancing and urgent intervention are the new essential features to be considered. These goals have become all the more urgent as cities seek to mitigate undesirable outcomes of changes to public transport operations (mostly related to reduced passenger numbers and service frequencies), such as increased numbers of trips made by private motor vehicles. Many cities are acting rapidly to address the accessibility and public health needs associated with both the pandemic itself and the restrictions on crowds and movement imposed to control it. One action is to provide new cycling infrastructure that offers both space for physical distancing and protection from road safety risks.

To better support increased cycling while also facilitating physical distancing, many cities are quickly implementing ambitious schemes to reorganize street space (Cokelaere et al. 2020; Koran 2020; Kuntzman 2020; Laker 2020; Reid 2020b). Emergent bike lanes are a part of those schemes, with the challenge to make sure they're still safe and future-proof. According to the Pedestrian and Bicycle Information Center (pedbikeinfo.org), as of July 2020 approximately 330 cities and 50 countries around the globe have reported such types of interventions, consisting mostly of reallocating space on traditionally car-dominated streets for people to cycle and walk. Cities are closing entire road sections to cars or giving priority to pedestrians and cyclists over vehicle traffic. The result is more space for pedestrians and cyclists.

In many cases this type of change is being achieved through the deployment of safe bicycle infrastructure. Safe bike lanes can provide safe bike routes using existing street space, with the ability to move more people per hour than car lanes. Speedily implemented infrastructure can do more than provide an important and immediate form of mobility for citizens during the health crisis. It allows people to reimagine their streets, with less space for cars, and see how this can work. It also has the potential to reshape city streets to reduce carbon emissions and address climate change, make them more livable, and improve public health, accessibility, and equity for the long term (8-80 Cities 2016).

Around the globe, the sudden rise of emergent bike lanes is already benefiting cities by allowing them to reconsider or scale-up their existing bike lane networks and plans.

Innovation and adaptation during the time of a global health emergency opens up the unexpected opportunity to generate pressure to reduce dependency on private motor vehicles, rethink and orient public space more equitably, and establish safe traffic speeds through design. Bicycle infrastructure that is well-designed and correctly implemented enhances overall safety and accessibility and favors those who choose walking and cycling as their mode of travel.

Such pandemic-responsive safe cycle lanes have the potential to form the foundation of cities' future bicycle networks, so it is important to get them right at the beginning by implementing a safe network of connected routes that can be adapted to meet present and future challenges.

ABOUT THIS RESOURCE

The purpose of this resource is to provide cities with guidance that is easy to understand and apply on how to create emergent bike lanes that do not sacrifice safety and can enhance or establish a permanent bicycle network over the long term, with special consideration given to the physical distancing needs of pandemic conditions. The guidance outlines a set of requirements and principles that cities should take into consideration to ensure that temporary bicycle infrastructure is safe and interconnected in terms of both specific corridors and networks. Facilitating increased cycling is a positive response to the global health emergency, but even temporary infrastructure must be designed and implemented carefully and to a high standard, or it could inadvertently create more risk for road users and/or reinforce negative stereotypes about cycle infrastructure. It is very important that temporary materials and designs do not compromise safety.

A second objective is to maintain the momentum of change. As traffic volumes rise again after the lockdowns, whether this momentum will continue (Goldbaum 2020) will depend largely on the quality of the new cycling infrastructure (Sui and Prapavessis 2020). Cycling should be an integral part of a city's transport system, not only during the pandemic but in the long term. The aim of this guide is to assist with the design of high-quality, safe, temporary cycling measures that also create the foundation for systemic and lasting changes that nurture the culture of cycling, facilitate the development of quality bicycle networks, and more broadly, move cities and urban mobility toward a sustainable future.

This guidance equips government agencies, designers, and civil society organizations that are participating in the health crisis response with an understanding of how to protect cyclists through safe and appropriate design. Cities are investing considerable effort and resources to implement safe cycling lanes under very challenging conditions, and this energy should not be wasted.

This guidance focuses principally on the design features of safe emergent bike lanes. For additional guidance on planning and policy processes, please refer to "Additional Resources" on page 60.

METHODOLOGY

The main question addressed by the authors of this paper is, What guidance can we provide to cities that want to implement bike lanes quickly in response to the upsurge in demand created by the COVID-19 pandemic and how to ensure they remain and grow beyond?

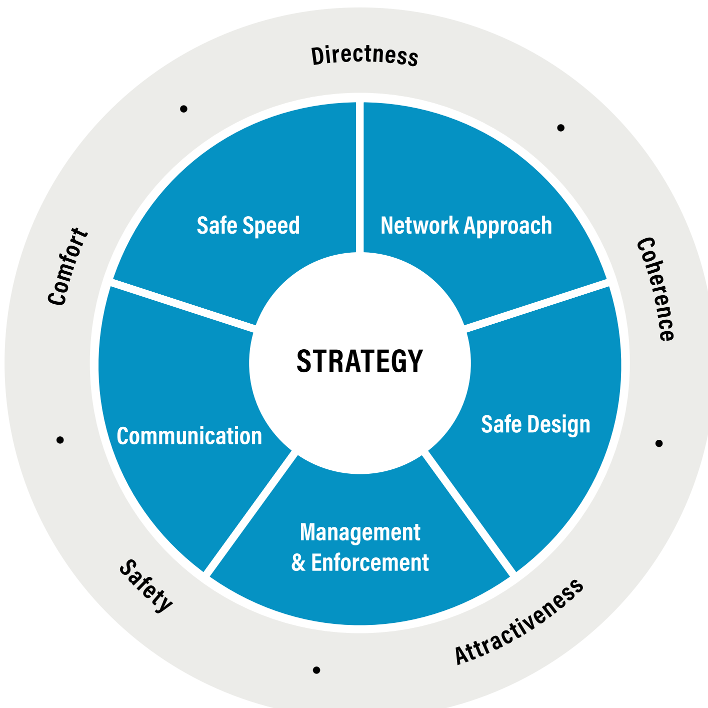
The authors held a series of weekly online meetings in May and June 2020, bringing together expert contributors from all over the world (See the acknowledgments on page 65). Discussions reviewed the current best practices, perspectives, and experiences of the authors and of contributors who work on bicycle lane safety, planning, design, and implementation all over the world.

Together, the group identified and organized key content that should be included in this guide, taking into account the particular need for cities to respond rapidly. The group then defined and populated a framework for the guide, including the elements of a strategic approach to bike lane planning, the key performance requirements of new systems, and the guiding principles of bike lane design. This framework is illustrated in Figure 1.

The online meeting process was accompanied by an iterative writing process that integrated comments and suggestions from the contributors on each draft. Given the international nature of the author and contributor team and the intended audience, particular attention was given to clearly differentiating between which parts of the guidance could safely be adapted for a particular local context and which parts are fundamental and inflexible for safety.

The structure of this guide was designed to meet the objective of supporting the immediate need of cities for accessible and reliable information about safe emergent bike lanes. The guide has been divided into straightforward sections to help practitioners understand the good practices and design principles that must be considered.

Figure 1 | Strategies, principles, and key requirements for new cycling infrastructure



Source: Authors.

STRATEGIC APPROACH

Although the current pandemic conditions are causing rapid shifts in health risks and the consequent requirements for public health guidance, any bicycle infrastructure created in response must be considered within the wider context of current and future city planning for community and mobility needs. A strategic approach to safe bicycle lanes should adopt the following approaches:

- **Integrate cycle networks and policy planning:** Emergent bicycle lanes can be an immediate response to the health emergency, but they should also be safe and well-designed solutions that are integrated into the permanent bicycle network, both existing and planned. For this reason, it is key to plan ahead using methodologies that help to objectively determine the optimum location of new cycling facilities (Larsen et al. 2013; Duthie and Unnikrishnan 2014; Mauttone et al. 2017).

  Where a plan for new bike lanes already exists, the most appropriate strategy may be to accelerate implementation, using temporary materials in the interests of speed. In cases where a long-term cycle network plan does not exist, emergent lanes can form the foundation for developing a plan by identifying key emergency bicycling needs at the neighborhood and city levels. Either way, solutions must be safe and thorough.

- **Clarify the duration of the measures:** Depending on the project needs, goals, and materials selected, the duration of nonpermanent bike lanes could range from a few days to a few years, but it is desirable that they become permanent in the future. It is important that expectations be clearly understood and agreed upon within the planning team and communicated to wider stakeholders.
- **Build the case for permanent changes:** Cities should act fast to implement safe cycling infrastructure but also engage with stakeholders, responding to any community needs or concerns and clearly communicating with road users about any changes in road use or layout. Temporary infrastructure provides a focal point to actively engage the public on cycling measures. It allows new cyclists to try it out, and drivers to experience adapted spaces. As long as the new infrastructure can make cycling safe, easy, and comfortable for everybody, rapid construction greatly increases the likelihood of cycling (Winters et al. 2010) and provides solid ground for the development of routine cycling, even in cities without a previous tradition of cycling (Marqués et al. 2015).
- **Allow for adaptation:** Temporary cycling infrastructure responds quickly to new travel demand and allows people to experience new street designs; it also has the advantage of being adjustable. Adapting or changing designs to address issues that emerge after implementation is in fact a normal and expected part of the process. Monitoring is key to measure the results of the implementation of the preliminary bike lanes. Therefore, cities should collect data to illustrate the environmental, health, and socioeconomic benefits of investing in cycling infrastructure, both temporary and permanent, as well as the disadvantages of implementations that didn't work well and their unintended consequences. It enables use of the findings to build community and political support for transitioning temporary infrastructure into long-term suitable changes to the streetscape and travel patterns.
- **Assess impacts:** Performance indicators can help determine the qualitative and quantitative changes that occur as a result of deploying new bicycle infrastructure. Particularly for emergent bicycle lanes, getting real-time and immediate feedback on design layout is an essential step to ensure the success of the measures, so adaptations can improve safety quickly if tweaks are needed.

KEY REQUIREMENTS

We identify five interconnected requirements for a successful bicycle network: safety, directness, coherence, comfort, and attractiveness (CROW 2007; European Commission 2018a). In response to health emergencies such as the COVID-19 pandemic, cycling infrastructure must now also provide for physical distancing needs (WHO 2020).

Given the fast-paced nature of emergency response and the temporary materials being used, we recommend the following four priority requirements (see the "Key Requirements" in Figure 2):

- **Safety:** A safe travel network for cyclists is one with appropriate segregation and infrastructure for the traffic speeds and volumes on a given street, and design that offers clear visibility and ease of maneuverability even for novice cyclists and minimizes the chance of collisions in conflict zones. Equally, traffic speeds and volumes can be altered to make the environment safer for all road users.
- **Directness:** To ease travel, cycle lanes should be as direct as possible and minimize time disruptions by giving priority to cyclists where possible. Guaranteeing relative directness can be just as important, meaning that bicycle routes are faster and more direct than car routes (thanks to modal filters, for instance) where applicable. This can make cycling a more competitive travel mode than driving.
- **Coherence:** A coherent cycle lane network is one that is well connected and continuous; links common origins, destinations, and mobility hubs; and matches the travel needs of the community. Uniform infrastructure, signage, and pavement markings can enhance coherence, as can supporting information such as map totems or portable maps.
- **Physical distancing:** To enable users to maintain recommended physical distance from other cyclists using the lane, or pedestrians using the adjacent sidewalk, sufficient

lane width must be provided for overtaking and avoiding potential bottlenecks at, for example, intersections. Recommended physical distancing varies from one to two meters (m) in different countries and locales (CDC 2020; ITF 2020).

Many elements of the remaining two requirements—comfort and attractiveness—are already addressed within the priority requirements (CROW 2007). Such elements include things like comprehensibility (the ease of identifying and following routes), conflict prevention, personal security, ease of maneuverability, and regular maintenance). Other elements of comfort and attractiveness, such as quality of surface paving, aesthetics of materials, and integration with the surrounding environment, should be addressed later, once emergent bike lanes are transformed into permanent ones.

GUIDING DESIGN PRINCIPLES

To ensure that these requirements are met, we recommend that cities consider using a set of guiding principles when introducing emergent bike lanes. The principles, listed in Figure 1, are summarized below and presented in detail in this paper's main section, "Design Principles for Safe Emergent Bicycle Lanes."

Establish and maintain safe motor vehicle speeds: To encourage cycling and protect people on bikes, motor vehicles should be limited to speeds that are safe for cyclists, not only on streets with bicycle lanes but throughout urban areas. This can be achieved through a combination of regulation, street design, and enforcement.

Maintain a coherent network: Emergent bike lanes should form a coherent network that is integrated with existing bike lanes, safe intersections, bicycle and shared mobility infrastructure such as parking places for bicycles, and low-speed zones. Networks should connect major origins and destinations as directly as possible, which is a highly valued attribute for people who use bicycles as their means of transportation (Broach et al. 2012).

Ensure safe design: The physical design of bike lanes must prioritize the safety of cyclists and pedestrians. The potential rider's perception of cycling safety is often the deciding factor in the uptake of cycling (Rissel et al. 2002; Hull and O'Holleran 2014). The design should also clearly communicate the changes to the streetscape, and which road users have priority. All road users, especially car drivers and freight vehicle drivers who present the greatest risk to vulnerable users, must be able to recognize new bicycle paths and be prepared to act with caution. Safe design encompasses lane setup and protection, managing conflict zones with traffic, managing other types of conflict zones (e.g., with other cyclists), and selection of materials and infrastructure elements.

Manage and enforce to ensure safety: Curbside parking, delivery, and freight loading should be controlled by traffic officers or related professional staff onsite so that the circulation of cyclists on the bicycle lanes does not become blocked.

Communicate with and engage all road users: It is crucial that all road users know clearly what is changing in terms of street layout and use. Cyclists and pedestrians need information on the best routes for their travel, as well as higher-risk areas and how to protect themselves. Changes can be conveyed by consistent and predictable design, while the wider context and detail can be communicated through engagement events and traditional and social media. Engagement is also important in order to identify demand for routes that should be prioritized, gain community support, and address concerns. Effective engagement can build awareness about the newly proposed cycle tracks and the need for more cycling in urban areas, thus encouraging people to use the network, and contribute to monitoring and improving the performance of bicycle lanes.

The strategic approach, key system requirements, and safe design principles are well illustrated by the experience of Oslo, Norway (Box 1).

Box 1 | A Strategic Approach to Designing Safe Bicycle Infrastructure in Oslo

In 2015, Oslo launched a new strategy for implementing bike lanes, with the goal of establishing a new set of norms for bike lane design and construction, in order to install as much infrastructure as possible. Prior to this, one-way 1.5-meter (m) bike lanes on both sides of the street were the norm, with little room for flexibility. In practice, streets that were strategically important for biking often ended up with no bike infrastructure at all, because there was always some part of the street where there was not enough space. It became clear that a new approach was necessary, one that accepted the value of making the right compromises, if the city was to achieve its goal of upgrading 60 kilometers of its bike network between 2015 and 2019, and reaching a bike modal share of 25 percent in 2025, up from 6 percent in 2018.

The new strategy establishes a bike lane 2m wide, but with the option to be flexible where necessary (see Figure B1.1). In many cases, a 2m bike lane is now constructed on the uphill side of the street only (this side is prioritized because the speed differential between cars and bicycles is greater, and cyclists feel less comfortable when cars are passing them). To facilitate safe biking, a new guideline for planning bike lanes was established that car lanes should default to the minimum width (2.75m, 3m, or 3.25m, depending on traffic type and speed), so that all extra space can go to bike lanes. This is now measured from the middle of the street, and any excess space is then made available for bike lanes, in contrast to the previous approach, which measured a 1.5m bike lane from the curb, then left any excess space for cars, sometimes leading to car lanes as wide as 4m. The result is that bike lanes built in Oslo after 2016 often vary in width. For example, in some cases, such as behind bus stops, they allow bike lanes of 1.3m, if that is all that can fit. Where bike lanes do not fit, speed limits can be reduced and speed management interventions such as speed humps can be installed as needed.

The strategy involves recategorizing many new bike lanes as *strakstiltak* (literally, "immediate measures"), a term that suggests that the lanes are preliminary. This approach enabled greater speed and agility in both planning and installation. Focusing on preliminary lanes has reduced tensions in the planning phase. For example, business owners and local residents (who use parking spaces) are more likely to support bike lanes if the possibility exists to make future changes to the street layout, such as restoring parking or further improving the lane design. However, the term *preliminary* does not mean the bike lanes are temporary. Users must know that if they start biking, they can rely on the bike lanes to still be there in the future. Rather than temporariness, *preliminary* creates an expectation for future improvement.

Safety is a priority for Oslo's strategy. Traditionally, the planners and road engineers in Oslo had only considered safety in terms of crashes. The new philosophy also considers *perceived safety*. Most people, but especially women, children, or the elderly, will not use bikes if they feel unsafe. Perceived risks include being run over, having your bike stolen, crime, and bullying from other road users (such as verbal abuse or other conflict). Furthermore, fearful or anxious road users tend to be more distracted and can act in ways that are less safe than road users who feel calm and secure. Preliminary bike lane projects have been much better at reacting to such needs than those that go through formal planning procedures and use permanent materials, because there is more room to make adjustments and improve, once initial use and comfort levels have been evaluated. There is usually no need to compromise on safety.

The city has found that this approach has generated a strong positive feedback cycle. Preliminary bike lanes lead to more people bicycling, which in turn leads to increased demand and support for even better bike infrastructure.

Top tips from Oslo for quickly expanding your bike infrastructure:

- When building quickly, you won't be able to get anything done if you let perfection get in the way. Set norms but be flexible.
- Minimize car lane widths in order to maximize bike lane widths (see Figure B1.1).
- Compromise on infrastructure, but not safety, by slowing speeds, narrowing lanes, and using traffic calming devices on street sections that do not have space for separated lanes.
- Select the terminology carefully to convey the opportunity for testing, feedback, and improvement.

Figure B1.1 | In Oslo, this bike lane has been widened to improve safety

Source: Personal communication with Anders Hartmann, senior advisor for road safety, Asplan Viak AS, and former bicycle coordinator for the City of Oslo. June 2020.
Photo: Kathrine Andi/shutterstock.com

DESIGN PRINCIPLES FOR SAFE EMERGENT BICYCLE LANES

In this section, we explain in detail the basic principles that should guide the design of safe emergent bicycle lanes and recommendations based on best practices and discussions with our global team of authors and collaborators.

In this section we present the basic principles that we believe should guide the design of safe emergent bicycle lanes and recommendations based on best practices. There is no standard recipe for design, and one guide cannot exhaustively address all options. Rather, the basic principles should be tailored to the local context. However, one common element is that emergency bike lane designs must be flexible and the implementors must be willing to experiment and (quickly) adjust if necessary. The reallocation of road space is a tough and politically delicate issue, but in these extraordinary times we should aim to be bold and ambitious and understand the importance of not only providing more space for cyclists but also reducing the pull-factors contributing to constantly increasing use of private cars.

ESTABLISH AND MAINTAIN SAFE MOTOR VEHICLE SPEEDS

Motor vehicle speeds are one of the most important risk factors for cyclists suffering a fatal injury (Brindle 1992; Kim et al. 2007; Ohlin et al. 2017). The probability for serious injury is one out of five when a car hits a pedestrian at 30 kilometers per hour (km/h). Vehicle speeds on streets where cyclists and cars share the road should be set at safe levels according to the type of road, with the purpose of keeping travel speeds and impact speeds as low as possible within city areas where crashes might occur (Rosén and Sander 2009; Kröyer 2015). When assessing the speed levels of vehicles in a corridor, it must be ensured that the *operating speed*—that is, the actual speed at which vehicles are traveling—does not exceed the safe *speed limit*. In locations where street design or enforcement is not aligned with the speed limit, the true vehicle speed may be substantially higher, necessitating either a higher level of segregation for cyclists or traffic calming interventions to limit the operating speed.

Figure 2 | Speed limits in city centers and residential areas can contribute to safe bicycle networks and other benefits

Photo: Roxy Tacq/iRAP.

Figure 3 | Installing a speed bump near a bike lane in Denmark

Note: This type of bump is semipermanent as it is made of rubber that is bolted to the road surface.
Photo: Anne Eriksson.

Figure 4 | Bolt-down rubber speed cushions

Photo: Nacto, shutterstock.com.

Consider installing low-speed zones: Cities are increasingly introducing street, school, neighborhood, city center, or even citywide zones with speed limits of 20 mph or 30 km/h (Figure 2), which should be the default speed limit in all residential areas (Lindenmann 2005; SWOV 2018). These zones are most effective when they are “self-reinforcing,” thanks to traffic calming measures such as speed humps (Figure 3), speed cushions (Figure 4), channelization, and lane narrowing (NACTO 2013, 2016).

Provided that traffic volumes are low and there is only one lane in each direction, cyclists can safely share the street with other vehicles in this type of zone. In 30 km/h zones, traffic volumes under 2,000 vehicles/day are acceptable for the implementation of *bicycle boulevards* or shared streets with mixed traffic (Andersen 2012; NACTO 2014; Schultheiss et al. 2019). The implementation of such zones should increase in response to the pandemic, because improving road safety is an additional way to reduce pressure on hospitals (Reid 2020a).

Consider strategic street closures: Many cities are temporarily closing some streets to cars. This is one effective way to provide safe, dedicated spaces for cyclists and pedestrians without the need for speed limits or design changes. In some cases, these streets may permanently become car-free; for example, London has implemented bold plans to close the city center to cars (Sims 2020).

Target collector roads and arterial corridors: These roads in particular need good-quality, dedicated cycling infrastructure. The higher the vehicle speeds and vehicle traffic volumes, the more visual and physical separation measures are needed to protect the safety and comfort of cyclists. In arterial

corridors with emergent bicycle lanes, the speed limit should not be higher than 50 km/h (WHO 2018), and physical barriers should be installed to segregate car traffic and bicycle lanes.

Align the cycling infrastructure with the operational speed of a street: As vehicle speeds increase, bicycles and cars need greater physical separation (Schultheiss et al. 2019). Cyclists can share the space with vehicles on streets with operational speeds of 30 km/h or lower. Streets with operational vehicle speeds higher than 30 km/h should preferably have physical separation, or at least a painted line or moveable cones separating the bike lane. From 40–50 km/h, heavier barriers or fixed plastic bollards are recommended, as long as their dimensions and location pose as little risk of injury as possible to cyclists who might accidentally hit them. This type of physical segregation can't totally protect cyclists in the case of a car leaving the vehicle lane due to driver error. This is why managing operational vehicle speeds is so important, and why cycle lanes should be located further from the roadside where speeds are over 50 km/h. Bike lane width must be sufficient (see the section "Ensure Safe Design" below) and appropriate materials selected (see the subsection "Select appropriate materials" below, Table 3).

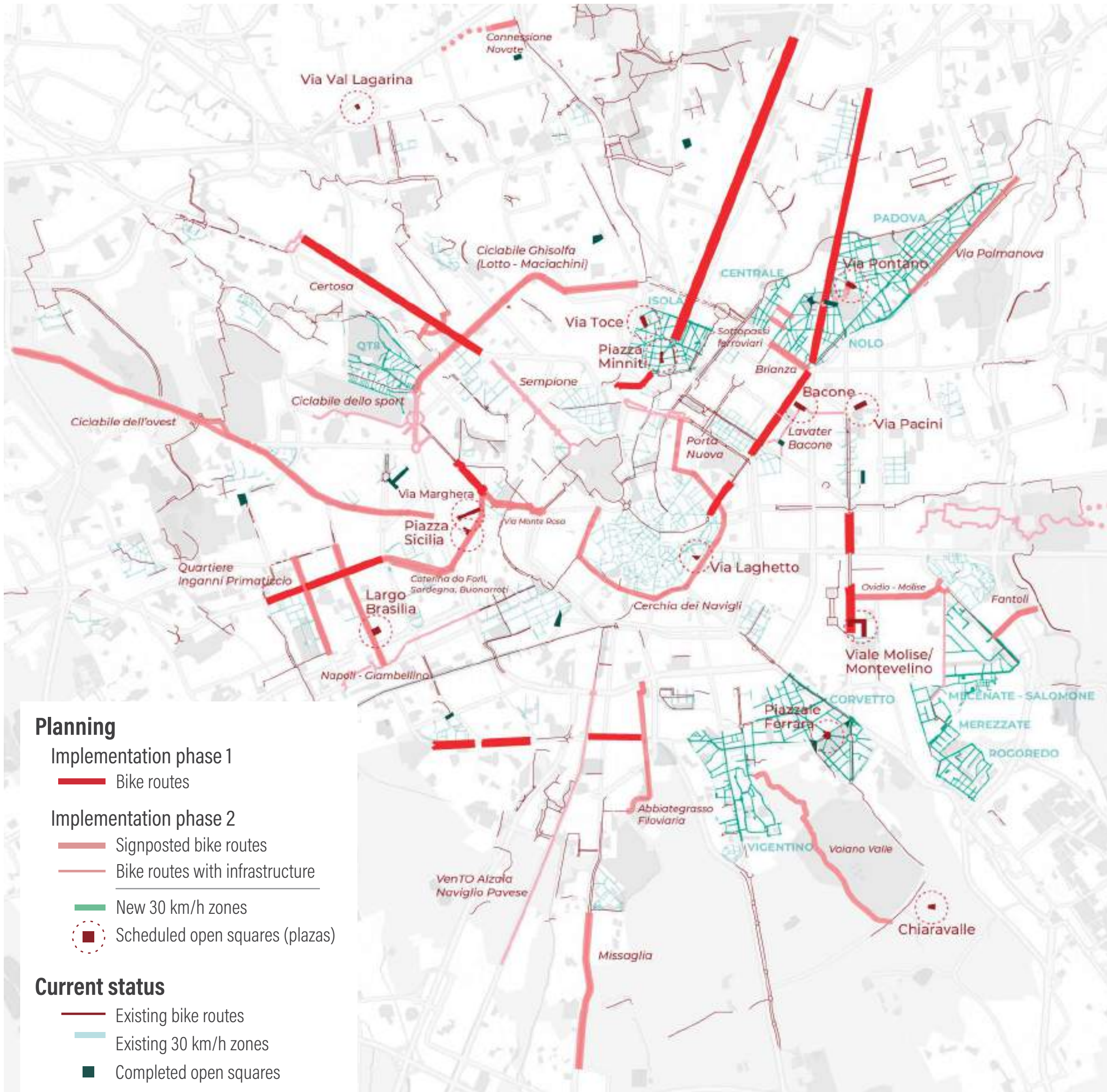
Design for speed management: Where bike lanes are installed, accompanying interventions to limit the speed of car traffic should be considered. Physical interventions like speed humps, curb extensions or relocations, changing the horizontal alignment of a road, and other interventions such as painting wider stripes to achieve narrowed car lanes help keep speeds low (World Bank 2019). Where there is insufficient room for separate bike lanes, speed and volume management can provide safer conditions for bicycles and motor vehicles to share the roadway.

Traffic calming measures should not be applied within bike lanes, because they can cause falls and injuries and distract cyclists from paying attention to traffic. The use of simple speed bumps, speed radars, or cameras are examples of recommended traffic calming measures.

MAINTAIN A COHERENT NETWORK

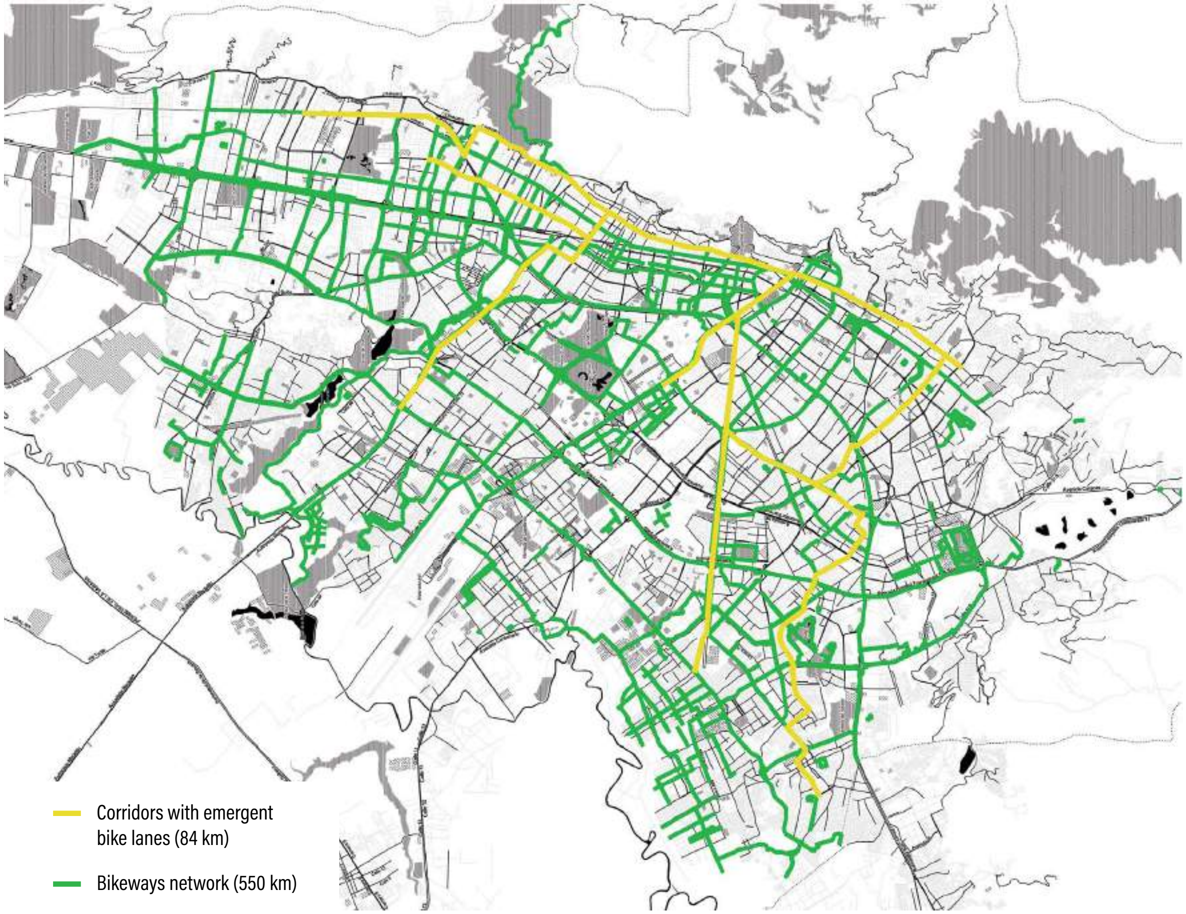
Many cities now find themselves needing to quickly activate any existing long-term plans or rough drafts and identify a cycling network. The selection of safe bike lane routes must consider both safety and convenience. Existing and newly deployed cycling infrastructure (commonly in arterial and collector roads) should be interconnected with low-speed streets to form the most efficient network (see examples in Figures 5 and 6). Network development should also include the regulation of vehicle speeds and the enhancement of cycling infrastructure on all the streets chosen. Safe emergent bicycle lanes can expand a city's existing cycling network, fill key gaps, and help support further growth in cycling rates (Milakis and Athanasopoulos 2014).

Figure 5 | *Strade Aperte*: Implementation plan for cycle routes and high-quality pedestrian space in Milan



Source: Comune di Milano / Flickr. English translation modified.

Figure 6 | Emergent bike lanes are used to both connect and expand the existing network in Bogotá



Source: Alcaldía Mayor de Bogotá.

Connecting important destinations: In the short term, an emergent network of bike lanes should prioritize and connect the locations of essential services that will remain open during any pandemic-related lockdowns. Considering the expected transition to permanent infrastructure, important points of interest, such as schools, public transport hubs, private and shared mobility parking, recreational facilities, community centers, hospitals, supermarkets, and other essential services should also be linked by the bicycle network.

Directness: Connections should allow cyclists to take the shortest possible route to their destinations. Directness is rated very highly as a cycle lane attribute by cyclists who make utilitarian trips (Broach et al. 2012). Cycling requires effort, and unnecessary detours should be avoided. Detours must be kept small and overall travel time for cyclists minimized (PRESTO 2010). The directness of the network can be calculated by measuring the proportion of a route that has bicycle infrastructure and the level of diversion required from the shortest path to remain on bicycle infrastructure (Boisjoly et al. 2019).

Coherence across the network: The design and implementation of the whole bike network should follow a consistent visual identity and design standard (based on national standards), providing easily understandable and usable infrastructure for all road users (Hull and O'Holleran 2014). This approach applies to all the necessary elements of a bike system; for example, lane configuration, signs and markings, and, if possible, materials.

ENSURE SAFE DESIGN

The design of safe bike infrastructure should consider the spatial needs for safe bicycle maneuvering, overtaking, and—in the context of the COVID-19 pandemic—physical distancing. In addition, providing a high degree of separation from motor traffic has been important for increasing bicycle use by women and other population groups that are underrepresented in cycling (Garrard et al. 2008). The share of bicycle trips taken by women has surged much more than among men during the pandemic (Goldbaum 2020). The recent rapid shift to bicycle travel has increased the proportion of new cyclists, who are less experienced and prone to making mistakes. Therefore, well-protected and spacious bike lanes are desirable where possible.

LANE DIMENSIONS AND PLACEMENT

In emergent cycle lanes there will be novice cyclists, and in adjacent lanes there will be motorists who are not used to driving near people on bicycles. Lane width needs to be determined by the operational speed of the road and the traffic volume. In general, we recommend a minimum width of 2.2 m for one-way bicycle lanes. However, when speed and volume conditions allow, planners should be flexible in implementing narrower lanes in specific segments if the available space does not allow for a 2.2 m bike lane. Advantages and disadvantages of varying lane widths are summarized in Table 1. The width of bicycle lanes should be decided with these principles in mind:

- The width should accommodate the width of bicycles, some buffer space between cyclists, and space for passing. In cities with many novice cyclists, a wider buffer space should be considered.
- Emergent bike lanes should have the same width as any possible future permanent cycle tracks, so they can be easily upgraded.
- Bike lanes must also provide enough space to allow for slowing down, stopping, and dismounting.
- The width should also consider the comfortable circulation of different cycling speeds, from children to elderly people, as well as electric-assisted bicycles and micromobility vehicles, such as rickshaws, tricycles, e-scooters, or cargo bikes.

KEY CONSIDERATIONS FOR SELECTING BIKE LANE WIDTHS

A curbside vehicle lane or parking lane can be turned directly into a bike lane. In this case, the bike lane is as wide as a vehicle lane, usually ranging from 2.8m to 3.5m. These widths will provide adequate or comfortable room, respectively, for cyclists (Figure 7).

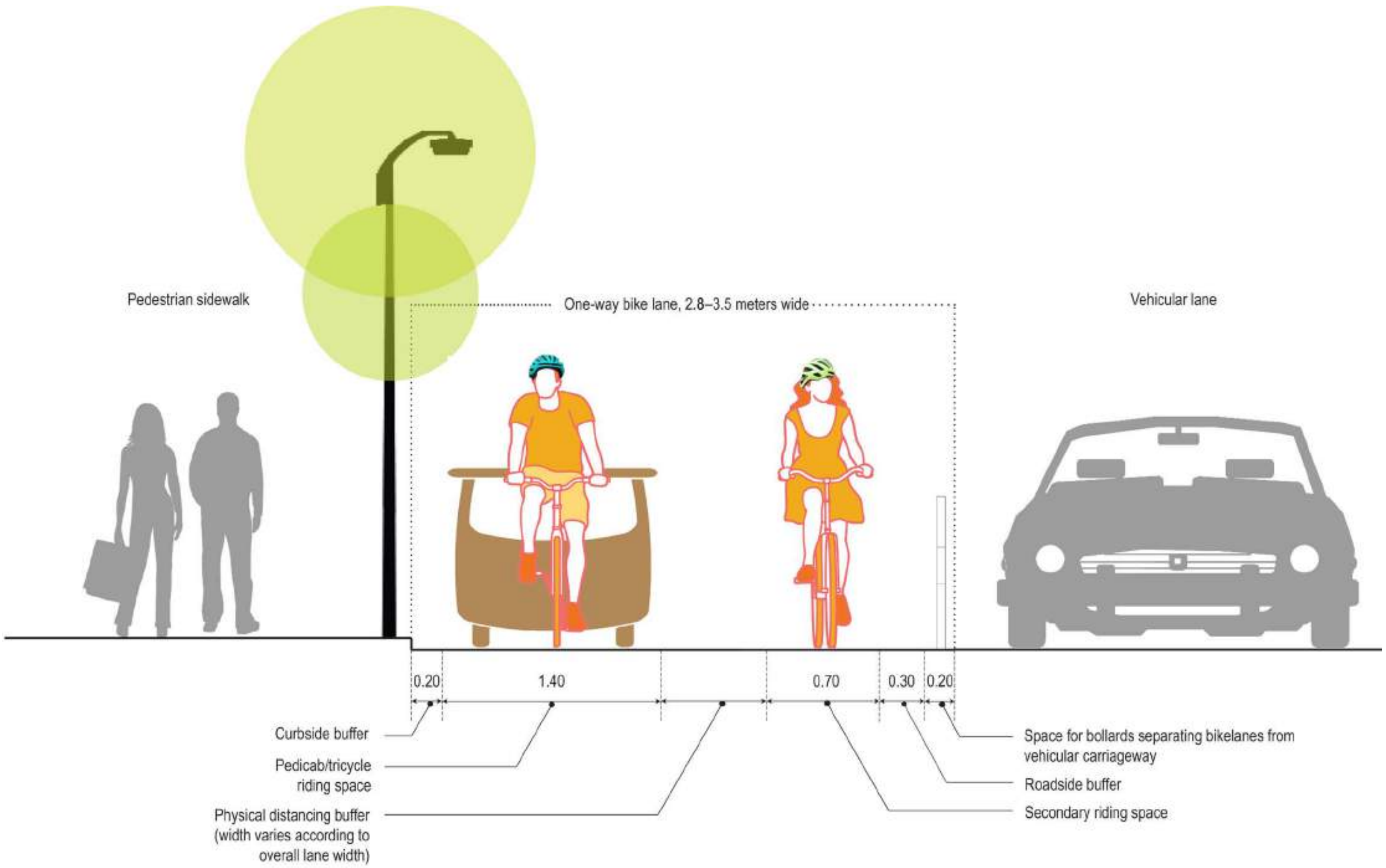
In general, a 2.2m width is the minimum for a desirable bike lane, enabling two cyclists to ride side by side comfortably (Figure 8). This width can also accommodate a cargo bike or a rickshaw. Where available space does not allow for 2.2m, a minimum bike lane width of 1.5m can be considered (Figure 9), as long as speeds and traffic volumes are low enough. This is the minimum space for one cyclist and some buffer

space. However, this width is not acceptable on arterial roads with high vehicle speed and traffic volume, other than for very short stretches (under 100m) that are deemed necessary for the continuity of the network. If the 1.5m bike lane is to cover a long segment, then width should be reassessed to accommodate any changes in posted speed and traffic volumes.

Do not use a "deceptive" lane width that encourages cyclists to believe they can pass when the lane cannot accommodate two cyclists beside one another. This means that bike lane widths between 1.5 and 2.2m should be avoided. See more details in Table 1.

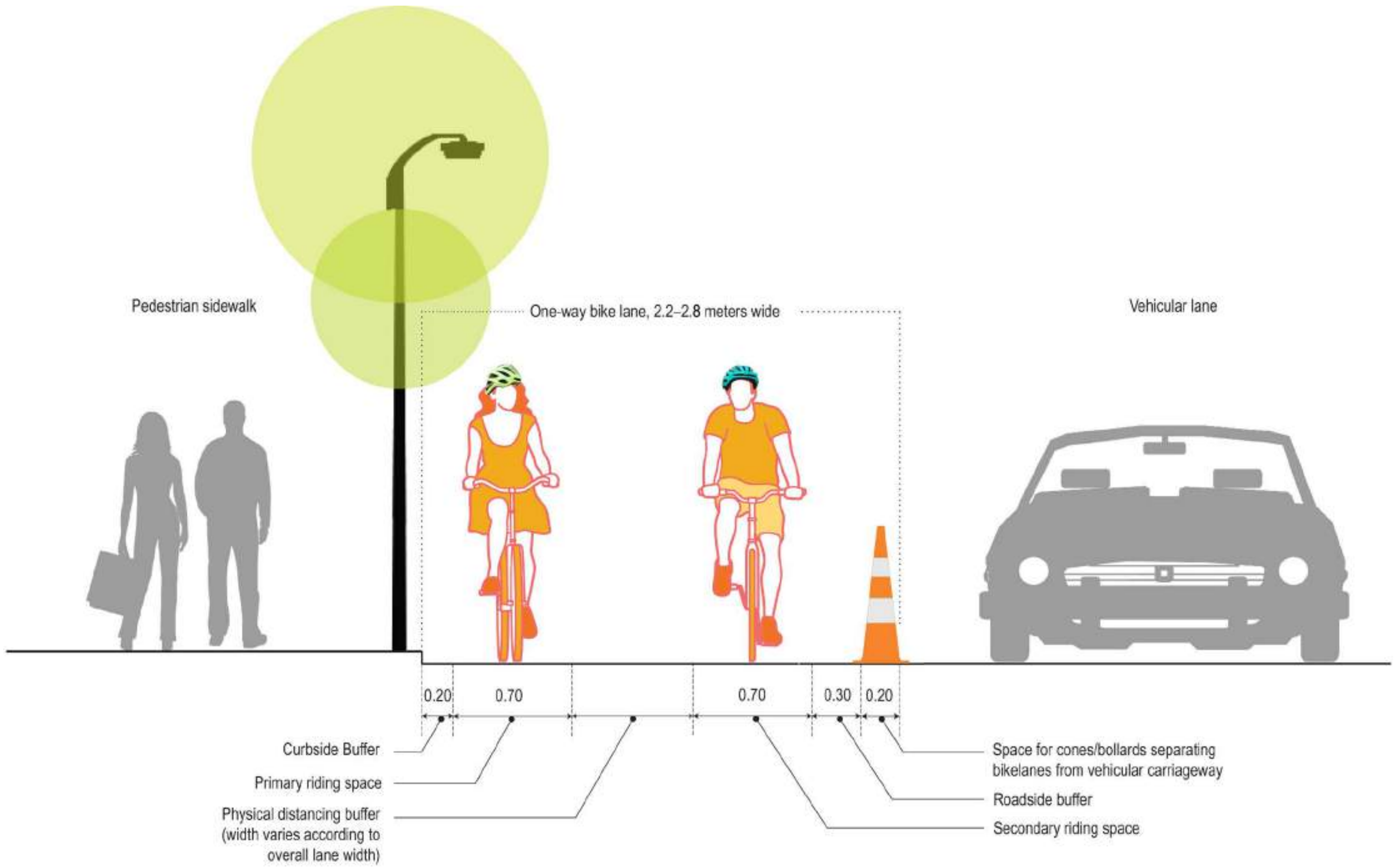
Depending on the expected volume of bicycles, widths ranging between 2.2m and 3.5m can facilitate a safe and comfortable circulation of cyclists and other micromobility vehicles such as rickshaws, tricycles, or cargo bikes, which are common in many cities around the world.

Figure 7 | Bicycle lane widths of 2.8–3.5 meters are desirable



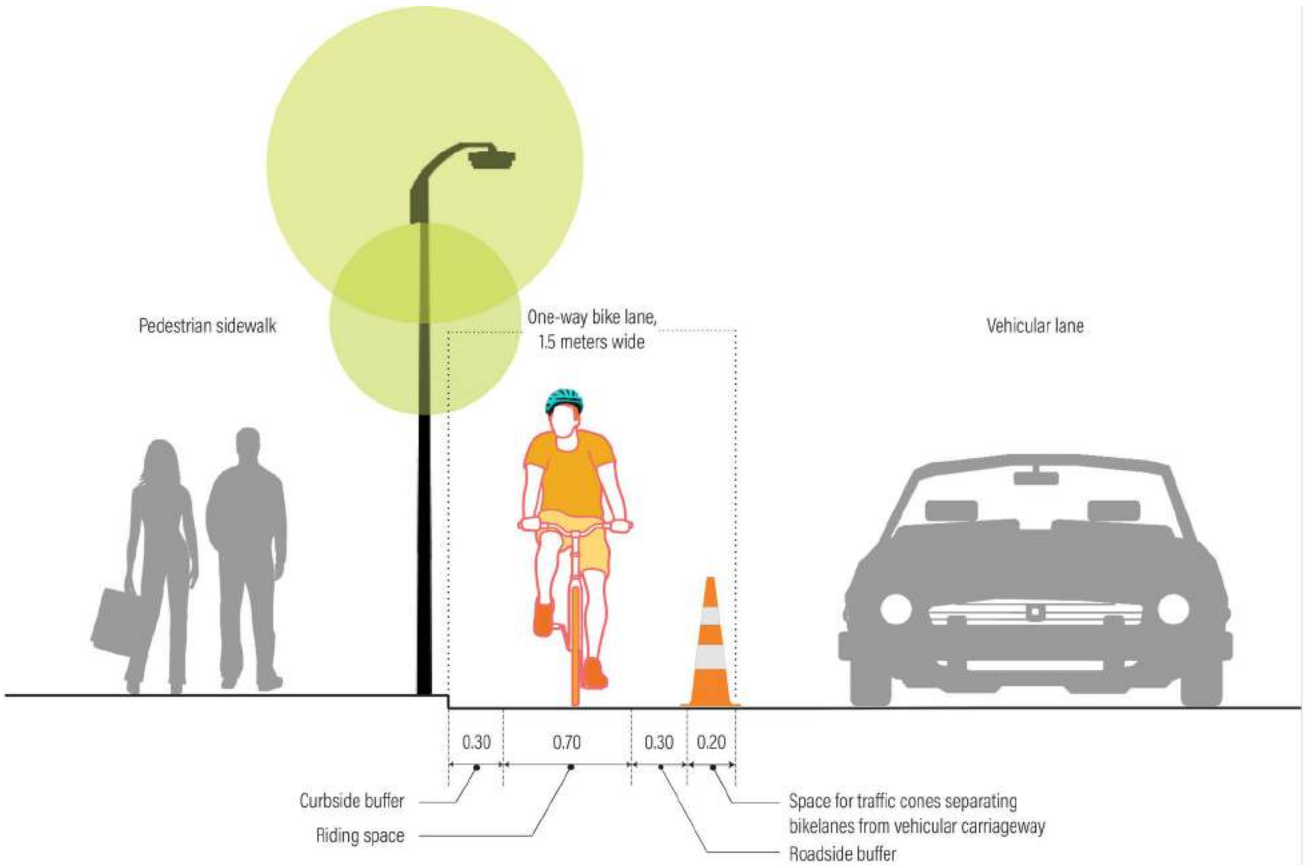
Source: Authors.

Figure 8 | Bicycle lane widths of 2.2–2.8 meters can accommodate two cyclists side by side



Source: Authors.

Figure 9 | Bicycle lane width of only 1.5 meters is the minimum consistent with basic safety



Source: Authors.

Table 1 | Bike lane widths: Advantages and disadvantages

LANE WIDTH	ADVANTAGES	DISADVANTAGES
Narrow From 1.5m Minimum acceptable ONLY under specific circumstances	▪ Although they do not have the ideally desired width, they send a clear visual message to drivers, making them aware of the presence of bicycles on the road. ▪ We can use them to allow the continuity of bike infrastructure, when space is limited. ▪ Acceptable only if the roadway elements allow for a lower width than the minimum recommended. ▪ Where possible, an available space of more than 1.5m would allow for a buffer zone in addition to a single bike lane (the capacity of the lane would hold good for just one bicycle, eventually allowing smaller cargo bikes to go through). ▪ It is not advisable to build a bicycle path with a width between 1.6 and 1.7m, as this width gives an indication that passing is possible and hence the result would be conflicts and accidents between bicycle riders. ▪ A bicycle path from 1.8m gives acceptable space to pass another cyclist—but if there is traffic of cargo bikes then 2.2m is a preferable width. ▪ May be used for short stretches on busier roads where it is essential to maintain continuity of a network but only with physical segregation.	▪ Preferable on roads with speeds lower than 40 km/h, low bicycle and low motorized traffic volumes. ▪ Lanes may become more unsafe if bicycle or car traffic increases; will need to be reassessed. ▪ Without adequate space for buffer zones or physical separators, lanes can be uncomfortably narrow and dangerous for inexperienced cyclists; more at risk of being encroached upon. ▪ Insufficient space for cyclists to pass one another. If a lane is not physically segregated, this may encourage cyclists to move into the roadway to pass. ▪ Might be too narrow for three-wheelers or cargo bikes of certain types.
Medium 2.2–2.8m Acceptable	▪ Allow safe passing or space for two regular bicycles side by side. ▪ Allow space for three-wheelers or cargo bikes. ▪ A space under 2.5m wide can be used for one bicycle lane and a buffer zone, which increases safety. ▪ The definition of "acceptable" can also be flexible and depends on what possibilities a city has for making spaces for emergent bike lanes.	▪ Might not be wide enough if three-wheeler or cargo bike volumes are high. ▪ Without segregation or a buffer, may be frequently encroached on by vehicles. ▪ Sufficient space may not be available on all streets.
Wide 2.8–3.5m Desirable	▪ Allow safe passing, including of three-wheelers and cargo bikes. ▪ Use the same dimensions as typical vehicle lanes, avoiding complicated logistical operations for the rearrangement of space. ▪ Very safe, comfortable, and inclusive for children, elderly riders, inexperienced riders, and family rides. ▪ Dimensions close to 3.5m allow for the installation of buffer zones, which increase safety for cyclists without compromising comfort. ▪ Appropriate on roads with high motorized vehicle speeds and volumes. ▪ Provide sufficient space for high volumes of cyclists and if bicycling increases over time.	▪ May create the impression of an excessively wide space being taken for bicycles in times of low demand. ▪ Sufficient space may not be available on many streets.

Source: Authors.

Lane placement: A safe bike lane should be located on the same side of the street as car traffic heading in the same direction and adjacent to the sidewalk (Figure 10). For example, in countries where cars drive on the right, a bike lane should be placed on the far right of the road (Figure 11), and vice versa. This placement improves accessibility for cyclists, as it is easier for cyclists to reach their destination from the bike lane.

Things to avoid:

Counterflow: Bike lanes going in the opposite direction to vehicle traffic can significantly increase the risk of crashes or near misses at driveways or intersections, as vehicle drivers may forget to check for cyclists traveling in the direction opposite to that of motor vehicle traffic. Counterflow bike lanes should only be considered where a street is one-way for motor vehicles, and cycle access and convenience is important—for example, in the city center where it is important to be able to cycle in both directions on all streets. If cyclists are allowed to cycle against the direction of traffic on one-way streets, the trip will be somewhat easier by bike than by car (Andersen 2019). However, special attention should be given to intersections, where the counterflow lane should be made visible or given priority. Counterflow bike lane designs should be avoided on multilane one-way streets. Before installing a counterflow bike lane, the street might be reduced to one lane or opened to two-way traffic instead.

Bidirectional bicycle infrastructure: Two-way bicycle lanes increase the risk of conflicts, especially at intersections, where drivers may have difficulty seeing cyclists coming from both directions, or forget to look for cyclists coming from the direction opposite to car traffic (Box 2). Evidence suggests that building one-way cycle tracks reduces injury severity even in the absence of intersection treatments (Thomas and DeRobertis 2013). Consider using bidirectional bike lanes only where a missing link in the network must be connected and installing a bike lane on both sides would be difficult. Measures to increase safety at intersections should be especially considered, such as dedicated signals or slow-down warnings for both cars and cyclists as they approach intersections (Figure 13).

An excessively wide vehicle lane next to a bike lane: The width of car lanes adjacent to bicycle lanes should be set to safe yet practical dimensions. This often involves narrowing them, because narrower lanes encourage safer speeds and make it possible to open up spaces for bike infrastructure. Research on urban arterials has found that a 1 m difference in lane width can change operational speeds by 15 km/h (NACTO 2013).

Narrow car lanes: Car lanes should generally not be narrower than 2.8 m because vehicles will then be unable to fit. This can cause space to be wasted or lead motor vehicles to invade the bike lane. In determining lane width, planners should also consider any necessary requirements for the safe circulation of buses, as well as of emergency and cargo vehicles.

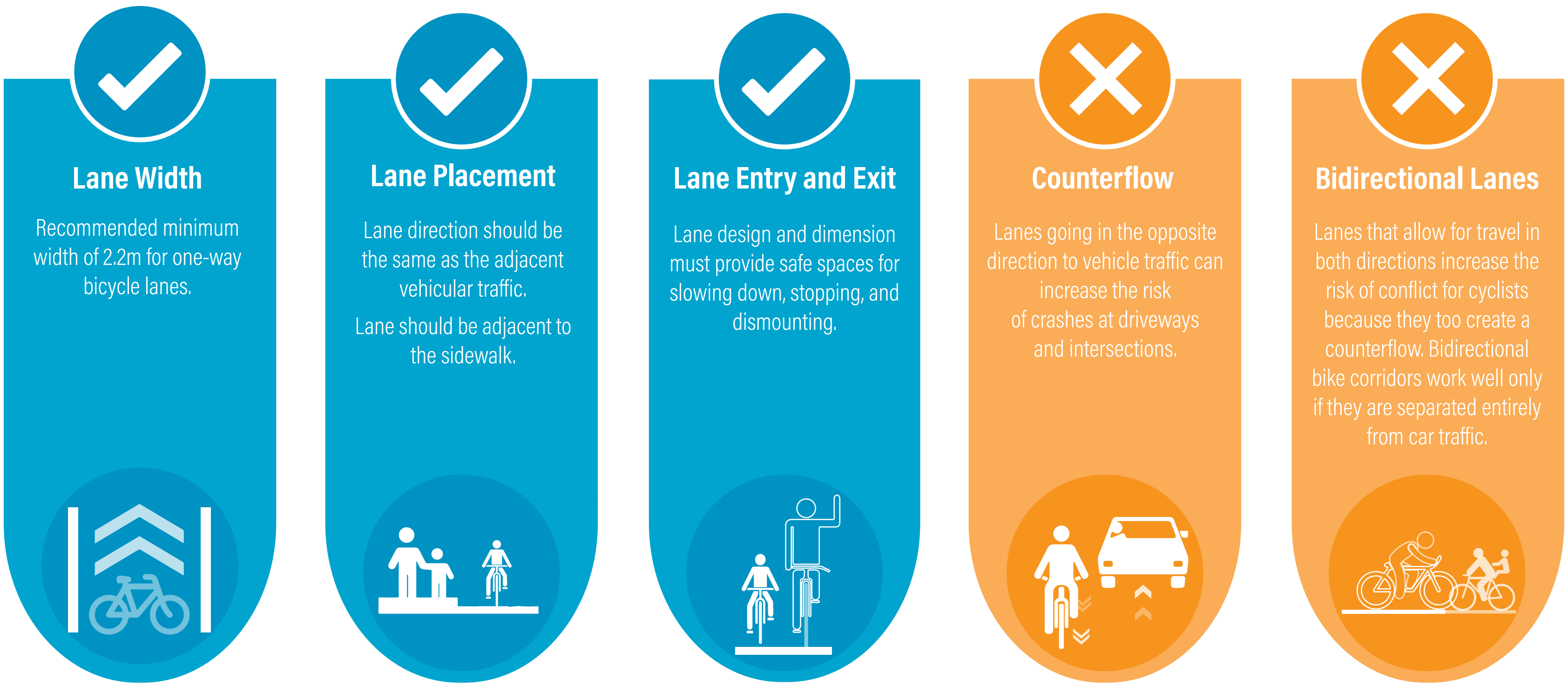
Figure 10 | In Nykøbing F, Denmark, a bicycle lane is located next to the sidewalk and separated from the vehicle lane by a parking lane and a curbstone

Photo: Anne Eriksson.

Figure 11 | An expanded bicycle lane in Berlin gives enough space for cyclists to physically distance, while narrowing the widths of car lanes

Photo: Technische Universität Berlin.

Figure 12 | Do's and don'ts for bike lane design



Source: Authors.

LANE SEPARATION AND DEGREES OF SEPARATION

Vehicle speed is the key factor when determining the necessary level of separation between road users. Measures to reduce speed and volume of car traffic should be considered before resorting to physical separation (Figure 13). In residential areas, school areas, low-speed zones and low-traffic zones, the use of car-free streets (Figure 14) and shared streets (Figure 15) should be the preferred solution for the connectivity of the cycling infrastructure network.

Then, in deciding the best type of segregation when the speed and the traffic volumes of the road increase, cities should also consider the number of people walking and cycling, pedestrian crossing patterns, and demand for curbside access where applicable (ITF 2018).

Where operational vehicle speeds are between 30 km/h and 40 km/h—or under 30 km/h with high traffic volume—lane separation using pavement marking or light cones is recommended (Figures 11 and 23). Above 40 km/h, the bicycle lane should be using physical separators such as curbs, bumpers, bollards, or barriers that are heavy or bolted in place (Figures 16 and 17). These elements must be installed in a way that involves the lowest possible risk of cyclists impacting them by accident. In addition, bidirectional off-road bicycle tracks are only recommendable if they are entirely segregated from the vehicles with elements that protect cyclists from high-speed traffic (Figure 18).

Figure 13 | Selecting appropriate bike infrastructure according to vehicle speeds

Shared Bicycle Streets
Speed: Up to 30 km/h
Volume: Less than 2,000 vehicles/day

- Suitable where traffic calming measures ensure the speed limit is obeyed
- May include bicycle signage and pavement markings

Bike Lane
Speed: Up to 40 km/h
Volume: Less than 6,000 vehicles/day

- Suitable where traffic calming measures ensure the speed limit is obeyed
- Bike lanes are separated from vehicular carriageway by traffic cones, plastic bollards, safety barricades, etc.

Protected Bike Lane
Speed: Up to 50 km/h
Volume: More than 6,000 vehicles/day

- Physically segregated lane adds comfort and security for cyclists on arterial roads
- Must include separation using semi-permanent, or permanent dividing materials such as bollards, planters or curbs

Off-Road Bike Track
Speed: Above 50 km/h

- Exclusive track for bicycles for recreation, or to obviate the need to travel on high speed corridors
- Most appropriate for linear corridors, former rail routes, parks, streams or waterfronts

Source: Authors.
Photos (L-R): Bikemore; Bicycle Dutch; Cambridge Bicycle Safety; Dutch Cycling Embassy.

Painted marking, and—if deemed necessary—the use of light elements for reinforcing segregation (such as cones, freestanding barriers, bolted-down bollards, or the like) are recommended on roads with an operational speed between 30 and 40 km/h. This solution is also acceptable on streets with traffic volumes under 6,000 vehicles/day (Andersen 2012; Schultheiss 2019).

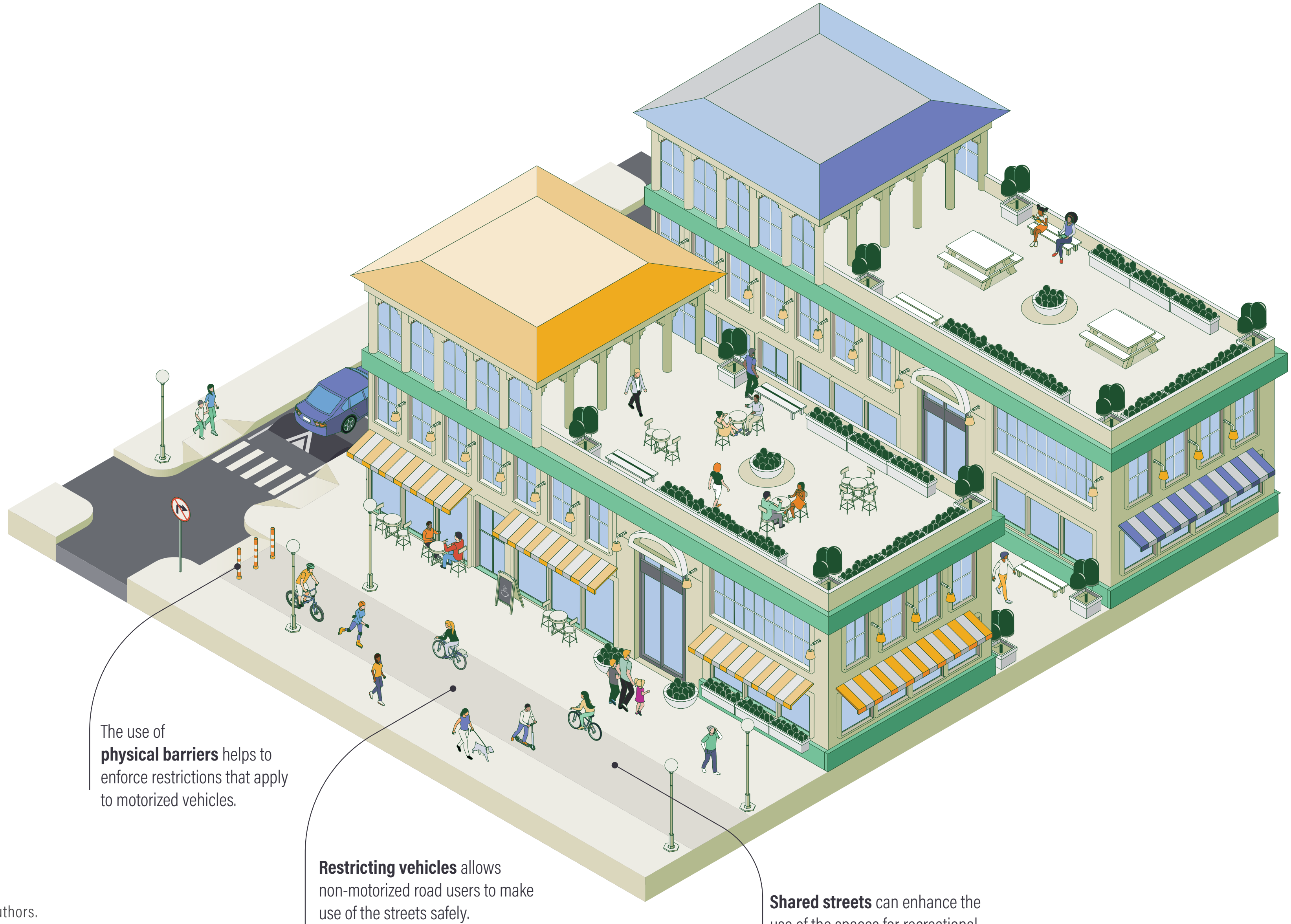
Fixed separators such as bolted-down bollards can be used on roads with a speed of 40 km/h and above, in addition to pavement markings. This type of separation becomes necessary on streets with traffic volumes over 6,000 vehicles/day and traffic of heavy vehicles (Andersen 2012; Schultheiss 2019).

Physical barriers must not create a safety hazard for cyclists. Using flexible materials such as plastic can reduce the risk of injury if cyclists accidentally hit the barriers (Figures 19 and 20).

Bollards and barriers placed close to intersections should be selected and positioned carefully so they don't block the driver's side mirror view when turning. This is especially important for turning heavy vehicles that need to be aware of any cyclists traveling straight through an intersection where they should instead yield.

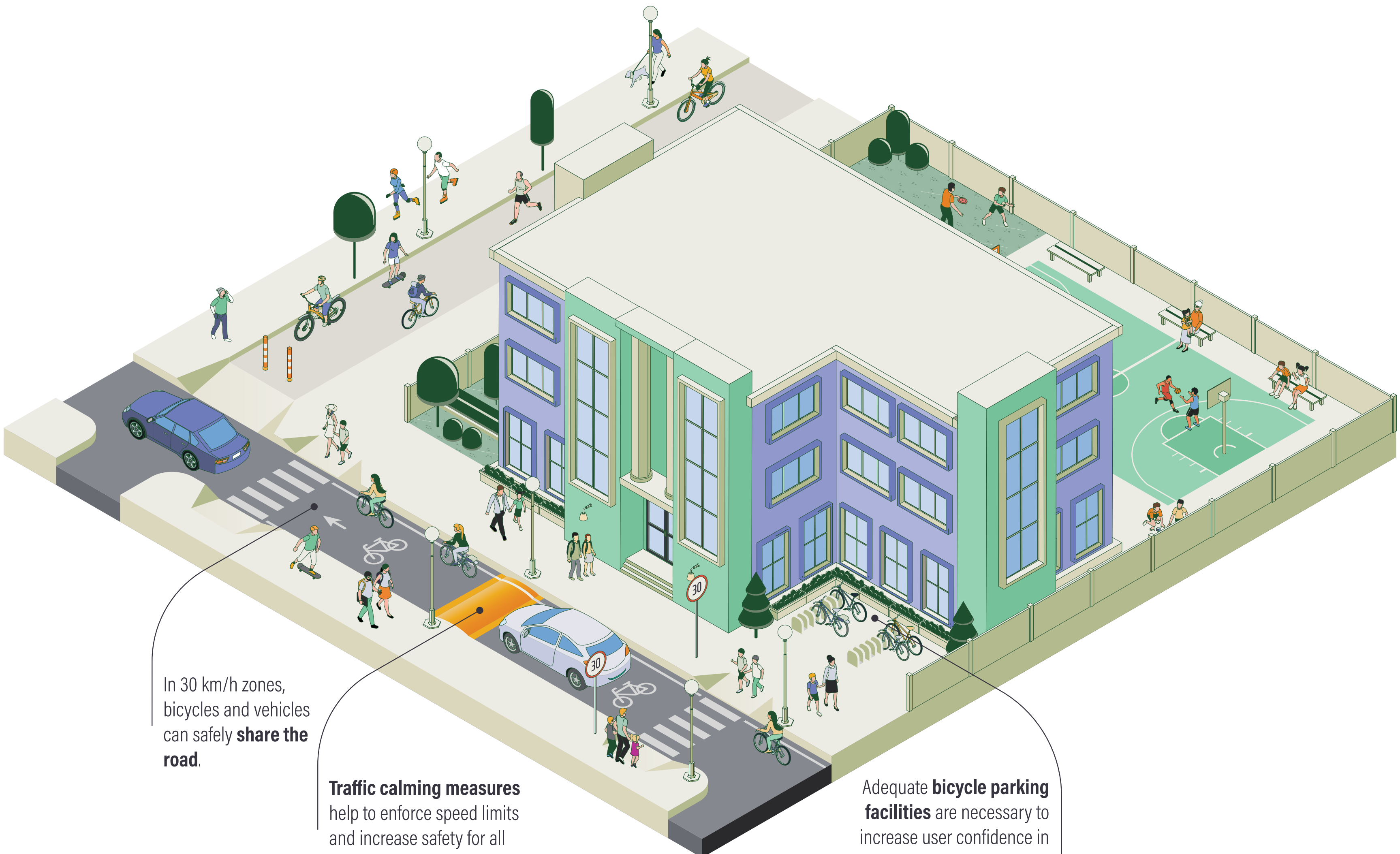
Buffer zones between bicycle lanes and car lanes help increase both safety and comfort for cyclists (Figures 16, 20, and 21), but buffer zones should have a clearly designed transition area at the approach to intersections to make it easier for turning cars to see cyclists and ensure safe turning movements of vehicles.

Figure 14 | Car-free zone



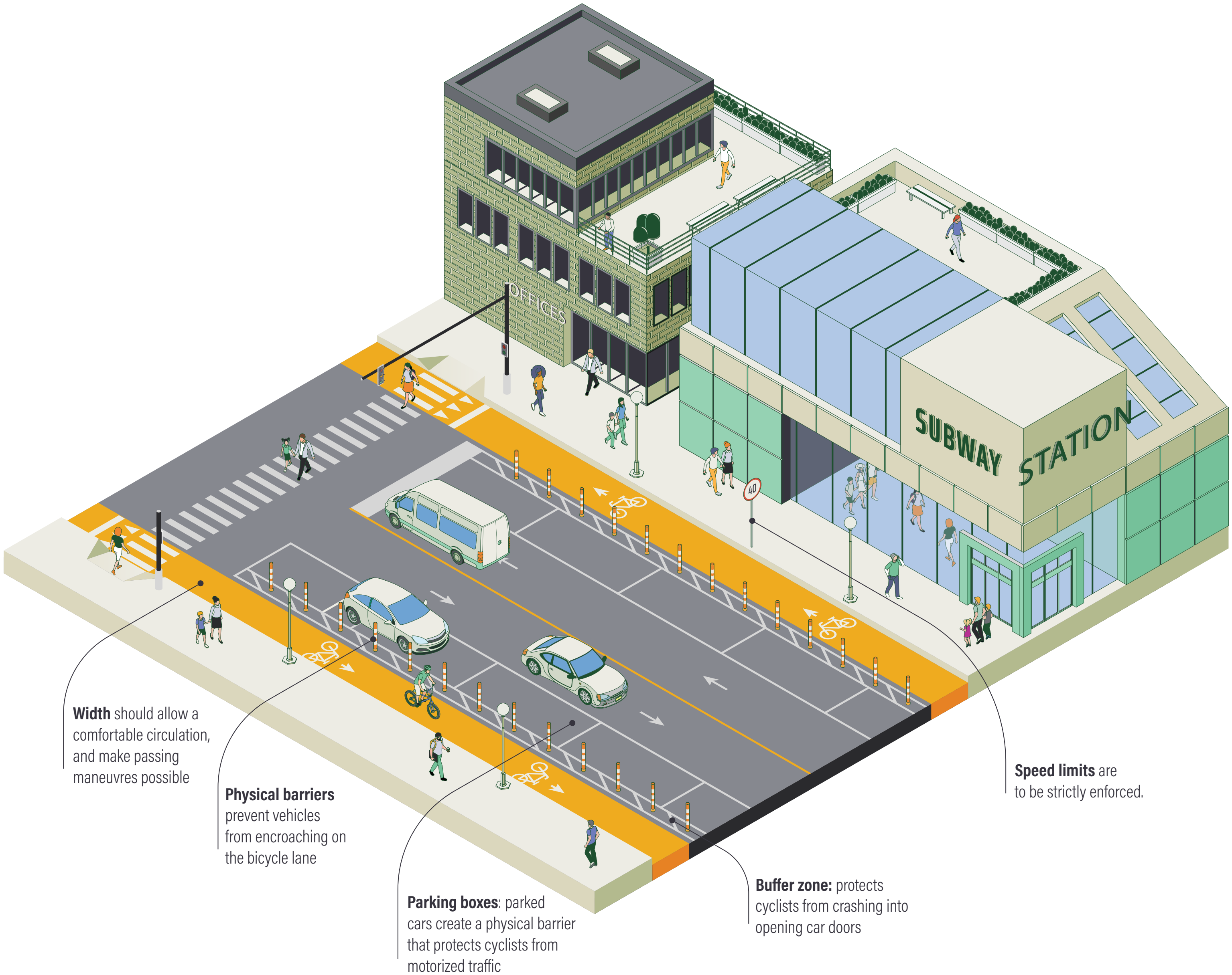
Source: Authors.

Figure 15 | A shared street or bicycle boulevard



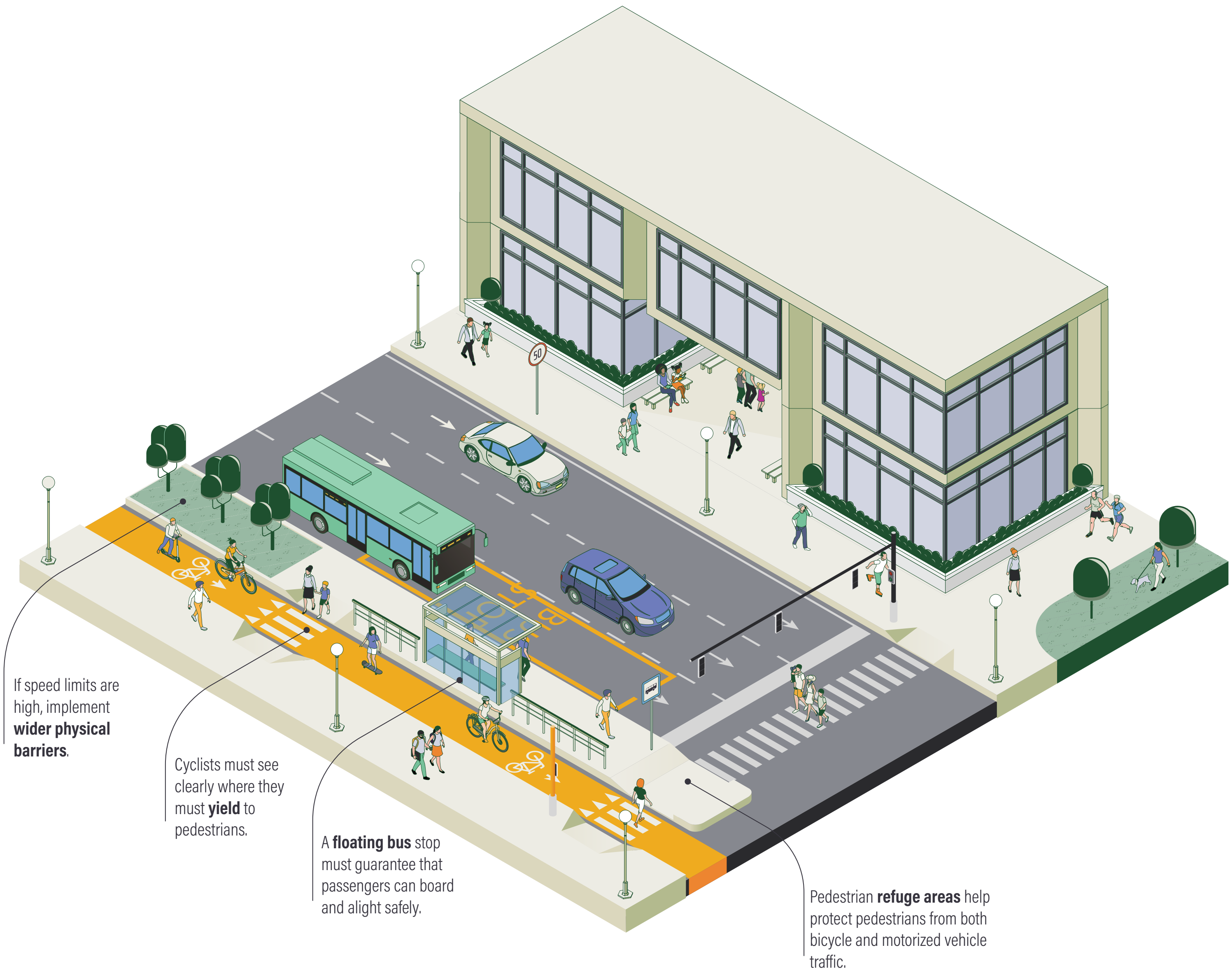
Source: Authors.

Figure 16 | Bike lanes on a 40 km/h street



Note: Plastic cones or similar elements require frequent monitoring in case they need to be protected, replaced, repaired, or rearranged due to deterioration from traffic, theft, or environmental conditions.
Source: Authors.

Figure 17 | Bike infrastructure on a 50 km/h arterial corridor



Source: Authors.

Figure 18 | Off-road bicycle tracks

Source: Authors.

Figure 19 | Temporary vertical separation created by plastic traffic barrels protects cyclists from injury if they hit the barrier (Brampton, Ontario)

Note: Temporary signs recommend physical distancing of 2m between cyclists.
Photo: Centre for Active Transportation.

ADDITIONAL DESIGN CONSIDERATIONS FOR CORRIDORS

Parked cars: Parked cars obstruct the views of all road users and may cause accidents. Any car parking near or adjacent to bicycle lanes must be very carefully considered and managed. If possible, car parking should be removed when installing bike lanes. When reallocating street space, the need for pedestrian space (including physical distancing), bus lanes, and loading zones should be prioritized over car parking lanes. Where this is not feasible, compromise solutions include retaining parking in some designated locations, or using parked vehicles to separate the bike lane from traffic.

Figure 20 | Parked cars provide a buffer and help protect cyclists in the bike lane

Photo: Bicycle Coalition for Greater Philadelphia.

Parked cars should not be located between the bike lane and the sidewalk, as this will result in frequent conflict between cars and cyclists. Therefore, if parking cannot be removed, we recommend installing the bike lane between parking and the sidewalk. Parked cars then provide a physical barrier between the traffic and cyclists (Figures 16 and 20).

Another advantage of a 3m wide bike lane, as recommended in this guidance, is that it allows a buffer zone for car doors to open. In the case of a bike lane narrower than 3m, a buffer zone should be painted between the parking lane and the bike lane to prevent cyclists from being hit by car doors. Sometimes it is better to have a narrower bike lane (e.g., 2.5m) with a buffer to demarcate the safe space and prevent "dooring."

Figure 21 | Bicycle lane protected by buffer and planters in Portland, Oregon

Photo: Roy Simmons.

Signs, markings, and wayfinding: The correct signs and markings should be installed to clarify right-of-way, help navigation, orient road users, and make bike lanes more visible. They should be easily understandable and visible to both cyclists and motorists.

Visibility: Bike lanes must be visible from car lanes. As street lighting is one of the key additional factors that improve cyclist safety (Reynolds et al. 2009), lighting conditions on the road should be inspected to make sure cyclists are visible at night, especially at intersections. Reflective materials can be used to warn drivers of the existence of bike lanes at night. There are many options for temporary reflective infrastructure, such as cones, bollards, or traffic barrels.

LIMITING CONFLICTS: INTERSECTIONS, ROUNDABOUTS, BUS STOPS, AND BUILDING ENTRANCES

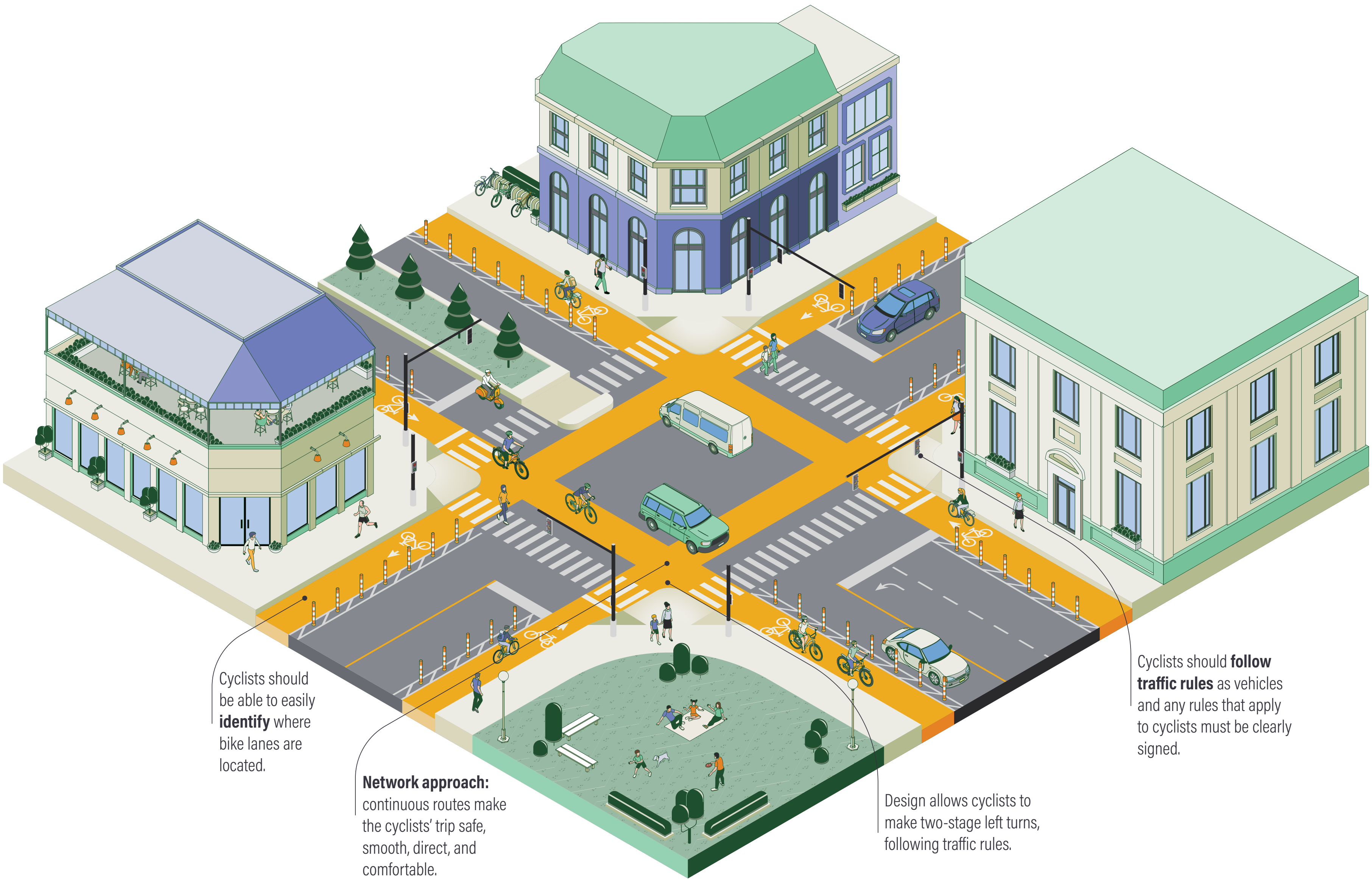
Intersections, bus stops, driveways, and building entrances are locations that frequently generate conflicts between cyclists and other road users. They should be designed so that it is easily understood who has the right-of-way.

Intersections

Most serious collisions in urban areas between cyclists and motor vehicles take place at intersections. It is well known that as many as 75 percent of crashes involving cyclists occur at intersections, so safe design is crucial (FHWA 1999; Isaksson-Hellman 2012; European Commission 2018b). Intersections are often the weakest link in the design and implementation of cycling networks when they should be the main focus. Counterintuitively, it has been found that car drivers tend to pay less attention to cyclists when cyclists have their own infrastructure, which increases the risk of conflicts and traffic crashes when they need to merge into shared infrastructure at intersections (Jensen and Sørensen 2020). Once intersections are safe, the network can more easily be built out in every direction.

In principle, every intersection with a new or existing bicycle lane should provide protection for cyclists and highlight their right-of-way (Figure 22). Intersection design must take into account the objective safety of users (reducing actual numbers of collisions), and the subjective or perceived safety (creating a sense of safety for people while they are using the road), in order to ensure a safe bicycling culture. Intersections should ensure lower vehicular speeds by providing adequate traffic calming methods and clear signage and pavement markings, especially when cars are turning. Design should also aim to maximize the visibility of cyclists to drivers, especially where there are high volumes of heavy vehicles (such as buses and trucks and other vehicles that tend to have larger blind spots) and/or turning lanes. This is particularly important in countries where bicycling has not been widely practiced and vehicular drivers are not used to sharing roads with cyclists. To create the most appropriate design, cities need to research, observe, and adjust to what is safest for each location. Please refer to Figure 23 and Box 2 for more details on designing safe intersections.

Figure 22 | Intersection with bicycle lanes



Note: Plastic cones or similar elements require frequent monitoring in case they need to be protected, replaced, repaired, or rearranged due to deterioration from traffic, theft, or environmental conditions.
Source: Authors.

Figure 23 | Designing safe intersections for cyclists

Visibility

Parking spaces should be eliminated at least 10m ahead of intersections to increase visibility.

Bike lanes crossing intersections should be delineated with highly visible markings.

Bike boxes at intersections in front of a turning lane can provide more space and visibility for waiting cyclists, to avoid conflicts between straight-going cyclists and turning vehicles. This is particularly pertinent under pandemic conditions, where cyclists waiting at intersections also need sufficient space for physical distancing. Bike boxes should never be extended over two lanes or more, as it is dangerous to place inexperienced cyclists in front of lanes that are for straight-going traffic.

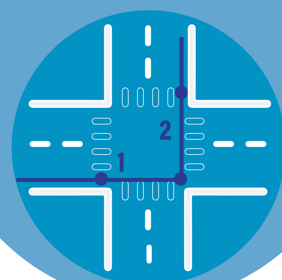
Turning

Stop-lines for cars should be set back at least **5m in signalized** intersections so that both cyclists and pedestrians are more visible to drivers.

A **two-step turn** for cyclists turning across traffic should be considered at signalized intersections.

Turning vehicles should have **separate turning lanes** at signalized intersections with bicycle lanes if space allows. This makes it easier and less stressful for drivers to yield to cyclists before turning, reducing the risk of collisions.

Temporary bollards can be installed to **extend curbs** and **slow turning cars** by reducing the corner radius.



Protection

Pedestrian refuge islands can be installed at intersections for crossing pedestrians and cyclists. They should be wide enough to accommodate one bike (2m) or a parent with a stroller. Two meters is sufficient unless pedestrian volumes call for a larger area. This is more important for major streets at nonsignalized intersections, or in the case of very wide roads that have insufficient signal timing for children or the elderly to walk all the way across.

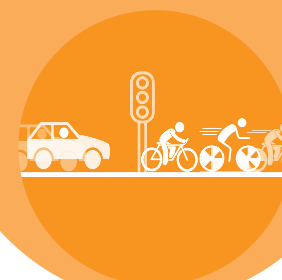
When a minor road is connected to a major road, a **raised crossing** can be considered on the minor road, to reduce the speed of cars as they turn onto that road.

Signals

Traffic signal phases should be reviewed and adjusted so that cyclists can cross larger intersections safely before any conflicting vehicles have a green light.

If resources allow, consider the implementation of **separate bicycle signals**.

For more recommendations on signals for cyclists, please see Box 2.



Source: Authors.

Box 2 | Designing Safe Intersections for Cyclists

To maximize safety at intersections with bicycle lanes, we must consider a great range of possible conflicts. The most common is turning cars hitting cyclists who are traveling straight ahead. Depending on the intersection configuration, a selection of the following recommendations for signals can be considered:

- Traffic signal phases should be reviewed and adjusted so that cyclists can cross larger intersections safely before any conflicting turning vehicles have a green light.
- At most large intersections with a cycle lane, cyclists should have their own light, and it has to be differentiated from the main signal. In Denmark, for example, the light is often smaller than the main signal and has a bicycle symbol.
- If resources allow, separate bicycle signals, such as pregreen signal phases for cyclists, can increase cyclist visibility by allowing them to advance before the vehicle traffic. This is especially useful if there is not enough space for a separate turning lane.
- To prioritize cyclist travel times on roads with many signalized intersections, signal timing can be coordinated and adapted to cyclist speeds to create a "green wave" for cyclists.
- Where there are fewer cyclists and a proper green wave is not installed, planners should ensure that cyclists don't have to stop unnecessarily at closely spaced signals. It is recommended that calculations be based on a 20 km/h travel speed (City of Copenhagen 2013).
- By using data from information technology support systems, data from cameras can be used in many practical ways to improve the flow of cyclists. The calculation of cyclist traffic volumes and cyclist travel times enables signal phases to be optimized. For example, if more than 300 cyclists are detected over a period of 15 minutes in certain locations in Copenhagen, or if travel time on a stretch is longer than 2 minutes 30 seconds, the traffic control system gives cyclists a longer green phase. Countdown signals can help to improve cyclists' behavior in traffic; longer green phases on rainy days are examples of application of these technologies (Cycling Embassy of Denmark 2018).

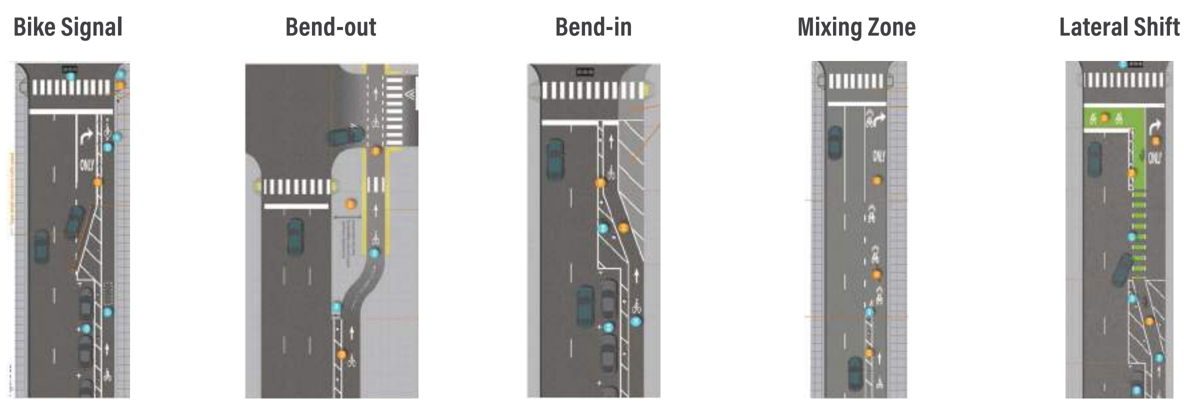
Source: Authors.

We identify five approaches to designing intersections involving bicycle lanes (Figure 24 illustrates these five types of intersections), though the first two are most commonly used (see comparison between them in Table 2).

1. Protected or "bend-out" intersection design aims to keep cyclists separated from car traffic for as long as possible. Extended corners slow the speed of turning traffic and provide refuge areas for pedestrians (Figures 25 and 26).

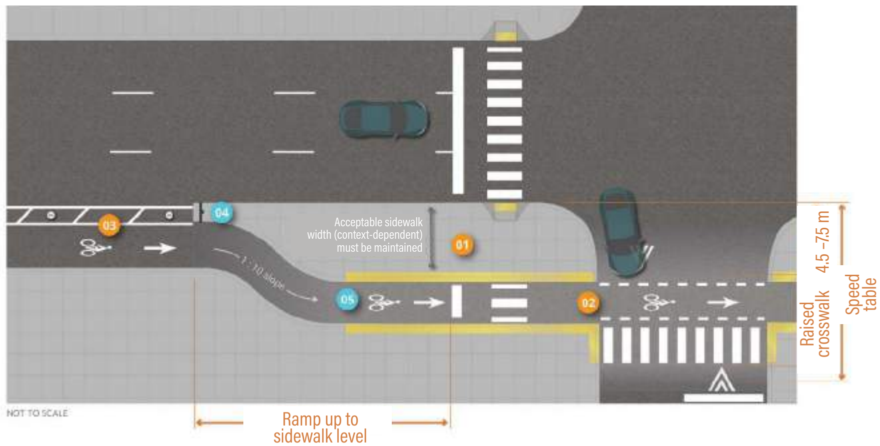
2. Merging or "mixing" lane design integrates cyclists into the traffic flow by mixing the turning cars with the cyclists who continue ahead in one single lane (Figures 27, 28, and 29).

Figure 24 | Types of intersection management for protected bike lanes



Source: Adapted from FHWA (2015).

Figure 25 | Typical layout of a protected intersection

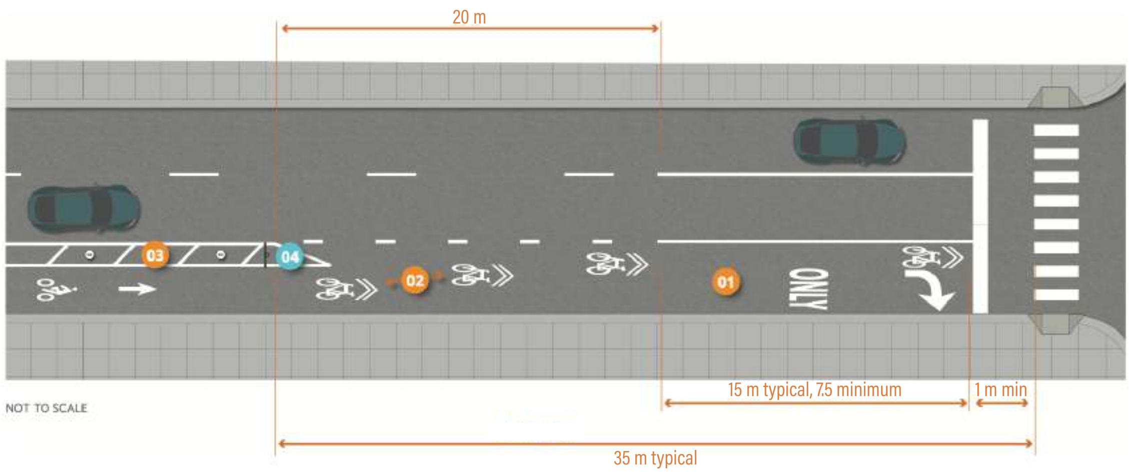


Source: Adapted from FHWA (2015).

Figure 26 | Protected intersections providing refuge for pedestrians and bus passengers

Source: City of Paris.

Figure 27 | Typical layout of a merging-lanes intersection



Source: Adapted from FHWA (2015).

Figure 28 | A bike lane buffer zone ending, allowing for bikes and turning traffic to mix prior to the intersection, Denmark

Photo: Google Images.

Figure 29 | Lateral shift design makes turning drivers aware that they must yield to cyclists going straight

Source: NACTO (2016).

3. Bicycle lane signals (lights) at an intersection can potentially eliminate turning conflicts by separating a cyclist's movement through the intersection from car turning movements (Figure 30).

4. In a lateral shift intersection, turning vehicles must cross a high-visibility bike lane, and they have clear responsibility for yielding.

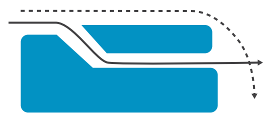
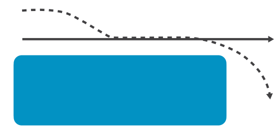
5. With a "bend-in" bike lane, the position of the bike lane moves closer to turning vehicles to increase cyclist visibility.

The design of bicycle lanes at intersections is fundamental to ensuring cyclists' safety. Some key elements of safe intersection design are summarized in Box 2.

Figure 30 | Traffic light for cyclists in Denmark

Photo: Cycling Embassy of Denmark (2018)..

Table 2 | The two most common types of approaches to intersections

	PROTECTED INTERSECTIONS (BEND-OUT)	MERGING LANES (MIXING ZONES)
Example		
Characteristics	Lanes are clearly separated, all the way into the intersection. Extended corners slow turning traffic	A bike lane and a car turning lane merge a few meters before an intersection. Merging slowly is **extremely important** for the safety of cyclists.
Advantages	Drivers are forced by design to reduce speeds due to the tightening of curb radii. Pedestrians can benefit from expanded refuge areas in corners. Cyclists have a stronger sense of safety and comfort in this type of infrastructure (Monsere and McNeil 2019). The higher perceived safety level is more likely to attract inexperienced cyclists.	Drivers are more likely to see cyclists before entering the intersection, which reduces the risk of the common "right-hook" collision (NACTO 2014). Easy to adapt the concept to locations with limited roadway space. Construction cost is usually lower than a protected intersection. It has been proved that this solution is safer in terms of objective safety (fewer number of crashes involving cyclists) (Jensen and Sørensen 2020).
Disadvantages	Cyclist visibility to right turning cars can be obstructed. The risk of right-hook collisions remains and must be minimized by additional design elements. Need more space than a merge design. Usually a permanent measure, requiring curb changes and therefore a higher construction cost.	In cities with little cycling culture, drivers might be less likely to yield to cyclists before merging into the same lane. This can be addressed by implementing traffic calming measures in merging lanes and a proper design to ensure that turning cars are slowing down and yielding to bikes traveling straight in their lane, especially in locations with little cycling culture. Drivers may not be familiar with the new design if only a few intersections use it. This can increase the chance of mistakes by right-turning drivers. May increase traffic stress of cyclists under high car traffic volumes, as cyclists are more exposed to traffic and forced to share space with vehicles. In particular, merging lanes may not be appropriate at intersections with very high peak automobile right-turn demand as feelings of traffic stress among cyclists could increase (NACTO 2014). Need traffic calming measures to be safe and ensure that cars merge slowly, especially in cities with little cycling culture. Cyclists might perceive them as more dangerous or more uncomfortable, leading to a lower subjective safety. Cyclists tend to have a less favorable view of this type of approach.

Source: Authors.

Roundabouts

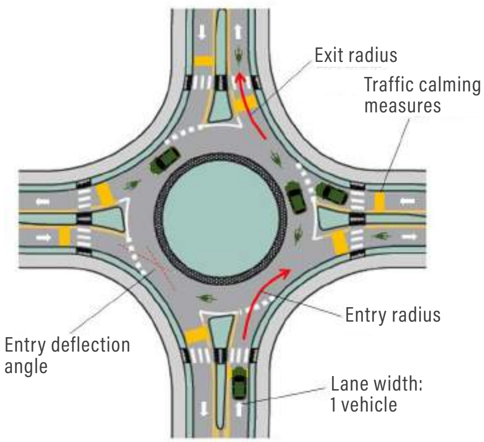
Roundabouts can be safer for cars than a multiple-approach intersection, because they reduce the risk of head-on and left-turn collisions and they slow down speeds. However, without traffic calming, they can be riskier for people walking and biking. Roundabouts with more than one lane are dangerous for cyclists because entering drivers can block the view of other drivers.

If few cyclists merge with traffic, cyclists should be highly visible by motorists and the speed of traffic must be slow enough to make the operation safe (Figure 31). When we merge vehicles with bicycles, their visibility is higher and everybody on the way is more likely to pay attention to who is occupying the lane.

In addition to specific design considerations for safe pedestrian-crossing facilities at roundabouts, which can be found elsewhere, we recommend these design principles for cyclists' safety:

- **A compact roundabout is safer for cyclists**: Single-lane roundabouts with tighter entry and exit radii, narrower lane widths, and a higher entry deflection angle are considered safer for cyclists (and easier to implement in urban environments). This slows down car speed when entering and exiting the roundabout, which allows more time for the driver to see and yield to the cyclists.
- **Speed**: Traffic speed within a roundabout **should be lower than 30 km/h**. We achieve this if cars and cyclists do not find themselves very "comfortable" navigating the roundabout, which forces a lower speed of circulation and makes cyclists more visible.
- **Increase visibility**: Mutual visibility between approaching drivers and cyclists and pedestrian crossing points should always be considered. Reducing speed can also improve visibility.
- **Mixed bicycle traffic**: Cyclists can only share the road with cars safely at a single-lane roundabout with low traffic volume and low speed.
- **Clear signs and markings**: If cyclists share streets with cars, clear markings of bicycles should be painted on roads. If a separate bicycle route is installed, clear signs should be installed to guide cyclists.
- **Consider alternative routes if safety cannot be met**: Where it is not feasible to provide suitable and safe roundabouts for cyclists and pedestrians, alternative routes or other forms of control should be considered, such as signals.
- Consider that in **starter cycling cities** with little cycling culture, drivers are less likely to accept or respect the right-of-way of cyclists. Thus, cyclists' right-of-way must be strongly underlined and enforced by making use of traffic signs, markings, and any other necessary traffic control devices.

Figure 31 | Key elements for the design of a compact roundabout



Source: Authors, adapted from FHWA (2015).

Bus stops

Cyclists passing a bus stop can collide with buses and with passengers embarking, disembarking, or crossing. To minimize conflicts at bus stops, we recommend the following guidance:

- **Never combine buses and bicycles in one lane**: Buses stop frequently while cyclists keep moving, which increases the risk of collisions.
- **Design bus stops to reduce conflict between buses and cyclists**: This can be achieved by a "bus stop bypass" (also called a floating bus stop) where a bike lane bypasses a bus stop from behind (Figure 32). Another protective option is to use an elevated bike lane at a bus stop (also called a "Copenhagen-style" bus stop), where the bike lane is higher than the carriageway (Figure 33).

- **Reduce conflict between cyclists and bus passengers**: The safety of passengers crossing a bike lane when approaching or leaving buses can be enhanced by installing yield markings and/or rumble strips to notify cyclists to yield to passengers. Another design option, if space is available, is to paint a refuge area between the bus lane and the bike lane. The refuge should be more than 2 m wide, enough for a parent with a stroller or a wheelchair user, and be visually differentiated by colors and markings.

- **Increase visibility**: The minimum measure is to use markings and colors to make bicycle lanes clearly visible. Spaces for cyclists and buses should be clearly demarcated to minimize confusion and conflict (Figure 34). As cyclists should be next to the curb, the bus lane should be moved to the outside of the bike lane. Markings must make clear to cyclists that they have to yield (Figures 34 and 35). Alternatively, a refuge space can be created for passengers so that they can stand and wait next to the bus lane, while cyclists can pass behind them (Figures 33 and 36).

Figure 32 | A floating bus stop where bicycles pass a bus stop from behind

Photo: Cycling Embassy of Great Britain.

Figure 33 | Copenhagen-style bus stop in London, where bike lane is elevated and markings indicate that cyclists must yield to passengers

Photo: Cycling Embassy of Great Britain.

Figure 34 | A schematic design of a bus stop with bike lane, with clear markings and color pavement to separate the spaces for passengers and cyclists

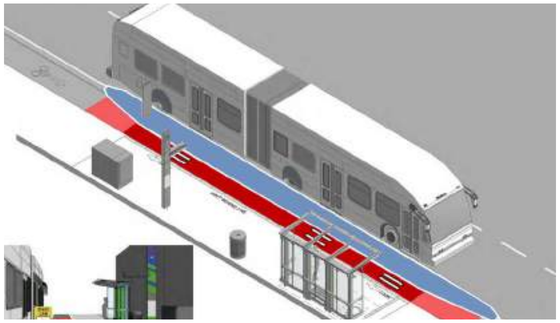
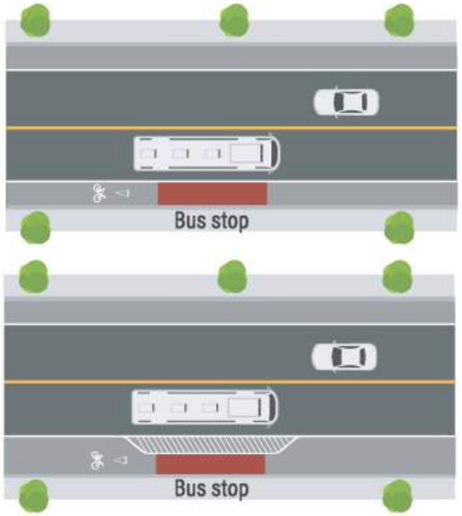


Photo: Adapted by authors from TriMet/bikeportland.org.

Figure 35 | Requiring cyclists to yield at bus stops and creating refuge islands can reduce conflict



Source: Authors.

Figure 36 | Permanent cycle track with bus stop and parking on a bicycle superhighway in Copenhagen

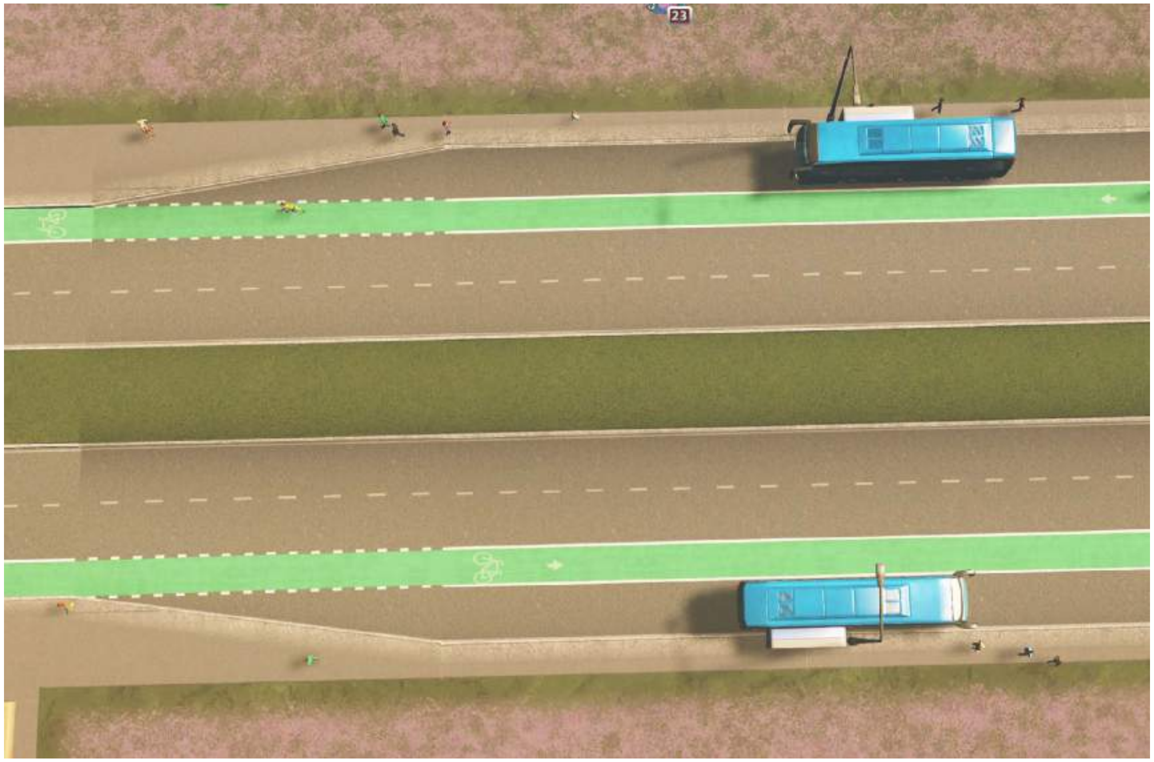
Photo: Lukasz Katlewa / Wikimedia Commons.

In exceptional cases, where space is sufficient (i.e., cyclists can circulate freely) and bus frequency is low (fewer than four buses/hour), buses could occupy or cross the bicycle lane to approach the bus stop, making the cyclists merge left and pass buses boarding and alighting passengers (Figure 37). In this case, the bike lane should have visible markings.

Other design considerations

Sidewalk activities: For safety and accessibility, we recommend locating bike lanes adjacent to the sidewalk. However, pedestrians are the most vulnerable road users of all, and their needs and safety must also be taken into consideration when planning a bike lane. Installing properly designed ramps to improve accessibility between sidewalks and cross-streets would bring additional benefits for

Figure 37 | Bus stop crossing the bicycle lane



Source: Adapted from Steam Community.

pedestrians as well as cyclists. The width of the sidewalk should be sufficient to allow for the number of people walking. If it is not, people may spill into the bike lane or be constrained by the close proximity of fast-moving bicycles. In this case, it may be necessary either to extend the sidewalk during construction of the bike lane or to install a wider bike lane.

Conflict at building entrances, garages, and driveways: Special attention should be paid to signs and markings at these high-conflict points so that drivers who are entering or exiting are aware that they must yield to cyclists. Bollards should preferably not be used to protect bike lanes in these locations, as they can obstruct or even harm cyclists. Markings can be used to make minor entrances more visible to cyclists and the cycle lanes more visible to drivers (Figure 38). The speed of motorists can be reduced through elevated surfaces or small turning radii, for instance.

Figure 38 | Markings can indicate entrances to buildings

Photo: Dianne Yee. FHWA (2015).

Figure 39 | Safe bike and micromobility lane created by plastic barriers, Manila

Photo: Jilson Tiu/Greenpeace.

Figure 40 | Plastic traffic barriers are widely used for the opening of new bicycle corridors in Mexico City

Photo: Manuel Solá Pacheco / SEMOVI-CDMX.

Bike parking near bike lanes: Sufficient bike parking space should be allocated in high-demand locations, to complement the bike lane network. Parking should ensure bicycle security, should be easily accessible from the bike lane, and should allow additional space for mounting and dismounting from a bicycle without hindering other cyclists or pedestrians. Make sure bike parking does not block the sidewalk by leaving at least 2 m of free space, or by placing bike parking between the bike lane and the roadway.

SELECT APPROPRIATE MATERIALS

A wide range of materials is available to construct emergent bike lanes (Street Plans Collaborative 2016). Selection should be determined by the expected duration of the installation and the level of protection required. Other local variables include what is available and affordable, what will be easily recognizable to users, what will be resilient to local conditions (strong wind or rain, risk of theft, being hit by vehicles, etc.), and what will be acceptable in the local context.

The durability of nonpermanent materials can range significantly, from days (cones) to months or even years (paint, bolt-down rubber, plastic, metal, or concrete), and one bike lane may evolve with different materials being used over time. If a design is to be made permanent, the type of separation may need to change in design as well as material. For example, low-rise concrete curbstones are preferable to any permanent vertical design, because vertical dividers such as bollards present more of an injury risk to cyclists when they are made from concrete (Figures 39 and 40).

Table 3 describes the characteristics of selected materials and their suitability for short- or longer-term deployment.

Table 3 | Options for materials for safe bike lanes: Immediate implementation and long-term transition

TIME FRAME	MATERIAL TYPE	CHARACTERISTICS	NOTES ON COSTS
Short to medium term (visual separation only—impermanent)	▪ Chalk ▪ Chalk paint ▪ Adhesive street markings ▪ Paint ▪ High-quality reflective paint	▪ Require monitoring due to deterioration from traffic or environmental conditions ▪ Markings have limited duration ▪ Visual messages to any road users are easy and cheap to provide	▪ Implementation cost can be kept to a minimum since many of these elements may already exist in a city's inventory and staff can be redirected to implementation and maintenance tasks. ▪ Cost of painting has been estimated at $4 per meter; a dedicated painted lane has been estimated at $38 a meter (monetary values, converted to US$, from Benni et al. 2019).
Short term (physical separation)	▪ Freestanding barriers ▪ Large cones (minimum height: 700 mm) ▪ Traffic barrels ▪ Signs on wheels (portable traffic sign stands) ▪ Banners	▪ Rapidly deployable ▪ Rapidly adaptable to changing conditions or performance review ▪ Vulnerable to theft, weather, vehicles ▪ Require frequent monitoring to protect, replace, repair, or rearrange due to the above ▪ Businesses might find them undesirable ▪ Ideal for a limited number of days but not for longer periods	▪ Implementation cost can be kept to a minimum since many of these elements may already exist in a city's inventory and staff can be redirected to implementation and maintenance tasks. ▪ The cost of a planter-protected cycle track has been estimated to be around three times the cost of a dedicated painted lane (Benni et al. 2019).
Medium term (semipermanent)	▪ Plastic/rubber bollards (bolt down) ▪ Planter boxes ▪ Rubber/plastic/concrete speed humps (bolt down) ▪ Rubber/plastic/concrete curbstones (bolt down)	▪ Moderately rapidly deployable and adaptable to changing conditions or performance review ▪ Present a significant risk when hit by cyclists and motorcyclists ▪ With a wide enough lateral separation, it is not necessary to install such devices ▪ Durable, can be left in place for the long term if desired and approved ▪ Must be frequently monitored to ensure function and safety ▪ Vulnerable to removal due to policy or priority changes or political pressure	▪ The cost of a bollard-protected cycle track can be around 1.5–3 times that of a planter-protected cycle track (Benni et al. 2019).
Long term (permanent)	▪ Concrete/asphalt ▪ Guardrails	▪ Lock in safe design permanently ▪ Require formal design, planning, and permitting processes; may require multiple authorities to give permission; may take many years to get to implementation ▪ More effective to prevent cars from encroaching ▪ May be more expensive to install	▪ The cost of a concrete curb- or median-protected cycle track can be 10–15 times that of a bollard-protected cycle track (Benni et al. 2019).

Note: Reference values and cost scales can change from country to country, depending on multiple factors.

Source: Authors.

MANAGE AND ENFORCE TO ENSURE SAFETY

To maintain the safety and integrity of bike infrastructure, ongoing management and enforcement is required after installation.

Speed limit enforcement: Compliance with vehicle speed limits should be strictly enforced by making the best use of available resources, including human (traffic police, enforcement operations, location and duration of checkpoints), technical (temporary or permanent traffic calming infrastructure, speed detection devices, cameras, etc.), and financial ones. This is especially pertinent in the context of a pandemic, as in many places travel restrictions have resulted in much lower traffic volumes, which can encourage drivers to exceed the speed limit. In cases where police resources are limited, and/or trust in police is low, cities may choose to prioritize automated enforcement or self-enforcing infrastructure design, such as traffic calming measures to increase speed compliance (Welle et al. 2015).

Bike lane management: Lanes should be monitored frequently by traffic authorities for encroachment by parked or paused vehicles or other activities. Those responsible for impeding the use of the lanes should be warned and/or sanctioned. Where enforcement capacity is limited, lane segregation can be self-enforcing. Bollards, planters, or curbs can prevent drivers from parking in bike lanes.

Curbside management: To reduce the risk of encroachment or conflict with bike lane use, delivery services by motor vehicles should be regulated in time and space, to assure that vehicles will not use bike lanes for parking or stopping, especially at peak hours when cyclists use the streets most. Designating special areas for loading and unloading operations, or passenger pick-up and drop-off can also be beneficial. Deploying information campaigns and using signboards or signages to warn ride-hailing drivers and delivery personnel is also helpful for cyclists' safety.

Intersection monitors, cycling monitors, and related staff: One option for dangerous or large intersections, especially those with new or safe cycle infrastructure, is the addition of "intersection monitors." Monitors hired by cities can oversee intersections, guiding traffic to ensure efficient circulation and the safety of pedestrians and cyclists. Cycling monitors may be available alongside new safe bike lanes, or at key cyclist hubs, to provide basic help and orientation to cyclists, especially new bike users. This type of role can provide training and professional opportunities for young people and also reduce the need for police engagement with cyclists (see Box 3).

Box 3 | Building community engagement with monitors, guides, and law enforcement

Bike lane monitors, guides, and police officers can all contribute to the safety of cyclists. For example, in Bogotá, Colombia, a large team of monitors forms a key part of the people-oriented logistics and operations program that guarantees safety and wellness for the 1.5 million users of the one-day *ciclovía* corridors in Bogotá every Sunday (Vergel-Tovar et al. 2018). The monitors enforce traffic rules on the *ciclovía* corridors and intersections, keep public order, and provide assistance and first aid if required in certain emergency situations (Figure B3.1).

In Mexico City, police officers on bicycles patrol the Paseo de la Reforma daily. The most iconic boulevard in Mexico City, the Paseo features wide bicycle lanes and public bikeshare docking stations. The bicycle police issue warnings to people breaking traffic rules and offer friendly advice on how to use the road safely.

Figure B3.1 | Cycling monitors help keep cyclists safe in the middle of traffic, Bogotá

Photo: Secretaría Distrital de Movilidad, Bogotá.

Training and equipping police officers with bicycles can also help monitoring and enforcement operations as well as increase awareness of cycle safety among law enforcement personnel. However, this should be undertaken with careful consideration of the local context. In locations where trust in police and/or police resources is low, staff from other agencies may be given this role—for example, transport, park, education, or public transport staff. Increasing the number of such trained professionals can be a valuable part of the promotional and management strategy for the new emergent bike lanes.

COMMUNICATE WITH AND ENGAGE ALL ROAD USERS

Communication and engagement campaigns can be used to help the public contribute to the planning and prioritization of safe bike lanes. More generally, good communication helps people understand new traffic patterns, be alert to risks, and be more attentive on the road. Over the longer term, outreach promotes permanent changes to bicycle infrastructure and a bicycle-friendly culture where cycling is seen as a safe, convenient, and normal way to travel. Typically, communication and engagement activities are carried out over long periods of time and are based on building trust. Targeting these efforts appropriately is key and involves identifying immediately impacted stakeholders (e.g., businesses on cycle routes) and more face-to-face engagement than is normal for transport projects.

Community engagement and feedback: The success of temporary measures depends greatly on community involvement, understanding, and a sense of ownership of the newly implemented bicycle infrastructure (Rissel et al. 2010; Crane et al. 2016). The COVID health emergency has compelled cities to respond quickly to new travel and spatial needs, but this should not be at the cost of community support or understanding (Box 4). The goal of safe bike infrastructure is to satisfy travel needs, improve safety, and enhance the community's overall quality of life during a very challenging pandemic. Businesses, for example, are under unprecedented stress, making further unexpected disruptions particularly disturbing for them.

Any measures to be implemented should be properly discussed with members of the community, so they can see their opinions and concerns properly reflected in any transformation that their streets will undergo. Community engagement is sometimes challenging, but community feedback is essential to support the implementation process at every stage. Collecting opinions and conducting follow-up studies after implementation is also

Box 4 | Mesa Bici: Guiding Emergent and Long-Term Bicycle Policy in Peru

The Mesa Bici (Bicycle Board) program was created in 2015 to spotlight urban mobility issues and accelerate the implementation of sustainable mobility solutions in Peru, especially walking and biking. It provides a platform for technical knowledge-sharing and networking among like-minded organizations, foundations, local officials, and experts.

In response to the COVID-19 pandemic, the government of Peru identified the development of a national sustainable mobility policy as one of many measures that could help to maintain physical distancing, reduce the risk of transmission, and provide mobility especially to essential workers.

To support the initiative, Mesa Bici introduced a public platform consisting of online meetings, webinars, and shared e-documents to garner support and feedback from experts for the implementation of initiatives to promote cycling, walking, betterment of public spaces, and overall sustainability. Cycling enthusiasts and government officials were invited to help develop cycling policies and proposals as well as implement safe cycling infrastructure to protect public health and tackle rampant motorization, an unexpected result of the COVID-19 pandemic.

The open platform rapidly gained support and attention. It brought together more than 30 participants, including 16 national-level advocacy groups. Mesa Bici successfully helped liaison between the community, the traffic authorities, and public officials. The network learned about upcoming plans and provided feedback for the implementation of emergency bike lanes and supportive infrastructure.

The network and its expert members offered recommendations on the development of the national sustainable mobility policy to help boost public transport use, provide safe and connected infrastructure to walk or cycle, and discourage private car use in the new circumstances created by COVID-19. The network also produced a guidance document on the technical and social aspects of policies to encourage cycling that should be considered by the implementing authorities in Peru (Lima Cómo Vamos n.d.).

Mesa Bici also advocated for measures and policies from city officials to reduce speeds, design safe streets, implement cycle lanes, and build a cohesive network of cycle lanes to link key areas and create cycle-friendly cities.

The participatory process created by Mesa Bici has provided a strong and united voice for public space, health, and sustainable mobility advocates in Peru. It has created a mechanism for direct engagement in government processes, to foster a positive cycle of collaboration between government and civil society. This has provided crucial expertise and legitimacy to government efforts to rapidly deploy high-quality sustainable urban mobility policies that help the nation tackle the pandemic.

Source: Personal communication and text elaborated by Mariana Alegre Escorza, executive director, Lima Cómo Vamos. Lima, Peru, October 2020.

necessary both to learn what adaptations are necessary to the bike lane design and routes and to quantify the benefits of the intervention. It is not unusual to find tension between a rapid deployment and a proper discussion of plans. There might be an additional need to show the benefits quickly, and to demonstrate flexibility in the initial stages after implementation.

Informing the public about street design changes: Vehicle drivers, cyclists, pedestrians, and adjacent residents or businesses must receive information about what has changed or is changing in terms of street layout and use (Pucher and Buehler 2008). Effective communication is needed with all road users through guides, campaigns, road design, signs, and markings, so that users are aware of the change of traffic patterns and the existence of bike lanes and cyclists. In the case of rapid deployment, there is usually a much greater need for face-to-face engagement with those directly impacted. The importance of social distancing and the potential for emergent bike lanes to transition into long-term infrastructure are two aspects that should be conveyed clearly and honestly.

Facilitating safe behavior: Campaigns should target drivers to ensure that they are aware of more cyclists on the road, yield to pedestrians and cyclists, and follow traffic rules. Campaigns should also provide onsite information to cyclists and community members on rights-of-way (when to yield) and on high-risk areas or situations–for example, next to a heavy vehicle, biking at night, or crossing an intersection. Cyclists need information on social distancing measures while biking, such as safe passing distances or the use of face masks. More general safety instruction includes information on the benefits of lights and reflecting devices, helmets, bells, good brakes and other hardware, safe transportation of children and goods, and cycle maintenance.


Food
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CONCLUSIONS AND KEY TAKEAWAYS

This guide aims to support cities that are making efforts to rapidly improve biking in their cities and gain momentum in their bike-friendly policies and infrastructure.

Cities with emergent cycling infrastructure have the opportunity to use the experience to further improve them, attract support from users, and make the new routes permanent over the long term. But the time to act is now.

Creating cycle-friendly cities is a process that can be improved over time. Most cities find that once they embark on efforts to become more welcoming to people using bicycles, a positive feedback loop is created where more people want to travel by bike and demand expanded, safer, and more comfortable infrastructure so they can do so (Broach et al. 2012; Krizek 2014). This guide aims to support cities that are making efforts to rapidly improve biking in their cities and gain momentum in their bike-friendly policies and infrastructure. The key takeaways from this guide can be summarized as follows:

The global COVID-19 pandemic has changed the way people travel and interact in cities, with implications for the immediate, short, and long term.

In response to the crisis, many cities are moving swiftly toward sustainable mobility options. Projects that were planned for construction over the long term have been accelerated for immediate implementation.

Cycling has seen a rapid increase in uptake under health emergency conditions as a practical and resilient travel demand solution that allows for physical distancing while also meeting physical and mental health needs.

Emergent, or temporary, bicycle lanes are a fast and effective way for cities to facilitate safe cycling while at the same time meeting health emergency, mobility, and accessibility needs.

The safe bicycle lane strategy should integrate cycle networks and broader transport planning, respond to community needs and concerns, engage multisectoral stakeholders, select appropriate materials, and monitor and adjust as experience is gained.

Bike lanes for utilitarian trips should meet a number of key requirements: safety, cohesion, directness, comfort, and attractiveness. In the context of the current global pandemic, physical distancing is an added requirement.

Cycling infrastructure and management should be as safe and proactive as possible due to the increased numbers of new and/or inexperienced cyclists on the road.

The key principles for creating a bicycling network that meets the key requirements are safe car speeds, a cohesive network approach, safe design, management and enforcement, and communications and engagement.

For safe and comfortable cycling, bikes can share road space with cars on streets with an operational speed of 30 km/h or lower but should be physically segregated

on streets with higher speed limits or operational speeds, particularly arterial roads with large traffic volumes.

In corridors with temporary cycling infrastructure, speed reductions could be just as useful as segregated bike lanes, and even preferable in some settings.

Emergent bike lanes should be integrated into any existing bike infrastructure network. Where an urban bicycling strategy or plan already exists, routes should be selected based on fast-tracking the implementation of already planned lanes or adding additional connections or extensions to the existing network. Where no proposed lanes or plans exist, route selection should focus on connecting key destinations and services.

Emergent lanes should still be well designed and safe. Lane configuration must take into account maneuvering, varied sizes of micromobility options, physical distancing, and the inexperience of new cyclists. A minimum width of 3m is recommended wherever possible to accommodate these considerations.

Intersections are the most common location for collisions between vehicles and bicycles. Even emergent bike lanes that are not intended to be permanent should be designed with special consideration for intersections—to slow turning traffic, alert drivers to cyclists, and provide clarity for all road users.

Safe bike lanes must be monitored and managed over time to avoid speeding by adjacent vehicles, encroachment, or damage. They should also be rapidly adapted if problems become evident.

Communication and engagement before and during installation are crucial to ensure that community needs are met, foster support for safe bike lanes, and facilitate the transition to permanent infrastructure if the benefits and demand are demonstrated.

Once cities have installed and tested temporary bicycle infrastructure in the short to medium term, they have the opportunity to use the experience to further improve it, attract support from users, and make the new routes permanent over the long term. **But the time to act is now.**

ADDITIONAL RESOURCES

This guidance focuses narrowly on the design considerations of safe bike lanes. For more information on planning processes, policy, materials, and street design, we recommend the following resources:

- "Making Safe Space for Cycling in 10 Days: A Guide to Temporary Bike Lanes from Berlin" (Mobycon 2020)
- "Re-spacing Our Cities for Resilience" (ITF 2020)
- "Streets for Pandemic Response and Recovery" (NACTO 2020)
- "Tactical Urbanism" (Street Plans Collaborative 2016)
- "Cities Safer by Design" (Welle et al. 2015)
- "Basic Quality Design Principles for Cycle Infrastructure and Networks" (European Commission 2018a)
- "Sustainable and Safe: A Vision and Guidance for Zero Road Deaths" (Welle et al. 2018)
- "Pop-Up Placemaking Tool Kit" (Team Better Block and AARP 2019)
- "Separated Bike Lane Planning and Design Guide" (FHWA 2015)
- Databases:
    - "COVID19 Livable Streets Response Strategies" (Street Plans 2020)
    - "COVID Mobility Works Public Database" (2020)
- "Designing Cycling Infrastructure" https://cyclingsolutions.info/category/designing-cycling-infrastructure/
- "Planning Cycling Infrastructure" from the website Cycling Solutions by the Cycling Embassy of Denmark. This website will be constantly updated with articles. https://cyclingsolutions.info/category/planning-cycling-infrastructure/
- "Dutch Cycling Best Practices guide" https://dutchcycling.nl/en/projects/best-practices

GLOSSARY

Every country has its own terminology related to bicycle infrastructure, and what means one thing in one place may signify something different in another. In order to facilitate the use of this document at a global scale, and avoid confusion, we provide here the definition of the terms we have selected as best fit *for the purposes of this publication*. This is not an exhaustive list of terms, and readers are encouraged to check what terminology is used in their own city or country.

Bicycle infrastructure: Refers to any type of intervention on a road in order to allocate space for the safe circulation of cyclists. It encompasses all the different elements listed below.

Bicycle (bike) lane: Refers to a space *on the roadway* (usually reallocated from a vehicle lane or a parking lane) for exclusive use by cyclists, usually, but not always, delineated by paint or some other type of marking or physical barrier.

Depending on the intended duration and other characteristics, bike lanes can be classified into various types, some of which overlap with one another:

- **Pilot bike lane**: A temporary bike lane installation with a specific and limited duration, for the purpose of testing something—usually the operation, impact, and public response to a certain design in a certain location. The duration of a pilot can range from a single day to several years, depending on material selection and purpose.
- **Emergent bike lane**: A new type of pandemic-responsive bike infrastructure whereby space—usually a car lane—is rapidly reallocated for cyclists by installing temporary physical segregation measures, such as cones or plastic barriers. Typically, emergent bike lanes are installed without any specified duration and scaled up rapidly across cities as a response to changes in mobility and activity under pandemic conditions. Emergent bike lanes can also be implemented as pilot schemes with a specific and limited duration.
- **Pop-up, interim, preliminary, temporary, pilot, and semipermanent bike lanes**: Each of these overlapping terms conveys a slightly different duration or other quality of an emergent bike lane, and may be understood differently by different people, so clarity is very important at the level of individual schemes. For example, a *pop-up* installation lasting just a few days may be implemented with cones; an *interim* project may use paint, stickers, or barriers; and a *semipermanent* installation may use bolted down separators or moveable but durable dividers such as planters, in addition to road markings. In Oslo (Norway), categorizing them as *preliminary* enabled greater speed and agility in both planning and installation, and involved an expectation of future improvement (see Box 1).

Permanent bike lane: A dedicated space for bike travel that is designed, installed, and maintained with materials appropriate for long-term durability. It cannot be easily removed. The following are typical types of permanent bike lanes:

- **Bicycle track**: A dedicated cycle way with a curb separating and protecting it from motorized traffic. Permanent by definition.
- **Bicycle path**: A dedicated cycle path through or alongside recreational areas, with few or no conflicts with motor traffic.
- **Bicycle boulevard**: Also referred to as a shared bicycle street, this is a local street with low traffic volume and low vehicle speed that features design treatments to prioritize bicycle travel.

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DUTCH CYCLING EMBASSY

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THE LEAGUE OF AMERICAN BICYCLISTS since 1880

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www.bikeleague.org/content/about-league

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Urban Cycle Planning was founded by Lotte Bech in 2011 with the aim to promote cycling for the benefits of life quality in the cities of the world and for health and mobility for all citizens.

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