

CITY OF SEATTLE

RESOLUTION _____

..title

A RESOLUTION relating to the Seattle Center City Bike Network; establishing an implementation schedule for Seattle Department of Transportation delivery of capital projects that are elements of the Center City Bike Network; and requesting quarterly status updates to the Chair of the Sustainability and Transportation Committee through 2019.

..body

WHEREAS, the safety, health, economic, environmental, space efficiency, and equity benefits of bicycling as a viable form of transportation, and investing in safe bike infrastructure that is comfortable for people of all ages and abilities, are well established, and reflected in city transportation, climate and land use policies; and

WHEREAS, the effects of climate change have a disproportionate impact on communities of color, negatively affecting family and public health outcomes; and

WHEREAS, in 2013 The City of Seattle (City) adopted the Climate Action Plan, which recommends prioritizing transit, walking, and biking over auto travel, with a goal to triple the amount of bicycling from 2007 levels by 2017; and

WHEREAS, in 2014 the City adopted the Bicycle Master Plan, to create a citywide connected network of cycle tracks, protected bike lanes, trail, and greenways with a goal of quadrupling ridership by 2030; and

WHEREAS, demographic information shows that current ridership correlates with current demographics across the city, except by gender, where there is an overrepresentation of male-identified riders, which survey data shows is due to a lack of safe options for cycling; and

WHEREAS, studies have found that Black and Latinx cyclists make up a rapidly growing segment of the riding population; and

1 WHEREAS, a recent study found that barriers to cycling include that fewer than 20 percent of
2 adult Black and Latinx cyclists and non-cyclists feel comfortable in existing bicycle
3 lanes, and that adult Black and Latinx cyclists and non-cyclists have an increased fear of
4 exposure to theft or assault or being targeted for enforcement; and

5 WHEREAS, long-standing dis-investment in street infrastructure means that Black and Latinx
6 riders are disproportionately likely to be killed by a car compared to their white
7 counterparts; and

8 WHEREAS, in 2015 the City adopted a Vision Zero policy and plan, with a goal of achieving
9 zero traffic fatalities and serious injuries by 2030; and

10 WHEREAS, in 2016 the Seattle Department of Transportation (SDOT) adopted the Center City
11 Bike Network, with a goal of implementing a connected, protected bicycle lane network
12 in downtown Seattle by 2020; and

13 WHEREAS, the 2016 City Comprehensive Plan sets non-single-occupancy-vehicle (non-SOV)
14 mode share goals for downtown work and non-work trips as 85 percent and 90 percent,
15 respectively; and

16 WHEREAS, in late 2016 implementation of the Center City Bike Network was put on hold while
17 the City partnered with transit agencies and other stakeholders to develop the One Center
18 City near-term recommendation for mobility in downtown Seattle; and

19 WHEREAS, SDOT collaborated with King County Metro, Sound Transit, and the Downtown
20 Seattle Association to identify near-term transportation improvements to assist in
21 managing the large volume of simultaneous construction projects through the Center City
22 between 2019 and 2021, as part of the One Center City initiative; and

1 WHEREAS, the 2017 One Center City recommendations included a two-way protected bike lane
2 on 4th Avenue to be implemented in 2018; and

3 WHEREAS, in April 2018 the City announced the delay of the 4th Avenue two-way protected
4 bike lane until 2021; and

5 WHEREAS, in 2018 an all ages and abilities bike infrastructure route is still needed to connect
6 from downtown to surrounding neighborhoods in the south, north, and east; and

7 WHEREAS, connecting routes to surrounding neighborhoods, and between neighborhoods,
8 particularly in historically neglected communities with higher needs of safety
9 improvements for pedestrians and cyclists must be a focus for the city in making
10 connections with the Center City Bike Network; and

11 WHEREAS, between 2019 and 2021 downtown Seattle is expected to experience the “period of
12 maximum constraint” in which traffic congestion on downtown streets is anticipated to
13 peak, increasing the need for safe, efficient transportation options to manage individual
14 trips and minimize overall congestion; and

15 WHEREAS, in 2016 City Council allocated in the 2017 City budget \$5 million (\$1 million in
16 2017 and \$4 million in 2018) to accelerate buildout of the Center City Bike Network; and

17 WHEREAS, in 2016, as part of the City’s purchase of the Pronto bikeshare system, a City
18 Council proviso required that SDOT demonstrate that the 9th Ave N Protected Bike Lane
19 (Westlake Ave N to Denny Way) be on schedule to be completed prior to an expansion of
20 the bike share system; and

21 WHEREAS, in 2017, and upon the dissolution of the Pronto bikeshare system, Mayor Murray
22 committed \$1.25 million in funding, including to complete a missing link of the 4th
23 Avenue bicycle lane and planning for the extension to Vine Street and accelerating

1 design and outreach for the east/west connections in the Center City bicycle network,
2 both of which were set to begin in 2017; and

3 WHEREAS, in 2018 the Washington State Convention Center Community Benefits Package
4 included \$16 million for building protected bike lanes on Pike/Pine and 8th Ave, and that
5 funding will be available by mid-2018; and

6 WHEREAS, in Resolution 31814 the Council requested quarterly written reports “on the
7 implementation and performance of the One Center City program through 2021”; and

8 WHEREAS, implementation of the Center City Bike Network must be coordinated with the rest
9 of the Once Center City near-term recommendations; NOW, THEREFORE,

10 **BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF SEATTLE, THAT:**

11 Section 1. The City of Seattle commits to establishing an “all ages and abilities” bicycle
12 connection from the Westlake Cycle Track, through Downtown Seattle, to the intersection of 2nd
13 Avenue South and South Main Street, with the following missing connections completed no later
14 than December 31, 2019, as approximately shown in Attachment A to this resolution:

15 A. Protected bike lanes heading in the northbound and southbound directions on 9th
16 Avenue North from Harrison Street to Denny Way;

17 B. Protected bike lanes heading in the northbound and southbound directions on Bell
18 Street from Denny Way to 7th Avenue;

19 C. A one-way protected bike lane on 7th Avenue from Bell Street to Blanchard Street;

20 D. A one-way protected bike lane on 8th Avenue from Bell Street to Pine Street. An
21 approved conceptual design for the segment between Pine Street and Pike Street will be
22 complete by December 31, 2018 in coordination with King County Metro and the Washington
23 State Convention Center;

1 E. A one-way protected bike lane on Pike Street from 6th Avenue to 8th Avenue;

2 F. A one-way protected bike lane on Pine Street from 8th Avenue to 7th Avenue;

3 G. Signage at Pine Street and 4th Avenue installed by December 31, 2018 to guide
4 people on bikes safely through the intersection. A one-way protected bike lane on Pine Street
5 from 5th Avenue to 4th Avenue is expected to be completed in 2021 with the Pike Pine
6 Renaissance; and

7 H. A two-way protected bike lane on 2nd Avenue Extension from South Washington
8 Street to South Main Street.

9 Section 2. The City of Seattle commits to establishing an “all ages and abilities”
10 connection from the intersection of South Main Street and the 2nd Avenue Extension to
11 Dearborn Avenue S by no later than December 31, 2019. In advancing this connection, the
12 Seattle Department of Transportation (SDOT) is requested to complete outreach and approved
13 conceptual design by no later than May 31, 2019.

14 Section 3. The City of Seattle commits to establishing an “all ages and abilities”
15 connection from the Second Avenue protected bike lane to the Broadway Avenue protected bike
16 lane, by no later than December 31, 2019 (with SDOT’s outreach and approved conceptual
17 design completed by no later than December 31, 2018), as shown in Attachment A to this
18 resolution and consisting of the following:

19 A. Two one-way protected bike lanes on Pike Street, Pine Street, or a combination
20 thereof from Bellevue Avenue to Broadway Avenue; and

21 B. An interim facility on Pike Street and Pine Street from 8th Avenue to Bellevue
22 Avenue during the Convention Center construction; and

1 Section 4. Where permanent connections described in Sections 1 through 3 of this
2 resolution may be limited due to construction activities, the Seattle Department of Transportation
3 is requested to make every good faith effort to establish “all ages and abilities” temporary
4 connections, such as, but not limited to:

5 A. Working with developers and adjacent property owners in revising traffic control
6 plans to accommodate bicycle travel in addition to pedestrians; or

7 B. Creating bicycle paths using existing adjacent right-of-way and temporary barriers to
8 separate bicycles and vehicular traffic.

9 Section 5. The City of Seattle commits to completing 100 percent design for a two-way
10 protected bike lane on Fourth Avenue between South Main Street and Vine Street by no later
11 than May 31, 2019.

12 Section 6. The City of Seattle commits to completing a 100 percent design for an “all
13 ages and abilities” facility on Bell Street between 2nd Avenue and Denny Street, by no later than
14 December 31, 2019. The facility will be a two-way protected bike lane on Bell Street from
15 Denny Street to 5th Avenue. The segment from 5th Avenue to 2nd Avenue will have additional
16 traffic calming to facilitate an “all ages and abilities connection”.

17 Section 7. The City of Seattle commits to establishing a neighborhood greenway from 5th
18 Avenue S to 12th Avenue S along King St, by no later than December 31, 2019.

19 Section 8. The City of Seattle commits to establishing an “all ages and abilities”
20 connection from Yesler Way to King St, along 12th Avenue S, by no later than December 31,
21 2019.

22 Section 9. The City Council requests an update to the Traffic Control Manual for In-
23 Street Work to be implemented by no later than September 1st, 2018. This update shall provide

1 guidance for addressing work that encroaches upon a bike lane, bike trail, shared lane, signed
2 bike route or a road or sidewalk commonly used by bicyclists. An accessible, safe, and clearly
3 defined route shall be provided, and maximum effort shall be made to provide a convenient
4 bicycle way separate from active work areas.

5 Section 10. The City Council requests that SDOT provide quarterly written reports back
6 to City Council on the progress of the commitments made in this resolution ~~to the Chair of the~~
7 ~~Sustainability and Transportation Committee~~ at the start of each calendar quarter, from
8 September 1, 2018 through the end of 2019. The report should include SDOT's evaluation of the
9 performance of the transportation system with the implemented bicycle infrastructure projects.
10 The report may be combined with the One Center City quarterly report, requested by Resolution
11 31814.

12 Section 11. The City Council requests that SDOT follow the design guidance of the
13 "Designing for All Ages & Abilities" report of the National Association of City Transportation
14 Officials as shown in Attachment B, in the design of the "all ages and abilities" facilities
15 described in this Resolution.

16 Section 12. The City Council recognizes that SDOT will make decisions about which
17 projects to build within the overall context of meeting the One Center City goal of moving
18 people safely and efficiently through Center City.



Designing for All Ages & Abilities

Contextual Guidance for
High-Comfort Bicycle Facilities



National Association of
City Transportation Officials

December 2017

Streets that are safe and comfortable for All Ages & Abilities bicycling are critical for urban mobility.

NACTO cities are leading the way in designing streets that are truly safe and inviting for bicyclists of All Ages & Abilities and attract wide ridership. This guidance—developed by practitioners from cities across North America—builds on NACTO's *Urban Bikeway Design Guide* and sets an **All Ages & Abilities** criteria for selecting and implementing bike facilities. Building bicycle infrastructure that meets this criteria is an essential strategy for cities seeking to improve traffic safety,¹ reduce congestion,² improve air quality and public health,³ provide better and more equitable access to jobs and opportunities,⁴ and bolster local economies.⁵

This All Ages & Abilities facility selection guidance is designed to be used in a wide variety of urban street types. It considers contextual factors such as vehicular speeds and volumes, operational uses, and observed sources of bicycling stress. In doing so, it allows planners and engineers to determine when, where, and how to best combine traffic calming tools, like speed reduction and volume management, with roadway design changes, like full lane separation, to reduce traffic fatalities and increase cycling rates and rider comfort.

The All Ages & Abilities criteria is a national and international best practice that should be adopted for all bicycle facility design and network implementation; lesser accommodation should require additional justification. Along with a problem-solving approach to street design, the All Ages & Abilities benchmark should be applied across a city's entire bicycle network to grow bicycling as a safe, equitable mode for the majority of people.

All Ages & Abilities Bike Facilities are ...

Safe

More people will bicycle when they have safe places to ride, and more riders mean safer streets. Among seven NACTO cities that grew the lane mileage of their bikeway networks 50% between 2007–2014, ridership more than doubled while risk of death and serious injury to people biking was halved.⁶ Better bicycle facilities are directly correlated with increased safety for people walking and driving as well. Data from New York City showed that adding protected bike lanes to streets reduced injury crashes for all road users by 40% over four years.⁷

Comfortable

Bikeways that provide comfortable, low-stress bicycling conditions can achieve widespread growth in mode share. Among adults in the US, only 6–10% of people generally feel comfortable riding in mixed traffic or painted bike lanes.⁸ However, nearly two-thirds of the adult population may be interested in riding more often, given better places to ride, and as many as 81% of those would ride in protected bike lanes.⁹ Bikeways that eliminate stress will attract traditionally under-represented bicyclists, including women, children, and seniors.

Equitable

High-quality bikeways expand opportunities to ride and encourage safe riding. Poor or inadequate infrastructure—which has disproportionately impacted low-income communities and communities of color—forces people bicycling to choose between feeling safe and following the rules of the road, and induces wrong-way and sidewalk riding. Where street design provides safe places to ride and manages motor vehicle driver behavior, unsafe bicycling decisions disappear,¹¹ making ordinary riding safe and legal and reaching more riders.



SE Mill Street, PORTLAND
(photo credit: Portland Bureau of Transportation)

Who is the “All Ages & Abilities” User?

To achieve growth in bicycling, bikeway design needs to meet the needs of a broader set of potential bicyclists. Many existing bicycle facility designs exclude most people who might otherwise ride, traditionally favoring very confident riders, who tend to be adult men. When selecting a bikeway design strategy, identify potential design users in keeping with both network goals and the potential to broaden the bicycling user base of a specific street.



Children

School-age children are an essential cycling demographic but face unique risks because they are smaller and thus less visible from the driver's seat than adults, and often have less ability to detect risks or negotiate conflicts.



Seniors

People aged 65 and over are the fastest growing population group in the US, and the only group with a growing number of car-free households.¹² Seniors can make more trips and have increased mobility if safe riding networks are available. Bikeways need to serve people with lower visual acuity and slower riding speeds.



Women

Women are consistently under-represented as a share of total bicyclists, but the share of women riding increases in correlation to better riding facilities.¹³ Concerns about personal safety including and beyond traffic stress are often relevant. Safety in numbers has additional significance for female bicyclists.



People Riding Bike Share

Bike share systems have greatly expanded the number and diversity of urban bicycle trips, with over 28 million US trips in 2016.¹⁴ Riders often use bike share to link to other transit, or make spontaneous or one-way trips, placing a premium on comfortable and easily understandable bike infrastructure. Bike share users range widely in stress tolerance, but overwhelmingly prefer to ride in high-quality bikeways. All Ages & Abilities networks are essential to bike share system viability.



People of Color

While Black and Latinx bicyclists make up a rapidly growing segment of the riding population, a recent study found that fewer than 20% of adult Black and Latinx bicyclists and non-bicyclists feel comfortable in conventional bicycle lanes; fear of exposure to theft or assault or being a target for enforcement were cited as barriers to bicycling.¹⁵ Long-standing dis-investment in street infrastructure means that these riders are disproportionately likely to be killed by a car than their white counterparts.¹⁶



Low-Income Riders

Low-income bicyclists make up half of all Census-reported commuter bicyclists, relying extensively on bicycles for basic transportation needs like getting to work.¹⁷ In addition, basic infrastructure is often deficient in low-income neighborhoods, exacerbating safety concerns. An All Ages & Abilities bikeway is often needed to bring safe conditions to the major streets these bicyclists already use on a daily basis.



People with Disabilities

People with disabilities may use adaptive bicycles including tricycles and recumbent handcycles, which often operate at lower speeds, are lower to the ground, or have a wider envelope than other bicycles. High-comfort bicycling conditions provide mobility, health, and independence, often with a higher standard for bike infrastructure needed.



People Moving Goods or Cargo

Bicycles and tricycles outfitted to carry multiple passengers or cargo, or bicycles pulling trailers, increase the types of trips that can be made by bike, and are not well accommodated by bicycle facilities designed to minimal standards.



Confident Cyclists

The small percentage of the bicycling population who are very experienced and comfortable riding in mixed motor vehicle traffic conditions are also accommodated by, and often prefer, All Ages & Abilities facilities, though they may still choose to ride in mixed traffic.

Choosing an All Ages & Abilities Bicycle Facility

This chart provides guidance in choosing a bikeway design that can create an All Ages & Abilities bicycling environment, based on a street's basic design and motor vehicle traffic conditions such as vehicle speed and volume. This chart should be applied as part of a flexible, results-oriented design process on each street, alongside robust analysis of local bicycling conditions as discussed in the remainder of this document.

Users of this guidance should recognize that, in some cases, a bicycle facility may fall short of the All Ages & Abilities criteria but still substantively reduce traffic stress. Jurisdictions should not use an inability to meet the All Ages & Abilities criteria as reason to avoid implementing a bikeway, and should not prohibit the construction of facilities that do not meet the criteria.

Contextual Guidance for Selecting All Ages & Abilities Bikeways						
Roadway Context				All Ages & Abilities Bicycle Facility		
Target Motor Vehicle Speed*	Target Max. Motor Vehicle Volume (ADT)	Motor Vehicle Lanes	Key Operational Considerations			
Any		Any	Any of the following: high curbside activity, frequent buses, motor vehicle congestion, or turning conflicts [‡]	Protected Bicycle Lane		
< 10 mph	Less relevant	No centerline, or single lane one-way	Pedestrians share the roadway	Shared Street		
≤ 20 mph	≤ 1,000 – 2,000			Single lane each direction, or single lane one-way	Low curbside activity, or low congestion pressure	Bicycle Boulevard
≤ 25 mph	≤ 500 – 1,500	Multiple lanes per direction	Low curbside activity, or low congestion pressure			Conventional or Buffered Bicycle Lane, or Protected Bicycle Lane
	≤ 1,500 – 3,000					Buffered or Protected Bicycle Lane
	≤ 3,000 – 6,000			Protected Bicycle Lane		
	Greater than 6,000					
Greater than 26 mph [†]	≤ 6,000	Single lane each direction	Low curbside activity, or low congestion pressure	Protected Bicycle Lane, or Reduce Speed		
		Multiple lanes per direction		Protected Bicycle Lane, or Reduce to Single Lane & Reduce Speed		
	Greater than 6,000	Any	Any	Protected Bicycle Lane, or Bicycle Path		
High-speed limited access roadways, natural corridors, or geographic edge conditions with limited conflicts		Any	High pedestrian volume	Bike Path with Separate Walkway or Protected Bicycle Lane		
			Low pedestrian volume	Shared-Use Path or Protected Bicycle Lane		

* While posted or 85th percentile motor vehicle speed are commonly used design speed targets, 95th percentile speed captures high-end speeding, which causes greater stress to bicyclists and more frequent passing events. Setting target speed based on this threshold results in a higher level of bicycling comfort for the full range of riders.

[†] Setting 25 mph as a motor vehicle speed threshold for providing protected bikeways is consistent with many cities' traffic safety and Vision Zero policies. However, some cities use a 30 mph posted speed as a threshold for protected bikeways, consistent with providing Level of Traffic Stress level 2 (LTS 2) that can effectively reduce stress and accommodate more types of riders.¹⁸

[‡] Operational factors that lead to bikeway conflicts are reasons to provide protected bike lanes regardless of motor vehicle speed and volume.

The All Ages & Abilities Design Toolbox

Five major types of bikeway provide for most bike network needs, based on the contextual guidance on page 4. This list is organized from more to less shared operation with automobiles. Each facility type is appropriate as an All Ages & Abilities bikeway in relevant street contexts. The NACTO *Urban Bikeway Design Guide* provides detailed guidance on bikeway facilities.



Argyle Street, CHICAGO
(photo credit: Chicago DOT)

Low-Speed Shared Streets allow bicyclists to comfortably operate across the entire roadway. Shared streets target very low operating speeds for all users, typically no greater than 10 mph. The volume of people walking and bicycling should be much greater than vehicle volume to maintain comfort. Issues for bicycling in shared environments arise from conflicts with people walking, who may be expected at any point across the street's width. Materials and street edges must be appropriate for bicycling; materials are often varied to delineate road space, but any seams or low mountable curbs must be designed to avoid creating fall hazards for bicyclists.



SE Taylor Street, PORTLAND
(photo credit: Greg Raisman)

Bicycle Boulevards (or neighborhood greenways) provide continuous comfortable bicycle routes through the local street network. Bike Boulevards are characterized by slow motor vehicle speeds and low volumes. Sometimes these are present by the very nature of the street and its function (e.g. narrow streets with no major destinations), but sometimes design work is needed, such as adding traffic calming elements, filtering most motor vehicle traffic off, and/or prioritizing bicycles at major and minor street intersections. In this way, bicycling is made comfortable across the entire roadway. Directional markings and wayfinding signage provide riders with intuitive, coherent routing.



Laurier Avenue E, MONTRÉAL
(photo credit: Dylan Passmore)

Buffered & Conventional Bicycle Lanes provide organized space for bicycling, and are often part of street reconfiguration projects that improve safety and comfort for all users. Bicycle lanes are an important tool to improve comfort and safety on streets where the number of passing events is too high for comfortable mixed-traffic bicycling, but where curbside activity, heavy vehicles, and lane invasion are not significant sources of conflict. Buffered bike lanes are almost always higher comfort than conventional bike lanes. In many cases, cross-sections with room for buffered bicycle lanes also have room for protected bicycle lanes.



Dunsmuir Street, VANCOUVER
(photo credit: Paul Kreuger via Flickr)

Protected Bicycle Lanes (also known as Separated Bike Lanes or Cycle Tracks) use a combination of horizontal separation (buffer distance) and vertical separation (e.g. flex posts, parked cars, or curbs) to protect people bicycling from motor vehicle traffic. The combination of lateral buffer distance and vertical separation elements (such as flexible delineators, curbs or height differences, or vehicle parking) can ameliorate most of the stressors of on-street bicycling. The robustness of bikeway separation often scales relative to adjacent traffic stress.



Cultural Trail, INDIANAPOLIS
(photo credit: Green Lanes Project)

Shared-Use & Bicycle Paths have in many cities served as the early spines of an All Ages & Abilities network. Paths can provide a continuous corridor, but usually do not take riders to their destinations. High pedestrian volumes, driveways, obtrusive bollards, sharp geometry, and crossings all degrade bicycling comfort, but often require long project timelines to eliminate. To become useful for transportation, paths work best when connected to an on-street network that meets the same high benchmark of rider comfort, and design provides bicycle-friendly geometry. Ideally, bicycles should be separated from pedestrians where significant volume of either mode is present, but where space limitations exist, multi-use paths are still valuable.

Motor Vehicle Speed & Volume Increase Stress

Whether or not people will bicycle is heavily influenced by the stresses they encounter on their trip. These stressors impact their actual physical safety and their perceived comfort level.

For all roadways and bike facilities, two of the biggest causes of stress are vehicular traffic speed and volume. These factors are inversely related to comfort and safety; even small increases in either factor can quickly increase stress and potentially increase injury risk.¹⁹ The stresses created by speed are compounded by vehicular volume, and vice versa.

Slower or less confident bicyclists experience "near misses"—or non-injury incidents that cause stress—much more frequently per trip than faster riders, which can contribute to discouraging people from riding who would otherwise do so.²⁰

SPEED

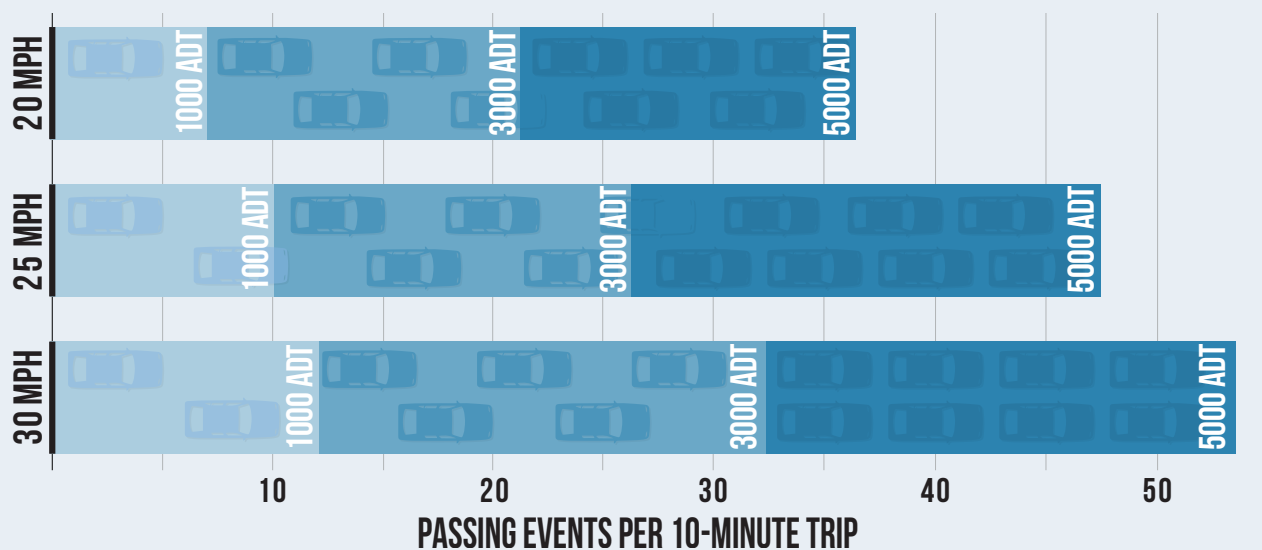
High motor vehicle speeds and speeding introduce significant risk to all road users, narrowing driver sight cones, increasing stopping distance, and increasing injury severity and likelihood of fatality when crashes occur.²¹ Most people are not comfortable riding a bicycle immediately next to motor vehicles driving at speeds over 25 mph. Conventional bike lanes are almost always (with rare exceptions) inadequate to provide an All Ages & Abilities facility in such conditions.

VOLUME

When vehicular volumes and speeds are low, most people feel most comfortable bicycling in the shared roadway as they are able to maintain steady paths and riding speeds with limited pressure to move over for passing motor vehicles. However, as motor vehicle volume increases past 1,000 – 2,000 vehicles per day (or roughly 50 vehicles in the peak direction per peak hour), most people biking will only feel comfortable if vehicle speeds are kept below 20 mph.

Conflicts Increase with Speed & Volume

This chart illustrates the number of passing events (at increasing motor vehicle average speed and volume) experienced over a 10-minute period by a bicyclist riding 10 mph. As motor vehicle speed and volume increase, they magnify the frequency of stressful events for people bicycling.



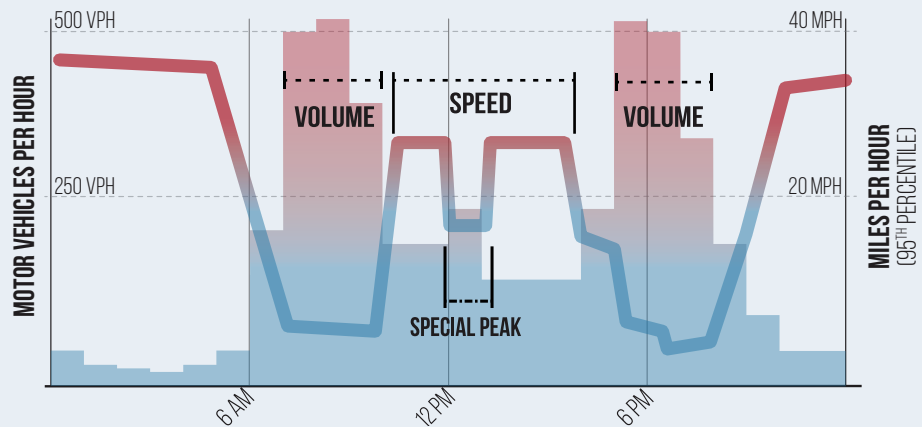
Motor Vehicle Speed and Volume Amplify One Another as They Increase

The frequency at which a person bicycling is passed by motor vehicles is one of the most useful indicators of the level of stress of a roadway or bike facility. Passing events increase with speed and volume, decreasing rider comfort and safety. Where car traffic is routinely above 20 mph, or where traffic volume is higher than 50 vehicles per direction per hour, pressure on bicyclists from motor vehicles attempting to pass degrades comfort for bicycling and increases risk.

- » **At speeds of 20 mph**, streets where daily motor vehicle volume exceeds 1,000 – 2,000 vehicles, frequent passing events make shared roadway riding more stressful and will deter many users.
- » **Between 20 and 25 mph**, comfort breaks down more quickly, especially when motor vehicle volume exceeds 1,000 – 1,500 ADT. When motor vehicle speeds routinely exceed 25 mph, shared lane markings and signage are not sufficient to create comfortable bicycling conditions.
- » **Motor vehicle speeds 30 mph or greater** reduce safety for all street users and are generally not appropriate in places with human activity.
- » **Where motor vehicle speeds exceed 35 mph**, it is usually impossible to provide safe or comfortable bicycle conditions without full bikeway separation.

Sources of Stress Change Throughout the Day

Large fluctuations in motor vehicle traffic volume between morning, mid-day, afternoon, and nighttime result in radically different bicycling conditions on the same street throughout the day. The example at right shows a street with roughly 500 vehicles per direction per hour during the peak. While queuing stress occurs at peak times, low off-peak volume results in dangerously high motor vehicle speeds.



Peak vs. Off-Peak

The variation in speed and volume conditions between peak and off-peak hours can manifest as two distinct issues that decrease comfort and safety.

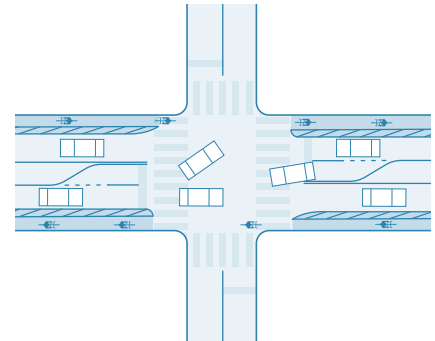
- » **During high-volume peak periods**, motor vehicle queuing prevents comfortable mixed-traffic operation and increases the likelihood of bicycle lane incursions, unless physical separation is present.
- » **During off-peak periods**, speeds can rise quickly, especially on wide and multi-lane streets, unless the street's design and operations specifically discourage speeding. Streets with very low off-peak volumes that also see little speeding, including many small neighborhood streets, may indicate All Ages & Abilities conditions if peak volumes are managed effectively.
- » **Special Peaks** occur on streets that experience intensive peak activity periods. Schools have multiple short windows of time where pedestrian and motor vehicle activity are intense at exactly the time and place where the appeal of All Ages & Abilities bicycling is most sensitive. Downtown cores and retail streets experience intensive commercial freight activity throughout the day including at off-peak times, adding importance to the creation of protected bike lanes.

Changing the Street: Design, Operation, Networks

Not every solution that helps to create safe and comfortable bicycling conditions will be a geometric design. Creating a network of high-comfort bicycle facilities that meet the All Ages & Abilities criteria requires leveraging the full suite of design, operational, and network strategies to transform streets. Strategies can be implemented incrementally to address sources of stress and conflict, change demand for access and movement, and ultimately transform streets for all users by continuously increasing comfort and creating more opportunities to make more trips by bicycle.

Change Design

Design strategies change the cross-section of a street in order to provide bike lanes, buffered bike lanes, protected bike lanes, or other dedicated bicycle infrastructure. Creating dedicated space for bicycling— either by reducing the number of motor vehicle lanes or their width—usually does not involve substantial changes to motor vehicle volume or the types of vehicles that can use a street, and has substantial benefits for the safety of all street users. 4-to-3 and 4-to-2-lane (with left turn pocket) conversions are widely used, and many other street redesigns apply the same basic principle of organizing movements and modes into dedicated space to improve the efficiency of each space.



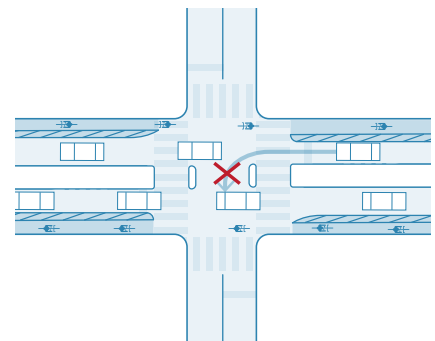
Examples:

- Repurpose Motor Vehicle Lane
- Convert from Buffered to Protected Bike Lane

Change Operation

Operational changes—such as speed reduction, signalization and other conflict management, and proactive curbside management—improve bicycling conditions by reducing the level of traffic stress on a street. Operational strategies make streets more predictable, efficient, and safe without necessarily changing the street’s cross-section or the types of vehicles allowed.

On all facility types, reducing motor vehicle speeds to 20 – 25 mph is a core operational strategy for improving bicycle comfort and meeting the All Ages & Abilities criteria. In addition, reducing speeds can also make it easier to enact other safety changes, such as changes to intersection geometry, signalization, turn lanes, and turn restrictions. Since operational changes do not impact what types of vehicles can use the street, they usually do not require significant planning beyond the street itself, and are often the easiest type of change to implement.



Examples:

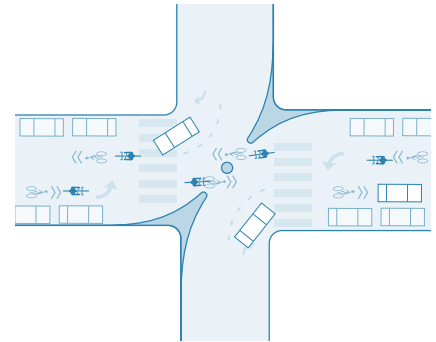
- Signal Separation of Conflicting Movements
- Low-Speed Signal Progression

Change the Network

Diverting motor vehicle traffic from a street, changing travel direction, (dis)allowing specific types of curbside access, and making other changes to the role of a street in the motor vehicle network are powerful ways to create All Ages & Abilities bicycling conditions. Such network changes allow the street to be transformed into a comfortable bicycling environment without requiring dedicated space.

Bicycle boulevards and shared streets, in particular, often rely on network changes to create the low-speed, very low-volume conditions necessary for cyclists to feel safe and comfortable. Prohibiting through-traffic (requiring all motor vehicles to turn off the street at each intersection), either through physical diverters or signage, is an effective strategy for reducing speed and volume.

Changes to the motor vehicle network can open up opportunities for better bikeway designs. For example, converting a high volume or high speed street from two-way to one-way or removing all curbside parking can provide space for a protected bike lane.



Examples:

- **Bicycle Boulevard**
- **Time-of-Day Regulations**



Ames Street, CAMBRIDGE
(photo credit: People for Bikes)

Low-Speed, Low-Volume Roadways Can Be Shared

See the Urban Bikeway Design Guide for detailed guidance on Bicycle Boulevards, Conventional Bike Lanes, Buffered Bike Lanes, and Left Side Bike Lanes.

Bicycle Boulevards & Shared Streets

Bicycle boulevards and shared streets place bicycle and motor vehicle traffic in the same space at the same time. These facilities meet the All Ages & Abilities criteria when motor vehicle volumes and speeds are so low that most people bicycling have few, if any, interactions with passing motor vehicles.

What to do:

- » **Use both peak-hour volume and off-peak speed** to determine whether a shared roadway can serve as an All Ages & Abilities bike facility. High peak period volumes or high off-peak speeds create a high-stress bicycling environment. These sources of stress can be addressed through speed management or volume management, or may indicate the need for a separated bicycle facility.
- » **Set a 20 – 25 mph target speed (10 mph on shared streets)** for motor vehicles in the majority of urban street contexts. Use the 95th percentile motor vehicle speed, along with the overall speed profile of motor vehicle traffic, to determine whether high outlying speeds exist, since even small numbers of motor vehicles traveling at high speeds can degrade the comfort of people bicycling on shared roadways.
- » **Manage motor vehicle speeds** through operational and network tools such as speed humps, pinchpoints, and neighborhood traffic circles.
- » **Reduce motor vehicle volume** by constructing diverters, prohibiting through traffic, or removing parking. The All Ages & Abilities condition is likely to be reached below approximately 1,000 – 1,500 vehicles per day or approximately 50 vehicles per hour per direction.
- » **Use time-of-day analyses** to match regulations or access restrictions to demand. Commercial setting can also work with bike boulevards if stressors are managed. Prioritize delivery and freight access off-peak, or allow only transit and bikes at peak periods.



SE Ankeny Street Bike Boulevard, PORTLAND
(photo credit: NACTO)



Brookline Street, CAMBRIDGE
(photo credit: City of Cambridge)

Conventional & Buffered Bicycle Lanes

Conventional and buffered bike lanes on urban streets delineate space for bicyclists but provide no physical separation between people bicycling and driving. With on-street parking, they also place the bicycle between parked vehicles and moving motor vehicles. Since bicyclists must enter the motor vehicle lane to avoid conflict with turning vehicles, parking maneuvers, double parking or curbside loading, or open doors, it is important for passing events to be minimized.

What to do:

- » **Set target speeds at or below 25 mph.** Speeds of 20 – 25 mph improve comfort and allow drivers to more easily react when bicyclists need to move into the motor vehicle lane. Use strategies such as lower progression speed and shorter signal cycle lengths to reduce the incentive for drivers to speed, and reduce top-end speeding incidents.
- » **Discourage motor vehicle through-movement to reduce volumes.** Lower motor vehicle volumes reduce the number of passing events. Depending upon the presence and intensity of other operational stressors, an All Ages & Abilities condition may be reached below approximately 3,000 – 6,000 vehicles per day, or approximately 300 to 400 vehicles per hour.
- » **Reduce curbside conflicts**, especially freight, loading, and bus pull-outs (see page 15). Carefully manage loading activity and parking demand. On one-way streets with transit activity, move the bike lane or buffered bike lane to the left side of the street to alleviate intersection and curbside conflicts. On streets with heavy curbside use but low motor vehicle volume, consider moving truck traffic or curbside loading to other streets.
- » **Address intersection conflicts** through motor vehicle turn prohibitions, access management, and signal phasing strategies. Due to the likelihood of both left- and right-turning conflicts from bi-directional motor vehicle traffic, use the same motor vehicle volume threshold on two-way streets as on one-way streets.
- » **Increase buffer distance** where traffic characteristics adjacent to the bike lane decrease comfort, including large vehicles or curbside parking. Where adjacent sources of stress are present, a buffered bike lane can improve comfort by increasing shy distance between bikes and motor vehicles. Where multiple motor vehicle lanes, moderate truck and large vehicle volumes, or frequent transit indicate that most bicyclists will need more separation to be comfortable.

Separate Bicyclists When Speed & Volume are High

Protected Bicycle Lanes

Protected bike lanes (including raised bikeways) create All Ages & Abilities conditions by using physical separation to create a consistently exclusive, designated bicycling space. The physical protection offered by protected bike lanes means that they can often meet the All Ages & Abilities criteria even in higher speed, high volume, or unpredictable conditions. Protected bike lanes improve the overall organization of the street, and increase safety for people walking, bicycling, and in motor vehicles.

What to do:

- » **Build protected bike lanes where motor vehicle speed consistently exceeds 25 mph**, where daily motor vehicle volume is higher than approximately 6,000 vehicles per day, where curbside conflicts are expected, or wherever there is more than one motor vehicle lane per direction.
- » **Manage intersection and curbside conflicts** with transit boarding islands, protected (bend-out or offset) intersection designs, signal phasing, and other turn management strategies.
- » **Reduce speeds through operational strategies**, such as signal time, lower signal progression, and shorter signal cycles.
- » On streets with parking, **reverse the position of the parking and the bike lane to create physical separation** between the bike lane and moving motor vehicle traffic.
- » On streets without parking, **add vertical separation elements** (e.g. delineators, barriers, raised curbs) in an existing buffer, or raise existing curbside bike lanes.
- » On streets with multiple motor vehicle lanes in each travel direction, **convert one travel lane to a protected bike lane**, better organizing the street and improving safety for people biking, walking and driving.²²
- » **Convert conventional or buffered lanes to protected lanes** if motor vehicle speeds and volumes cannot be otherwise reduced and where there is high curbside activity or peaks of intensive demand such as retail-heavy streets, or around schools, large employers, institutions, and entertainment districts.



Second Avenue, SEATTLE
(photo credit: Adam Coppola for Green Lanes Project)

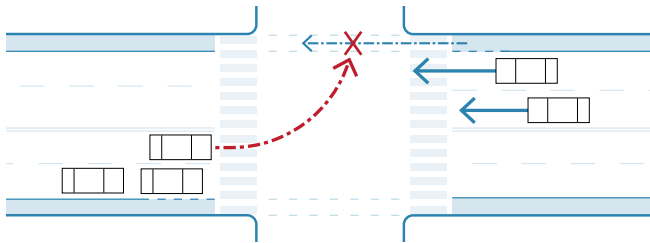
Strategies to Reduce Other Sources of Stress

In addition to motor vehicle speed and volume, All Ages & Abilities bikeway facility selection should respond to street conditions that increase bicycling stress and often degrade comfort and safety for all people using the street. These sources of stress can be addressed through design, operations, and network solutions that either remove the source of stress or separate it from bicycle traffic.

Multiple Motor Vehicle Lanes

Source of Stress

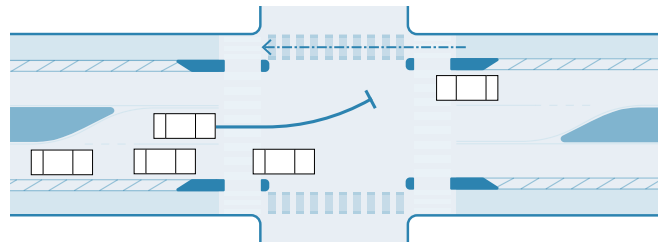
Motor vehicle traffic on multi-lane streets, whether two-way or one-way, is less predictable than on streets with a single lane per direction of travel. Lane changes, acceleration and passing, and multiple-threat visibility issues degrade both comfort and safety. Corridors with a major through-traffic function and multiple motor vehicle lanes are inherently unpredictable biking environments.



A common "multiple threat" conflict, where reduced visibility for motor vehicles turning across multiple travel lanes increase bicyclists' risk at crossings. The 4-to-3 lane conversion is a common technique for managing motor vehicle traffic flow while reducing the multiple threat conflict, though two-way left turn lanes introduce turn conflicts at mid-block locations (e.g. driveways).

Design Strategy

Reduce the cross-section to one motor vehicle travel lane per direction, where possible. On streets where multiple through lanes in one direction are used to allocate very high motor vehicle traffic capacity, provide physical protection and manage turns across the bikeway. 4-to-3 or 5-to-3 lane conversions paired with protected bikeways are transformative for both bicycling and walking safety and comfort.²³

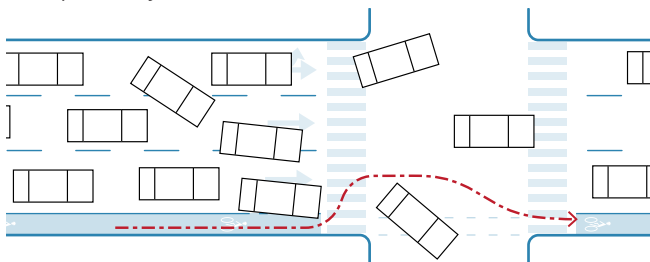


Motor Vehicle Queuing

Source of Stress

Motor vehicle congestion presents safety and comfort issues for people bicycling. Queued traffic moves at unpredictable speeds and will often invade conventional or buffered bike lanes.

Queuing encourages both motorists and bicyclists to engage in unpredictable movements. Bicyclists may weave through queued cars when bicycle facilities are obstructed, where motorists are also prone to move unexpectedly.

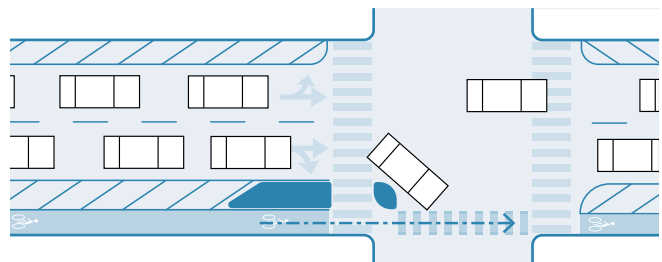


Bicyclists are more likely to try to weave through congested traffic, especially when bikeways are impeded, but motor vehicles become unpredictable. Separation and protection prevent queued vehicles from permeating bicycle space and maintain bikeway integrity throughout the day.

Design Strategy

Protected bike lanes should be implemented where motor vehicle invasion of the bike lane is likely to occur otherwise. Visual and physical barriers can prevent encroachment on the bikeway.

Bicycle facilities should be designed with capacity for growing ridership, including passing of slow-moving cargo bicycles.



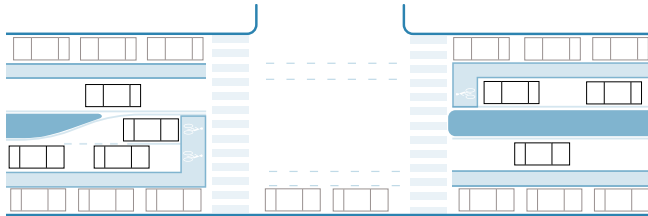
Strategies to Reduce Other Sources of Stress

Intersections

Source of Stress

Motor vehicles turning across the bikeway typically require people bicycling to negotiate with motor vehicles, a significant stressor at all but the very lowest speed conditions. Bicycle design treatments that require people biking to cross or mix with motor vehicle traffic are stressful at all but low volumes.

Bicycle left turns, especially on busy streets, can be very stressful or even dangerous for bicyclists, especially if bikes are expected to merge with fast-moving traffic or turn across multiple lanes.²⁵



Design Strategy

Provide separation in space and time between bicycles and vehicles to the extent possible, or reduce speed and maximize visibility between drivers and bicyclists. Tighter effective corner radii, raised crossings, and protected intersection designs are effective in slowing motor vehicle turning speed and placing bicyclists in a priority position.

Provide appropriate intersection treatments to accommodate desired turning movements, including bike boxes, two-stage queue boxes, phase separation, or protected intersections (also known as “offset” or “bend-out” crossings) that organize and give priority to people bicycling.



Sharp grade or direction changes, such as sharp lateral transitions approaching the intersection, require people biking to slow down and may increase fall risks. Frequent starts and stops also create instability at intersections.

Reduce or mitigate situations that increase risk of falling and instability. Design intersection approaches and transitions with bicycle-friendly geometry; place bicycle movements first in the signal phase; time signal progressions to bike-friendly speeds; and rotate stop signs to face cross streets.

Trucks & Large Vehicles

Source of Stress

High volumes of truck traffic degrade adjacent bicycling safety and comfort. This is often the case on major streets, or in commercial or industrial places.

Large vehicles have large blind spots, increasing risk of side-swipe and right-hook crashes.

Large vehicle noise and exhaust increase bicycling stress and present public health issues.

Design Strategy

Provide protected bicycle facilities—or, at minimum, buffered bike lanes—on observed or designated trucking routes, regardless of general motor vehicle speed and volume.

Use buffers to increase the distance between truck and bicycle travel paths. Consider protected intersection geometry (also known as “offset” or “bend-out”).

Provide wide lateral separation—such as with wide buffers, planters or planting strips, or parking-protected facilities—to dissipate pollutants entering the bikeway.²⁶

Curbside Activity

Source of Stress

Frequent freight and passenger loading either happens in the bikeway or adjacent in the curbside lane. Loading activities increase conflicts crossing the bike lane, or even blockages by double-parked vehicles that imperil bicyclists and rapidly decrease assurances of safety.

High parking turnover results in frequent weaving and door zone conflicts.

Freight loading is present throughout the day, but motor vehicle speed and volume are consistently low.

Car doors open into the bicycle travel path during vehicle exit and entry, but parking turnover is low to moderate.

Design Strategy

Provide designated truck loading zones and provide space for other curbside uses to prevent blockages of the bicycle lane. Consider restricting freight loading to off-peak periods. If frequent freight or passenger loading is observed, provide protected bicycle facilities regardless of speed and volume, or move passenger and freight loading uses to a cross-street.

Where parking turnover is high, provide protected bikeways regardless of speed to avoid sudden conflicts and reduce injury risk, or remove parking. Cities should establish local guidance on acceptable levels of parking maneuvers across bicycle lanes.

Implement a robust bike boulevard or shared street treatment with traffic calming strategies to provide comfort and safety across the entire roadway.

Provide a wide marked buffer adjacent to the vehicle door zone to guide bicyclists clear of dooring conflicts for both buffered and protected bike lanes.

Frequent Transit

Source of Stress

Buses merge across conventional bike lanes to access curbside stops. At all but the lowest bus frequencies, conventional “pull-out” transit stops degrade comfort and increase transit delay.

Bikes and transit travel at similar average speeds but different moving speeds, as buses stop and accelerate frequently. Overtaking buses and bicycle leapfrogging decrease riding comfort in mixed conditions.

Core transit routes and trunklines often operate on streets with dense destinations and demand for bicycle access. In some cases, right-of-way width may constrain design decisions and facility types that can be implemented.

Design Strategy

Provide spot protection using transit boarding islands, which are compatible with protected, buffered, and conventional bicycle lanes. Boarding islands create in-lane transit stops, which improve bus reliability and travel time.

Provide dedicated bicycle facilities. On one-way streets, left-side bicycle facilities can be used to separate bikes and transit vehicles.

On trunkline transit streets, it is even more important to accommodate users in dedicated lanes, since the major streets are where people need to get to their destinations. If the primary demand for the corridor is through travel, it may be possible to consider providing high-quality bike infrastructure on parallel, nearby, and continuous routes, while allowing local bicycle access on the transit street. To improve All Ages & Abilities bicycling conditions, use low-speed signal progressions and other calming measures consistent with transit effectiveness. As on all transit routes, pedestrian safety is the foremost design need.

The NACTO *Transit Street Design Guide* provides detailed guidance for streets with frequent bus transit routes.

References

- 1 Anne C Lusk, Peter G Furth, Patrick Morency, Luis F Miranda-Moren, Walter C Willett, & Jack T Dennerlein. Risk of injury for bicycling on cycle tracks versus in the street. *Injury Prevention* (2011).

M. Anne Harris, Conor CO Reynolds, Meghan Winters, Mary Chipman, Peter A. Crompton, Michael D. Cusimano, and Kay Teschke. "The Bicyclists' Injuries and the Cycling Environment study: a protocol to tackle methodological issues facing studies of bicycling safety." *Injury prevention* 17, no. 5 (2011): e6-e6.
- 2 Study of 1st, 8th, and Columbus Avenues in New York found that after installation of protected bike lanes on each, average motor vehicle travel times throughout the day were either unchanged or fell as much as 35% at parts of the day.

Protected Bicycle Lanes in NYC. New York City Department of Transportation, 2014. nyc.gov/html/dot/downloads/pdf/2014-09-03-bicycle-path-data-analysis.pdf
- 3 Economic analysis estimates that for every \$1,300 New York City invested in building bike infrastructure in 2015 "provided benefits equivalent to one additional year of life at full health over the lifetime of all city residents."

Jing Gu, Babak Mohit, and Peter Alexander Muennig. "The cost-effectiveness of bike lanes in New York City." *Injury Prevention*, September 2016. Accessed via: injuryprevention.bmj.com/content/early/2016/09/09/injuryprev-2016-042057
- 4 Lower-income workers spend proportionally more of their income on transportation, are significantly more likely to commute during evening and weekend hours where transit service is less frequent, and most likely to commute by bicycle.

The New Majority: Pedaling Toward Equity. League of American Bicyclists & Sierra Club, 20. Accessed via: bikeleague.org/sites/default/files/equity_report.pdf
- 5 Clifton, Kelly J, Christopher Muhs, Sara Morrissey, Tomás Morrissey, Kristina Currans, & Chloe Ritter. "Consumer Behavior and Travel Mode Choices." Oregon Transportation Research and Education Consortium, Transportation Research Board, Washington, DC (2012).
- 6 Kate Fillin-Yeh & Ted Graves. *Equitable Bike Share Means Building Better Places for People to Ride*. National Association of City Transportation Officials (2016).
- 7 Wolfson, H., 2011—Memorandum on Bike Lanes, City of New York, Office of the Mayor, 21 March 2011. http://www.nyc.gov/html/om/pdf/bike_lanes_memo.pdf
- 8 Dill, Jennifer. "Categorizing Cyclists: What do we know? Insights from Portland, OR." Portland State University, presented at Velo-City Global 2012, Vancouver BC. Accessed via: http://web.pdx.edu/~jdill/Dill_VeloCity_Types_of_Cyclists.pdf

Jennifer Dill & Nathan McNeil. *Revisiting the Four Types of Cyclists: Findings from a national survey*. Submitted to the 95th Annual Meeting of the Transportation Research Board (2016).
- 9 Kate Fillin-Yeh & Ted Graves. *Equitable Bike Share Means Building Better Places for People to Ride*. National Association of City Transportation Officials (2016).
- 10 Alex Armlovich. *Poverty and Progress in New York City XI: Vision Zero and Traffic Safety*. Manhattan Institute, May 25, 2017. Accessed via www.manhattan-institute.org/download/10306/article.pdf
- 11 After implementation of the Prospect Park West bikeway in Brooklyn, the percentage of bicyclists riding on the sidewalk fell from 46% of all riders to 3%.

Measuring the Street: New Metrics for 21st Century Streets. New York City Department of Transportation, 2012. www.nyc.gov/html/dot/downloads/pdf/2012-10-measuring-the-street.pdf
- 12 "B25045. Tenure By Vehicles Available By Age of Householders." American Community Survey 2010–14 5-year estimate, US Census Bureau (2016).
- 13 Peter Tuckel, William Milczarski, et al. "Bike Lanes + Bike Share Program = Bike Safety An Observational Study of Biking Behavior in Lower and Central Manhattan." Hunter College, City University of New York (2014).
- 14 Kate Fillin-Yeh & Ted Graves. *Bike Share in the US: 2010-2016*. National Association of City Transportation Officials (2017). Accessed via: <http://nacto.org/bike-share-statistics-2016>
- 15 Charles T. Brown, and James Sinclair. *Removing Barriers to Bicycle Use in Black and Hispanic Communities*. No. 17-03327. 2017.
- 16 League of American Bicyclists, "The New Majority: Pedaling Towards Equity." p.2. Accessed via http://bikeleague.org/sites/default/files/equity_report.pdf & Smart Growth America, "Dangerous by Design 2014." p.20. Accessed via: <http://www.smartgrowthamerica.org/documents/dangerous-by-design-2014/dangerous-bydesign-2014.pdf>

"Pedestrian Fatalities in New York City." Epi Data Brief, New York City Department of Health & Mental Hygiene. March 2017, no. 86. <http://www1.nyc.gov/assets/doh/downloads/pdf/epi/databrief86.pdf>
- 17 "S0802: Means of Transportation to Work by Selected Characteristics." American Community Survey 2011–15 5-year estimate, US Census Bureau (2016).
- 18 Mekuria, Maaza C., Peter G. Furth, and Hilary Nixon. "Low-stress bicycling and network connectivity." Mineta Transportation Institution (2012).
- 19 A study of crashes involving pedestrians in the US estimated a 10% risk of severe injury for people walking hit by a vehicle traveling over 20 mph; severe injury risk increased to 50% if the vehicle was traveling over 30 mph, and 90% over 40 mph.

Brian C. Tefft. *Impact Speed and a Pedestrian's Risk of Severe Injury or Death*. AAA Foundation for Traffic Safety, 2011. Accessed via: www.aaafoundation.org/sites/default/files/2011PedestrianRiskVsSpeed.pdf
- 20 Rachel Aldred. "Cycling near misses: Their frequency, impact, and prevention." *Transportation Research Part A: Policy and Practice* 90 (2016): 69-83.
- 21 Bruce Schaller, Ryan Russo, Joshua Benson, Sean Quinn, Matthew Roe, and Seth Hostetter. *Making Safer Streets*. New York City Department of Transportation (2013).
- 22 Huang, Herman, J. Stewart, and Charles Zegeer. "Evaluation of lane reduction" road diet" measures on crashes and injuries." *Transportation Research Record: Journal of the Transportation Research Board* 1784 (2002): 80-90.
- 23 Jack Cebe. *An Evaluation of "Road Diet" Projects on Five Lane and Larger Roadways*. Georgia Institute of Technology (2016).
- 24 *Separated Bike Lane Planning and Design Guide*. Massachusetts Department of Transportation, 2015. Accessed via: www.massdot.state.ma.us/highway/DoingBusinessWithUs/ManualsPublicationsForms/SeparatedBikeLanePlanningDesignGuide.aspx
- 25 Don't Cut Corners: *Left Turn Pedestrian & Bicyclist Crash Study*. New York City Department of Transportation (2016). Accessed via: <http://www.nyc.gov/html/dot/html/about/leftturnstudy.shtml>
- 26 Christine Kendrick, Adam Moore, Ashley Haire, Alexander Bigazzi, Miguel Figliozzi, Christopher Monsere, & Linda George. "The impact of bicycle lane characteristics on bicyclists' exposure to traffic-related particulate matter." *90th Annual Meeting of the Transportation Research Board* (2010).