Denver Bikeway Design Manual

Volume 1

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DENVER
THE MILE HIGH CITY

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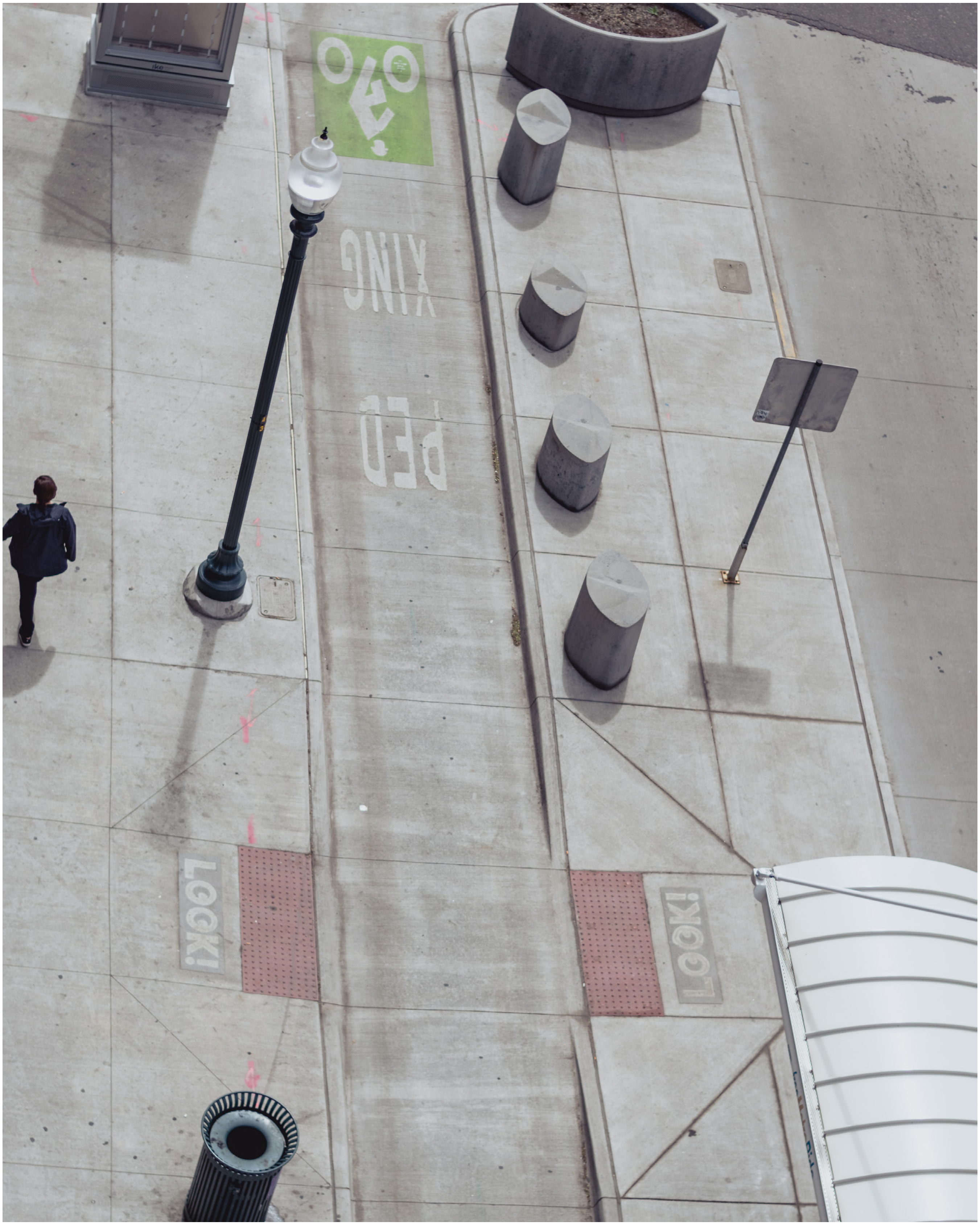
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INTRODUCTION

The Denver Bikeway Design Manual (the Manual) was developed to guide the City and County of Denver Department of Transportation and Infrastructure (DOTI) and its partners in selecting and designing appropriate on-street bikeways. A bikeway is defined as the space in the public right-of-way that is reserved exclusively for bicyclists and micromobility users or that is designed to safely accommodate bicyclists and micromobility users.

Whereas other City planning documents and datasets define where and what types of bikeways to build, this Manual defines how to design them. While each project will have unique constraints, the Manual presents preferred solutions with guidance for handling compromises, as well as design principles. The Manual will help DOTI and its partners design, construct, and operate world-class bikeways in an efficient and consistent manner.

The Bikeway Design Manual is a comprehensive document that contains all of the primary information needed to design bikeways in Denver, including design standards.

Basis for Manual

The content of the Manual is research-based and uses nationally accepted best practices, including the following standards and guidelines:

- *A Policy on Geometric Design of Highways and Streets, 7th Edition* *(American Association of State Highway and Transportation Officials (AASHTO), 2018)*
- *Manual on Uniform Traffic Control Devices* *(MUTCD) (Federal Highway Administration (FHWA), 2009)*
- *Guide for the Development of Bicycle Facilities* *(AASHTO, 2012)*
- *CDOT Roadway Design Guide, Chapter 14* *(Colorado Department of Transportation (CDOT), 2018)*
- *Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts* *(FHWA, 2016)*
- *Separated Bike Lane Planning and Design Guide* *(FHWA, 2015)*
- *Highway Capacity Manual (HCM)* *(Transportation Research Board, 2010)*
- *Urban Bikeway Design Guide* *(National Association of City Transportation Officials (NACTO), 2014)*
- *Bikeway Selection Guide* *(FHWA, 2019)*
- *Don't Give Up at the Intersection* *(NACTO, 2019)*

The Manual also aligns with related DOTI documents, including the latest *Transportation Standard Drawings for the Engineering Division*, the latest *Traffic Signal, Sign and Pavement Marking Standards*, the Transportation Engineering Plan Review Submittal Requirements, Denver *Complete Streets Design Guidelines, Complete Streets Design Standards, Denver's Storm Drainage Design & Technical Criteria,* and other DOTI policies and procedures.

Manual Contents

The Manual is divided into two volumes, as described below.

Volume 1 sets overall bikeway design principles for Denver and provides contextual information for facility design guidance, including design user characteristics and how to select bikeway types. Volume 1 addresses the project design process and includes guidelines on the implementation, maintenance, and operation of bikeways.

Volume 2 provides detailed design guidance, standard drawings, and considerations for three major types of linear bikeways: conventional and buffered bike lanes, protected bike lanes, and neighborhood bikeways. It provides standard drawings to address specific design situations, including but not limited to bus and bicycle interactions, mitigating turning movement conflicts, traffic calming and diversion, and bicycle signals and detection.

VISION AND GOALS

The City and County of Denver aims to increase mobility options, improve safety, address climate change, improve public health, and make infrastructure more accessible through a series of projects and initiatives. Denver's past planning efforts have identified the following targets;

- 20% of all trips are made by walking, rolling, and bicycling by 2050
- Eliminate traffic fatalities and serious injuries on Denver streets by 2030
- 100% of households are within 1/4 mile of a high comfort bicycle facility by 2050

The Denver Bikeway Design Manual will help DOTI and its partners achieve these outcomes by helping DOTI design, construct, and operate world-class bikeways in an efficient and consistent manner by defining and outlining specific guidance for selecting bikeway facility types and designing them.

The Manual reflects state-of-the-art bicycle facility design and provides detailed information for designing facilities for a wider range of Denverites.

Core Network Bikeways

The Denver Moves: Bikes Update (2024) process identified a need for a "Core Network" of bikeways to provide a spine of high-comfort bicycle facilities built to accommodate higher volumes of bicyclists and provide direct routes across the city. Many peer cities, including Portland, Minneapolis, Boston, and Seattle have similar hierarchies of bikeways that help guide investment in higher-quality, direct routes through their cities.

Streets on the Core Network were identified with input from community using the following guiding principles:

- Direct bikeways that traverse the city and have as few jogs and detours in the route as possible
- A spacing of about a mile apart, with greater density in and near downtown.
- Streets that can accommodate bikeways that can move greater numbers of people biking and scooting comfortably, including wider protected bike lanes, neighborhood bikeways, and trails.

The goals of Denver's Core Network are outlined below:

- Build a connected backbone network of bikeways that facilitates direct, longer distance travel.
- Bikeways on the Core Network should allow higher volumes of bicyclists at varying speeds to pass one another safely and comfortably.
- Core Network bikeways should strive to use permanent construction materials (concrete) and include green infrastructure elements to make streets enjoyable walk, roll, scoot, or bike on.

More guidance is provided throughout Volume 2 of this Manual regarding design parameters and features to consider when designing a bikeway on a Core Network street. These goals and design parameters should be seen as an aspirational long-term vision for developing a world-class core bikeway network that attracts users of all ages and abilities. It should serve as a guide for where to prioritize higher levels of investment both for DOTI-led and private development projects.

DESIGN USER

Research shows that the provision of high-comfort, connected bicycle networks improves bicyclist safety and encourages bicycling for a broader range of users.[1,2,3,4] People's relative comfort operating with or near motor vehicle traffic varies widely. A family with small children may have very different ideas of comfort than a confident recreational bicyclist who spends hours every week riding. Many people are interested in bicycling for transportation, but are dissuaded by the potential for stressful interactions with motor vehicles. The Manual will help practitioners design for a wider range of users so that more Denverites feel comfortable bicycling for both transportation and recreation.

1. Sanders, R. L. We can all get along: The alignment of driver and bicyclist roadway design preferences in the San Francisco Bay Area. Transportation Research Part A, Vol. 91, 2016, pp. 120-133.
2. Dill, D. and McNeil, N. Revisiting the Four Types of Cyclists. In Transportation Research Record 2587. TRB, National Research Council, Washington, DC, 2016.
3. Handy, S.L., Y. Xing, and T.J. Buehler. Factors Associated with Bicycle Ownership and Use: A Study of Six Small U.S. Cities. Transportation, Vol. 37, No. 6, 2010, pp. 967-985.
4. Winters, M., G. Davidson, D. Kao, and K. Teschke. Motivators and Deterrents of Bicycling: Comparing Influences on Decisions to Ride. Transportation, Vol. 38, No. 1, 2010, pp. 153–168.

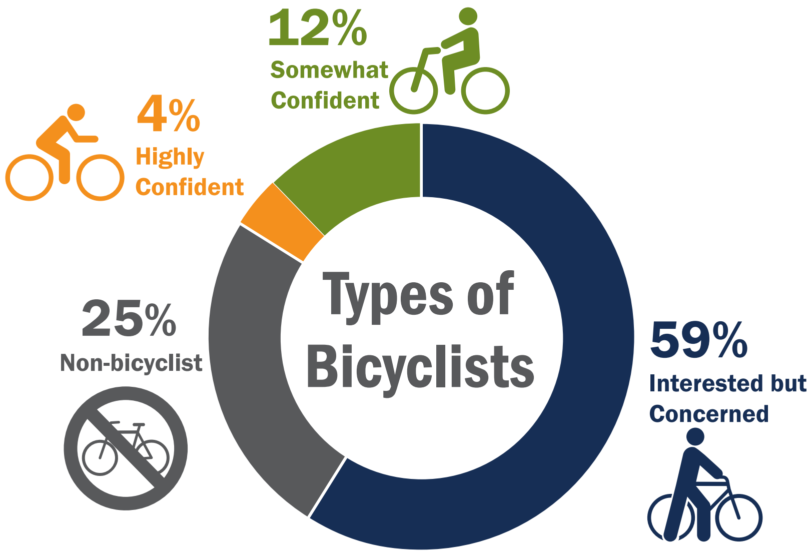


Figure 1: Types of Bicyclists in Denver
(*DRCOG Active Transportation Plan, 2019*)

Types of Bicyclists

Of adults who have stated an interest in bicycling, research has identified three types of potential and existing bicyclists: Highly Confident, Somewhat Confident, and Interested but Concerned.

National research[2] has shown that between 51 and 56 percent of the population identify as *Interested but Concerned*; they are interested in bicycling but concerned about safety. Local research from the Denver Regional Council of Governments (DRCOG) has similar findings (Figure 1). The population identified as *Interested but Concerned* is most comfortable biking when separated from motor vehicles or on low-volume, low-speed streets like neighborhood bikeways, and tends to bicycle more for recreation than for transportation.

Selecting a design user is often the first step in assessing a street's compatibility for bicycling. The design user should be used to select a preferred type of bikeway treatment for different contexts.

To maximize the potential for bicycle mode shift and to provide safer and more comfortable facilities for a wide range of people in Denver, the *Interested but Concerned* bicyclist is the primary design user for this Bikeway Design Manual.

Note that some bicyclists may fall into different categories in different circumstances. A dedicated bike commuter may be *Highly Confident* while commuting but *Interested but Concerned* while biking with a child. Additionally, bicycling is not the only means of traveling in Denver without a car. The short trips afforded by other light vehicles like scooters (electric and manual), electric skateboards, one-wheels, and bikeshare—collectively known as micromobility—are changing the face of urban travel. In addition, electric-assist bikes (e-bikes), delivery shells, and pedicabs, all of which have different dimensions and travel speeds, must also be considered. Vehicles that fall into the micromobility category fall somewhere between driving and walking in terms of speed and mobility; however, like bicyclists and pedestrians, they all should be considered vulnerable users of the roadway due to their disproportionate risk of injury in a collision with motor vehicles. As such, micromobility users are encouraged to use bikeways and are legally allowed to do so in Denver. When this Manual refers to "bikes" or "people bicycling," it is implied that this refers to other micromobility devices as well.

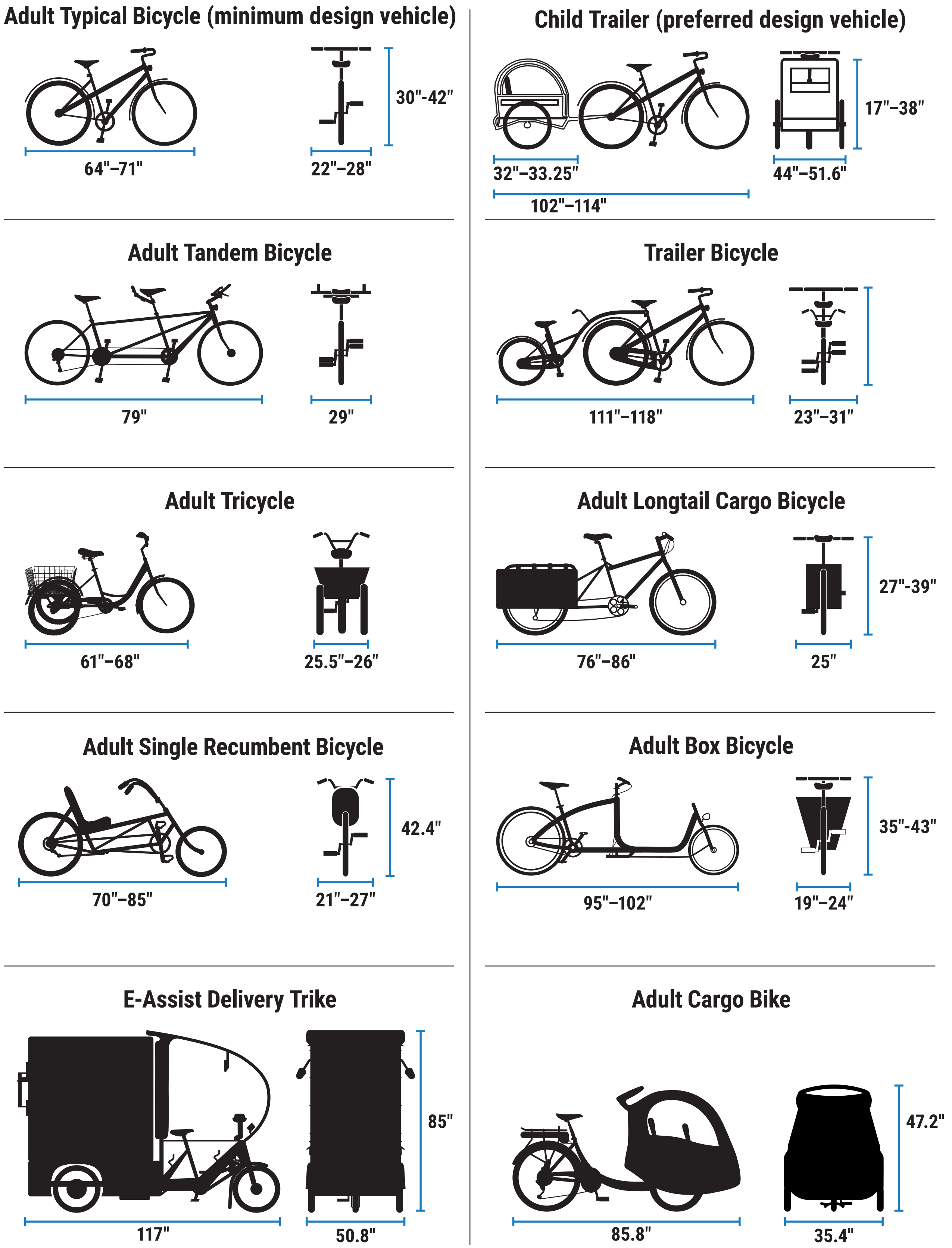


Figure 2: Dimensions of Typical Adult Bicycles

Bicycle Types

Figure 2 shows key dimensions for the more common types of adult bicycles, including a typical upright bicycle, recumbent bicycle, etc., that can be expected on most bikeways in Denver. Values in the figure are used to provide a conservative estimate that encompasses most bicyclists including children's bicycles and e-scooters, which are generally smaller than most adult bicyclists.

For the purpose of this Manual:

- **The minimum design vehicle is the adult typical bicycle (design length = 6')**
- **The preferred design vehicle is the adult typical bicycle with a trailer (design length = 10')**

As the popularity of e-bikes and e-scooters are becoming more widespread, it is important to take into consideration the varying operating speeds of these devices being used in Denver's bikeways.

The acceleration characteristics and sustained operating speeds for an e-bike or e-scooter are typically faster than what most people can attain with a non-electric bicycle. In locations with anticipated high bicycle and e-scooter ridership, such as downtown or on Denver's Core Network, wider bikeways should be considered to increase bicyclist and scooter operators' levels of comfort when passing one another.

Bicyclist Operating Speed

The speed of an adult bicyclist can vary considerably depending on trip purpose, facility type, roadway grade, physical ability, bicycle type, cargo weight, and riding companions. Although some adults may be able to maintain faster speeds (e.g., 25 to 30 mph) on level grades and attain speeds higher than 35 mph on steep descents, typical adult bicyclists average 8 to 12 mph on flat terrain, and steep inclines may result in speeds comparable to walking (2 to 3 mph). Research has found the median cruising speed for urban bicyclists to be 9.7 mph, with a 15th percentile speed of 8.2 mph.[5] Designers should use a design speed of 8 mph for bicycles on flat terrain at intersections. 10 mph should be used as the design speed for all other flat terrain locations.

5. Paulsen, K., C.M. Monsere, S.R. Thompson, and M.A. Figliozzi. A Comparison of Bicyclists' Performance Characteristics at Urban, Suburban, and Dedicated Path Intersections in Oregon. Presented at ITE Western District Annual Meeting, Phoenix, Arizona, 2013.

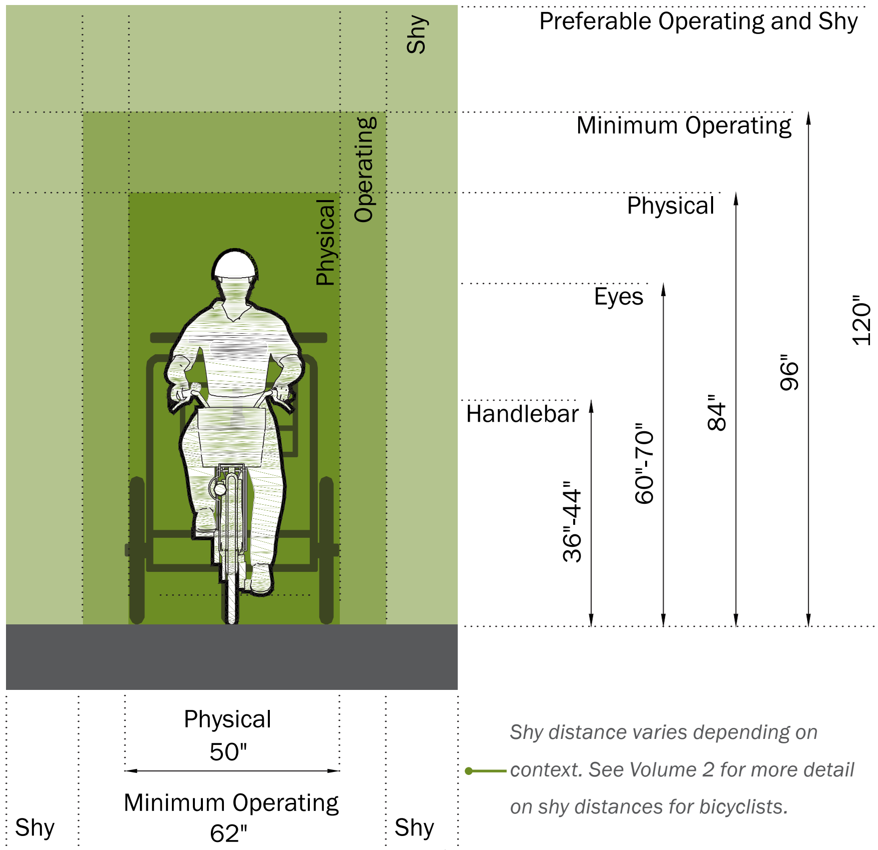


Figure 3: Design Bicyclist Operating Space

Bicyclist Operating Space

Designers should understand the principles of typical bicyclist operating space when designing bikeways. When developing design parameters for bikeway widths, designers should consider the space occupied by the bicyclist and their bicycle, their operating space, and any additional shy space to vertical objects or obstructions needed to improve their comfort and safety. These combined operating and shy spaces are used to establish lane width requirements for conventional and buffered bike lanes, protected bike lanes, and neighborhood bikeways in this Manual. Figure 3 shows the typical operating space for the design bicyclist used in this Manual.

The physical space for each bicycle is determined by the width and length of the widest or longest portion of the bicycle. This width is typically the handlebars on most bicycles, or the wheels on adult tricycles, child trailers, or adult cargo bicycles. To accommodate most bicyclists, the recommended design user is an adult bicyclist with a child trailer. To accommodate the side-to-side movement of almost all bicyclists, the minimum effective operating space clear of all obstructions should be 62 inches. This accounts for the 50-inch physical width of a typical adult bicyclist with a trailer, as well as 6 inches of space on either side to account for most people's natural variation in bicycle trajectory. The 62 inches of operating space should be measured from the center of the bike lane striping. This establishes the following operating space dimensions:

- 62-inch horizontal width (measured from the center of the bike lane striping)
- 8-feet vertical height
- 10-feet length

This operating space should provide a smooth, rideable surface clear of surface defects, joints, and other potential obstructions. Joints should be a maximum of 0.5-inch in width. The provision of shy space to vertical objects, parked or moving motor vehicles, and other bicyclists operating within a bikeway is also important to improve bicyclist comfort and safety. See Volume 2 for more details on bikeway, buffer, and clear space requirements for different types of bikeways.

CORE DESIGN PRINCIPLES

The core design principles included in this section are intended to guide the designer in decision-making. The design treatments presented in this Manual adhere to three core design principles at locations where motorists may interact with bicyclists: minimize motor vehicle speed, maximize visibility, and use separation. Adhering to these three principles will result in more high-comfort facilities that users of all ages and abilities can enjoy.

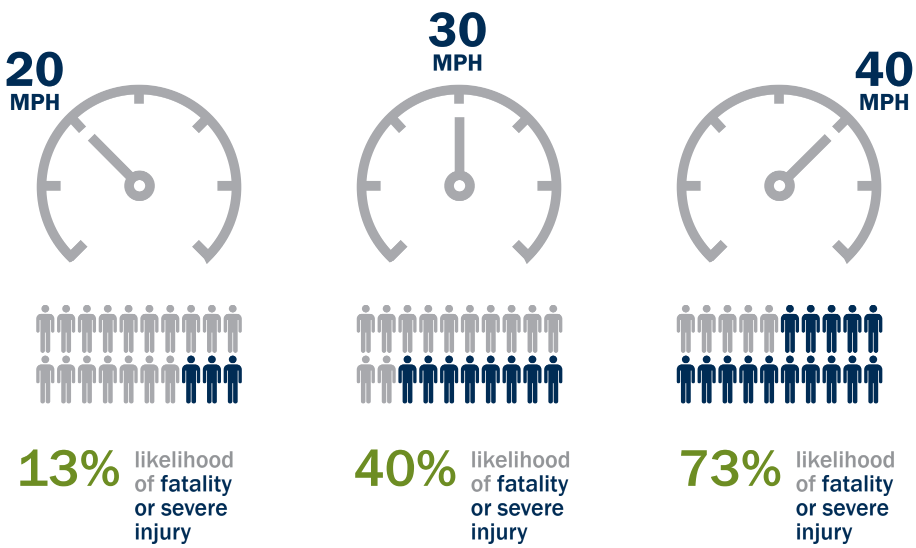


Figure 4: Impacts of Speed on Vulnerable Street Users[7]

Minimize Motor Vehicle Speed

Motor vehicle speed plays a substantial role in the severity of collisions. In a 2017 study,[6] the National Transportation Safety Board (NTSB) found that speed increases crash risk in two ways: it increases the likelihood of being involved in a crash and it increases the severity of injuries sustained by all road users in a crash. This danger results from the large difference in mass between motor vehicles and vulnerable road users. Figure 4 shows the impact of speed on the severity of collisions between motor vehicles and people walking and biking. Therefore, managing and minimizing motor vehicle speed, especially at conflict zones such as intersections, should be the primary consideration in the selection and design of bikeways and design treatments.

The Dutch Sustainable Safety Program,[8] a pioneering approach to reducing transportation-related fatalities, states that roads with balanced speeds, directions, and masses are the safest. This means that reducing the mass and speed differential between modes is critical to safety.

Vehicle speed affects both visibility and reaction time. Therefore, roadways with lower vehicle speeds are more appropriate for bikeways in order to achieve a higher level of comfort and safety. On streets with higher volume and speed, the risk and severity of collisions with vehicles rises, warranting additional protection for the bikeway.

6. Safety Study: Reducing Speeding-Related Crashes Involving Passenger Vehicles, NTSB/SS-17/01, National Transportation Safety Board, Adopted July 25, 2017
7. Tefft, B. C. Impact speed and a pedestrian's risk of severe injury or death. Accident Analysis & Prevention. 50. 2013.
8. See Bicycle Network Planning and Facility Design Approaches in the Netherlands and the United States at https://www.fhwa.dot.gov/environment/bicycle_ pedestrian/publications/network_planning_design.

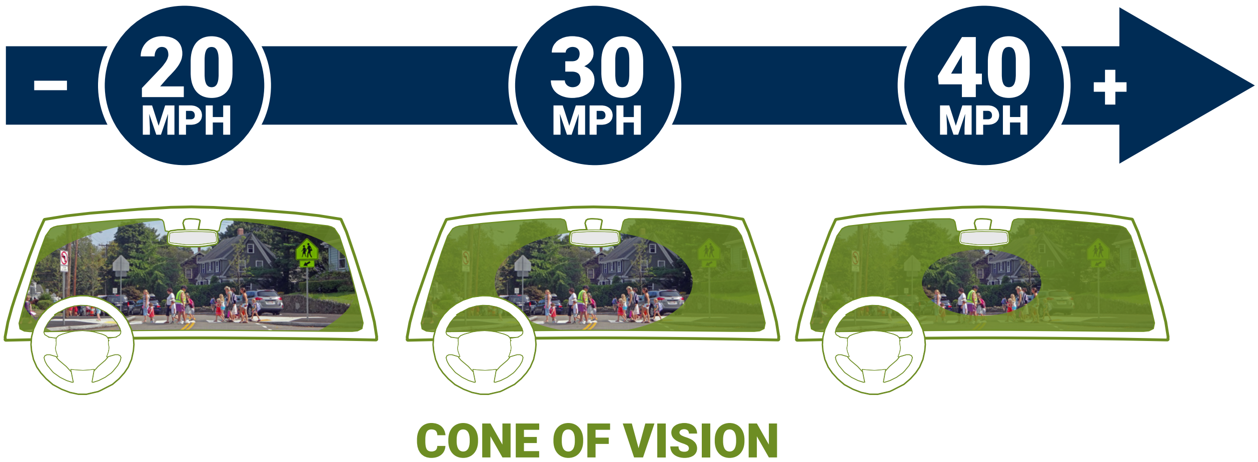


Figure 5: Relationship Between Vehicle Speed and Cone of Vision

Maximize Visibility

When all users are visible to one another on a roadway, there is a higher level of awareness that can lead to more predictable behavior and safer interactions between drivers, pedestrians, micromobility users, and bicyclists.

Providing the best possible visibility of and for bicyclists begins with facility selection. As motor vehicle speeds increase, a driver's cone of vision shrinks and elements in the periphery, like bicycles and micromobility users, may not be visible, as shown in Figure 5.

In the design of bikeways, proper visibility can be provided through roadway and intersection geometry which slows vehicle turning speeds and minimizes exposure, signalization strategies which separate conflicting movements, and lighting which illuminate conflict areas (almost 50 percent of fatalities occur in periods of darkness).[9]

The visibility of and for bicyclists should be an overriding design consideration, whether along the roadway or when drivers and bicyclists must share roadway space (at an intersection, lane change, facility transition, or transit stop).

9. National Center for Statistics and Analysis. Traffic Safety Facts 2014: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. DOT HS 812 261. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, DC, 2016.

Use Separation

Providing separation between motorists, bicyclists, and pedestrians is a key strategy to make bicycling more attractive to the *Interested but Concerned* bicyclist on streets with higher vehicle speeds and volumes. Separation can prevent conflicts and serious injuries and creates a vastly more comfortable environment for all users of the roadway, especially bicyclists who don't feel comfortable mixing with higher speed and volume motor vehicle traffic. Research has found that there is a significant relationship between provision of bicycle facilities and how safe and comfortable people feel bicycling, as well as how often they bicycle.[1, 2, 3, 4]

Various studies have found that bicycle and pedestrian crashes, even those involving motorists, tend to be underreported.[10, 11] A lack of crashes does not always indicate that there are no incidents, as studies have shown that near misses between vulnerable roadway users and motor vehicles are more common than collisions.[12, 13] It is also possible that some streets are deemed so unpleasant or unsafe that only the bravest or those without choice will bicycle there. Bicyclists who experience near miss crashes or hear about others' experiences with near misses are likely to avoid certain routes or stop bicycling altogether.[14] Thus, a small number of crashes do not necessarily indicate that the street is safe, but rather that there may be fewer people bicycling or unreported crashes.

The two primary tools roadway designers can use are space and time. Physical separation (space) from motor vehicle travel lanes creates a safer biking experience along linear segments of bikeways. Traffic control and signalization (time) can be used to separate bicyclists from other roadway users in time. Both tools have their place in bikeway design.

The degree of separation should be influenced by a number of roadway characteristics, including motor vehicle speed and volumes, the mix of vehicle traffic (such as a higher percentage of trucks or buses), curbside activity (such as parking and frequency of driveways), frequency of intersections, and direction of operation. For example, on roadways with low vehicle speeds and volumes, which fall under the design parameters for a neighborhood bikeway, physical separation is not necessary to create a safe and comfortable environment for bicyclists. These streets are calm and slow enough that *Interested but Concerned* cyclists will find them comfortable despite the lack of a bike lane separated from vehicle traffic. Ultimately, the design user of the bikeway and their needs should inform the level of separation.

10. Lopez, D. S, D. B. Sunjaya, S. Chan, S. Dobbins, and R.A. Dicker. Using Trauma Center Data to Identify Missed Bicycle Injuries and Their Associated Costs. Journal of Trauma and Acute Care Surgery, Vol. 73, No. 6, 2012, pp. 1602-1606.
11. Stutts, J. C., and W.W. Hunter. Injuries to Pedestrians and Bicyclists: An Analysis Based on Hospital Emergency Department Data. FHWA-RD-99-078. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1997.
12. Sanders, R. L. Perceived Traffic Risk for Cyclists: The Impact of Near Miss and Collision Experiences. Accident Analysis and Prevention, Vol. 75, 2015, pp. 26-34.
13. Joshi, M.S., V. Senior, and G.P. Smith. A Diary Study of the Risk Perceptions of Road Users. Health Risk Society, Vol. 3, No. 3, 2001, pp. 261–279.
14. Aldred, R. (2016). Cycling near misses: Their frequency, impact, and prevention. Transportation Research Part A: Policy and Practice, 90, 69-83.

BIKEWAY SELECTION

When building out an interconnected bicycle network, it is important to consider the context of each street. Residential streets with low vehicle volumes and speeds will not need the same level of physical protection as a high-volume downtown street might. This section outlines three types of bikeways and how to carefully consider when each might be appropriate.

Facility Definitions

This Manual covers three categories of on-street bikeways:

Conventional and buffered bike lanes: facilities within the street where space is designated exclusively for bicycle and micromobility users using only painted lines to separate them from motor vehicle traffic.

Protected bike lanes: facilities within the street, or outside the street but within the street right-of-way, where space is designated exclusively for bicycle and micromobility use. Within the street, separation is typically provided with painted lines to define horizontal buffer space and vertical protection elements like concrete curbing, flexible delineator posts, engineered rubber curbs, planters, or other elements. Planters are only to be used in special conditions when approved by DOTI and a maintenance agreement is in place. This designation also includes raised protected bike lanes, which are elevated to sidewalk or intermediate level and separated from traffic by a vertical curb.

Neighborhood bikeways: streets designed to prioritize bicycle traffic by minimizing motorized traffic volumes and operating speeds. Treatments include pavement markings, signs, traffic calming, and traffic control. These treatments must be installed collectively to ensure low motor vehicle volumes and speeds and high ease of use for bicycle riders.

Protected bike lanes, neighborhood bikeways, and trails are considered high-comfort bikeways. High-comfort bikeways provide the most physical protection, fewer and slower motor vehicles, and are the preferred routes for Interested but Concerned riders. Conventional and buffered bike lanes, when used on streets with acceptable vehicle speeds and volumes, can be comfortable but are typically less preferred routes for Interested but Concerned riders.

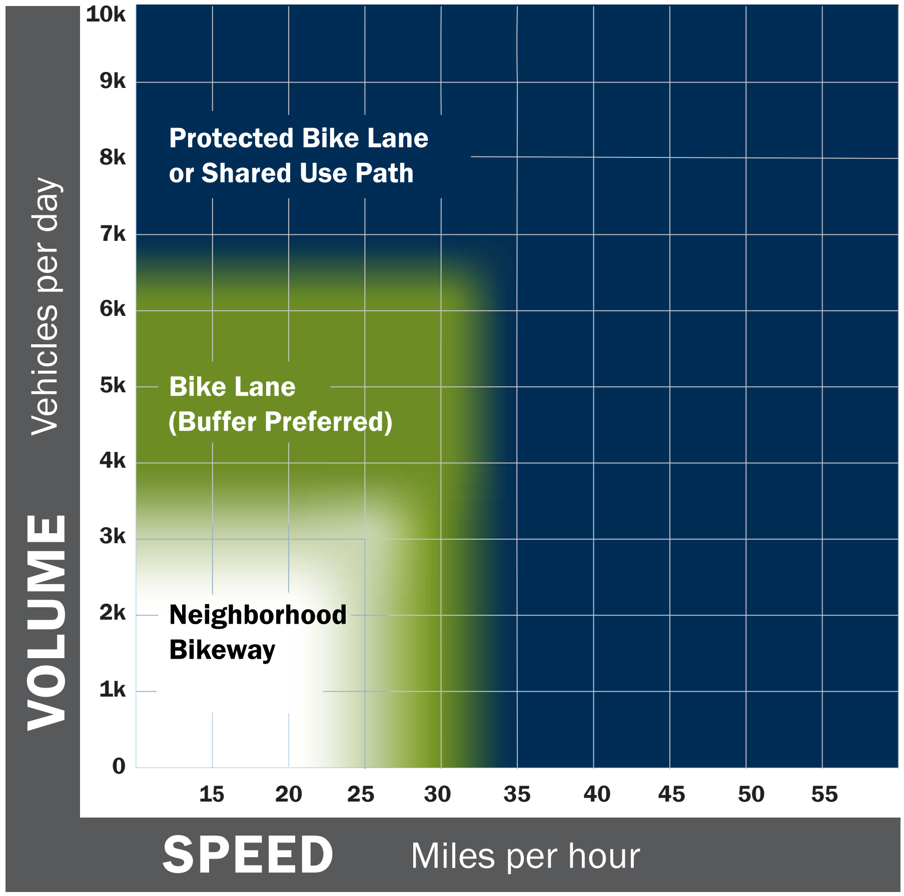
Initial Facility Selection

The selection of a preferred bikeway requires a balance of data analysis and engineering judgment working within relevant constraints for the project. This Manual provides a framework for selecting a preferred bikeway type given different traffic conditions and land use contexts.

Proximity to motor vehicle traffic is a significant source of stress and discomfort for bicyclists. As mentioned, crash and fatality risks sharply rise for vulnerable users when motor vehicle speeds exceed 20 mph. Further, as motorized traffic volumes increase above 6,000 vehicles/day, it becomes increasingly unsafe and uncomfortable for motorists and bicyclists to share roadway space. For example, on a roadway with 10,000 vehicles/day, a bicyclist traveling at 10 mph will be passed approximately every four seconds by a motor vehicle during the peak hour. Research indicates bicyclists feel more comfortable operating on streets where bicyclists are separated from high speed motor vehicle traffic.[15] While there are no physical barriers in place separating people biking from motor vehicles on low-volume neighborhood bikeways, the very low instances of vehicles passing makes these streets high-comfort facilities as well.

The bicycle facility selection chart[16] in Figure 6 identifies bicycle facilities that improve the operating environment for *Interested but Concerned* bicyclists at different roadway operating speeds and traffic volumes. The *Somewhat Confident* bicyclist will also prefer treatments noted in this chart. Designers should select facility types based on this chart to serve the largest share of the population, increase rates of bicycling, and provide facilities that are comfortable for most users.

15. Sanders, R. L. We Can All Get Along: The Alignment of Driver and Bicyclist Roadway Design Preferences in the San Francisco Bay Area. Transportation Research Part A: Policy and Practice, Vol. 91, 2016, pp. 120-133.
16. Schultheiss, et al., Bikeway Selection Guide, Federal Highway Administration, 2019.



Notes

1 *Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.*

Figure 6: Bicycle Facility Selection Chart

Facility Selection Refinement

Conditions for Increasing Separation

There are a variety of other considerations that may indicate the need for greater separation between bicyclists and motor vehicles (such as additional buffer width, additional vertical buffer elements, or other measures) than what is shown in Figure 6. These include the conditions on the following pages.

UNUSUAL MOTOR VEHICLE PEAK HOUR VOLUMES

On roadways that regularly experience unusually high peak hour volumes, more separation can be beneficial, particularly when the peak hour also coincides with peak volumes of bicyclists. Typical motor vehicle peak hour volumes are generally in the range of 8 to 12 percent of average daily traffic. Examples of roadways with unusually high peak volumes may include local roads near schools, hospitals, or popular event locations, such as stadiums. Some roads may experience peak periods of shorter durations than an hour, such as school drop-off locations. Higher peak hour volumes may be seasonal or may only occur during certain months or weeks of the year. Despite the shorter peak period, providing additional separation may still be appropriate in these cases.

HIGH PERCENTAGES OF LARGE VEHICLES

Higher percentages of trucks and buses increase crash risks and discomfort for bicyclists due to vehicle size, weight, and decreased visibility of bicyclists due to blind spots. This is a particular concern for right turns, where large vehicles may appear to be proceeding straight or even turning left prior to right turn movements. Additional buffer width between a protected bike lane and the travel lane at an intersection can improve visibility in these locations. Additional separation between bicyclists and motorists is particularly important on streets where heavy vehicles are more than five percent of traffic.

PARKING TURNOVER AND CURBSIDE ACTIVITY

Conflicts with parked or temporarily stopped motor vehicles present a risk to bicyclists. High parking turnover and curbside loading may expose bicyclists to being struck by opening vehicle doors or people walking in their travel path. Vehicles stopped within bicycle lanes or travel lanes, such as delivery vehicles, may force bicyclists to merge into an adjacent travel lane. In locations with high parking turnover or curbside loading needs, providing protected bike lanes in lieu of conventional or buffered bike lanes can help alleviate conflicts. Considerations should be made for the loading and access needs of adjacent businesses, either through roadway design or by accommodating such needs in a nearby location, and consideration should be made to deter loading within the bike lane. Locations with high parking turnover or curbside demand may include metered or two-hour on-street parking zones, commercial districts, and locations with high ride-hailing demand.[17]

CONTRAFLOW BIKEWAYS

In some situations, it may be necessary to install "contraflow" bikeways that allow bicyclists to make connections in the opposite direction of the flow of vehicle traffic, typically on one-way streets. In these situations, it is important to increase separation of roadway users to enhance bicyclist safety and comfort.

VULNERABLE POPULATIONS

The presence of high concentrations of children and seniors should be considered during project planning and bikeway selection. These groups may only feel comfortable bicycling on high-comfort facilities and may be less confident in their bicycling abilities. Children in particular are less visible to motorists, have inadequate experience bicycling in the roadway, and have reduced traffic awareness skills compared to adults. Locations with high volumes of vulnerable populations may include areas near hospitals, schools, and parks.

NETWORK CONNECTIVITY GAPS

While motor vehicle volumes and speeds may indicate that a shared facility is appropriate, continuing protected facilities may be preferable to provide a consistent bikeway along a corridor and improve legibility of a low-stress bicycle network with a uniform level of comfort throughout the route. Examples include on-street connections between two major shared use paths, where routes connect to parks or other recreational opportunities, or where a primarily protected bike lane facility passes through a neighborhood on a local street for a segment of the corridor.

TRANSIT CONSIDERATIONS

The provision of bicycle lanes on corridors with relatively frequent transit headways will result in interactions between the transit vehicles and bicyclists that will negatively impact bicyclists' level of comfort and safety. As noted in FHWA's *Separated Bike Lane Planning and Design Guide*, options for minimizing conflicts with transit include creating floating bus stops that transition a bike lane to a protected bike lane through the bus stop area (see Volume 2), placing a bike lane or protected bike lane on the left side of a one-way street (out of the way of transit stops along the right side), or choosing to install a bikeway on a nearby parallel corridor away from transit.

17. ITE. Curbside Management Practitioners Guide. November 2018.

DRIVEWAY FREQUENCY

Frequent driveways compromise the linear integrity of bikeways, forcing bicyclists to frequently negotiate with motor vehicles crossing their path of travel. Frequent driveways may limit the ability to provide sufficient physical protection for a protected bike lane, resulting in a need to provide a sidewalk level bikeway to provide physical separation from motor vehicles. Volume 2 contains additional details for how to design for streets with low and high volume driveways

BICYCLIST VOLUMES

If the anticipated peak hour bicycle volume in the upcoming five years is estimated to be more than 500 bicycles per hour, designers should consider upgrading the facility to a protected bike lane and using maximum bicycle lane and buffer widths. Where higher volumes of bicyclists exist, care should be taken to provide sufficient space for people biking to pass one another safely within the bike lane.

FIRE CODE

Bikeway designers should take into consideration the minimum fire code requirements for building access and ensure that adequate space or routes are provided to meet the code. See the latest version of the Denver Amendments to the International Fire Code for details.

Selecting the "Next Best" Facility

Designers may encounter situations where the preferred bikeway type is not feasible. In these cases, designers should consider reducing travel lane width, eliminating travel lanes, rerouting to a parallel route, or selecting the "next best" facility. "Downgrading" should be considered infrequently and very carefully while keeping in mind the project purpose and objectives. A downgraded facility may result in reduced safety, failure to serve the needs of the design user, out-of-direction travel, a gap in the bikeway network, and the potential for improper use or undesired activity such as sidewalk or wrong-way riding. The decision-making process should also consider the overall bikeway network connectivity, rider safety, skill level and comfort, and accessibility of the bikeway.

One-way vs. Two-way Considerations

The direction of a protected bike lane relative to the flow of motor vehicle traffic, its location within the roadway, and its operation as a one-way or two-way facility is determined by several factors. These factors include the roadway network, destinations along the route, driveway frequency, presence and type of nearby bikeways, and bikeway network continuity and legibility. For example, it may be desirable to provide a two-way protected bike lane to improve the legibility of the bicycle network on:

- one-way streets where wrong-way bicycling is likely
- street segments which connect to side paths or other two-way protected bike lanes

The selection and design of bikeways and intersection treatments should provide a consistent design that is easy to understand by all roadway users and addresses safety concerns inherent in two-way facilities.

Typically, on two-way streets, one-way protected bike lanes on each side of the street are preferred because they are more intuitive and consistent with roadway operations for motor vehicles. They also make intersections and connections simpler and easier to understand and navigate. Similarly, one-way bike lanes are generally preferred on one-way streets.

However, there may be conditions that warrant different configurations, such as a bikeway that operates contraflow to motor vehicle traffic or constrained environments like limited available right-of-way, challenging motor vehicle operations (bus lanes, parking, driveways, turning movements), land use characteristics (destinations concentrated on one side), and connections to the bicycle network.

Additionally, designers should observe user behavior when adding or retrofitting a bikeway. If two-way riding is common, the designer should consider how to allow for those movements in the most intuitive way possible. This may mean choosing to design a two-way bicycle facility or ensuring that the contraflow movement is provided in the immediate vicinity, such as the adjacent parallel street.

When determining the directionality of bikeways, there are many factors to consider. Safety, connectivity to the larger network, directness, convenient access, minimizing out-of-direction travel, available right-of way, intersection operations, maintenance, and feasibility are top considerations. Designers should ensure that, in addition to the core design principles, they take care to provide clear and intuitive transitions, minimization of conflicts, and convenient connectivity to the larger network, among other objectives.

On a two-way facility, bicyclist crash risk is elevated compared to a similar one-way facility due to reduced motorist awareness of the contra-flow moving bicyclist.[18, 19] This increased crash risk can be substantially mitigated by:

- adding green colored crossings and supportive traffic control signs to improve motorist awareness[20]
- slowing motorist turning speeds with raised crossings, centerline hardening, or offset crossings[21]
- separating bicyclist movements at signalized intersections where conflicting turning motorist volumes during peak hours are high (see Volume 2, Figure 3-7)[22, 23, 24]

Design Variance Process

This Manual includes preferred and minimum dimensions for various treatments and bikeway types. Designers are expected to apply the preferred dimension to ensure that the bikeway provides a high degree of comfort for bicyclists and micromobility users. This may require reducing travel lane widths to minimum allowed dimensions or removing travel or parking lanes.

When a designer recommends the minimum bikeway facility dimension for distances greater than 150 feet, or when the minimum dimensions are not met (for any distance), the designer shall document the bikeway design variance with DOTI. The bikeway design variance documentation should:

- Clearly describe and document the variance sought for each occurrence; and
- Justify the variance by providing a detailed assessment on why the preferred dimension is not feasible.

The bikeway design variance shall be reviewed by the DOTI project manager, who may recommend the approval of the variance if all the following conditions apply:

- The designer has diligently conducted an assessment and exhausted all other means to implement the preferred dimension; and
- Implementation of the preferred dimension will impose undue financial burden on the project.

If the DOTI project recommends the bikeway design variance, the project manager is required to gain final approval for the variance from the City Traffic Engineer and any approved variances should be documented in a memo that is submitted with plan sets. In compliance with the City Charter, DOTI has the sole discretion to approve or disapprove the variance. The bikeway design variance is an internal DOTI approval process and final approval must come from the City Traffic Engineer.

18. Wachtel, A., and Lewiston, D. (1994). Risk Factors for Bicycle-Motor Vehicle Collisions at Intersections. ITE Journal, pp. 30-35.
19. Wessels, R. (1996). Bicycle Collisions in Washington State: A Six-Year Perspective, 1988-1993. Transportation Research Record 1538, pp. 81-90.
20. Smith, R. L. and T. Walsh. Safety Impacts of Bicycle Lanes. In Transportation Research Record 1168. TRB, National Research Council, Washington, DC, 1988.
21. Schepers, J. P., Kroeze, P. A., Sweers, W., and Wüst, J. C. (2011). Road Factors and Bicycle–motor Vehicle Crashes at Unsignalized Priority Intersections. Accident Analysis and Prevention, 43(3), pp. 853-861.
22. Madsen, T., and H. Lahrmann. Comparison of Five Bicycle Facility Designs in Signalized Intersections Using Traffic Conflict Studies. Transport Research Part F, Vol. 46, 2017, pp. 438-450.
23. Zangenehpour, S., Strauss, J., Miranda-Moreno, L. F., & Saunier, N. (2016). Are Signalized Intersections With Separated bike lanes Safer? A Case–control Study Based on Automated Surrogate Safety Analysis Using Video Data. Accident Analysis and Prevention: 86, pp. 161-172.
24. Massachusetts DOT Separated Bike Lane Planning and Design Guide, Chapter 6 Signals. https://www.mass.gov/lists/separated-bike-lane-planning-design-guide

DESIGN & IMPLEMENTATION PROCESS

In order to ensure consistency in design, all designers internal and external to DOTI should follow the process described in this chapter. The following section describes the general steps designers should take when working on bikeway projects in Denver.

Design Steps

STEP 1: Consult Denver Bicycle Facility Map

The Denver Bicycle Facility Map identifies the locations and types of existing and planned bicycle facilities throughout the city. Designers should consult the latest version of this map to document the planned bikeway type and its significance the overall bicycle network.

However, the map does not represent all possible bikeways in Denver; streets that are not identified in the map may also be considered for a bicycle facility per other DOTI objectives or opportunities.

STEP 2: Check street designations/plans

- **High Injury Network:** Denver's High Injury Network (HIN) consists of the streets with the highest number of fatal and injury crashes. Proposed bikeways along and across these streets should employ greater levels of protection and separation from motor vehicle traffic. Extra care should be taken at intersections in particular by designing protected intersections and separating bicycle and motor vehicle movements where possible.

- **Green Streets:** Designers should check the latest *Green Infrastructure Implementation Strategy* and any updated design guidelines from DOTI to identify whether any section of the bikeway project has been designated as a Green Street opportunity. If any section is identified, the designer should coordinate with the DOTI project manager and contact appropriate staff to determine design preferences.

- **Parkways and Boulevards:** Over 30 streets in Denver have been designated as Parkways and Boulevards. The designer should consult the 2005 *Design Guidelines: Denver's Designated Parkways and Boulevards* document and any updated related documents for information focused on preservation of character, original features, and other street features. Most importantly, the DOTI project manager should coordinate with Denver Parks and Recreation as the bikeway design is developed and finalized.

- **Water Quality Basin Scorecard:** Several areas in Denver have been designated as high-priority water basins as part of the *Green Infrastructure Implementation Strategy*. If the project is in such an area, designers should look for opportunities to coordinate with appropriate staff to implement green infrastructure features in the project.

- **Transit Priority:** The *Denver Moves: Transit Plan* (2019) identified transit priority streets across the city for targeted investments. These streets are split into Capital Investment Corridors (CIC) and Frequent Transit Network Streets (FTN). Designers must check if the project falls on a CIC or FTN street, and coordinate with the PM and DOTI's Transit Team about design elements such as bus stops or station access as needed.

- **Safe Routes to School:** The Safe Routes to School (SRTS) program in DOTI seeks to collaborate with schools using data-driven decision-making. Project managers should coordinate with the SRTS program where projects are near schools to make it safer and easier for students to bike to school.

- **OneBuild:** Project managers should look for opportunities to leverage ongoing or planned projects along the corridor and coordinate improvements to reduce redundancies.

- **State Highways:** Project managers should coordinate with the Colorado Department of Transportation (CDOT) regarding applicable design standards where bikeways run along state highways or CDOT-owned property.

- **Fire Truck Primary Route:** Designers should contact Denver Fire Department fire prevention review staff to check whether any segment of the project corridor overlaps with a primary route for a specific fire station. Primary fire truck routes are based on a street's use by the Fire Department for emergency response.

STEP 3: Choose a facility type based on the Bicycle Facility Selection Chart

The Bicycle Facility Selection Chart in Figure 6 shows the volume and operating speed thresholds for various types of bikeways. Designers should use the chart to determine the preferred bikeway type for any specific street in Denver. During the design phase of the bikeway, more detailed existing conditions of the street (e.g., number of driveways, turning volumes, extensive grades, pavement condition, drainage issues, etc.), will require additional design treatments outlined in Volume 2.

In some cases, the bikeway type may need to be modified from what was originally planned to better align with existing conditions and to ensure that it follows the design principles. It is important that bikeways are easily legible and remain consistent in design. If, for example, a roadway has some segments with vehicle speeds and volumes that warrant a protected bike lane and others that only warrant a buffered bike lane, the higher level of protection should be carried through the entire facility. Final decisions on bikeway type should focus on making the street safer for all users.

STEP 4: Identify an appropriate community and stakeholder engagement plan

The designer should coordinate early with the DOTI project manager to determine the level of community engagement needed for the bikeway project. Appropriate DOTI and other City stakeholders should also be engaged. Projects that are potentially controversial may require more outreach to ensure that concerns from community members and potential users are adequately addressed. Other projects which have already been vetted by the community through prior planning or design efforts may warrant less intensive community engagement.

STEP 5: Determine implementation method

If a bikeway is to be accommodated through a street reconfiguration, designers should first seek to reduce travel or parking lane widths to the minimum allowable width for its street type as outlined in the *Complete Streets Design Standards*. If a lane width reduction does not provide adequate width needed for the preferred bikeway type, designers should follow the Street Reconfiguration Decision-Making Flowchart, located in Appendix A, to make decisions about travel lane or parking lane removal.

If the project is a new street or street reconstruction project, designers should design per the *Complete Street Design Standards,* including the preferred bikeway widths, early on within the scope of the project.

STEP 6: Identify key design treatments

Once the bikeway type and plan for street reconfiguration or reconstruction are selected, the designer should follow the guidance and standard details provided in this Manual to design a safe and comfortable bikeway. The designer should carefully select the appropriate buffer size and type based on the goals of the project, right-of-way, and the funding available. When designing intersections, the designer should anticipate turning movements of all bicyclists who are entering and exiting the facility from other bikeways. In addition, the designer should evaluate and mitigate potential conflicts with pedestrians, micromobility users, transit users, loading/unloading vehicles, and turning vehicles. For projects that impact existing pedestrian accessible routes, including but not limited to crosswalks or sidewalks, designers should ensure the design is in accordance with the latest PROWAG and CCD standards for accessibility requirements. Ensure that ADA parking spaces are maintained through the design or relocated in coordination with the Curbside and Parking team.

When curb lines are changed, a drainage memo needs to be submitted to DOTI before proceeding with design. If conditions are not explicitly addressed in the standard drawings presented in Volume 2 of this Manual, designers should rely on the design principles presented in Volume 1 and sound engineering judgment to find appropriate design solutions.

Design Production and Review

Bikeway projects may be implemented through in-house DOTI construction, work-order projects with on-call contractors, hard-bid processes, or developer-led projects. The design plan sheet requirement for each may vary. When preparing the design plans, designers should follow the Bikeway Engineering Plan Submittal Checklist in Appendix B.

Implementation

DOTI's OneBuild program is aimed at coordinating the design and delivery of various projects among different divisions within the department. The goal of the program is to find synergies between projects to maximize efficiency and reduce waste of public tax dollars. In order to ensure that bikeway design is coordinated with other DOTI and City efforts, the designer shall follow the appropriate OneBuild process.

Methods of Implementation

This section describes the various implementation methods available for bikeway design projects.

POP-UP

This implementation method is typically community-driven and in place for one day to a week. Designers shall coordinate with the Community Streets Program and the City Traffic Engineer for assistance with implementation considerations. Right-of-way occupancy permits may be required and designers should follow Encroachment Rules and Regulations for the general placement and height criteria.

PILOT/DEMONSTRATION

A low-risk strategy for implementation uses low-cost installation methods and materials to demonstrate the benefits and tradeoffs of a project on a temporary basis. These projects usually differ from pop-ups in that they use more durable materials, stay in place for several months to years, and there is usually more robust evaluation of public opinion and traffic patterns before and after installation. The temporary nature of these types of projects allows for rapid changes to be made if needed. Demonstration projects provide the opportunity to test a concept and solicit public feedback before committing significant resources to permanent installation. This implementation strategy should include a specific evaluation plan, with data collection/analysis, to gauge each project's success and inform next steps, along with careful selection of project locations.

INTERIM

Due to budget and time constraints, some bikeway projects may be implemented on an interim basis. This strategy uses low-cost materials to implement the project and typically avoids more costly project elements like drainage modifications. However, all design elements of the project, e.g. turn radius, buffer size, etc., should be based on the core design principles presented in this Manual and able to accommodate the ultimate design treatment without having to make major changes to the bikeway and intersection geometry. This ensures that all users remain familiar with the operation of the bikeway.

DOTI monitors interim projects to ensure that interim bikeways fulfill project goals. Changes are made as necessary and results are measured and reported. Generally, interim facilities are upgraded using more durable or aesthetic materials, depending on funding.

RESURFACING

Bikeways are often implemented as part of maintenance projects and other ongoing DOTI efforts. When evaluating the pavement condition of streets to determine which ones will be selected for resurfacing, DOTI also looks for opportunities to implement bicycle facilities on those streets. DOTI also identifies which streets to resurface based on the Denver Bicycle Facility Network Map.

RECONSTRUCTION/NEW CONSTRUCTION

When new roadways are constructed or reconstructed, whether privately or publicly funded, they should include sidewalks and bicycle facilities where feasible, as they should improve connectivity and accessibility for all users. Streets without adequate bikeway infrastructure can be major barriers for people bicycling.

CAPITAL PROJECTS

Capital projects can include Capital Improvement Program (CIP), Community Transportation Network, Vision Zero, and other projects that are not associated with resurfacing or new construction. Capital projects should also follow these guidelines and consult the Denver Bicycle Facility Network Map to determine whether to include a bikeway and select an appropriate facility type.

MAINTENANCE & OPERATIONS

The maintenance and operation of bikeways can require additional resources to ensure that they are safe and operable for all users. Designers should be aware of the life-cycle cost of their design and associated materials to ensure that the bikeway remains in good condition. Use of new materials require approval of DOTI Operations Administration and Office of Asset Management.

Maintenance Considerations

Some of the potential issues that should be taken into consideration during design include:

- Street sweepers and snow plows shall be able to access the bikeway. Current equipment requires 7 feet between curbs for sweeping and snow removal.
- Bikeways along drainageways should be swept promptly following large storm events.
- If there are low points on the bikeway, adequate drainage should be provided to keep stormwater flow outside of the bicyclists' operating space. Inlet grates on bikeways should use the bike-friendly design per CCD STD DWG S-716.
- Manholes should be flush within one-quarter inch below the pavement surface to avoid impacting snow plow machinery.
- Utility cuts should cover the entire width of the bike lane to prevent uneven riding surfaces.
- All wastewater infrastructure must be accessible by DOTI Wastewater Management Division maintenance vacuum and jet trucks.
- If all other factors are equal (number of conflict points, right-of-way availability, predictability, etc.), consider designing bicycle facilities on the north side of a roadway to avoid shading snow and ice during winter months.
- If not on City right-of-way, consider maintenance ownership of facilities with other entities (BID, property owner, etc.)

Vertical objects may be struck by motor vehicles and require regular replacement if they are not designed properly. Maintenance and operation crews should plan on refreshing pavement markings and trimming any adjacent vegetation on a regular basis.

Raised Protected Bike Lane Maintenance

Regular maintenance of raised protected bike lanes is an important consideration when deciding to implement this type of bikeway facility. During the conceptual design phase, designers should coordinate with one of the following entities to identify appropriate maintenance responsibility and protocols for the facility after construction. The project location will determine appropriate maintenance entity for the facility. Maintenance for the bike facility could be the responsibility of the DOTI Green Infrastructure program, Denver Parks and Recreation, local maintenance districts, business improvement districts, general improvement districts, or a master developer agreement with a private land developer.

Snow Maintenance

Denver regularly updates its Snow Response Plan based on changing priorities, equipment, and funding. The key points of the current snow maintenance plan related to bikeways in Denver are as follows:

- Conventional and buffered bike lanes are plowed to the curb and additional de-icing measures on vehicular lanes are extended to include the bike lane.
- Protected bike lanes are plowed every time snow accumulates, consistent with the “Snow Plowing Response” criteria.
- Neighborhood bikeways receive additional snow plowing, as outlined below:
  - When deployed, the residential plows clear most of the street and, as feasible, clear the roadways to expose pavement.
  - Local streets with neighborhood bikeways receive de-icing agents or materials, as feasible.
- Continue to expand education for both snow plow drivers and the general public on how to properly maintain clear space for people walking and biking when it snows.

APPENDIX

A Denver Street Reconfiguration Decision-Making Flowchart

Designers should use the chart on the following page to decide how to implement the selected bikeway type.

B Bikeway Engineering Plan Submittal Checklist

Designers should use the plan submittal checklist contained in this Appendix to fulfill the City's construction plan and documentation requirements.

Appendix A - Denver Street Reconfiguration Decision-Making Flowchart

This flowchart guides preliminary decision-making for bikeway implementation requiring more pavement width than is currently available. This version is intended for internal CCD use only.

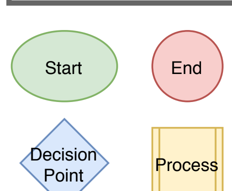
This flowchart assumes corridor alignments from *Denver Moves Bicycles* and facility types from *Denver Moves Bicycles* and the *Bikeway Design Manual.*

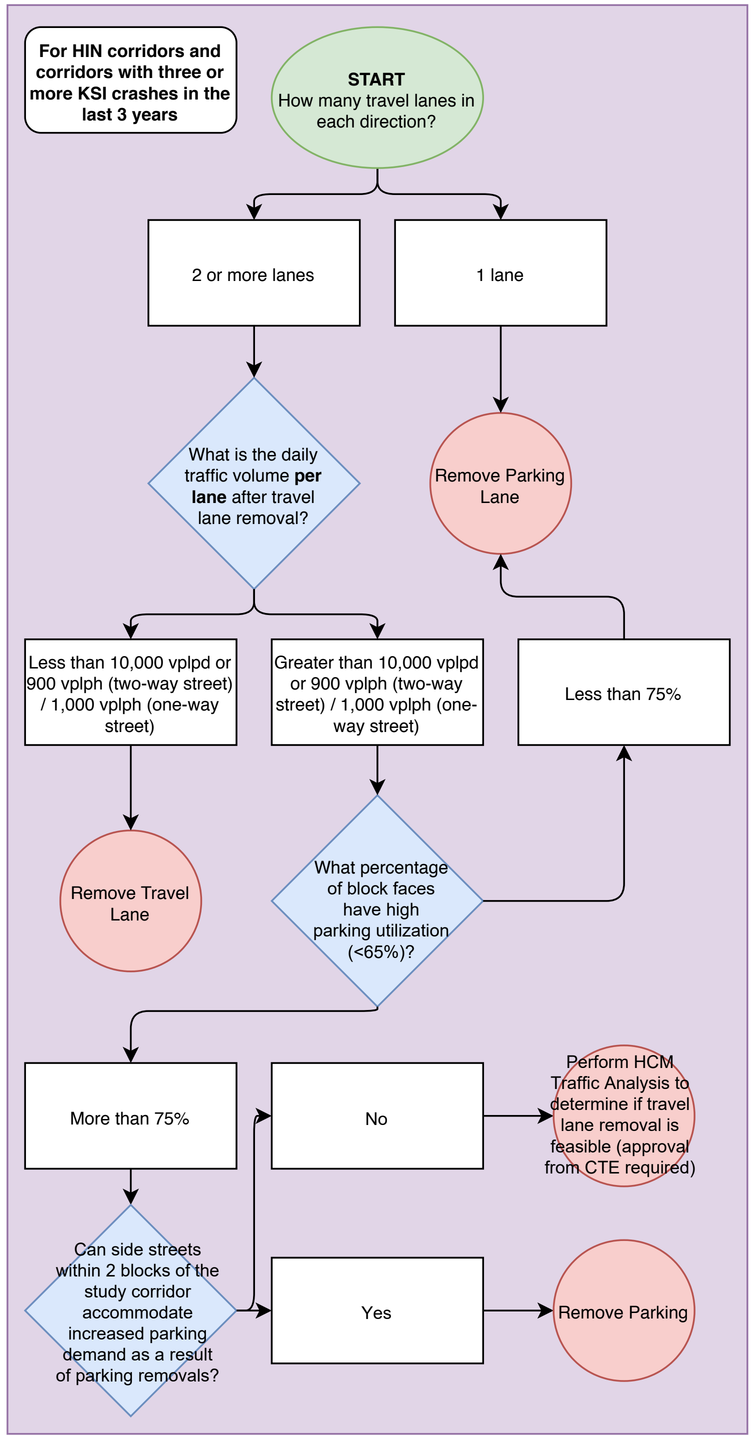
Glossary

HIN (High Injury Network) - the corridors with the highest number of fatal and injury crashes as presented in the *Denver Vision Zero Action Plan*; represents 5 percent of Denver's streets but accounts for 50 percent of traffic fatalities
KSI (killed and severely injured) crash - a crash resulting in a fatality or severe injury
parking utilization - the percentage of available parking that is occupied
public parking - includes on-street parking and off-street parking (surface lots and parking garages) that are open to the public
street type - describes adjacent land use and character as established in *Blueprint Denver*
vplpd - unit for describing motor vehicle traffic volumes; vehicles per lane per day
vplph - unit for describing motor vehicle traffic volumes; vehicles per lane per hour

References

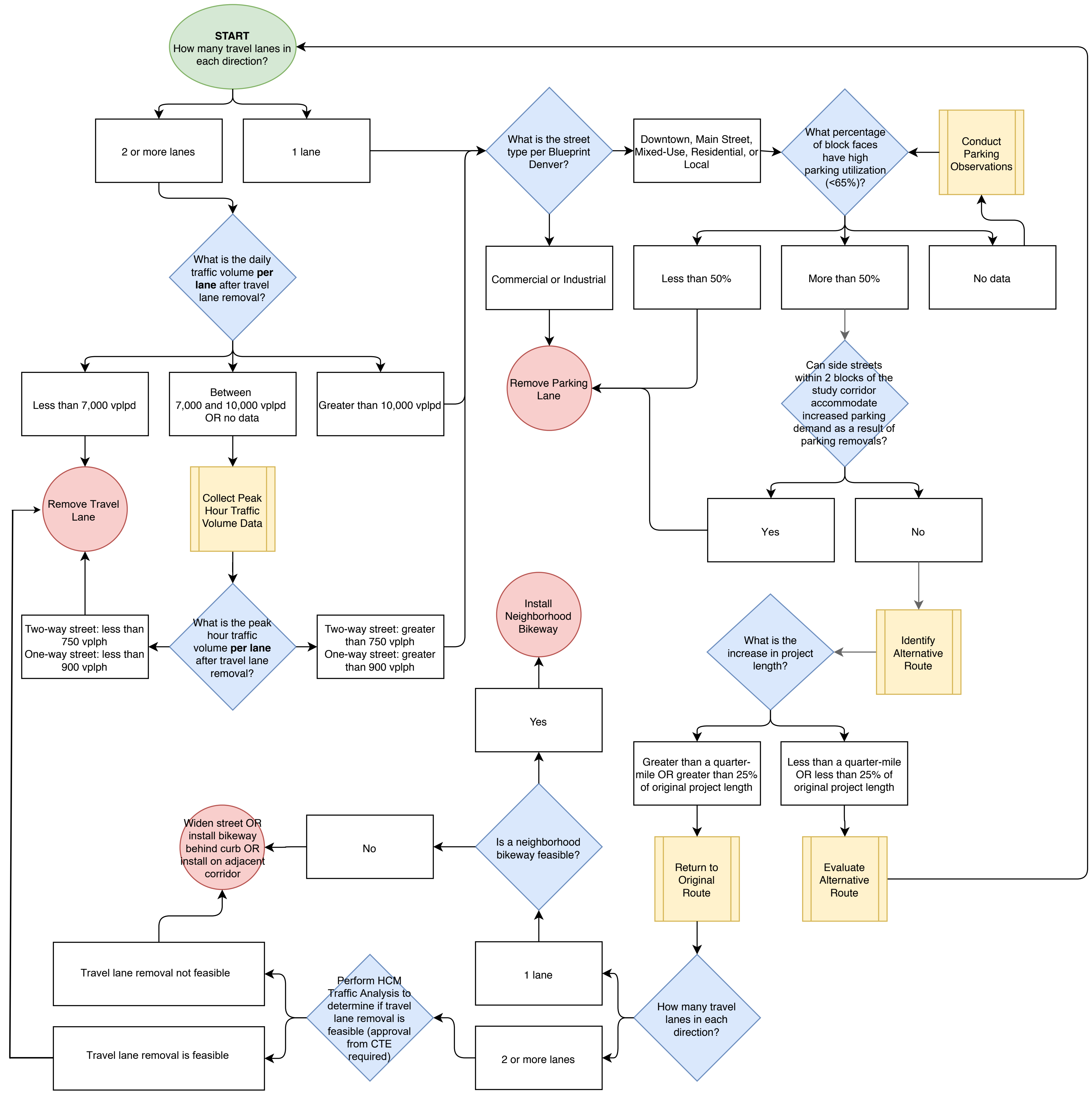
Blueprint Denver - Denver's transportation and land use master plan that established a context-sensitive street typology
Denver Moves Bikes - Denver's bikeway network master plan; updated in 2024
FHWA Road Diet Informational Guide - describes benefits, supportive conditions, and design guidance for travel lane removals, i.e., road diets
Procedure Statement for Parking Field Survey (P.T.46) - a Denver Department of Public Works Transportation & Mobility Procedure Statement that defines the process for performing field surveys of parking utilization
FDOT Lane Elimination Guidance and Service Volume Tables





Notes

1. Parking studies should address impacts to existing ADA spaces, loading zones, and land-blocked parcels along the corridor.
2. When removing a travel lane, projects shall run HCM analysis to identify signal optimization and other operational treatments to mitigate potential addition of delay/queueing.
3. When considering travel lane removal, projects should consider Denver Moves Transit high and medium capacity network needs.
4. When traffic diversion is expected, the project should analyze potential traffic pattern changes for surrounding network



201 W. Colfax Avenue, Dept. 508
Denver, CO 80202
www.denvergov.org/content/denvergov/en/transportation-infrastructure

Appendix B – Bikeway Engineering Plan Submittal Checklist

Purpose	Bikeway Engineering Plans are a set of construction plans and documentation prepared by City and County of Denver (CCD) staff and/or the consultant which document roadway changes required for a proposed bikeway design project. This document is used by CCD and consultants to ensure that all bikeway projects are prepared consistent with CCD standards and expectations. For larger projects with roadway reconstruction, the CCD TEP Plan Requirements will apply as described within this checklist. This Submittal Checklist document sets forth the minimum standards, deliverables, and deliverable contents necessary for Bikeway Engineering Plan submittals and approvals by CCD. Variations from the specified deliverables and contents shall be included in the project RFP phase and verified during the project kickoff meeting. This Submittal Checklist applies to two of the most common type of CCD bikeway projects: those constructed In-House by CCD crews and those constructed through a Work Order by an on-call contractor. Bikeway Project Deliverables – Page 1 Plan Set Contents – Page 3 Bikeway Plan Sheet Requirements – Page 5 Cost Estimate Requirements – Page 9 Specifications Checklist – Page 10 Bikeway Project Review – Page 10

Bikeway Project Deliverables	**Project deliverables are summarized by checklists below for the following design stages:**
	• Concept Design (All projects)
	• 30% Design (Complex projects that include civil roadway work or detailed survey)
	• 60% Design (All projects)
	• 90% Design (All projects)
	• 100% Design (All projects)
	
	For non-complex projects, 60% and 90% deliverables may be combined into one 90% deliverable to meet budget and/or schedule constraints. Two reviews through CIP process are still required.
	
	Concept Design Deliverables
	❑ Proposed Roll Plot – typically over aerial and/or City provided survey
	❑ Existing Conditions Roll Plot (if needed)
	❑ Concept Cross Sections
	❑ Concept Design Memo/Fact Sheet with justification for the recommended design (if needed and defined in project scope)
	    ❑ Existing Conditions
	    ❑ ADA compliance assessment (if needed)
	    ❑ Traffic analysis of critical intersections
	    ❑ Safety analysis of the corridor
	    ❑ Curbside and parking analysis of the corridor (if needed)
	    ❑ Bike and scooter parking location analysis
	    ❑ ROW and Adjacent Property Impact analysis (if needed)
	    ❑ Major structures impact (if needed)
	    ❑ Design Alternatives in plan or typical section format
	    ❑ Planning-level cost estimate
	    ❑ Warrant analysis (if needed)
	    ❑ Diversion analysis (if needed)
	    ❑ Drainage and utility impacts (if needed)
	    ❑ Design Variance Memo (if needed)
	    ❑ Public involvement summary

Bikeway Project Deliverables (continued)	**30% Design Deliverables** ❑ Plan Set ❑ Cost Estimate ❑ Wayfinding Preliminary Placement Plan ❑ Design Variance Memo (if needed) ❑ Written Responses to Comments **60% Design Deliverables** ❑ Plan Set ❑ Cost Estimate ❑ Turning Templates ❑ Construction Specification Outline ❑ Design Variance Memo (if needed) ❑ Written Responses to Comments **90% Design Deliverables** ❑ Draft Final Plan Set ❑ Drainage Memo with impacts on existing storm drain inlets, street conveyance, and water quality, as needed ❑ Cost Estimate ❑ Turning Templates ❑ Draft Construction Specifications ❑ Design Variance Memo (if needed) ❑ Written Responses to Comments **100% Design Deliverables** ❑ Final Plan Set ❑ Final Cost Estimate ❑ Turning Templates ❑ Construction Specifications ❑ Design Variance Memo (if needed) ❑ Written Responses to Comments **A detailed breakdown and description of each deliverable is included in the following sections. Special attention should be paid to the type of project and variations between In-House Construction and Work Order projects.**

Plan Set Contents	**The following checklists summarize the plan sheets by design level for Work Order Projects:**

Concept Design Sheets

- ❑ Roll Plot (for each alternative)
- ❑ Concept Cross Sections

30% Design Sheet Index

- ❑ Cover Sheet
- ❑ Summary of Quantities, Legend, & General Notes (SOAQ placeholder)
- ❑ Typical Sections
- ❑ Existing Survey Plan (if needed)
- ❑ Striping Plan (with bike parking locations, where applicable)
- ❑ Roadway Layout Plan (if needed)

60% Design Sheet Index

- ❑ Cover Sheet
- ❑ General Notes
- ❑ CCD Standard Drawings List
- ❑ Summary of Quantities, Sign Tabulations, Legend, Abbreviations
- ❑ Typical Details (pavement markings, wayfinding signage)
- ❑ Existing Survey Plan (if needed)
- ❑ Typical Sections
- ❑ Signing & Striping Plan, including wayfinding signs (signing and striping plans may be separated if needed and approved by DOTI PM); Plans should be at 1:40 scale unless otherwise approved by DOTI PM
- ❑ Traffic Signal Design (if a traffic signal is proposed or if an existing signal needs to be modified)
- ❑ Roadway Layout Plan (if needed)
- ❑ Cross Sections (if needed)
- ❑ Details (all non-standard improvements, each proposed curb cut and curb ramp)

90% Design Sheet Index

- ❑ Cover Sheet
- ❑ General Notes
- ❑ CCD Standard Drawings List
- ❑ Summary of Quantities, Sign Tabulations, Legend, Abbreviations
- ❑ Typical Details (pavement markings, wayfinding signage)
- ❑ Typical Sections
- ❑ Alignment and Survey Control Plan (if needed)
- ❑ Right-Of-Way Plan (if needed)
- ❑ Site Preparation Plan (if needed)
- ❑ Signing & Striping Plan, including wayfinding signs (signing and striping plans may be separated if needed and approved by DOTI PM); Plans should be at 1:40 scale unless otherwise approved by DOTI PM
- ❑ Traffic Signal Design (if a traffic signal is proposed or if an existing signal needs to be modified)
- ❑ Roadway Layout Plan (if needed)
- ❑ Cross Sections (if needed)
- ❑ Intersection Detailed Layout (if needed)
- ❑ Concrete Jointing Plan (if needed)
- ❑ Details (all non-standard improvements, each new or rebuilt curb cut and curb ramp)

Plan Set Contents (continued)	**100% Design Sheet Index** ❑ Cover Sheet ❑ General Notes ❑ CCD Standard Drawings List ❑ Summary of Quantities, Sign Tabulations, Legend, Abbreviations ❑ Typical Details (pavement markings, wayfinding signage) ❑ Typical Sections ❑ Alignment and Survey Control Plan (if needed) ❑ Right-Of-Way Plan (if needed) ❑ Site Preparation Plan (if needed) ❑ Signing & Striping Plan, including wayfinding signs (signing and striping plans may be separated if needed and approved by DOTI PM); Plan should be at 1:40 scale unless otherwise approved by DOTI PM ❑ Traffic Signal Design (if a traffic signal is proposed or if an existing signal needs to be modified) ❑ Roadway Layout Plan (if needed) ❑ Cross Sections (if needed) ❑ Intersection Detailed Layout (if needed) ❑ Concrete Jointing Plan (if needed) ❑ Details (all non-standard improvements, each new or rebuilt curb cut and curb ramp) ❑ CAD files Design Notes: (1) For detailed grading, intersection detailed layout sheets shall be included for legibility. (2) For projects that require alternatives, each should have a separate set of roll plot or cross sections at the concept design stage. (3) Roadway Layout sheets to include profile beginning at 60% design if constructing at least 100 continuous feet of sidewalk, curb and gutter, alley, roadway improvements or when required in the concept review comments. (4) Utility, lighting, stormwater, irrigation, landscaping, and traffic control plans shall be included if applicable and comply with CCD standards. (5) For projects requiring utility, stormwater, signal, or roadway work, survey should be performed and incorporated by the 30% design stage. Bikeway designs with green infrastructure shall comply with CCD standards and the Ultra-Urban Green Infrastructure Guide. Green infrastructure may require specific grading, structural, and drainage profile sheets.

Bikeway Plan Sheet Requirements

The following drawing sheet summary describes the information needed for each type of plan sheet beginning with Concept Design. Each subsequent submittal phase shall meet the additional content checklist while fulfilling the previous design stage's checklist.

1. **Roll Plot**
   - ❑ Project name
   - ❑ Project location
   - ❑ Concept design over aerial (may include GIS-based linework or topographic survey where available or provided)
   - ❑ May be illustrative in nature (e.g., pavement shapes with color). All linework should clearly indicate proposed improvements (i.e. don't show asphalt hatch where there is no resurfacing or pavement work, identify pedestrian accessible route with proposed cross-slope)
   - ❑ Consultant name, roll plot date, north arrow, scale, legend
   - ❑ Legible text when printed full size
   - ❑ Right-of-way limits including easements

2. **Concept Cross Sections**
   - ❑ Project name
   - ❑ Typical sections with full range of design options demonstrating alternatives under consideration
   - ❑ Include bullet point list of key features underneath each section. These may include aspects such as design speed, parking provision, cost comparison
   - ❑ Show cars, bikes, bike buffer physical features, trees, pedestrians on graphics
   - ❑ Dimension each section element
   - ❑ Label curb types and pavement material

3. **Cover Sheet**

   30% Design
   - ❑ Include "BIKEWAY ENGINEERING PLAN" centered on top of the cover
   - ❑ Include "NOT FOR CONSTRUCTION" and design submittal stage
   - ❑ Vicinity and key map (may be combined)
     - ❑ Street names, sheet key, project area clearly highlighted, north arrow, scale
   - ❑ Project name and bikeway type
   - ❑ Project location
   - ❑ Consultant name and contact information
   - ❑ Sheet index
   - ❑ Plan set date
   - ❑ Design stage
   - ❑ Contacts – Engineer & Project Manager

   60%/90%/100% Design
   - ❑ Approval (title) block with a separate CCD project number box.
   - ❑ Include note on project length by bikeway facility type, lane miles of new Bond or CIP funded bikeway
   - ❑ CIP Project number

4. **General Notes**

   30% Design
   - ❑ Not included

   60%/90%/100% Design
   - ❑ Bikeway Project General Notes and applicable Site-Specific Notes (see below, sheet location dependent on content quantity)
   - ❑ Include full set of general notes expected for final design. Include Utility, Drainage, Removals, Existing Items, Project Plans, Specifications, Permits, Environmental, Traffic, Tree Protection, Erosion Control, and Noise Control Notes as needed by improvements. Additionally, add sections as applicable by CCD comments.

5. **Summary Of Quantities, Sign Tabulations, Legend, Abbreviations**

   Divide into separate sheets as required.

   30% Design
   - ❑ Blank placeholder SOAQ sheet for next design stage
   - ❑ Legend for all project work not included in CCD standards

Bikeway Plan Sheet Requirements (continued)	60%/90%/100% Design ❑ Include table with item code, item description, and units of measure and quantities. Item code to meet CCD specification standards. ❑ Sign tabulations table by sheet with sign codes and work to be performed ❑ Abbreviations table ❑ Symbols table ❑ Hatching table ❑ Keynote legend – multiple divided by design section **6. Typical Details** 30% Design ❑ Not included 60%/90%/100% Design ❑ Typical pavement marking details ❑ Applicable Bikeway Design Manual (BDM) details ❑ Typical design details ❑ Wayfinding sign details **7. Existing Survey Plan** 30%/60% Design ❑ Existing locations and widths of roadways and ROW for main and intersecting streets ❑ Location and widths of existing alleys, driveways, sidewalks, ramps, landscaped areas and tree spaces ❑ Existing utility lines and storm drain structures with sizes and rim and invert elevations ❑ Existing pole locations and overhead utilities ❑ Existing bike parking separate from paid parking meters and pay boxes ❑ Numerical and bar scale, north arrow ❑ Locations and elevations of benchmarks and all reference points. ❑ Existing contour lines at 1-foot vertical intervals ❑ Spot elevations at an interval required by the specific project 90%/100% Design ❑ Not included in its own plan sheet. Typically, incorporated into proposed utility plan or site preparation plan. ❑ Subsurface Utility Plans (SUE) (if required) **8. Alignment and Survey Control** 30% Design ❑ Not included 60%/90%/100% Design ❑ Base line for main roadway(s) with required data ❑ Base lines for intersecting roadways ❑ Control lines for applicable design elements such as EOP or FL ❑ Traverse lines with required data ❑ Control points for baseline(s) and traverse lines ❑ Clearly identify base line names and convention (if multiple needed) ❑ Tables showing the necessary geometric data to satisfy all requirements for a project including, curve data, baseline control coordinates table, traverse line control coordinates table, superelevation table and horizontal and vertical control tables ❑ Note project datum and coordinate system ❑ Section and range line ❑ Numerical and bar scale, north arrow **9. Right-Of-Way Plan** 30%/60% Design ❑ Not included 90%/100% Design ❑ Right of Way (provide length and bearing) ❑ Easements (type and width) ❑ Proposed lines with clear dimensions and areas ❑ Property owner with lot number and basic descriptions ❑ Numerical and bar scale, north arrow

Bikeway Plan Sheet Requirements (continued)

10. Typical Sections

30% Design

- ❑ Typical section drawings must show all typical sections required for a complete project including all roadway sections at critical and transitional locations where road width and/or cross-slope changes. Stations must be indicated under each section to show actual location.
- ❑ Typical section drawings must show all design items required as follows:
- ❑ Proposed pavement types
- ❑ Lane widths for driving, bicycling and parking lanes
- ❑ ROW and roadways widths
- ❑ Curbs and gutters: types, materials and dimensions
- ❑ Sidewalks: widths
- ❑ Tree spaces and turf grass areas
- ❑ Bioretention, bioswales, and any other green infrastructure facilities
- ❑ Medians: widths, and materials
- ❑ Scale and graphic scale on all sections.
- ❑ Drainage facilities (if being revised or critical to layout)

60%/90%/100% Design

- ❑ Typical section drawings must show all typical sections required for a complete project including all roadway sections at critical and transitional locations where road width and/or cross-slope changes. Stations must be indicated under each section to show actual location.
- ❑ Typical section drawings must show all design items required as follows:
- ❑ Proposed pavement types; all materials must be specified using the correct name and size per the current CCD Standard Specifications and Pay Item
- ❑ Lane widths for driving, bicycling and parking lanes
- ❑ ROW and roadways widths
- ❑ Normal crown section, cross slopes
- ❑ Curbs and gutters: types, materials and dimensions
- ❑ Drainage channels, pipes and culverts: side slopes, invert elevations and dimensions
- ❑ Sidewalks: widths, sections and slopes
- ❑ Tree spaces and turf grass areas
- ❑ Bioretention, bioswales, and any other green infrastructure facilities
- ❑ Medians: widths, sections, materials and slopes
- ❑ Scale and graphic scale on all sections.
- ❑ Drainage facilities (if being revised or critical to layout)

11. Site Preparation Plan

30%/60% Design

- ❑ Not included

90%/100% Design

- ❑ Removal plan with removal key notes and quantity removal table on each sheet
- ❑ Tree protection
- ❑ Temporary Erosion and Sediment Control (TESC) components
- ❑ For complex projects with concrete curb work, utilities, or roadway improvements, separate key notes by plan category are recommended.

12. Signing and Striping Plans

30% Design

- ❑ Callouts for each type of striping per plan sheet (include typ. to reduce callout total)
- ❑ If using construction key notes for plan set, include key notes for each type of striping
- ❑ Existing and proposed signage with dimensions from proposed curb return or other fixed object
- ❑ Existing and proposed pavement markings
- ❑ Existing and proposed bike and scooter parking locations, where applicable
- ❑ Pavement marking removals
- ❑ Lane flow arrows & lane widths
- ❑ Numerical and bar scale, north arrow
- ❑ When design is over aerial, proposed pavement markings to be shown in color
- ❑ All bicycle green and colored pavement treatments should be represented in color
- ❑ Match lines between sheets should not be placed closer than 75' from the PC/PT of the intersection corner radius

Bikeway Plan Sheet Requirements (continued)	60%/90%/100% Design ❑ All items listed in 30% design ❑ Include all existing and proposed signs (including wayfinding) on plans with all proposed improvements ❑ Proposed signs identified on plans with sign codes noted ❑ Existing and proposed signage with dimensions from PCR for proposed signs ❑ Dimension all striping improvements for constructability ❑ Dimension all striping radii ❑ Pavement marking dimensions from the flowline ❑ Station and offset dimensions for all tapers ❑ Include separate key for signal pole and mast arm signage where signal plans are not included in full set ❑ Detail all signage removals, relocations ❑ Label all existing fire hydrants ❑ Label all existing inlets and manholes ❑ Include quantity summary table on each plan sheet with key notes to reflect type of pavement marking ❑ Baseline to be shown on striping plans when required for roadway design ❑ Note all signalized intersections ❑ Match lines between sheets should not be placed closer than 75' from the PC/PT of the intersection corner radius **13. Signal Plans** 30% Design ❑ Not included at this stage; include note on signing and striping plan at locations of expected improvements 60%/90%/100% Design ❑ Full signal design with notes, legend, details as required for construction ❑ Numerical and bar scale, north arrow ❑ ROW, curb line, sidewalks and roadway ❑ Signal locations, elevations and sections of pole ❑ Controller locations ❑ Manhole and pull box locations ❑ PEPCO connection locations ❑ Pole and mast arm types and attachment details ❑ Conduit locations ❑ Locations of all existing and proposed utilities ❑ Location, type and number of traffic signal heads and pedestal signal heads ❑ Dimensions ❑ North arrow and scale **14. Roadway Layout Plans** All Design Phases ❑ Meet Phased CPEP Checklist **15. Cross Sections** 30% Design ❑ Not included at this stage, roadway layout plans to show extents of pavement 60%/90%/100% Design ❑ Meet Phased CPEP Checklist **16. Intersection Layout Plans** All Design Phases ❑ Meet TEP Plan Requirements. This section should cover intersection grading, detailed curb ramp grading (showing compliance with CCD and ADA standards), and detailed horizontal design.

Bikeway Plan Sheet Requirements (continued)	**17. Concrete Joint Plans** 30% Design ❑ Not included at this stage, roadway layout plans to show extents of pavement improvements 60%/90%/100% Design ❑ Meet TEP Plan Requirements **18. Details** 30% Design ❑ Not included at this stage 60%/90%/100% Design ❑ Do not include standard CCD details in the plans. Reference these by number on all plan, profile, and section (including typical) plan sheets – including but not limited to BDM, bike and/or scooter corral, and wayfinding sign details ❑ Provide any special, non-standard, or modified CCD details ❑ Note scale, material ❑ Details may cover type of bicycle facility and serve as a guideline Design Notes: (1) All sheets to include Dial Before You Dig logo in Title Block and most current version of the CCD Title Block. (2) All plan sheets to include north arrow and scale bar. (3) All project plan sheets to use key notes for callouts. For sets with roadway construction shown on striping plans, multiple shapes should be used for each key note design category.
Cost Estimate Requirements	All estimates shall include CCD and consultant logos (as applicable). Concept Design ❑ Planning-level based on quantified items presented on roll plot ❑ Estimate for each alternative (if applicable) 30% Design ❑ Summary of quantities with item numbers but not necessarily item codes 60%/90%/100% Design ❑ The cost estimate must include a breakdown of the work items with the quantity, units or measure, unit price, and the line item subtotal. ❑ Separate pavement markings by type or detail. ❑ Include and populate "checked by," "estimate by," and "date" sections. ❑ The cost estimate must be signed by a Professional Engineer (for projects designed by external consultants). ❑ The cost estimate must be approved by CCD prior to final plan approval.

Specification Checklist	**<u>In-House Projects</u>** No specifications expected for these projects unless noted by CCD in project kickoff meeting or in contract. ❑ Consultant to provide CCD with detail and product information to properly install and procure all materials. **<u>Work Order Projects</u>** ❑ Detailed Construction Specifications (Project Specials) shall contain any non-standard specifications or variations from CCD Standard Specifications or adopted CDOT Specifications. ❑ Project Specials must cover all special items from cost estimate and describe units of measurement. Specials should be organized to match the style and content of the Standard Construction Specifications. Bikeway project specifications must comply with the current version of CCD adopted practices and specifications. ❑ Specification package to include definition of General Contract Conditions, Standard Construction Specifications, and Project Specials.
Bikeway Project Review	**Review Process** Reviews shall incorporate and follow DOTI Capital Project Regulatory Review Process, which facilitates interdepartmental reviews. Projects with civil roadway, vertical elements or detailed survey work should undergo CPEP review at all deliverable stages. Projects may only need to undergo two reviews at 60% or 90% and 100% if approved by DOTI. Once all comments have been addressed, the DOTI Sign Off Sheet is required before construction (except for in-house work orders without vertical elements). **Review Time** Allow 10 business days for review of submittals for each design stage.