walk. bike. roll.

ACTIVE MODES PLAN

City of Fort Collins
FC Moves

APPENDICES

APPENDIX A:
INTERSECTION GUIDELINES FOR PEDESTRIAN AND BICYCLES

Fort Collins Intersection Guidelines for Pedestrian and Bicycles

November 2022

Acknowledgements

City of Fort Collins

Planning, Development, and Transportation
Administration

FC Moves

Engineering

Traffic

Prepared by: Toole Design Group

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Contents


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Chapter 1. Introduction

1. Introduction

1.1 Purpose of Guidelines

The Fort Collins Intersection Design Guide (referred to herein as the "guide") provides a framework to guide the City of Fort Collins, its partner agencies, and private developers in designing, constructing, and maintaining intersections across the City. The guidelines describe and illustrate design guidance for future investments and also provide specific information and parameters related to design, construction, and maintenance of Fort Collins' intersections.

The guidance presented herein should be implemented with engineering judgment. The guide integrates design flexibility that supports all modes of transportation while meeting requirements mandated by local, state, and federal authorities. Construction-ready design standards and details are not included, as these are provided in separate City of Fort Collins documents.

The guide includes best practices to ensure consistency and quality as the City's transportation network develops over time. The information provided is compatible with the inherent flexibility provided in Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), National Association of City Transportation Officials (NACTO), Manual on Uniform Traffic Control Devices (MUTCD), and Colorado Department of Transportation (CDOT) guidance. In some cases, the guide may include more innovative, people-first designs and approaches than the aforementioned guidance.

The guide supplements existing City of Fort Collins engineering practices by providing guidance on right-of-way decisions. The guide should be used by anyone advancing an intersection project in Fort Collins, including City staff and private developers. If there are inconsistencies between the guide and existing City policies, practitioners should look to the plans, manuals, and policies listed in **Section 1.4** of this guide for direction. References in this document are relevant at the time of publication. The City will evaluate and consider updating associated rules and regulations over time based on the best practices guidance provided in this document. Rationale for not incorporating best practice guidance should be documented.

Bicyclists Using a Marked Crossing

1.2 Policy Framework

1.2.1 Flexible Design

The safety of active modes users is a key consideration in the planning, design, construction, and operation of intersections because they are the most vulnerable transportation facility users. This approach encourages flexible design, which emphasizes the role of the planner and designer in determining appropriate design dimensions based on project-specific conditions and existing and future performance criteria more than on meeting specific nominal design criteria. Traditional approaches to roadway design took that position that, if the geometric design of a project met or exceeded specific dimensional design criteria, it would be likely to perform well.

1.2.2 Protecting Vulnerable Users

Due to the vulnerability of active modes users, including pedestrians, bicyclists, and those scootering and skating, crash rates and fatalities at or below nominal design criteria do not ensure a safe or comfortable facility for bicycle travel. Designers, engineers, and planners in Fort Collins must shift their practices to also consider the perception of safety and comfort at intersections. In many instances the use of minimum design criteria does not account for the user's perception of safety and comfort of intersection environments.

1.2.3 Perceived Safety

The perception of how safe a person feels in an intersection can have significant impacts on how they choose to use or avoid the facilities provided. Assessments of perceived safety and comfort for the same site will vary between observers but is increasingly measurable by comfort rating tools found in the *Highway Capacity Manual*. Perceived safety is analogous to "subjective" safety as defined by the *AASHTO Highway Safety Manual*.

1.2.4 Context and Engineering Judgement

The selection of an appropriate design value requires the application of engineering judgement supported by data (where appropriate and available) to develop cost-effective solutions that consider the preservation of scenic, aesthetic, historic, cultural, and environmental resources balanced within the constraints of design standards and guidelines to provide for the safety and mobility of all transportation users navigating intersections.

All design values presented in this document are in U.S. customary units.

1.3 Structure of this Guide

Chapter 2 of the Fort Collins Intersection Design Guide (referred to herein as the "guide") provides users with guidance for elements of design that are common to a wide range of intersection types. This chapter defines intersection configurations and overviews important objectives for designing safe intersections.

Chapters 3 and 4 provide guidance for identifying design controls and evaluating existing intersections to successfully select intersection treatments and solutions, and enabling safe and efficient movement through intersections.

Chapter 5 provides design guidance for specific intersection treatments including geometrics, pavement markings, signals, and beacons, and addresses the basic elements of intersection design that apply to the topics described in the previous chapters.

The concluding chapter, **Chapter 6**, provides details on routine and long-term maintenance and operations.

References to literature and resources are given in **Section 1.4** and in the **Appendix**. These references include works that:

1. Were cited and consulted during the development of this guide,
2. Contain standards, policies and procedures that align with this guidance document, and
3. Are of interest to the discussion of intersection design in Fort Collins.

1.4 Relationship to other Plans, Design Guides, and Manuals

The following plans, guides, manuals, and policies align with and provide the context for this Guide, and should be referred to as additional resources for intersection design in Fort Collins. **See the appendix** for further resources and literature that were reviewed and considered during the development of this guiding document.

1.4.1 Manual on Uniform Traffic Control Devices (MUTCD)

Signs, signals, and pavement markings are presented in the *Manual on Uniform Traffic Control Devices (MUTCD)*, which should be used in conjunction with this Guide. The MUTCD is incorporated by reference in 23 Code of Federal Regulations, Part 655, Subpart F, and is approved as the national standard for planning, designing, and applying traffic control devices installed on any street, highway, or bikeway open to public travel. The Federal Highway Administration (FHWA) issues the MUTCD, which contains all national design, application, and placement standards, as well as, guidance, options, and support provisions for traffic control devices used with bikeways. The jurisdiction implementing the bike facility must ensure that traffic control devices for the project conform with the MUTCD.

The FHWA may periodically issue Interim Approvals (IAs) to allow the use of new traffic control devices between updates of the MUTCD. Agencies that desire to use these treatments must request specific approval from the FHWA. A State Department of Transportation can request statewide approval from FHWA that will apply to all jurisdictions in the state. This Guide provides guidance for treatments that have been given Interim Approval status.

The guide also provides guidance for treatments that do not have Interim Approval status and require experimental approval by FHWA. Treatments that require FHWA experimental approval, but have been used by transportation agencies in efforts to improve bicycling conditions, are located at the end of their respective section and identified as experimental. The guide provides guidance for their use and highlights issues for designers to be aware of to inform experimentation efforts. It is anticipated that further guidance for these treatments will be developed as they are researched and observed under experimental processes. Designers who wish to experiment with these traffic control devices must request and receive approval from the FHWA using the procedure outlined in Paragraphs 8 through 11 of Section 1A.10 of the MUTCD.

1.4.2 American Association of State Highway and Transportation Officials (AASHTO) Guides

Highway Safety Manual (HSM)

The *Highway Safety Manual (HSM)* is the premier guidance document for incorporating quantitative safety analysis in the highway transportation project planning and development processes. The HSM was first published in 2010 – with a supplement for freeways published in 2014 – and presents contemporary scientific methodologies for estimating safety performance of highways and streets to inform the highway transportation decision-making process. Fort Collins uses the *HSM to* complete statistical reviews of intersections to identify locations where more crashes are occurring than would be expected.

A Policy on Geometric Design of Highways and Streets (the Green Book)

A Policy on Geometric Design of Highways and Streets (the Green Book) contains current design research and practices for highway and street geometric design. The Green Book acknowledges the need for prioritizing vulnerable road users and increasing safety and comfort at intersections.

1.4.3 2019 Fort Collins City Plan

The *2019 Fort Collins City Plan* is Fort Collins' comprehensive plan that guides how the community will grow and travel in the next 10-20 years. City Plan provides policy guidance and implementation actions to plan, build, and maintain streets, trails, intersections, and sidewalks using sustainable design principles and best practices. City Plan includes the Transportation Master Plan that supports the enhancement of safety for all modes through intersection improvements. The plan emphasizes the need to design street crossings at intersections consistent with the Fort Collins Traffic Code, the Land Use Code, the Manual on Uniform Traffic Control Devices (MUTCD), ADA, and the Larimer County Urban Area Street Standards (LUCASS) with regard to crosswalks, lighting, median refuges, bike boxes, corner sidewalk widening, ramps, signs, signals, and landscaping.

1.4.4 Fort Collins Traffic Code and Land Use Code

The *Fort Collins Traffic Code* and *Fort Collins Land Use Code* provide rules and regulations for standardized intersection development and improvements. The standards outlined in these codes exist to best align new design and construction with the existing transportation network and surrounding land use. This guide incorporates and expands upon the high-level intersection design standards outlined in both codes. This guide should be referenced for design solutions by the City of Fort Collins in conjunction with the Traffic and Land Use Codes.

1.4.5 Larimer County Urban Area Street Standards (LCUASS)

Larimer County, City of Loveland, and City of Fort Collins adopted the *Larimer County Urban Area Street Standard* (LCUASS) in 2021. These standards apply to the design and construction of new and reconstructed streets within the two cities and within the Growth Management Areas for Fort Collins and Loveland within Larimer County. These standards incorporate Fort Collins-specific design standards and guidelines outlined in the *Fort Collins Streetscape Design Standards and Guidelines*, *Fort Collins Master Street Plan*, *Fort Collins Traffic Operations Manual*, *Fort Collins Multimodal Transportation Level of Service Manual*, *Fort Collins Bus Stop Design Standards and Guidelines*, and *Roundabout Design Manual*. TThe City will evaluate and consider updating LCUASS based on the best practices guidance provided in this document. Rationale for not incorporating best practice guidance should be documented.

1.4.6 Compliance with Accessibility Guidelines

The Americans with Disabilities Act of 1990, a Federal law referred to as the ADA, requires public entities, such as state and local governments, to operate services, programs, and activities, including pedestrian facilities in public street rights-of-way, such that, when viewed in their entirety, are readily accessible to and usable by individuals with disabilities. The ADA requires that a public entity's newly constructed facilities be made accessible to and usable by individuals with disabilities to the extent that it is not structurally impracticable to do so. The ADA also requires that, when an existing facility is altered, the altered facility be made accessible to and usable by individuals with disabilities to the maximum extent feasible. Section 504 of the Rehabilitation Act of 1973, generally referred to as Section 504, includes similar requirements for public entities that receive Federal financial assistance.

1.5 Definitions

The following definitions are provided for the purposes of this Guide; therefore, definitions may vary when reviewing other sources.

Accessible – Describes a facility in the public right-of-way that complies with the Americans with Disabilities Act (ADA) and this guide.

Accessible Pedestrian Signal (APS) – A device that communicates information about pedestrian signal timing in non-visual format(s) such as audible tones, speech messages, and/or vibrating surfaces.

Alley – A street or highway intended to provide access to the rear or side of lots or buildings in urban areas and not intended for the purpose of through vehicular traffic.

Alteration – A change to a facility in the public right-of-way that affects or could affect pedestrian access, circulation, or use. Alterations include, but are not limited to, resurfacing, rehabilitation, reconstruction, historic restoration, or changes or rearrangement of structural parts or elements of a facility.

Arterial (Highway or Street) – A street that primarily serves through traffic and that secondarily provides access to abutting properties. An arterial may be interrupted by traffic control devices (e.g., signals, STOP signs, or YIELD signs).

Barrier – A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle.

Bicycle – A pedal-powered vehicle upon which the human operator sits. The term "bicycle" for this publication includes two-, three-, and four-wheeled human-powered and electrically assisted (E-Bike) vehicles, but not tricycles for children. In some states, a bicycle is considered a vehicle, while in other states it is not.

Bicycle Boulevard – Streets designed to prioritize bicycle traffic by minimizing motorized traffic volumes and operating speeds. They are also referred to as neighborhood greenways, slow streets, or bicycle priority streets.

Bicycle Box or Bike Box – A designated area on the approach to a signalized intersection, between an advance motorist stop line and the crosswalk or intersection, intended to provide bicyclists a visible place to wait in front of stopped motorists during the red signal phase.

Bicycle Facilities – A general term denoting provisions to accommodate or encourage bicycling, including bikeways, bicycle boulevards, bicycle detection, shared lane markings, wayfinding, in addition to parking and storage facilities.

Bicycle Lane or Bike Lane – A portion of the roadway that has been designated for preferential or exclusive use by bicycles by pavement markings and, if used, signs.

Bikeway – Any road, path, or facility intended for bicycle travel which designates space for bicyclists distinct from motor vehicle traffic. A bikeway does not include shared lanes, sidewalks, signed routes, or shared lanes with shared lane markings, but does include bicycle boulevards.

Blended Transition – A raised pedestrian crossing, depressed corner, or similar connection between the pedestrian access route at the level of the sidewalk and the level of the pedestrian crossing that has a grade of 5 percent or less.

Buffer – The space between the outside edge of the paved roadway (or face of curb, if present) and the near edge of the sidewalk.

Counterflow Bicycle Travel – Bicyclist traveling in a direction opposite from the normal flow of motorized traffic.

Clear Space – (1) A space free of sight distance obstructions to allow motorists and bicyclists in motion to see each other and yield (or stop) accordingly as they approach intersections or driveways. (2) A space free of obstruction for pedestrian maneuverability complying with PROWAG Section R404.

Collector (Highway or Street) – a highway that in rural areas connects small towns and local highways to arterial highways, and in urban areas provides land access and traffic circulation within residential, commercial, industrial, and business areas and connects local highways to the arterial highways.

Cross Slope – The grade that is perpendicular to the direction of pedestrian travel.

Crosswalk – The pedestrian accessible route within a street used to cross a street or portion of a street. Further defined in the Colorado Revised Statutes, Section 42-1-102, as that portion of a roadway ordinarily included within the prolongation or connection of the lateral lines of sidewalks at intersections or any portion of a roadway distinctly indicated for pedestrian crossing by lines or other marking on the surface.

Curb Extension – A section of sidewalk extending into the roadway at an intersection or midblock crossing that narrows the roadway width and reduces the crossing distance for pedestrians, reduces pedestrian exposure, and may help reduce traffic speeds by functioning as a traffic calming device.

Curb Line – A line at the face of the curb that marks the transition between the curb and the gutter, street, or highway.

Curb Ramp – A ramp that cuts through or is built up to the curb. Curb ramp types can be perpendicular or parallel, or a combination of parallel, perpendicular, and diagonal ramps.

Design Speed – A selected speed used to determine the various geometric design features of the roadway or bikeway.

Design User – The transportation system user (pedestrian, bicyclist, vehicle) considered while designing elements of an intersection and incorporating various accommodations.

Design User Profile – The selected transportation system user comfort profile used to select appropriate design solutions for an intersection.

Detectable Warning Surface – A standardized surface feature built in, or applied to, walking surfaces to indicate the boundary between a pedestrian route and a vehicular route where there is a curb ramp or blended transition, and at the edge of transit boarding platforms.

Diagonal Curb Ramp – A single curb ramp, serving two crossing directions, located at the midpoint of the curb return curve.

Drainage Inlet – Site where water runoff from the street, sidewalk, or site enters the storm drain system.

Driveway Crossing – An extension of a sidewalk across a driveway.

Engineering Judgment – The evaluation of available pertinent information, and the application of appropriate principles, provisions, and practices as contained in design guides, for the purpose of deciding upon the applicability, design, operation, or installation of design elements and traffic control devices. Engineering judgment shall be exercised by the designer through the application of procedures and criteria established by the engineer. Documentation of engineering judgment is recommended but not required.

Flare – Sloped surface that flanks a curb ramp and provides a graded transition between the ramp and the sidewalk. Flares are not considered part of the accessible route.

Grade – a slope that is calculated by dividing the vertical change in elevation by the horizontal distance covered, commonly expressed as a percentage.

Grade Break – the line where two surface planes with different grades meet.

Grade-Separated Crossing – a facility such as an overpass, underpass, skywalk, or tunnel that allows pedestrians and motor vehicles to cross each other at different levels.

Grate – a framework of latticed or parallel bars that prevents large objects from falling through a drainage inlet but permits water and some sediment.

HAWK Signal – A High intensity Activated crossWalK. See Pedestrian Hybrid Beacon

Highly Confident Bicyclist – A general term denoting bicyclists who have the most tolerance for traffic stress and are generally comfortable operating in mixed traffic. This group represents 4-7% of the general population.

Highway – A general term denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.

Intersection – The area where two or more user travel paths meet. Further defined in the Colorado Revised Statutes, Section 42-1-102 as the area embraced within the prolongation of the lateral curb lines or, if none, then the lateral boundary lines of the roadways of two highways which join one another at, or approximately at, right angles, or the area within which vehicles traveling upon different highways joining at any other angle may come in conflict. Where a highway includes two roadways thirty feet or more apart, every crossing of each roadway of such divided highway by an intersecting highway shall be regarded as a separate intersection. In the event such intersecting highway also includes two roadways thirty feet or more apart, every crossing of two roadways of such highways shall be regarded as a separate intersection. The junction of an alley with a street or highway does not constitute an intersection.

Island – A defined area between traffic lanes for control of vehicular movements, for toll collection, or for pedestrian refuge when raised. It includes all end protection and approach treatments. Within an intersection area, a median or an outer raised corner separation is considered to be an island.

Landing – Part of a pedestrian accessible route or walkway that provides space for turning, pedestrian pushbutton accessing, or resting. Landings are typically level with a cross slope and grade of 1.56 percent maximum.

Paved Shoulder – Portion of shoulder with concrete or asphalt surfacing to support vehicle loading and bicycle travel.

Major Street – The street normally carrying a higher volume of vehicular traffic.

Marked Crosswalk – A crosswalk designated with pavement markings.

Median – The portion of a highway separating opposing directions of the traveled way.

Median Island – An island in the center of a road that physically separates the directional flow of traffic.

Midblock Crossing – A crossing point positioned within a block rather than at an intersection.

Minor Street – The street normally carrying a lower volume of vehicular traffic.

Multilane Roundabout – A roundabout with more than one lane on at least one entry and at least part of the circulatory roadway.

Mutual Yielding – A general term describing the responsibility among motorists, bicyclists, and pedestrians to yield the right of way depending upon the timing of their arrival at an intersection or conflict point.

Parallel Curb Ramp – A curb ramp design where the sidewalk slopes down on either side of a landing.

Pedestrian – A person on foot or in a wheelchair.

Pedestrian Access Route (PAR) – A continuous and unobstructed path of travel provided for pedestrians within or coinciding with sidewalks and walkways.

Pedestrian Clearance Time – the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median.

Pedestrian Curb Cut – A break or cut in the vertical curb to eliminate curb barriers. Pedestrian curb cuts are typically provided where sidewalk does not exist or the pedestrian access route is at the same elevation as the crossing and a curb separates the PAR from the crossing.

Pedestrian Facilities – A general term denoting provisions to accommodate or encourage walking. Pedestrian facilities include, but are not limited to, accessible routes, sidewalks, crosswalks, crossing islands and medians, traffic control features, curb ramps, bus stops and other loading areas, shared use paths, and stairs.

Pedestrian Hybrid Beacon – A special type of traffic control device used to assist pedestrians in crossing a street or highway at a marked crosswalk at unsignalized locations, by warning and controlling traffic. It is placed in dark mode for roadway traffic between periods of operation, and when activated, displays both steady and flashing traffic control signal indications.

Perpendicular Curb Ramp – Curb ramp design where the ramp path is perpendicular to the edge of the curb.

Physical Barrier – A physical object that prohibits pedestrian, bicyclist, or motorist movement. This could be a curb, guardrail, fence, street amenities such as benches or planters, etc.

Public Right-of-Way – Public land or property, usually in interconnected corridors, that is acquired for or dedicated to transportation purposes.

Pushbutton – A button to activate a device or signal timing for pedestrians or bicyclists.

Pushbutton Information Message – A recorded message that can be actuated by pressing a pushbutton when the walk interval is not timing and that provides the name of the street that the crosswalk associated with that pushbutton crosses and can also provide other information about the intersection signalization or geometry.

Pushbutton Locator Tone – A repeating sound that informs approaching pedestrians that a pushbutton exists to actuate pedestrian timing or receive additional information and that enables pedestrians with vision disabilities to locate the pushbutton.

Ramp – A pedestrian pathway or access route with a slope greater than 5 percent. A ramp may or may not be part of a curb ramp.

Raised Bike Lane – A bike lane which is elevated above the adjacent motor vehicle travel lane.

Rectangular Rapid Flashing Beacon – A special type of traffic control device used to assist pedestrians in crossing a street or highway at a marked crosswalk at unsignalized locations, by warning vehicular traffic of crossing pedestrians. It consists of two rapidly and alternately flashed rectangular yellow indications placed under a pedestrian crossing warning sign or school crossing warning sign.

Right-of-Way – A general term denoting land, property, or interest therein, usually in a strip, acquired for or devoted to transportation purposes.

Right of Way (Assignment) – The right of one driver, bicyclist, or pedestrian to proceed in a lawful manner in preference to another driver, bicyclist, or pedestrian.

Roadway – The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways.

Roundabout – A circular intersection that generally provides yield control to all entering vehicles and that features channelized approaches and geometry to encourage reduced travel speeds through the circular roadway.

Running Slope – Also known as longitudinal slope. The slope that is parallel to the direction of travel.

Separated Bike Lanes – A bicycle lane that is physically separated from motor vehicle traffic by vertical elements as well as a horizontal buffer or elevation change from the street. These may also be referred to as protected bike lanes or cycle tracks. On-street parallel or angled motor vehicle parking can serve as the vertical elements.

Shared Lane – A lane where motor vehicles and bicycles share operating space.

Shared Lane Marking – A bicycle pavement marking symbol indicating a preferred bicyclist operating position in a shared travel lane.

Shared Street – A street that does not designate separate spaces for walking, bicycling or driving, where all users travel in the same area. Motor vehicle speeds on shared streets are intended to be very low.

Shared Use Path – A bikeway physically separated from motor vehicle traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other nonmotorized users. Shared use paths are also commonly referred to as trails, paths, or greenways.

Shoulder – The portion of the roadway contiguous with the traveled way that accommodates stopped vehicles, emergency use, conveyance of drainage, and lateral support of subbase, base, and surface courses. Shoulders, where paved, may be used by bicyclists and pedestrians.

Side path – A shared use path located adjacent and parallel to a roadway.

Sidewalk – An improved surface for pedestrian travel paralleling a highway, road, or street.

Somewhat Confident Bicyclist – A general term denoting bicyclists who have some tolerance for traffic stress and generally prefer physical separation from traffic but are comfortable operating in bicycle lanes. This group represents 5-9% of the general population.

Splitter Island – A raised median island used to separate opposing directions of traffic entering and exiting a roundabout.

Traffic Calming – the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users.

Traveled Way – The portion of the roadway that allows for the movement of through traffic, including vehicles, transit, and freight. It does not include such facilities as curbs, shoulders, turn lanes, bike lanes, sidewalks, or parking lanes. Divided highways are made up of two separate roadways, each with its own traveled way.

Truncated Domes – See Detectable Warning Surface.

Two-Stage Turn – The act of a bicyclist turning left in stages, by first crossing the perpendicular street, and then crossing the approach street during a gap in traffic or upon receiving a green indication at a traffic signal.

Two-Stage Bicycle Turn Box – A designated area at an intersection to provide bicyclists a place to wait to complete a two-stage turn outside of the path of moving traffic.

Uncontrolled Crossing– A crossing of a roadway which does not have yield, stop, or signal control facing approaching roadway users.

Unmarked Crosswalk – A crosswalk that exists legally by virtue of its position at an intersection, but which is not indicated by pavement markings.

Vehicular Way – A route provided for vehicular traffic, such as in a street, driveway, or parking facility.

Vertical Curb – Curb with a vertical or near vertical face intended to discourage vehicles from leaving the roadway.

Walk Interval – An interval during which the WALKING PERSON (symbolizing WALK) signal indication is displayed.

Walkway – A general term used to describe a paved or improved area for use by pedestrians. Walkways include sidewalks, shared use paths, curb ramps, blended transitions, etc.

Wayfinding – A general term for the provision of directional guidance for bicycle routes or destinations on signs.


PUSH BUTTON
FOR
PUSH BUTTON
FOR
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SPIN

Chapter 2. Intersection Design Objectives

2. Intersection Design Objectives

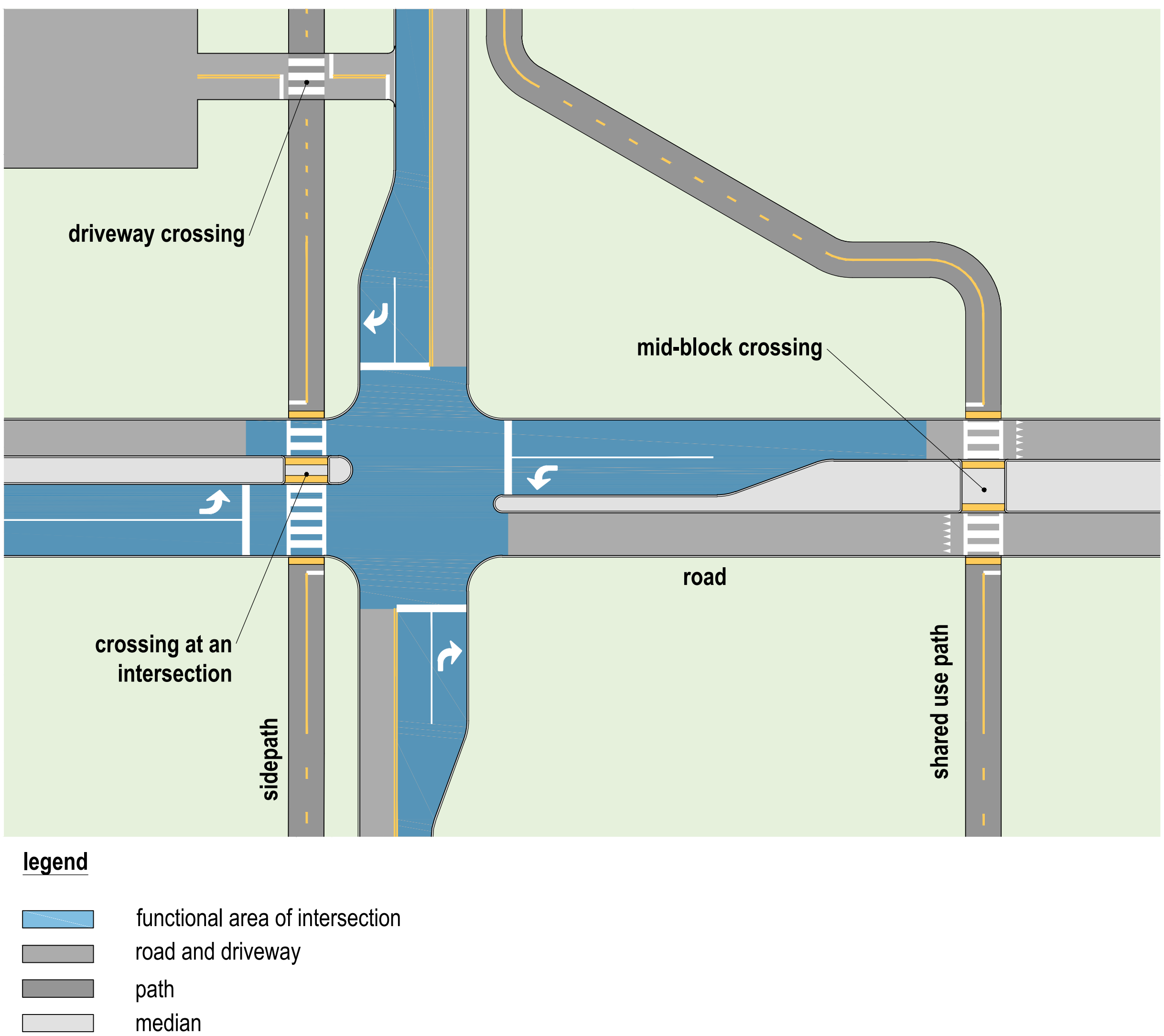
2.1 Characterizations of Intersections

Each intersection is unique and requires engineering judgment to determine an appropriate design to maximize safety. Intersection design is determined based on various elements of the surrounding environment. Intersection configurations can be decided based on:

- The types of intersecting facilities (shared use path, separated bike lane, bike lane, roadway, etc.)
- The number of lanes a pedestrian or bicyclist needs to cross
- Whether the roadway is divided or undivided
- The number of approach legs
- The speeds and volumes of traffic
- Existing traffic controls including uncontrolled and controlled (yield-, stop, or signal)

Due to the mixed nature of traffic at intersections (pedestrians, bicyclists, and motor vehicles), the designer should keep in mind the speed variability of each travel mode and its resulting effect on design values when considering design treatments. The fastest vehicle should be considered for approach speeds (typically the bicyclist and motor vehicle) because these modes have the greatest difficulty stopping for cross traffic at the intersection. By contrast, for departures from a stopped condition, the characteristics of slower users, including

Figure 1: Intersection Functional Area



pedestrians and bicyclists, should be considered due to their greater exposure to cross traffic.

Intersection crossings occur within the functional area of an intersection of two or more roadways (see Figure 1). Intersection crossings are typically parallel to at least one roadway and have unique operational challenges. Geometric design guidance for intersections should be applied to driveway crossings and alley crossings to promote safety and legibility for bicyclists and pedestrians (see Section 5.1). Grade-separated crossings pass over or under a roadway and eliminate conflicts between bicyclists and motor vehicles.

Crossings may be controlled or uncontrolled. Uncontrolled pedestrian or bicycle crossings of a roadway are locations where approaching motorists do not face yield, stop, or signal control. Section X provides guidance for evaluating uncontrolled crossings.

2.2 Intersection Design Objectives

The design of intersections has a significant impact on each intersection user's comfort, safety, and mobility. Bicyclists, pedestrians, and motorists inevitably cross paths at intersections unless their movements are grade-separated.

The design of intersections should consider how pedestrians, bicyclists, and other users navigate both the approach, departure, and the crossing of the intersection. Intersection design should strive to reduce conflicts and reduce the risk of injury for all users in the event of a crash. The geometric design features should complement traffic control devices to promote compliance as well as improve safety and comfort where users are expected to yield right of way.

The design principles described in this section apply to all intersections, but unique design considerations for roundabouts, interchanges, and alternative intersections can be found in Chapter 5.

2.2.1 Minimize Exposure to Conflicts

Intersections should be designed to minimize pedestrian and bicyclist exposure to motorized traffic and minimize bicyclist conflicts with both motorists and pedestrians. Pedestrians and bicyclists experience more exposure to motor vehicle traffic at locations with high traffic volumes and operating speeds, and the amount of exposure will vary based on the type of accommodation provided.

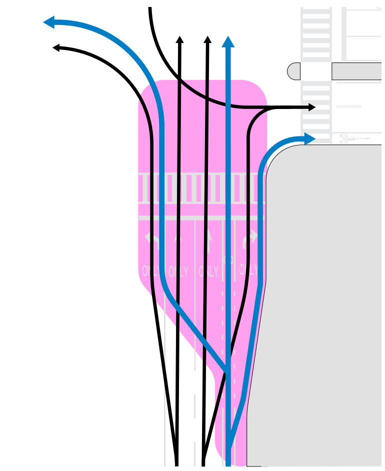
Exposure to conflicts can be eliminated using a variety of strategies; however, these strategies must be balanced against creating excessive delay or detour for each mode of travel. Where conflicts with motor vehicles involve high traffic volumes, high-speed turns across crosswalks and bikeways, or at locations with limited sight distance, steps should be taken to reduce or eliminate conflicts using strategies such as geometric design treatments (see Section 5.1), restricting turn movements, providing traffic signal phasing that manages conflicts (see Chapter 5.4), or providing grade separation where appropriate (see Chapter 5).

Where elimination of conflicts is not possible or practical, intersection designs should limit the amount of time and space that active mode users are in the following locations:

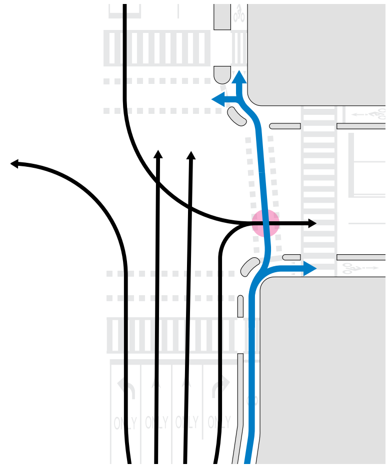
- Cross multiple vehicular travel lanes
- Operating between moving vehicular travel lanes
- Wait in areas exposed to moving motor vehicle traffic (e.g., waiting to turn left in a shared lane)
- Merging with motorists or where motorist turn across pedestrian and bicycle paths
- Cross pedestrian travel paths or other bicycle facilities

Figure 2 uses bicyclists as an example to illustrate active mode user exposure to potential motor vehicle conflicts in four common intersection designs.

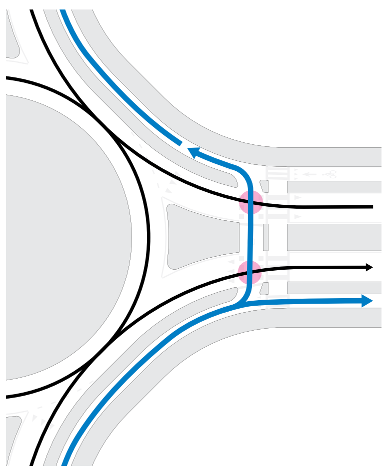
Figure 2: Comparison of Bicyclist Exposure to Motor Vehicles at Intersections



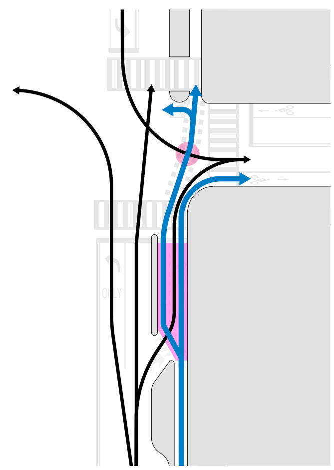
conventional bike lanes and shared lanes



protected intersections *



separated bike lanes through roundabouts *



separated bike lanes with mixing zones *

*** Left turn conflicts not depicted for two-stage turns**

<u>legend</u>

bicycle travel path

motorist travel path

potential conflict

Design of intersections should aim to not only minimize points of conflict, but also simplify areas of conflict, limit conflict frequency, and limit conflict severity. These objectives can be achieved by applying design elements presented in **Sections 2.2.2 through 2.2.7** and **Chapter 5**. For more information on minimizing conflicts at intersections, please refer to Chapter 8, Section 8.1.1 "Intersections as Conflict Locations" in the *Larimer County Urban Area Street Standards.*

While they do occasionally occur, crashes between bicyclists and pedestrians are comparatively rarer than those between bicyclists and motorists or between pedestrians and motorists. Crash risk between bicyclists and pedestrians can be minimized by providing clear sight distance between pedestrians and approaching bicyclists at locations where bicyclists cross a pedestrian facility. Care should be taken to avoid the placement of infrastructure within the approach clear space which may block either user's view of the other user. Due to the potential discomfort for both bicyclists and pedestrians, on facilities where bicyclists and pedestrians share the same space the width of the facility, speed differential between users, and frequency of these conflicts should be considered when designing the facility. It may be appropriate to separate bicyclists and pedestrians to reduce the frequency of conflicts between these users.

2.2.2 Reduce Speeds at Conflict Points

If conflict points cannot be eliminated, intersection design should minimize the speed differential between users at the points where travel movements intersect.

Reducing speeds of all users at conflict points may allow users more time to react to avoid a crash and can reduce the severity of a potential injury if a crash does occur. Intersections where bicyclists operate should be designed to ensure slow speed turning movements (10 mph or less) and weaving movements (20 mph or less) across the path of bicyclists. Additional guidance to improve safety at intersections is provided in **Chapter 5**.

2.2.3 Communicate Right of Way Priority

Bicyclists, pedestrians, and motorists should be provided with cues that both clearly establish which users have the right of way and consistently communicate expected yielding behavior. This may include features designed to meet accessibility guidelines.

The priority right of way should be communicated through the provision of traffic control devices, including:

- Marked crosswalks at shared use path crossings (see **Section 5.3.3**)
- Providing audible and vibrotactile devices for people with disabilities where appropriate (see **Section 5.1**)
- Regulatory or warning signs for crossing or turning traffic where appropriate (see **Section 5.5.6**)
- Signalization where appropriate (see **Section 5.4.2**)

2.2.4 Providing Adequate Sight Distance

It is necessary to provide adequate sight distances and visibility between bicyclists, motorists, and pedestrians as they approach intersections. Adequate sight distance is needed to perceive and avoid potential conflicts. See **Section 4.6** for a detailed discussion of sight distance considerations for various situations and types of intersection control.

2.2.5 Transitions to Other Facilities

Intersections are likely to be locations where active mode users transition into and out of different types of facilities. These transitions should be intuitive to all users of the intersection. It is also important to provide clear and direct paths for pedestrians across bicycle facilities and to provide intuitive separated bike lane intersection designs to reduce the likelihood that pedestrians will use a bike lane as a walkway or crossing. Specific solutions to blended transition designs can be found in **Section 5**.

2.2.6 Accommodating Persons with Disabilities

Intersections should be designed in accordance with accessibility guidelines. Attention should be given to ensuring that people with limited or no vision are given sufficient cues at intersections to prevent them from unintentionally moving into the street or a bike-only facility. Additional guidance relating to persons with disabilities is provided in the specific facility design chapters of this guide.

Intersection Design Accommodating All Users

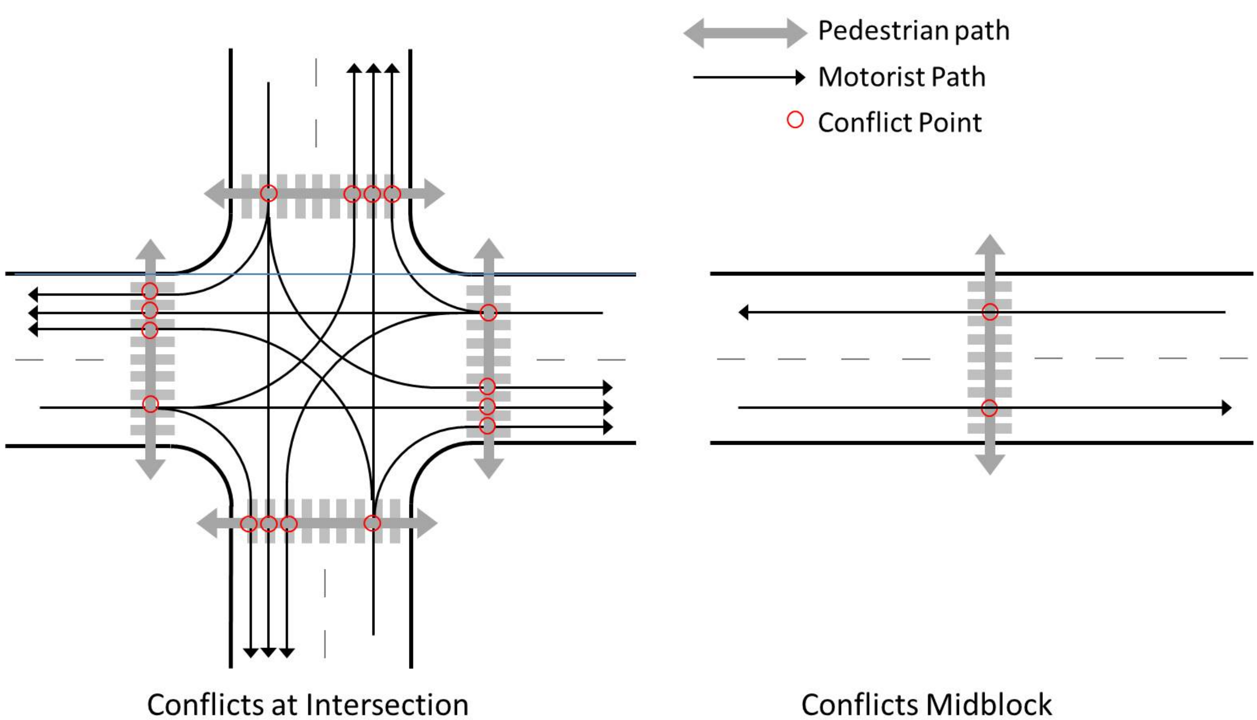
2.2.7 Midblock crossings

Drivers have a greater expectation of encountering pedestrians at intersections than at midblock crossings. Additionally, vehicles are typically travelling faster at midblock locations than at intersections. Consequently, where practical, pedestrians should be encouraged to cross roadways at intersections. However, there are situations for which midblock crossings are appropriate.

More than 70 percent of pedestrian fatalities occur away from intersections. Thus, it is critical to design midblock crossings that both increase drivers' awareness of the crossing and expectation of encountering pedestrians and encourage pedestrians to cross in the designated location. Midblock crossings are often more desirable for pedestrians because they provide a direct route to their destinations, and design features can be applied that promote safety when a midblock crossing is applied. In addition, crossings should be designed to clarify the legal and expected responsibilities of both drivers and pedestrians to make complying with those responsibilities intuitive.

Midblock crossings have fewer conflict points between vehicles and pedestrians, which is a safety advantage over crossings at intersections. When crossing at intersections, pedestrians should be aware of both right- and left-turning vehicles, in addition to through traffic. Drivers making left turns during a permissive signal phase and those making right turns during a red indication are often focused on identifying acceptable gaps in traffic to make their turns and may be less likely to notice pedestrians. At midblock crossings, pedestrians typically only have cross traffic to consider, and where islands or medians are provided, only one direction of traffic must be considered at a time. Figure 3 illustrates the number and location of potential vehicle-pedestrian conflict points at crosswalks at an intersection and a midblock crossing for comparison.

Figure 3: Potential Conflict Points at Intersection and Midblock Crossings



Midblock Crossing Design Principles

Principles for designing midblock crossings need to be different than those for intersections because of three main operational differences between the two: 1) there are many more potential crossing locations midblock than at intersections, 2) motorists are less likely to expect pedestrians crossing at midblock, and 3) pedestrians with vision disabilities have fewer audible clues for determining when to cross midblock.

These differences lead to design considerations for midblock crossings, which include the following:

- **The crossing location should be convenient for pedestrians.** Midblock crossings should be provided at locations where intersection crossings are not available or are inconvenient for pedestrians to use. Midblock crossings should be placed in convenient locations to encourage pedestrians to use them rather than other, more convenient, unmarked midblock locations.
- **The crossing location should alert drivers of the crossing as they approach it.** Drivers should be warned of the pedestrian crossing in advance of the crossing location, and the midblock crossing should be highly visible to approaching drivers. Lighting should be used to improve driver awareness of the crossing and the visibility of the pedestrians at night. The approach to the crossing should encourage drivers to reduce their speed prior to the crossing. Drivers should be given plenty of time to recognize the presence of a pedestrian and stop in advance of the crossing.
- **The crossing location should alert pedestrians of the opportunity to cross.** Signs and pavement markings should be used to clearly communicate where pedestrians should cross. In addition, aids should be provided for pedestrians with vision disabilities to recognize the presence of a midblock crossing and the opportunities for crossing. Auditory and tactile information should be provided for pedestrians with vision disabilities since cues present at an intersection crossing (such as the sound of traffic stopping and starting) are not always available at a midblock crossing.
- **The crossing location should alert drivers and pedestrians of their responsibilities and obligations at the crossing and provide opportunities to meet these responsibilities/obligations.** Vehicle approach, pedestrian approach, and traffic control design should provide pedestrians with clear messages about when to cross and drivers about where to yield. Where necessary, a raised refuge area should be provided for pedestrians to complete the crossing in stages. Traffic control devices can be used to create gaps in traffic for pedestrians to cross. In addition, MUTCD guidance should be used to establish a legal crossing.

Midblock Crossing Infrastructure

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Chapter 3. Design Controls

3. Design Controls

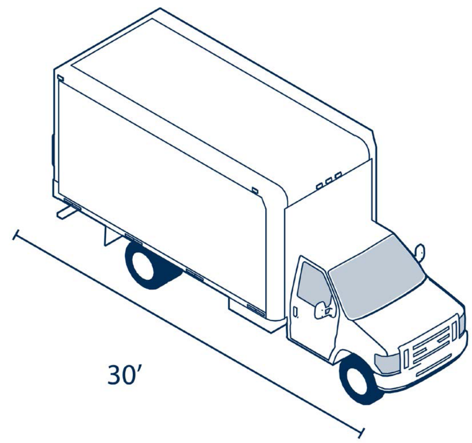
3.1 Design and Control Vehicle

Streets and intersections should enable safe and efficient movement by a variety of different vehicle sizes and types. It is important to consider the size of vehicles that will reasonably be expected to move through the intersection, the frequency of these movements, and the City's policy for lane encroachment when designing an intersection.

3.1.1 Design Vehicle

The design vehicle is the **least maneuverable** vehicle that routinely uses the street. Designers use a design vehicle to determine corner radii at intersections and should use this vehicle when conducting intersection analysis with software such as AutoTurn. The design vehicle for Fort Collins is a 30-foot single unit truck (SU-30) with a 42-foot turning radius (Figure 4).

Figure 4: The design vehicle is a 30-foot single unit truck (SU-30) with a 42-foot turning radius.



Designers should analyze impacts and select the smallest appropriate design vehicle to support safer pedestrian crossings, while still accommodating motor vehicle turns. If an intersection includes a bus route where buses are frequently required to make turns, an appropriately sized bus may be used as the design vehicle. The designer should be cognizant of the bus route and accommodate necessary turning movements through the intersection. If the bus route goes straight through the intersection, it is not necessary to make the bus the design vehicle.

Designers have the discretion to use a larger design vehicle than the default for Industrial Arterials, Downtown Arterials, Mixed-Use Arterials, Commercial Arterials and other streets where larger vehicles are anticipated to comprise more than 8 percent of the turning movements at the intersection, and no alternate route exists that would accommodate larger vehicle turns without compromising pedestrian safety. Examples of typical turning templates for these unique conditions include a WB-40, WB-50, WB-62, or in rare instances on Industrial Streets, a WB-67. Designers should be prepared to submit supporting documentation, including detailed AutoTurn or equivalent turning analyses, in support of their evaluation of specific corner designs. More information on street types can be found in the City's Master Street Plan.

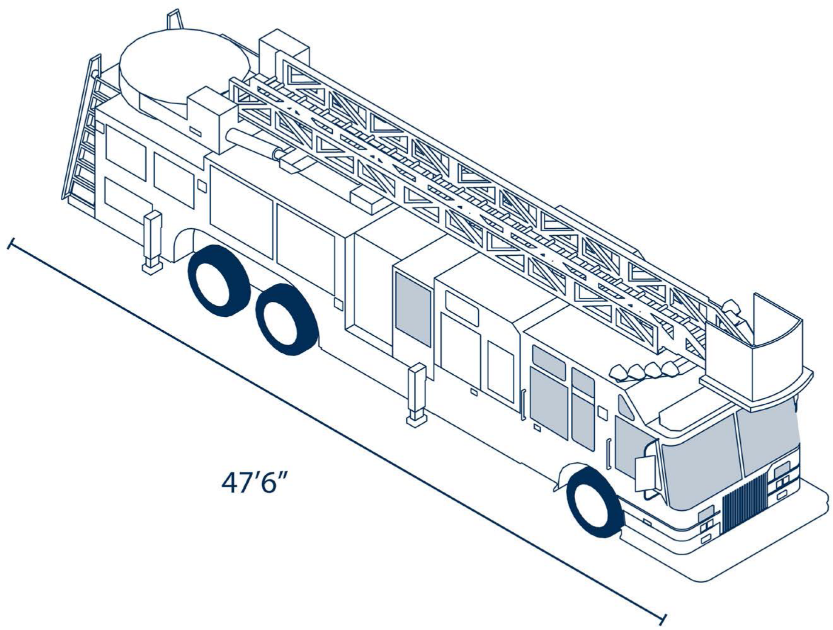
Conversely, in locations where vulnerable roadway users are frequent users of the street, smaller design vehicles should be considered. Smaller design vehicles should be used on Local and Shared Streets as well as near land uses such as schools, parks, and older adult housing.

3.1.2 Control Vehicle

The control vehicle is an **infrequent but necessary** user of the street. The control vehicle (Figure 5) for intersection design in many cities and in Fort Collins is a fire truck. The control vehicle can be assumed to use full encroachment at all intersections and may use all traversable parts of an intersection, including across centerlines. Encroachment is the ability for a vehicle to use space outside of its designated travel lane, but within the roadway, to navigate a turning movement.

Encroachment does not include tracking over curbs, bike facilities or onto the sidewalk area. Encroachment can occur on single lane and multilane roadways. Allowing large vehicles to encroach on adjacent travel lanes is an important consideration when designing intersections with shorter crossing distances for pedestrians and lowering turning speeds. Consultation should occur as needed with Fort Collins' Fire Code and Fire Official.

Figure 5: The Control Vehicle is a 47'6" Fire Truck with a 50-foot turning radius.



3.2 Layered Network

Overlay networks are zoning tools that require specific design standards for development in a designated area and must be considered when designing a street. An overlay can protect the existing character of the area or create a character above and beyond that in the base zoning.

Overlays do not affect the uses allowed or prohibited on a property. The information in this section can be combined with any street type and should be used alongside street type guidance to help set priorities, identify street design features, and create intuitive multimodal networks.

3.2.1 Pedestrian Priority Overlay

Pedestrian Priority overlays aim to create designs that serve high levels of walking. This overlay should indicate places where a vibrant, green, and shaded streetscape is desired to support economic vitality and sense of place.

At a minimum within Pedestrian Priority overlays, more width should be allocated to the amenity zone, sidewalk zone, and frontage zone and streets should be operated so that pedestrian convenience is paramount (e.g., shorter cycle lengths at traffic signals). Other streetscape design features—such as pedestrian-scale street lighting, sidewalk café design, and wayfinding—should be prioritized in Pedestrian Priority overlay areas. Where design and operations tradeoffs are needed, elements that promote pedestrian comfort should be given priority. These trade-offs may include removal of a general-purpose travel lanes or on-street parking, or siting new buildings with more generous setbacks.

The Pedestrian Priority Overlay is worth noting not only in how it effects the street design leading up to the intersection, but also how the intersection is designed. Intersections should consider increased pedestrians enhancements (e.g., curb extensions, marked crossings, etc.) in Pedestrian Priority Overlay areas.

Pedestrian Priority Overlay Design User Profile

Areas with Pedestrian Priority should meet the needs of limited-mobility users, including children, older people, parents with strollers, pedestrians who have vision impairments, and people using wheelchairs and other assistive devices, which will also create a more comfortable experience for all users. The pedestrian zone should never be less than 1.2 m (4 ft), which is the minimum width required for people using a guide dog, crutches, and walkers. Wheelchair users need about 1.5 m (5 ft) to turn around and 1.8 m (6 ft) to pass other wheelchairs.

3.2.2 Bicycle Priority Overlay

Bicycle Priority streets, and those with designated bikeways, should be designed and operated to prioritize people riding bicycles over other modes. Bicycle Priority streets are typically selected based on a street's motor vehicle volumes, motor vehicle speeds, width, and number of travel lanes. Sometimes, building appropriate Bicycle Priority streets requires trade-offs to prioritize safety for people using all modes of transportation. In these instances, it is appropriate to remove travel lanes and or on-street parking in order to build comfortable and convenient bikeways.

On Bicycle Priority streets and intersections, the following design criteria and street elements should be prioritized:

Protected Intersections

People biking are most vulnerable at intersections. Where space allows, protected intersections and adequate street buffers should be prioritized (Figure 7). Refer to **Section 4.7. Protected Intersections** and the *2014 Fort Collins Bicycle Master Plan* for details on designing protected intersections.

Bicycle Signals

When space is limited and high turning volumes are anticipated, separate bicycle signal phasing should be considered.

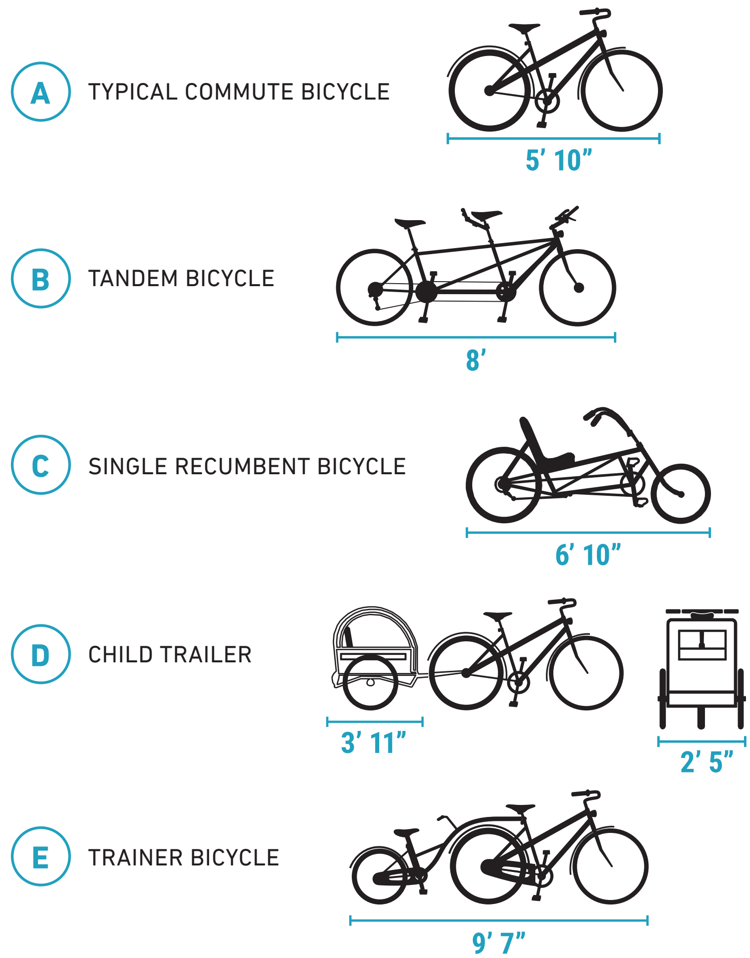
Bicycle Parking

End-of-trip facilities are particularly important to encourage bicycling. Bicycle parking in the amenity zone or curbside zone should be prioritized on most blocks.

Bicycle Priority Overlay Design User Profile

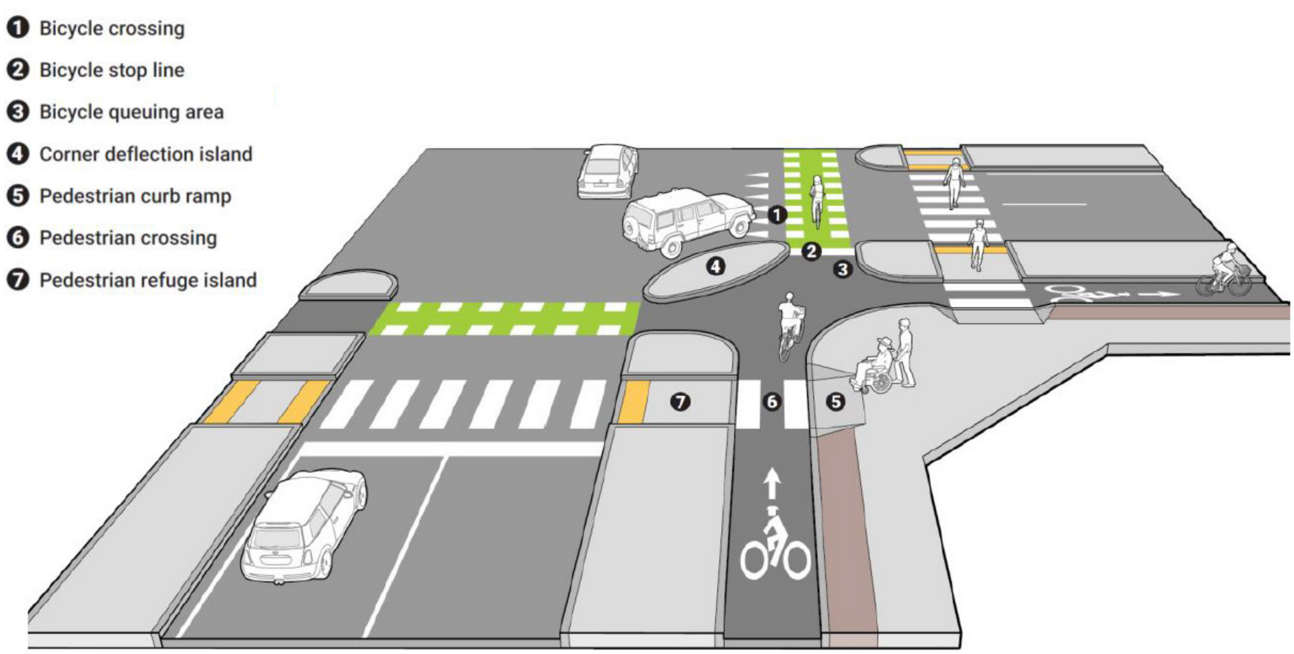
The minimum design vehicle for this overlay is the adult typical bicycle (85th percentile: 70” length, 27” width) whereas the preferred design vehicle is the adult typical bicycle with a trailer. See **Figure X** additional types of adult bicycles, including a typical upright bicycle, recumbent bicycle, etc., and their key dimensions that can be expected on most bikeways.

Figure 6: Dimensions of Typical Adult Bicycles



Source: AASHTO Guide for the Development of Bicycle Facilities, 4th Edition *AASHTO does not provide typical dimensions for tricycles.

Figure 7: Elements of a Protected Bike Lane in an intersection



Elements of a Protected Bike Lane Intersection, Source: Toole Design Group

3.2.3 Transit Priority Overlay

There are three tiers of Transit Priority overlay areas – (1) High-Capacity Transit Corridors can be rail or full bus rapid transit (BRT) corridors, (2) Medium-Capacity Transit Corridors are those with either a rapid bus or full BRT, and (3) Speed and Reliability Corridors. Each corridor type benefits from investments like transit-priority signals and transit lanes at key locations.

Where design and operations trade-offs are needed, transit reliability and access will be given priority in Transit Priority overlay areas. These trade-offs may include removal of a general-purpose travel lane or on-street parking.

The following factors play a role in deciding when and where to make these types of trade-offs and will impact the intersection design, including the allocation of roadway right of way.

Person Throughput. Transit-only lanes are justified if the shift from general-purpose travel lanes to transit lanes increases the total number of people that can be carried through a corridor.

- **Bus Volume.** Transit-only or BRT lanes are typically more useful when there are higher volumes of buses using the dedicated lanes. Refer to City policy to determine if bus volumes warrant use of dedicated transit lanes.
- **Speed.** The transit-only or BRT lane provides an increase in transit operating speed (for the distance of the lane or in the corridor), improves the overall person speed through the corridor, or improves service reliability.
- **Increased Reliability.** The transit-only or BRT lane dramatically improves reliability and reduces travel time on consistently delayed bus routes and formalizes existing bus operational patterns.

In Transit Priority overlay areas, the following design criteria and street elements should be prioritized, while balancing vegetation priorities.

Wider Outside Lanes

Outside travel lanes used by buses should be between 11’ and 12’ wide to accommodate transit vehicles.

Wider Sidewalk Corridors

Sidewalk corridors on frequent transit routes should be sufficiently wide to accommodate higher volumes of people walking and rolling to and from transit, as well as space for transit stop amenities.

Floating Bus Stops

Floating bus stops “float” between a protected bike lane and travel lane. They should be prioritized on streets with both transit and bicycle priority.

Transit Signal Priority

At key intersections, transit signal priority should be considered to increase speed and reliability of transit vehicles.

Transfort Max Bus Operating on the Mason Corridor Transitway (Source: Jeffrey Beall)

Transit Priority Overlay Design User Profile

Transit design vehicles for neighborhood corridors with low to moderate speeds most typically are the standard 40' non-articulated bus. The design vehicle should be based upon the typical fleet of the city's public transportation system with additional considerations for widely used private transit vehicles (serving universities or other institutions).

The Larimer County Urban Area Street Standards (LUCASS) identifies the All CITY-BUS (formerly B-40) as the transit design vehicles to be accommodated at intersections. These vehicles may use more than one traffic lane to complete the turn when turning from the correct lane without crossing into opposing traffic lanes and without tracking onto the curb at corners. This shall apply to all streets with Transit Priority. Additional information on transit deign vehicles can be found in the NACTO Transit Street Design Guide.

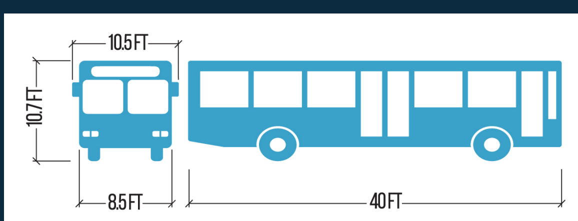


Table 1: Transit Priority Elements by Corridor

Element	Corridor Type		
	High Capacity Transit	Medium Capacity Transit	Speed & Reliability Corridor
Transit Priority	• Dedicated transit lanes, either center- of side-running • Running way treatments • Signal Priority	• Transit lanes (including bus-and-turn lanes) in strategic locations, at specific times, and/or in the peak travel direction • Running way spot improvements • Queue jumps/bypass lanes • Signal priority	• Queue jumps/bypass lanes in select locations • Signal priority in conjunction with queue jumps
Stop and Station Spacing	1/3 to 1/2-mile	1/4 to 1/2-mile	1,000 feet to 1/4 mile

3.2.3 School Zone Overlay

Elementary, middle, and high schools exist on all types of streets and, as such, these streets should be designed with slower speeds to prioritize students and allow them to safely walk, roll, bike, or scoot to and around the school grounds.

School Zone Required Elements:

- In order to ensure that people driving, biking, and walking in school zones know how to behave safely, it is important that all school zones include some of the same elements, such as signage, pedestrian crossings, and standard speed limits. School zone speed limits are set according to City policy; please refer to this policy for more direction.
- Signs let people know that they are entering a school zone and that they should drive with extra caution when children are present. On all streets that surround a school property, school zone and speed limit signs should be placed within one to two blocks of the school to alert drivers.
- All marked crosswalks in a school zone should be high-visibility (continental) to promote motorist yielding.

Other School Zone Considerations:

There are many engineering tools and designs that support safer streets, particularly around schools. Application of these elements vary depending on the problem being addressed, adjacent roadway context, speeds, and traffic volumes. Streets in school zones should be designed with a high degree of safety features for vulnerable users; **Table 2** shows the engineering treatments that are most appropriate for school zones.

Designers should also consider the operational characteristics of school zone overlay areas. For instance, streets bordering school facilities have special peaks during arrival and dismissal periods; curb ramps, transit stop platforms, and bicycle crossings may be sized with additional capacity to accommodate increased active user numbers, especially children and care-givers. Alternatively, time-of-day closures may be appropriate to accommodate school activities (i.e., “School Streets”).

School Zone Overlay Design User Profile

Within school zones, the design user should be the least agile member of the student population. For pedestrians, this is a young, slow walker with limited vertical visibility. For bikes, this is the adult typical bicycle with a trailer. Motorized vehicle design vehicles would likely be the typical buses that service the school.

In addition to coordinating education, enforcement, and encouragement activities in schools, Fort Collins’ Safe Routes to School program works with the community to identify engineering solutions that promote safety around Fort Collins schools. If the practitioner is designing a interesection within a school zone, they should coordinate with Safe Routes to School staff to ensure that any known issues are being addressed.

Table 2: School Zone Overlay Table (source: FHWA PEDSAFE)

Typical Engineering Treatments for School Zones		Performance Objective		
Treatment	**Application**	**Reduce Vehicle Speeds**	**Increase Visibility**	**Reduce Pedestrian Exposure**
Along the Roadway				
Roadway/Lane Narrowing (add bike or bus only lanes, sidewalks, medians, parking)	Arterial, Collector	✓		✓
Speed Cushions/Humps/Tables	Local	✓		
Chicanes	Local	✓		
Midblock Crossings	Arterial, Collector, Local		✓	✓
Raised Pedestrian Crossing (Midblock)	Collector, Local	✓	✓	✓
Median Refuge Island	Arterial, Collector	✓	✓	✓
Pedestrian Hybrid Beacon/ Rectangular Rapid Flashing Beacon	Arterial, Collector		✓	✓
Shared Street (Woonerf)	Collector, Local	✓	✓	
Play Street/Temporary Street Closure	Local		✓	✓
At Intersections				
Parking Setbacks (daylighting)	Arterial, Collector, Local		✓	
Curb Extensions	Arterial, Collector, Local	✓	✓	✓
High-Visibility Crosswalks (Continental)	Arterial, Collector, Local		✓	
Advance Yield/Stop Lines	Collector, Local		✓	
In-Street Pedestrian Crossing Sign	Collector, Local	✓	✓	
Raised Intersection	Collector, Local	✓	✓	✓
Smaller Curb Radii	Arterial, Collector, Local	✓		
Hardened Centerlines	Arterial, Collector	✓		
Mini Traffic Circles	Local	✓		
Leading Pedestrian Intervals	Arterial, Collector		✓	✓
Right Turn on Red Restrictions	Arterial, Collector			✓
Pedestrian Scale Lighting	Arterial, Collector, Local		✓	
Asphalt Art	Collector, Local	✓	✓	


W ELIZABETH ST 2400
STOP

Source: Alta Planning + Design

Chapter 4. Intersection Evaluation & Treatment Selection

4. Intersection Evaluation & Treatment Selection

4.1 Evaluation of Right of Way Assignment

There are three key factors that should be considered when designing interactions between bicyclists, motorists, and pedestrians in Fort Collins:

1. Motorists and bicyclists have a legal responsibility to yield to (or stop for) pedestrians in crosswalks.
2. Most state codes stipulate that a pedestrian may not suddenly leave any curb (or refuge median) and walk or run into the path of a vehicle that is so close that it is impossible for the motorist to yield.
3. Motorists have the legal responsibility to exercise due care to avoid colliding with any pedestrian or bicyclist.

The result is a mutual yielding or stopping responsibility among motorists, bicyclists, and pedestrians, depending upon the timing of their arrival at an intersection. Some states extend the rights and responsibilities of pedestrians at crosswalks to bicyclists, while others do not. Regardless, the mutual yielding or stopping responsibility is relevant in many locations where bicyclists cross paths with motorists or pedestrians. When designing intersections between bikeways and roadways, or between bikeways and pedestrian facilities, designers should understand the application of traffic control devices to communicate right of way, and the laws within their state regarding assignment of right of way for pedestrians and bicyclists (and other bicycle facility users).

The effectiveness of mutual yielding or stopping is dependent on clear sight lines between users (see **Section 4.6**), appropriate traffic control to communicate right of way, and sufficient lighting (see **Section 5**). The type of bicycle facility provided, and its configuration in relation to the motorist and pedestrian areas, has an impact on potential conflicts between bicyclists and other users.

4.2 Evaluations of Uncontrolled Roadway Approaches to Bicycle Crossings

Where it is determined that bicycle approaches to intersections must be yield- or stop-controlled, the designer should evaluate traffic characteristics and quantify crossing opportunities where motor vehicles have an uncontrolled approach to the bicycle crossing. At these locations, crossing opportunities are created when motorists stop or yield to crossing pedestrians or bicyclists, or when there are sufficient crossing opportunities (e.g., gaps) in traffic for pedestrians and bicyclists to cross.

Crossing opportunities are created when motorists yield to crossing bicyclists or when there are sufficient gaps in traffic. At crossings where the average delay experienced by a person exceeds 30 seconds due to insufficient or inconvenient crossing opportunities, pedestrians and bicyclists may begin to exhibit higher risk behaviors in order to cross the street. These behaviors include accepting shorter gaps between motor vehicles to cross or beginning to cross when gaps are only present on the near side of the roadway. These behaviors put the pedestrian or bicyclist at increased risk of a crash where:

- Motorists fail to yield or sufficiently reduce speed.
- Motorists are not provided sufficient time to yield due to their approach speeds or a late entry into the roadway by the pedestrian or bicyclists.
- An approaching motorist cannot see the person crossing due to a stopped vehicle blocking the motorist's view of the person crossing as in the case of a multiple threat crossing.

To reduce the likelihood of higher-risk crossing behavior, crossing opportunities during the motorist peak hours should be provided. Designers should evaluate the crossing opportunities provided during the peak hour, as well as the peak 15-minute period, similar to the evaluation of level of service for motorized traffic.

Where sufficient crossing opportunities are not provided, countermeasures should be provided to increase the frequency of opportunities (see **Section 4.4**).

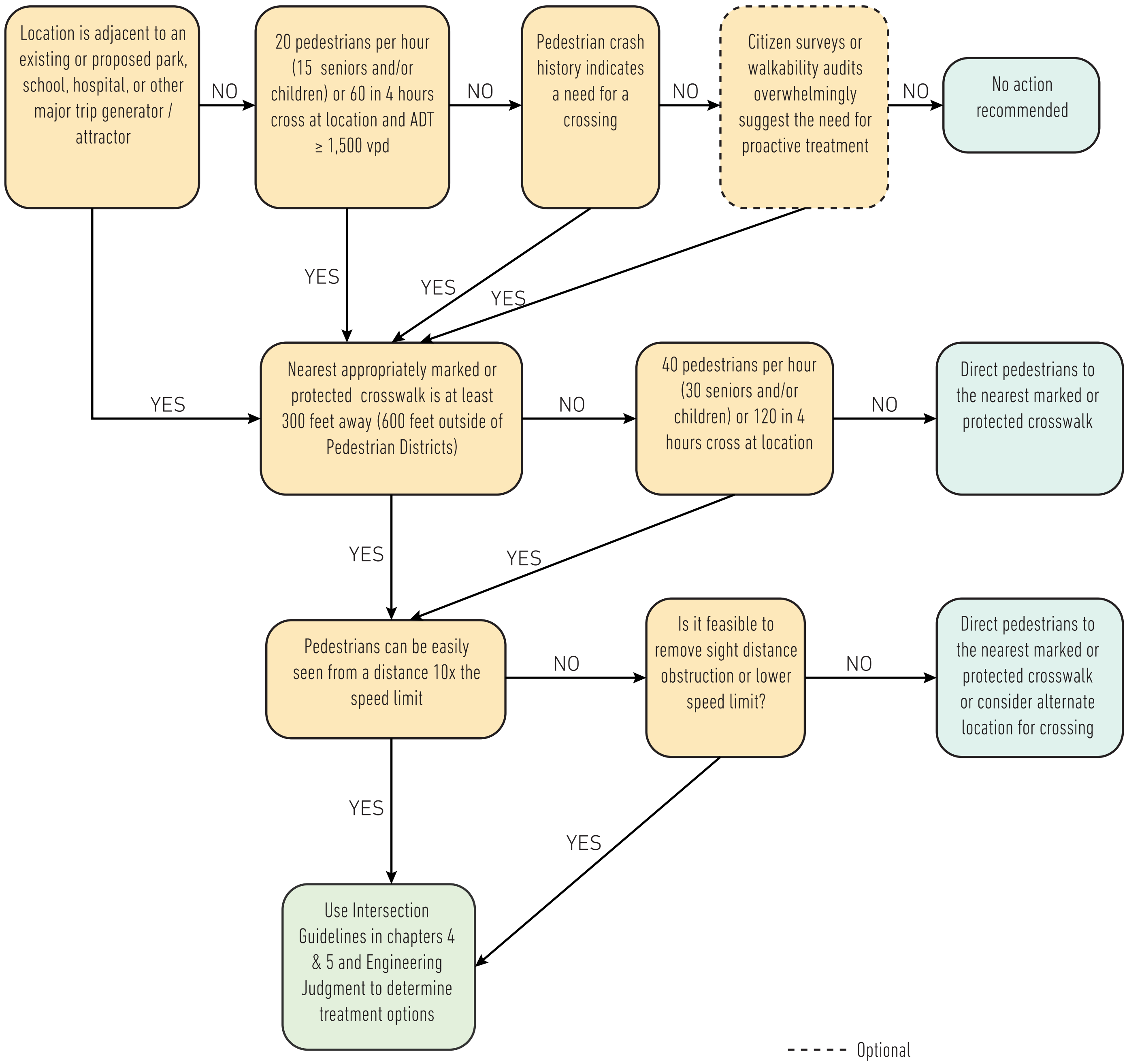


Figure 8: Fort Collins Crossing Policy, Pedestrian Plan, 2011

4.3 Volume Assessment

Average Daily Traffic (ADT) directly impacts the safety, comfort, and yielding likelihood (**Table 3**) on a street. Generally, a low-speed differential between motorists and bicyclists enhances the comfort and safety of bicyclists and reduces crash severity should a collision occur.

4.4 Considerations for Crossings with No Control

At locations where gaps and motorists yielding do not provide the recommended minimum crossing opportunities engineering countermeasures to increase motorists yielding should be considered. The FHWA *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations,* FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations,* and *NCHRP - Report 562 Improving Pedestrian Safety at Unsignalized Crossings* research has determined there are two distinct tiers of countermeasures that can increase motorist yielding (Tier 1 and 2 in Table 3-same as above) for motorist approaches to midblock and intersection crossings. For most roadways operating over 30 mph, it

Table 3: Uncontrolled Crossing Evaluation Table

Uncontrolled Crossing Countermeasure Evaluation Table												
Roadway Type	Vehicle ADT < 9,000			Vehicle ADT 9,000 - 12,000			Vehicle ADT 12,000 - 15,000			Vehicle ADT > 15,000		
(Number of Travel Lanes and Median Type)	Speed Limit (mph)											
	≤30	35	40≥*	≤30	35	40≥*	≤30	35	40≥	≤30	35	40≥
2 Lanes	1	1	2	1	1	2	1	1	3	1	2	3
3 Lanes	1	1	2	1	2	2	2	3	3	2	3	3
4 Lanes with raised median**	1	1	2	1	2	2	2	3	3	3	3	3
4+ Lanes without raised median	1	2	3	2	2	2	3	3	3	3	3	3

* Where the speed limit exceeds 40 mph, Tier 3 should be considered

** Raised medians must be at least 6 feet wide to serve pedestrians. See Figure 2-2 for different bicycle lengths to serve bicyclists. Where median width is less than these values, review category of 4+ lanes without raised median.

legend

Tier 1: 1

Tier 2: 2

Tier 3: 3

will be necessary for a traffic control device to display a red signal to require motorists to stop for bicyclists and pedestrians crossing roadways at locations where gaps in traffic are not sufficient (Tier 3 in Table 3).

The following guidance describes countermeasures which may be effective within each Tier based upon the FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*. In many contexts, the installation of multiple countermeasures may improve yielding and safety outcomes. Tier 1 should be considered as the base countermeasures that support Tier 2 and 3 countermeasures. Tier 1 and 2 countermeasures should support Tier 3 countermeasures.

4.4.1 Tier 1 Countermeasures

The goal of Tier 1 countermeasures is to clearly communicate the presence of a crossing to all users as the traffic volumes and speeds are conducive to motorists yielding. These roadways typically have only one through lane per direction of travel thus eliminating the risk of multiple threat crashes. These countermeasures include:

- Provide Crossing Markings and Signs
- Improve Sight Distance
- Reduce Approach Speeds

4.4.2 Tier 2 Countermeasures

The goal of Tier 2 countermeasures is to not only clearly communicate that pedestrians will be crossing, but create roadway design components that encourage motorists to naturally slow down. These countermeasures include:

- Optimize Geometric Design
- Reduce Approach Speeds
- Provide Active Beacon or Rectangular Rapid Flashing Beacon

4.4.3 Tier 3 Countermeasures

The goal of Tier 3 countermeasures is to require motorists to stop for crossing pedestrians or bicyclists at a pedestrian hybrid beacon or traffic signal or to eliminate the conflict using grade separation. These roadways have higher volumes of traffic with two or more through lanes per direction of travel where motorists generally do not yield. Tier 3 recommendations require an evaluation of MUTCD warrants for signalized treatments.

4.5 Considerations for Yield or Stop Control

In the case of permissive vehicular right and left turns across a bikeway, a turning motorist should yield to a through bicyclist unless the motorist is at a safe distance from the bicyclist to complete the turn at a reasonable speed prior to the bicyclist arriving at the conflict point. Bicyclists should yield to motor vehicles already within the intersection or so close that it is impossible to stop. Bicyclists and motorists must yield to (or stop for) pedestrians within a crosswalk. To facilitate these responsibilities, adequate sight distances and sight lines are needed between bicyclists, motorists, and pedestrians as they approach intersections.

At intersections with permissive turning movements where bicyclists and motorists are traveling in the same direction, there are two scenarios that occur depending upon who arrives first at the crossing. The two yielding scenarios are:

- **Turning motorist yields to (or for) through bicyclist.** This scenario occurs when a through moving bicyclist arrives or will arrive at the crossing prior to a turning motorist, who must stop or yield to the through bicyclist. For locations where bicyclists are operating on separated bike lanes, sidewalks, and side paths, vertical elements near the intersection, including on-street parking, should be set back sufficiently for the motorist to see the approaching bicyclist and provide sufficient time to slow or stop before the conflict point.
- **Through bicyclist yields to (or for) turning motorist.** This scenario occurs when a turning motorist arrives or will arrive at the crossing prior to a through moving bicyclist. This scenario can occur when a bicyclist approaches after a motorist has yielded to other people crossing in the intersection and the crossing is clear for the motorist to proceed. The motorist may begin turning as the bicyclist approaches, requiring the bicyclist to slow and potentially stop while the motorist completes the turning movement.

4.6 Sight Distance

The basic ability to see what lies ahead and to see intersecting users is fundamental to bicyclist safety, regardless of the facility type. Adequate sight lines and sight distances are needed to enable bicyclists and motorists to slow, stop, or maneuver to avoid a conflict at all locations where motorists and bicyclists intersect (e.g., street and roadway intersections, driveways, and alleys). Adequate sight lines should also be provided between bicyclists and pedestrians where they interact at crosswalks, intersections, bus stops, and other conflict areas.

AASHTO's *A Policy on Geometric Design of Highways and Streets* establishes a range of recommended sight triangles that correspond to requirements for motorists to have sufficient space to identify, react, and potentially yield to other traffic at an intersection based on the traffic control applied at the intersection. Applying the sight triangle requirements provided in the AASHTO guidance will result in sufficient sight distance for some bicycle facilities, such as shared lanes and conventional bike lanes.

Designers should consider the placement of bicyclists (often closer to the edge of the road in a shared lane environment, on the shoulder, or in a conventional bike lane) and their design speed when determining the sight triangles for these bicycle facilities. However, these sight triangles were developed primarily to allow motorists to judge gaps in approaching motorized traffic. They do not account for the fact that bicyclists may be operating on sidewalks, separated bike lanes, or shared use paths. This requires an understanding of mutual yielding or stopping responsibilities (see **Section 4.5**), which are not covered in AASHTO guidance. Additionally, street furniture, landscaping, and obstructions should be kept clear from sightlines. **Table 4** presents calculated stopping sight distances for vehicles by travel speed and roadway grade, demonstrating a more realistic assumption for reaction distances.

Table 4: Minimum Stopping Sight Distance vs. Grades for Various Design Speeds—1.5 Second Reaction Time

Stopping Sight Distance (ft) Based on Speed and Grade for a 1.5 Second Perception-Reaction Time											
Speed (mph)	Grade (Positive indicates ascending)										
	-10%	-8%	-6%	-4%	-2%	0	2%	4%	6%	8%	10%
10				32	31	31	30	30	30	29	29
11				36	35	35	34	34	34	33	33
12				40	40	39	38	38	37	37	37
15			56	54	53	52	51	51	50	49	49
18	76	74	72	70	69	67	66	65	64	63	62
20	89	86	84	82	80	78	76	75	74	72	
25	125	121	117	113	110	108	105	103	101		
30	167	160	155	150	146	142	138	135			
35	214	205	198	191	185	180	185	170			
40	266	255	246	237	229	222	216	210			
45	325	311	298	287	277	268	260	253			
50	389	371	356	342	330	319	309	300			

*Motor Vehicle calculated stopping distance, assuming wet conditions.

4.7 Protected Intersections Considerations for Bicyclists

Research has identified motor vehicle approach speed, roadway configuration, pedestrian assertiveness, vehicle class, and race of the pedestrian as having a major influence on motorist yielding rates. From the standpoint of pedestrian and bicyclist safety, as traffic volumes approach 9,000 vehicles/day, vehicle speeds exceed 30 mph, or the number of travel lanes to be crossed exceed two lanes, the rate of motorist yielding on the uncontrolled approach drops significantly which can create crossing challenges for people walking or bicycling.[1,2,3] Additionally, the injury risk for bicyclists and pedestrians increases substantially when they are struck by vehicles operating at speeds over 30 mph. Research has also identified that drivers are less likely to yield to Black pedestrians than white pedestrians, increasing the injury risk for street users who are black.[4]

Intersection design for separated bike lanes should strive to reduce conflicts and reduce the risk of injury for all users in the event of a crash. Intersections include not only bicycle crossings of streets, but also crossings with driveways, alleys, sidewalks, and other separated bike lanes or side paths. Intersections are likely to be locations where bicyclists transition into and out of separated bike lanes or side paths to other types of bikeway accommodations. These transitions should be intuitive to all users of the intersection, including pedestrians with disabilities. This section only covers issues that are unique to separated bike lane and side path intersection design. Specific design guidance for protected intersections can be found in Section 4.7 and Chapter 5.

4.7.1 Minimizing Exposure to Conflicts

A major goal in providing separated bike lanes is to minimize conflicts between bicyclists, pedestrians, and motorists at intersections. For this reason, it is preferable to maintain separation between the separated bike lane and the adjacent motor vehicle travel lanes at intersections. While one strategy in constrained locations has been to reintroduce the bicyclist into travel lanes at intersections (termed "mixing zones"), this is a strategy that is only appropriate in low-speed environments with infrequent turns across the bikeway, and is not a preferred design due to conflicts that are inherent in mixing zones.[5,6] At locations where there are more than 100-150 vehicle turns across the bikeway per hour, signal separation of turns across the bikeway may be preferred. Side paths should also remain separated up to intersections.

At intersection approaches, the designer should consider the many different directions in which a bicyclist may need to travel. In some contexts it may be beneficial to provide an opportunity for a bicyclist to exit the separated bike lane in advance of the intersection, or provide a two-stage bicycle turn box, to allow a bicyclist to proceed in the desired direction.

4.7.2 Reducing Speeds at Conflict Points

Intersections with separated bike lanes and side paths should be designed to ensure slow-speed turning movements for motor vehicles (10 mph or less) to improve yielding, reduce stopping distance requirements, and reduce crashes. Where they are used, mixing zones should be designed to encourage the weaving movement to occur at slow speeds (20 mph or less) near the corner, at a location where motorists have slowed their speed in anticipation of the turn so they are more likely to yield to bicyclists. Mixing zones are not appropriate for side paths.

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1 Bertullis, T. and D. Dulaski. Driver Approach Speed and its Impact on Driver Yielding to Pedestrian Behavior at Unsignalized Crosswalks. In Transportation Research Record 2464. TRB, National Research Council, Washington, DC, 2014.

2 Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord.

3 *National Cooperative Highway Research Program Report 562: Improving Pedestrian Safety at Unsignalized Crossings*. NCHRP, Transportation Research Board, Washington, DC, 2006.

4 Goddard, T., K. B. Kahn, and A. Adkins. Racial Bias in Driver Yielding Behavior at Crosswalks. T*ransportation Research Part F: Traffic Psychology and Behavior*. Vol 33, 2015, pp.1-6.

5 Schepers, J.P., P. A. Kroeze, W. Sweers, and J.C. Wust. Road Factors and Bicycle-Motor Vehicle Crashes at Unsignalized Priority Intersections. *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 853-861.

6 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.

Strategies for reducing speeds at conflict points should address motor vehicle traffic turning left, turning right, and weaving across the separated bike lane or side path at intersections and driveways. Strategies for reducing turning speeds include the following:

- Employ traffic calming measures on the road prior to the crossing, thereby reducing speeds on the approach
- Minimize the curb radius at the corner
- Provide a raised crossing
- Install a median or hardened center line
- Provide a mountable truck apron at the corner to reduce speeds but accommodate a large vehicle; where mountable aprons are installed, the pedestrian curb ramp and detectable warning strip should be set back along the curb line, clear of the large vehicle turn path.

Where conflicts are severe due to the volume of conflicting traffic, it may be necessary to consider traffic signal phasing to mitigate the conflicts.

4.7.3 Transitions Between Elevations

Raised crossings are an effective strategy to reduce motor vehicle turning speeds and conflicts with bicyclists at intersections and driveways.

At intersections and transit stops, or any location where the bikeway transitions from one elevation to another, it is necessary to provide transition ramps for bicyclists. The ramp for the bicyclist should provide a smooth vertical transition with a maximum slope of 8 percent (15 percent at driveways); however, a 5 percent slope is generally preferred. For side paths, any transitions must be consistent with pedestrian accessibility guidelines. The transition ramp should generally not be located within a lateral shift or curve in the bike lane alignment near an intersection.

Speed hump markings may be desirable at locations where the ramp is located in a constrained location or may otherwise be hard to detect for approaching bicyclists. Designers should consider raising the entire separated bike lane to intermediate or sidewalk level where the density of transit stops, driveways, alleys or minor street crossings would otherwise result in a relatively quick succession of transition ramps. Too many transition ramps in close proximity can result in an uncomfortable bicycling environment.

4.7.4 Right of Way Priority

In general, the separated bike lane and side path should be provided the same right of way priority as through traffic on the parallel street. Exceptions to this practice may be considered at:

- Locations with high volumes of conflicting turning traffic
- Locations where bicyclists must cross high-speed (greater than 30 mph) traffic

4.7.5 Sight Distance

Adequate sight distance is needed between bicyclists, motorists, and pedestrians as they approach the junction between separated bike lanes and side paths with streets, alleys, and driveways. When a separated bike lane or side path is located behind a parking lane, it may be necessary to restrict parking and other vertical obstructions near a crossing to ensure adequate sight distances are provided. This is primarily an issue at intersection and driveway locations with permissive right and left turns across the bicyclist path of travel.

At intersections and driveways with stop signs, where motorists must stop before turning across the separated bike lane or side path, the standard local parking restrictions adjacent to the intersection (recommended 20 ft minimum) may be adequate. At intersections with permissive turning movements where bicyclists and motorists are traveling in the same direction, parking restrictions (and the resulting sight distances) are a key consideration. To determine parking restrictions near the crossing, it is necessary to know the approach speed of the bicyclist and the turning speed of the motorist.

4.7.6 Restricting Motor Vehicles

Separated bike lanes and side paths are intended for use by bicyclists (and pedestrians) only. However, because of the close proximity of separated bike lanes and side paths to motor vehicle travel lanes, careful design consideration is necessary to communicate the intended user and restrict motor vehicle access.

Geometrically, the alignment of travel lanes across an intersection or in front of a driveway should be reviewed to ensure that the bikeway does not visually appear to be the receiving lane crossing an intersection or driveway. Locations with an offset intersection, along horizontal curves, or where turning movements occur should be carefully reviewed to address this issue, with edge lines and lane extension lines used where appropriate to identify the intended vehicle path.

Separated bike lanes and side paths should be marked with bicycle crossings and crosswalks, respectively, at intersections and driveways. These marked crossing treatments are often sufficient to communicate that motor vehicles are not the intended user of the bikeway. Bike lane symbol markings located close to an intersection or driveway can further reinforce the intended user. Green-colored pavement or markings in the bicycle crossing and/or close to an intersection or driveway can further enhance the conspicuity and reinforce that vehicles are not authorized.

KEEP RIGHT or KEEP LEFT signs (R4-7, R4-8), supplemented with an optional EXCEPT BIKES plaque, can be installed in the street buffer to reinforce that motorists should not enter the bikeway.

If the above-mentioned treatments have been implemented and found to be ineffective, changes to the width of the separated bike lane or side path may be considered. Visually narrowing the width of the bikeway using white edge lines should first be considered. For one-way separated bike lane, the use of flexible delineators or other vertical elements may be used to narrow the physical width of a one-way separated bike lane to no more than 6 feet at intersections and driveways, but these treatments should not be placed in the middle of a one-way separated bike lane. For two-way separated bike lanes or side paths, if the above treatments are found to be ineffective, some two-way separated bike lanes have included flexible delineator posts on the center line as a temporary measure to acclimate drivers to the lane configuration and then the flexible delineator is removed once driver education has occurred.

Restricting Motor Vehicle Access Signage


CROSSWAL
STOP ON R
PROCEED O
FLASHING R
WHEN CLEA


Source: Alta Planning + Design

Chapter 5. Treatment Design

5. Treatment Design

5.1 Geometrics

The following sections describe design measures that may be used to address specific design objectives for people walking and biking at intersections. Some of the measures improve conditions regardless of the pedestrian or bicycle facility type incorporated. For example, facilities that intersect at 90 degrees optimize sight lines and minimize crossing distances and, therefore, exposure. The principles that apply to design for pedestrians at crossings (controlled and uncontrolled) are usually applicable to bicycle crossings as both pedestrians and bicyclists are disproportionately vulnerable to injury or death in the event of a crash with a motor vehicle.

Several countermeasures have been shown to reduce pedestrian and bicyclist crashes at such intersections. This Guide provides a general overview of crossing measures; other sources, such as the *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*, should be consulted for more detail. Intersection geometry can also be used to create space for bicyclists and pedestrians to queue while waiting to cross the road. These queuing areas, such as the refuge medians and curb extensions described in the following sections, are separated from other moving traffic.

5.1.1 Raised Refuge Median, Median Islands, and Hardened Centerlines

At signalized intersections, single stage crossings are preferred. Where a wide intersection cannot be designed or timed to accommodate a pedestrian crossing of the intersection at one time, a crossing island or median must be provided with a pedestrian refuge. A crossing island should be considered where crossing distances are greater than 50 feet to better accommodate slower-moving pedestrians. When a crossing island is placed at a signalized crossing, use pedestrian recall to prevent "trapping" a pedestrian in the median. In any case, pedestrian crossing phases must be timed to accommodate pedestrians crossing the entire roadway.

Raised Refuge Median

Raised medians are curbed medians located between travel lanes that serve as a pedestrian refuge space. Triangular channelization islands adjacent to right -turning lanes can also act as crossing islands. Crossing islands can be coupled with other traffic calming features, such as partial diverters and curb extensions at mid-block and intersection locations.

Median Islands

The minimum width for a crossing island to provide an accessible refuge is 6 feet, measured from outside edge of the detectable warning surfaces, and the minimum width between detectable warning surfaces is 24 inches. Where medians are constructed using curbing and the detectable warnings are placed at the back of curb, the minimum width of the island is 7 feet, measured from curb face to curb face (each curb is 6 inches, so the accessible refuge, essentially, is still 6 feet). When pedestrians must cross more than three travel lanes before a refuge, crossing equipment (e.g., APS buttons) should be provided in the median. **Figure 8** illustrates a median crossing island with curbing where the detectable warning surface is placed at the back of the flush curb in the pedestrian refuge area. **Figure 9** illustrates crossing islands with a 6 feet width where detectable warnings are placed in line with the median island face of curb to meet accessibility requirements.

Median Island at Intersection

Figure 8: Median Crossing Island – Detectable Warning Surface Placed at Back of Curb

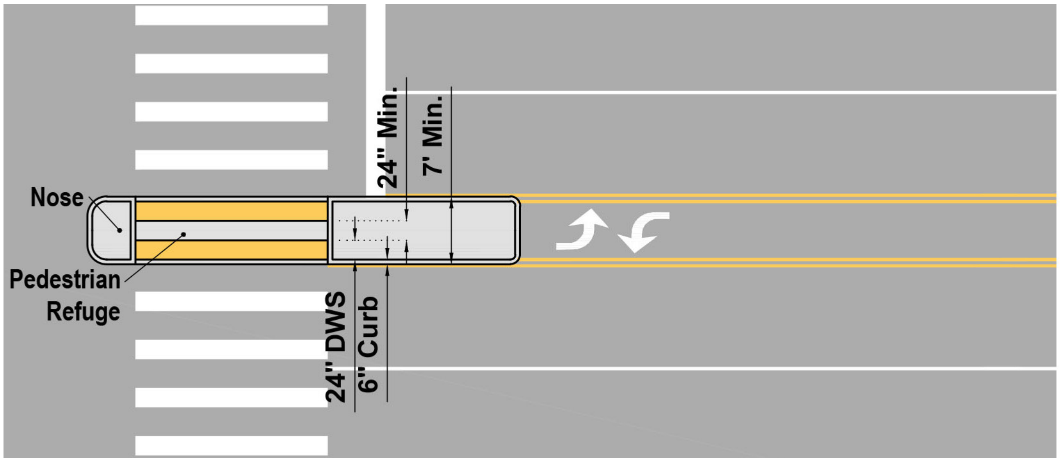
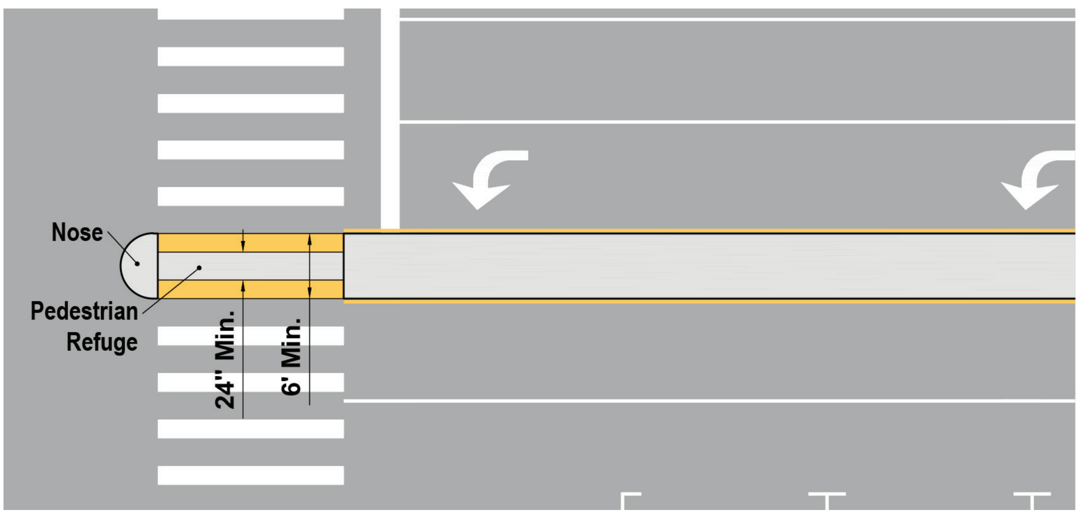


Figure 9: Median Crossing Island – Detectable Warning Surface Placed in Line with Island Face of Curb



For roadways with speeds of 50mph or greater, the preferred minimum width for crossing islands is 10 feet, which accommodates bicyclists with trailers and wheelchair users more comfortably. A width of 8 feet can be constructed if there are constraints, but it is not preferred. Cut-through openings should match the width of the corresponding crosswalk. A "nose" that extends past the crosswalk toward the intersection is recommended to separate people waiting on the crossing island from motorists, and to slow turning motorists. Traffic control equipment, vegetation, and other aesthetic treatments may be incorporated, but must not obscure pedestrian visibility. When less than 6 feet in width is available, designers can still provide a center median, also known as a hardened centerline, to channelize and slow the speeds of left- turning motorists as they prepare to cross the path of pedestrians and bicyclists. This treatment is especially important to provide where permissive left turns are permitted across the crosswalk to calm turn speeds. However, this treatment does not meet the definition of an accessible median refuge.

Hardened Centerline

A hardened centerline comprises a painted centerline supplemented by flexible delineators, mountable curb, rubber curb, concrete curb, "In-street Pedestrian Crossing" signs (R1-6), or a combination of these treatments. The dimensions of a hardened centerline will depend on the intersection geometry and vehicle turning radius. Hardened centerlines should be considered where higher-speed left turns occur concurrent with pedestrian and/or bicyclist movements, as they have been found to reduce the speed of left turning motorists by reducing the effective turning radius. Hardened centerlines can be appropriate on both the departure roadway and the receiving roadway to control the left turning motorist path of travel (See **Figure 10**).

Figure 10: Flexible Delineators and Hardened Centerline to Control Turning Speed

5.1.2 Curb Extensions

On streets with on-street parking, curb extensions can be used at intersections and mid-block crossings to extend the sidewalk or curb line into the parking lane. Curb extensions reduce crossing distance for pedestrians and bicyclists, improve sight distance for all road users, and prevent parked cars from encroaching into the crosswalk area. At intersections, curb extensions can better control the effective turning radius and can be used in conjunction with truck aprons (See **Section X**).

Design Considerations

Designers should consider the following for intersection and mid-block locations:

- Curb extensions are typically used where there is an on-street parking lane and its width is typically the width of, or 1 feet less than, the width of the parking lane. Curb extensions may be considered for use where shoulders exist if bicyclists are not expected to operate on the shoulder.
- Mid-block curb extensions can be co-located with fire hydrants to maintain access to hydrants and to reduce impacts to on-street parking.
- Curb extensions can create additional space for curb ramps, low-height landscaping, and street furniture where sidewalks are otherwise too narrow. Care should be taken to ensure that street furniture and landscaping do not block motorists' views of pedestrians.
- Curb extension designs should facilitate adequate drainage, either by providing inlets upstream of the curb extension, or by providing grading that maintains drainage flows along the curb line (in which situation the inset area should be constructed using concrete to improve durability, and drainage maintained along the bump-out). The designer should consider factors such as maintenance in the selection of drainage facilities, as some options may be more prone to clogging and require more routine maintenance to function properly, and the ability of bicyclists or pedestrians to safely traverse the structures or grating.
- Designers should consider providing reflective vertical elements to alert drivers and snowplow operators to the presence of curb extensions.
- The length of a curb extension should extend at least 20 feet on both sides of the crosswalk but can be longer depending on the use desired within the extension (e.g., stormwater management, bus loading, restricting parking) or where additional parking restrictions are desired (e.g., where "Advance Yield Here To Pedestrians" sign and yield lines are provided more than 20 feet from the crosswalk).
- Painted curb extensions may be used as an interim measure and should be paired with edge objects such as flexible delineators to create a sense of enclosure and buffer from motor vehicle traffic.
- Approaches to curb extensions can be created as a straight taper or using reverse curves, though reverse curves are easier for snowplow operators to guide along without catching the plow edge.

5.1.3 Corner Islands

A corner island allows the bike lane and side path to be physically separated up to the intersection crossing point where potential conflicts with turning motorists can be controlled more easily. It serves an important purpose in protecting the bicyclist from right-turning motor vehicle traffic. The corner island also provides the following benefits:

- Creates space for a forward bicycle queuing area.
- Creates additional space for vehicles to wait while yielding to bicyclists and pedestrians who are crossing the road.
- Reduces crossing distances where raised refuge medians are provided.
- Reduces motorist turning speeds.
- Can reduce through bicyclist speeds by adding deflection to the bike lane or side path.

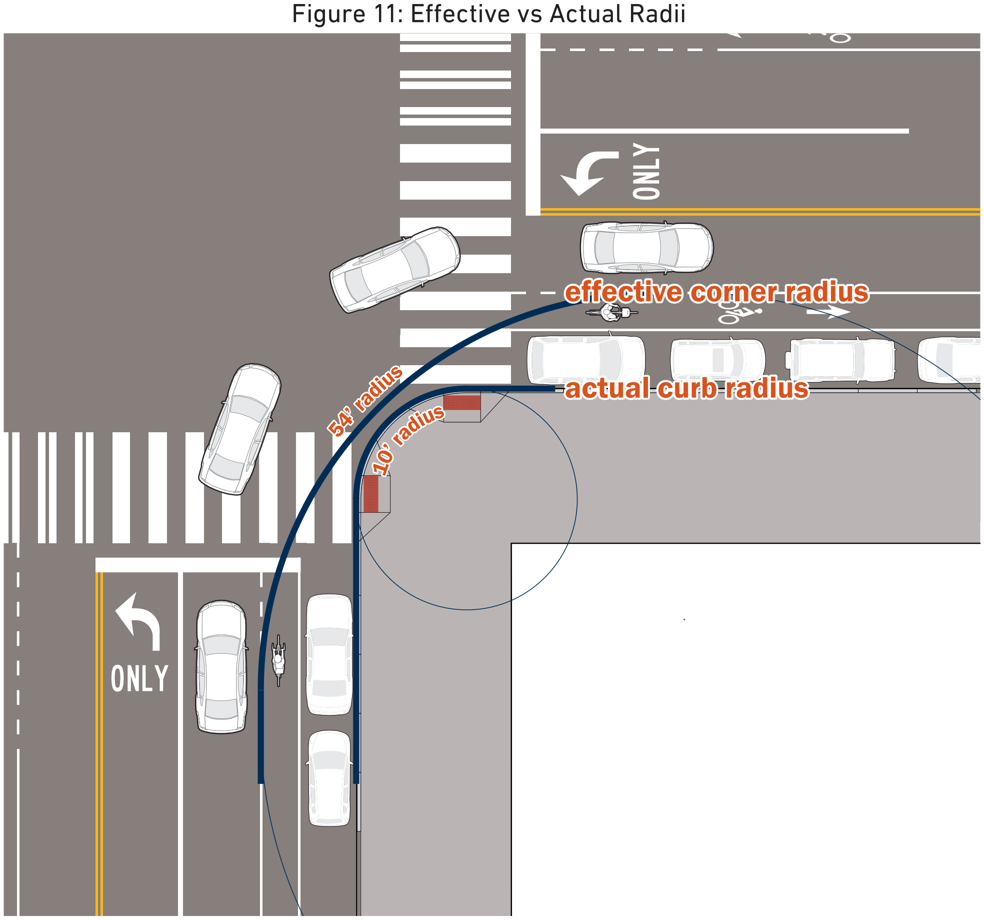
Design Considerations

The corner island geometry will vary greatly depending upon available space, the location and width of buffers, and the corner radius. The corner island should be constructed with a standard vertical curb to discourage motor vehicle encroachment. In retrofit projects, corner islands may be constructed with flexible delineators posts. Where the design vehicle exceeds an SU-30, a mountable truck apron can be considered to supplement the corner island; however, the corner island should not be eliminated, as it serves an important function to protect crossing bicyclists and pedestrians and control motorist speeds, as described above.

5.1.4 Curb Radius

Corner design has a significant impact on how well an intersection serves the diversity of roadway users. Two of the most important corner design elements are the effective corner radius and the actual curb radius. Actual curb radius refers to the curve that the face of curb line makes at the corner, while effective corner radius refers to the curve which motor vehicles follow when turning, which may be affected by on-street parking, bicycle lanes, medians, and other roadway features. Curb radii should be 10 feet for local roads and 25 feet for arterials and above. Sharper curb radii may be needed at intersections where further speed reductions are needed or larger vehicles are prevalent.

Figure 11: Effective vs Actual Radii



Design Considerations

- The smallest feasible curb radii should be selected for corner designs. Small curb radii benefit pedestrians by creating sharper turns that require motorists to slow down, increasing the size of waiting areas, allowing for greater flexibility in the placement of curb ramps, and reducing pedestrian crossing distances.
- A smaller curb radius should be used wherever possible including where:
  - There are higher pedestrian volumes
  - There are low volumes of large motor vehicles
  - Bicycle and parking lanes create a larger effective radius
- The maximum desired effective corner radius is 35' to accommodate large motor vehicles; however, all factors that may affect the curb radii must be taken into consideration. These include:
  - The street type
  - The angle of the intersection
  - Presence of curb extensions
  - The number and width of receiving lanes
- On streets where fire trucks and buses need to make tight turns and on frequent freight routes, larger turning radii may be necessary to accommodate turning movements.
- Small curb radii may be more difficult for large motor vehicles to negotiate. However, on-street parking or bicycle lanes may provide the larger effective radii to accommodate the appropriate design vehicle.
- The corner design must accommodate the design vehicle's turning path around the effective corner radius, which is based on street configuration (e.g., the presence of on-street bikeways, on-street parking, etc.).
- Where there are high volumes of large motor vehicles making turns, inadequate curb radii could cause large motor vehicles to regularly travel across the curb causing damage to the curb and compromising the pedestrian waiting area

At protected intersections with bike facilities, at least a 10 feet corner radius (15 feet preferable) should be provided where bicyclists make turning movements between bikeways. The radius may be reduced to a minimum of 5 feet in constrained conditions; however, the designer should recognize that this may require bicyclists with longer bicycle types (e.g., bicycle with trailer, adult box bicycle) to slow significantly to facilitate the turn.

5.1.5 Curb Ramps and Detectable Warning Surfaces

Pedestrian curb ramps are required to transition pedestrians from the sidewalk (and bicyclists and pedestrians from side paths) to the street where there is a change in elevation between the two. It is preferable to use the curb ramp style that will shorten crossing distances and provide directional cues to pedestrians. Parallel curb ramps may be necessary at locations where the sidewalk is constrained and the provision of a level landing requires an alternative approach. The curb ramp must meet pedestrian accessibility guidelines.

Curb Ramp Types

There are five types of curb ramps used in street corner designs:

- Perpendicular
- Parallel
- Blended Transition
- Combination
- Diagonal

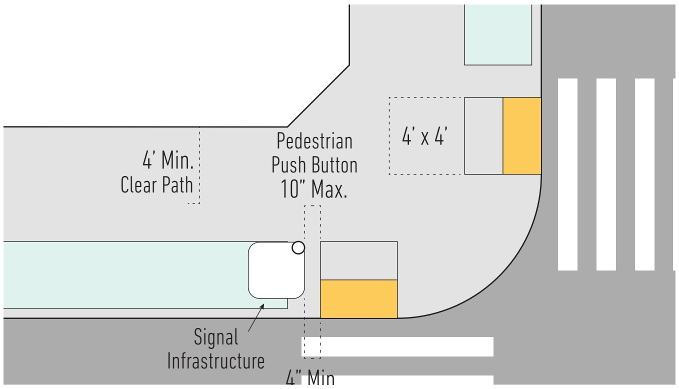
Curb ramps should be located entirely within the marked crosswalks (where they exist). Drainage grates or inlets should not be located within the crosswalk area, as wheelchair casters or cane tips could get caught.

Design Considerations

There are a variety of curb ramp designs. The appropriate type of curb ramp to be used is a function of sidewalk and border width, curb height, curb radius, and topography of the street corner. Three types of curb ramps are commonly used in street corner designs: perpendicular, parallel, and blended transitions. These types of curb ramps can also be used in various combinations. These general curb ramp types are illustrated in **Figure 12** through **15**. Table 5 summarizes the advantages and disadvantages of the respective curb ramp types.

Perpendicular Curb Ramps

These curb ramps are perpendicular or nearly perpendicular to the curb face. They are generally the preferred design for pedestrians, provided that a 4 feet (1.2 m) landing is available for each approach, although a 5-foot landing is preferred if space is available. Landings allow pedestrians to move completely from the curb ramp before turning to proceed along the sidewalk. If landings are not provided, perpendicular curb ramps may not be accessible and should not be used because they create severe cross slopes and rapid changes in cross slopes over short distances.



From perpendicular curb ramps, users will generally be traveling perpendicular to vehicular traffic when they enter the street at the bottom of the curb ramp. Where practical, the curb ramp path should be aligned with the crosswalk. At large curb return radii, if may not be possible to provide a curb ramp that is both aligned with the crosswalk and exactly perpendicular to the curb face. Generally, alignment of the curb ramp with the crosswalk is preferable to providing a ramp that is exactly perpendicular to the curb face.

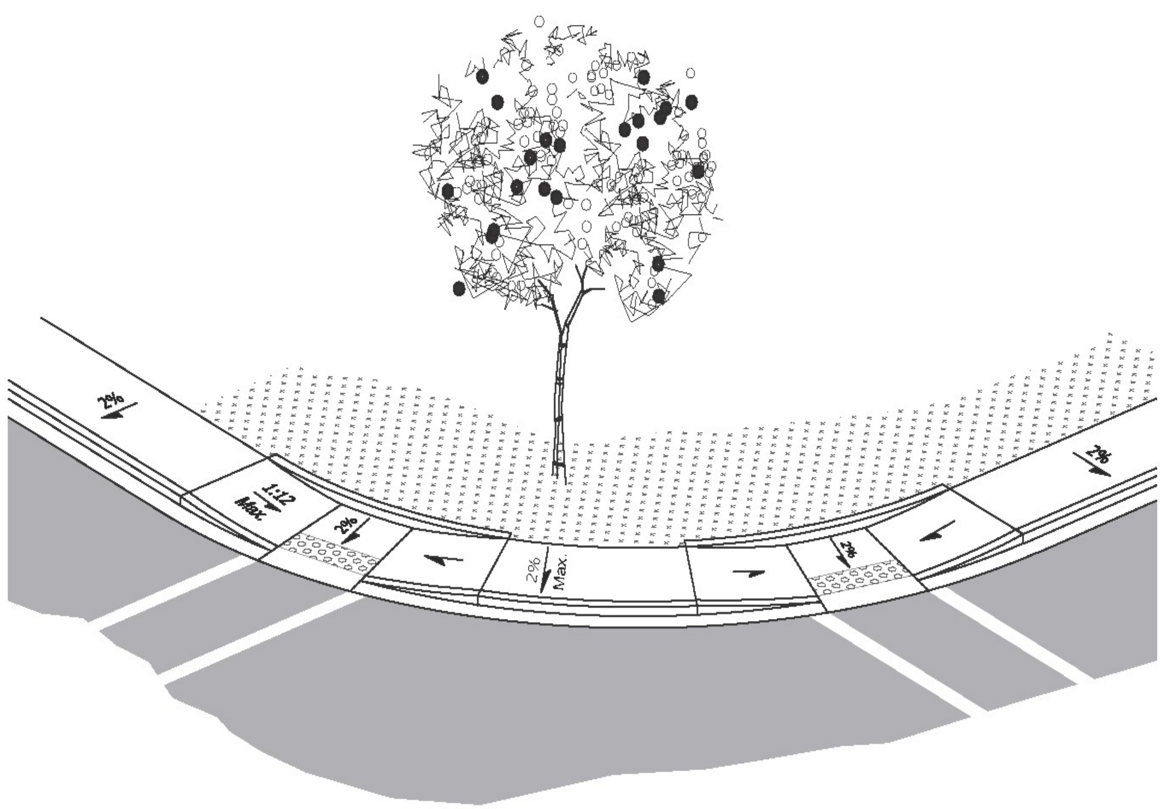
Single perpendicular ramps serving two crosswalks (sometimes referred to as diagonal ramps) are not recommended. Such ramps are typically not aligned with either of the crosswalks that extend across the intersecting streets. As a result, the single perpendicular curb ramp may direct pedestrians with vision disabilities or wheelchair users toward the center of the intersection, rather than toward either crosswalk. Where physical constraints prevent provision of separate perpendicular curb ramps for each crosswalk in alteration projects, a single perpendicular ramp (or diagonal ramp) may be used; the single perpendicular curb ramp needs a 4 feet by 4 feet (1.2 m by 1.2 m) clear space in the roadway to accommodate a turning maneuver (a 5 feet by 5 feet space should be used if space allows). A curb return radius of at least 20 feet (6.1 m) is generally needed so that the clear space does not encroach on a travel lane.

Parallel Curb Ramp

Parallel curb ramps are used where the available space between the curb and the property line is too constrained to permit the installation of both a perpendicular curb ramp and a landing. In some cases, merely reducing the curb radius can permit the construction of perpendicular curb ramps. Where this is not practical, the full width of the sidewalk is brought down to the street grade beyond the intersection crosswalk area with only a 2 percent drainage slope to the gutter. Thus, a parallel curb ramp has two curb ramps leading down towards a centered landing at the bottom of both curb ramps.

A 4 feet by 4 feet (1.2 m by 1.2 m) landing is needed between the two curb ramps, although a 5 feet by 5ft landing is preferred. The two curb ramps leading to the centered landing are oriented so the path of travel on the curb ramps is parallel to vehicular traffic on the adjacent street and the pedestrian's path of travel on the sidewalk. Detectable warning surfaces are needed on the landing at the curb line between the two curb ramps (See **Figure 12**). A landing at the top of a parallel curb ramp is required only if turning is needed. Parallel curb ramps result in pedestrians continuing along the sidewalk traveling down one curb ramp and up the other. For this reason, where practical, it is preferred that two perpendicular curb ramps be installed rather than parallel curb ramps.

Figure 12: Parallel Curb Ramps



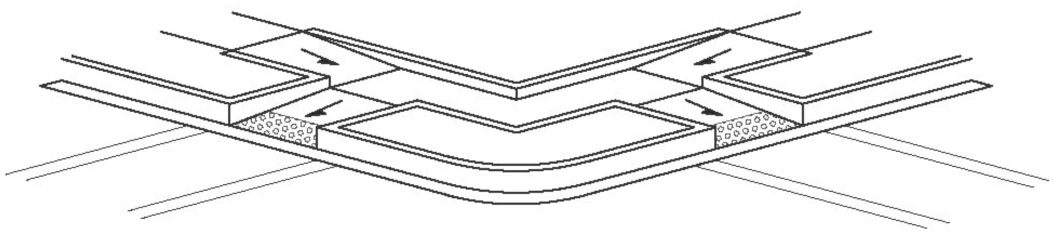
Blended Transitions

With a blended transition, the sidewalk elevation is lowered to the street level with a gradual change in slope. The maximum grade in the direction of pedestrian travel is 5 percent, and the maximum cross slope is 2 percent (except at pedestrian street crossings without yield or stop control where the cross slope is permitted to equal the street or highway grade). The maximum cross slope of the pedestrian access route around the blended transition is 2 percent. Blended transitions without accessible pedestrian signals (APSs) should be used sparingly since they provide limited directionality for pedestrians with vision disabilities.

Combinations

Curb ramps can also be designed using a combination of curb ramp types to take advantage of the characteristics of the different types of curb ramps. For example, a combined parallel and perpendicular curb ramp (See **Figure 13**) can use the concept of a parallel curb ramp to lower the elevation level of the landing and then use a perpendicular curb ramp to complete the remaining elevation gap between the landing and the street. This type of combined parallel and perpendicular curb ramp may be helpful where the sidewalk is narrow, has a steep grade, or has a high curb. Where sedimentation is a problem for parallel ramps, combination ramps should be considered as an alternative.

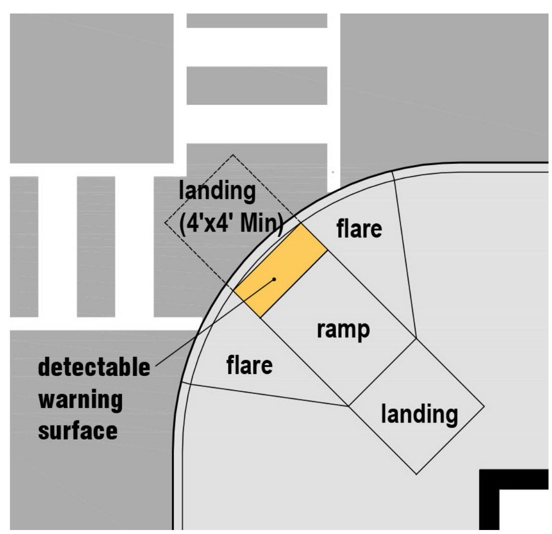
Figure 13: Combined Parallel and Perpendicular Curb Ramp



Diagonal

Diagonal curb ramps are a single curb ramp that is located at the apex of the corner (See **Figure 14**). Diagonal curb ramps are not acceptable designs for access to new sidewalks but may be applied in retrofit locations where a pair of perpendicular ramps is not feasible due to existing site constraints. This design directs a visually impaired person away from the crosswalk and into traffic. Therefore, the entire lower landing area must fall within the crosswalk that the ramp serves and cannot be located in the traveled lane of traffic.

Figure 14: Diagonal Curb Ramp Example



Considerations

Table 5 summarizes the considerations for curb ramp design.

Table 5: Considerations for Curb Ramp Design [adapted from (21)]

Best Design Practices and/or Design Requirements	Rationale
PROWAG requires turning space at the top of perpendicular curb ramps. Provision of level turning spaces at the top of other curb ramps represents a best practice.	Landings are critical to allow wheelchair users space to maneuver on or off of the curb ramp. Furthermore, they allow pedestrians continuing along the sidewalk to avoid negotiating a surface with a changing grade or cross slope.
Clearly identify the boundary between the bottom of the curb ramp and the street with a detectable warning.	Without a detectable warning, pedestrians with vision disabilities may not be able to identify the boundary between the sidewalk and the street.
Design curb ramp grades perpendicular to the curb.	Assistive devices for mobility are unstable if one side of the device is lower than the other or if the full base of support (e.g., all four wheels on a wheelchair) is not in contact with the surface. This commonly occurs when the bottom of a curb ramp is not perpendicular to the curb.
Place the curb ramp within the marked crosswalk area.	Pedestrians outside of marked crosswalks are less likely to be seen by drivers because they are not in an expected location.
The difference in grade between a gutter and adjacent curb ramp should not exceed 11 percent without providing a level strip of at least 24 in. (0.6 m).	Severe or sudden grade changes may not provide sufficient clearance for the frame of a wheelchair causing the user to tip forward or backward.
Curb ramps should be designed so that pedestrians do not need to turn or maneuver on the curb ramp surface.	Maneuvering on a steep grade can be very difficult for people with mobility disabilities.
Curb ramps should have a grade between 5 percent and 8.3 percent; and lengths not exceeding a length of 15 feet (4.6 m), exclusive of the landing.	Shallow grades are difficult for people with vision disabilities to detect, but steep grades are difficult for those using assistive devices for mobility.
A curb ramp and gutter should have across slope equal or less than than 2.0 percent.	Curb ramps should have minimal cross slope so users do not have to negotiate a steep grade and cross slope simultaneously.
Adequate drainage should be provided to prevent accumulation of water or debris on or at the bottom of the curb ramp.	Water, ice, or debris accumulation will decrease the slip resistance of the curb ramp surface.
Transitions from curb ramps to gutters and streets should be flush and free of elevation changes.	Maneuvering over any more-than-minimal vertical rise, such as a lip or defect, can cause wheelchair users to propel forward when wheels hit them.
Align the curb ramp with the crosswalk, so there is a straight path of travel from the top of the curb ramp to the center of the roadway to the curb ramp on the other side.	People using wheelchairs often build up momentum in the crosswalk to get up the curb ramp grade leading to the sidewalk on the opposing side of the roadway (i.e., they "take a run at it"). This alignment may also be useful for people with vision disabilities.

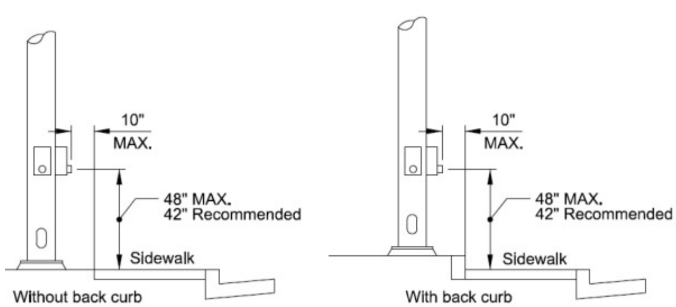
Curb Ramp Locations

It is desirable to provide an accessible route for persons with disabilities. When a curb ramp is built on one side of a street, a companion curb ramp is required on the opposite side of the street. Therefore, when normal project or work limits end within an intersection, the work limits must extend to allow construction of companion ramps.

In accordance with the *Larimer County Urban Area Street Standards (LCUASS)* "Chapter 16: Pedestrian Facilities Design and Technical Criteria," curb ramps shall be installed at all intersections for all new construction or reconstruction of curb and sidewalk, as follows:

- 4-Way Intersections: Access ramps shall be included at all intersection comers. Access ramps shall be constructed in accordance with the Construction Drawings from the *LCUASS*.
- T-Intersections: All "T" intersections shall have a minimum of three access ramps as detailed in the *LCUASS*.

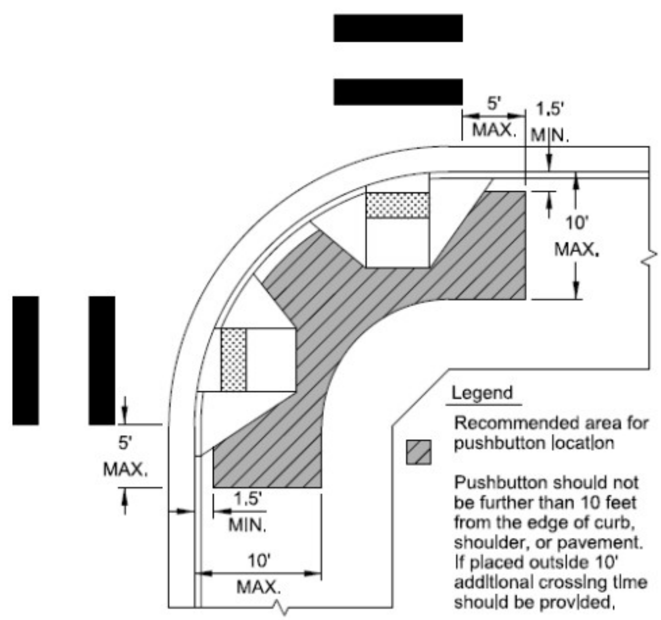
- Intersections may have unique characteristics that can make the proper placement of curb ramps difficult, particularly in retrofit situations. However, there are some fundamental guidelines that may be followed:
- Perpendicular curb ramps should be built at an angle perpendicular to the curb face; where the curb ramp meets the roadway, the full width of the curb ramp (exclusive of flares) must be within the crosswalk. Aligning the curb ramp with the crosswalk provides an additional cue for in-line travel across a street by pedestrians with vision disabilities.
- At large curb return radii, if may not be possible to provide a curb ramp that is both aligned with the crosswalk and exactly perpendicular to the curb face. Generally, alignment of the curb ramp with the crosswalk is preferable to providing a ramp that is exactly perpendicular to the curb face.
- One curb ramp should be placed for each direction of pedestrian travel. Where space is limited, a blended transition may be used to serve both directions of pedestrian travel.
- Curb ramps should not be located coincident with storm drain inlets, which can catch wheelchair casters or cane tips.
- Curb ramps should be designed for adequate drainage. The presence of a puddle of water at the base of a curb ramp can hide pavement discontinuities and can lead to icy conditions during cold weather.
- Curb ramps should be situated so they are adequately separated from parking lanes. Regulatory signs and parking enforcement can discourage vehicles from blocking or backing across a crosswalk or curb ramp.
- Use of curb extensions physically separates parked vehicles from the curb ramp.



Where the sidewalk is too narrow to accommodate the length of a curb ramp without exceeding the maximum grade or too narrow to accommodate a landing, alternatives include: (1) providing a gradual lowering of the sidewalk and curb height on the approaches to the corner; (2) purchasing or obtaining an easement from the adjacent property to provide additional right of way adjacent to the sidewalk; (3) installing a raised crossing; or (4) adding a curb extension.

Where a large turning radius cannot be made smaller, it may not be practical to align the curb ramp run entirely parallel to the crosswalk and still be perpendicular to the curb face. In these cases, an alternative is to install two perpendicular curb ramps aligned parallel to the crosswalk by introducing a short landing at the bottom of the curb ramp. This will improve wayfinding into the intersection for pedestrians with visual disabilities. Another alternative for large turning radii, where sufficient right-of-way is available, is to construct two perpendicular curb ramps leading to a single 5-ft (1.5 m) landing area just behind the curb line.

If a perpendicular approach is not provided, pedestrians who use wheelchairs would face a change in cross slope with only one front or rear wheel in contact with the ground. Thus, where a perpendicular approach is not provided, a grade break perpendicular to the direction of travel must be installed at the bottom of the ramp.

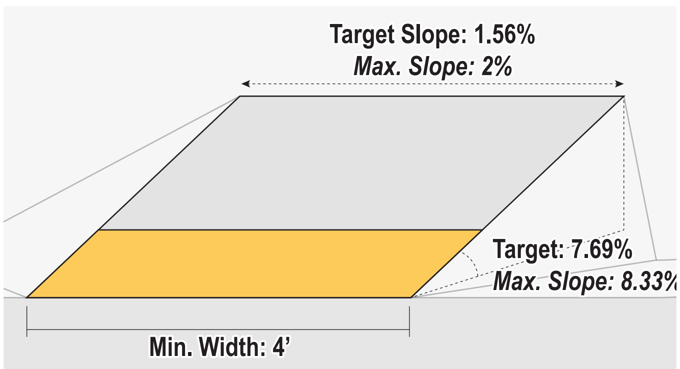


Curb Ramp Components

The basic components to the standard curb ramp design are explained in the following subsections and depicted on **Figure 15**.

Ramps

Ramps serve as the primary travel path for wheelchair users and other pedestrians traversing the curb between the sidewalk and the roadway. The grade of a ramp shall not exceed 8.33 percent. The cross slope shall not be greater than 2 percent. The minimum width of a curb ramp is 4 feet. To ensure ramp slopes do not exceed the maximum, ramps should be designed for 7.69 percent and 1.56 percent for running and cross slopes, respectively, to account for construction tolerances.

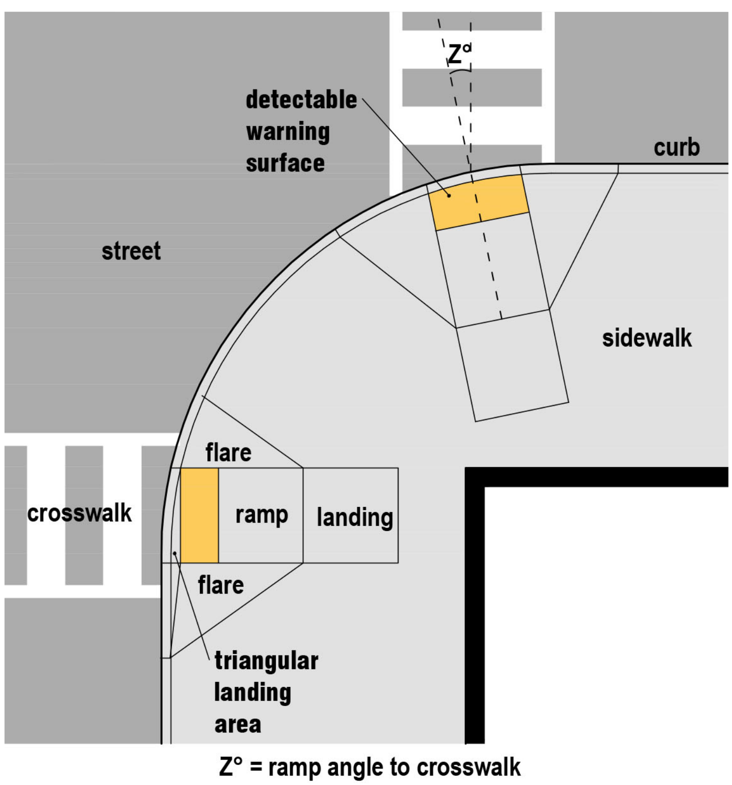


Gutters

Gutters facilitate the movement of water from the roadway into the local drainage system. Gutters require a counter slope (i.e., roadway cross slope) at the point at which the ramp meets the street for proper drainage. This counter slope should be 2 percent or less where possible, but shall not exceed 5 percent, and the change in angle must be flush, without a lip, raised joint, or gap. Lips or gaps between the curb ramp slope and counter slope can arrest forward motion by catching caster wheels or crutch tips. The algebraic difference between the ramp slope and the gutter counter slope cannot exceed 11 percent, or a 24-inch level strip must be provided between the two slopes.

In Fort Collins, barrier curbs should be used in accordance with Construction Drawings from the *LCUASS*. Otherwise, inflow curb and storm drainage inlets and systems shall be provided to carry storm water.

Figure 15: Perpendicular Curb Ramp Types: Non-Directional (top) and Directional (lower)



Landings

Landings provide a level area for wheelchair users to maneuver into or out of the curb ramp and can serve as turning areas. A level, 5 feet square landing is preferred; a 4 feet square landing is the minimum. Level landings are required at the top of ramps with slopes designed for 1.56 percent slope (2 percent maximum) in any direction.

Flares

Curb ramp flares are graded transitions from a curb ramp to the surrounding sidewalk. Flares are not intended to be wheelchair routes, are considered a non-walkable surface, and often serve as one of the cues used to identify the presence of a curb ramp. In most instances, flares are not required for curb ramps. When provided, flare slopes shall not exceed a 10 percent slope.

Side flares are essential in alterations when space for a top landing (36 inches deep minimum) is not available; in this instance, side flares with a max slope of 8.33 percent are necessary to accommodate wheelchair maneuvering that will partially occur at flares in the absence of full landing space at the top of the ramp unless a parallel-type curb ramp is provided. Parallel curb ramps provide an alternative in such conditions.

Detectable Warnings

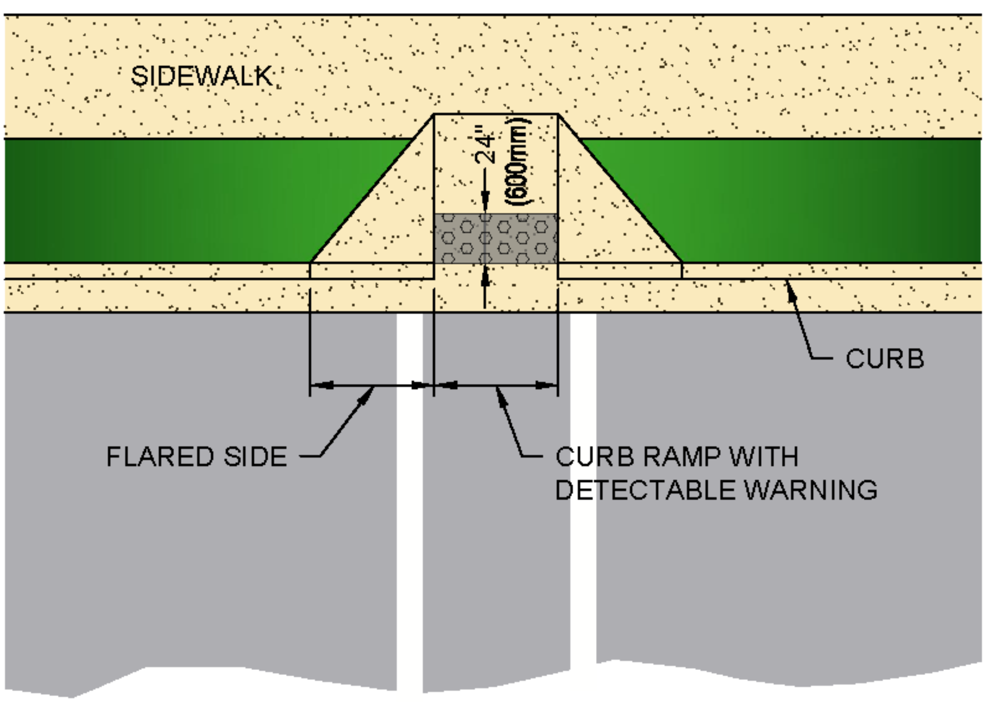
Detectable warnings are a distinctive surface pattern of truncated domes, detectable by cane or underfoot, used to alert people with vision disabilities of their approach to streets and raised crossings. Detectable warnings are also used at drop-offs on transit boarding platforms. The detectable warning surface indicates the boundary between pedestrian and vehicle routes where there is a flush rather than curbed connection. In fact, detectable warnings are a replacement cue for the curb to indicate the location of the street.

Detectable warnings are required on curb ramps at pedestrian street crossings on pedestrian access routes and must contrast visually with the adjacent surfaces. Detectable warning surfaces must extend a minimum of 2 feet (0.6 m) in the direction of pedestrian travel and must extend the full width of the curb ramp or blended transition (See **Figure 16**).

Truncated Domes

Truncated domes are specified as the detectable warnings to be used at the interface between the sidewalk and the roadway. They are to be included in all connections to all street crossings to mark the street edge where a Pedestrian Through Zone crosses a vehicular way.

Figure 16: Detectable Warning Treatment



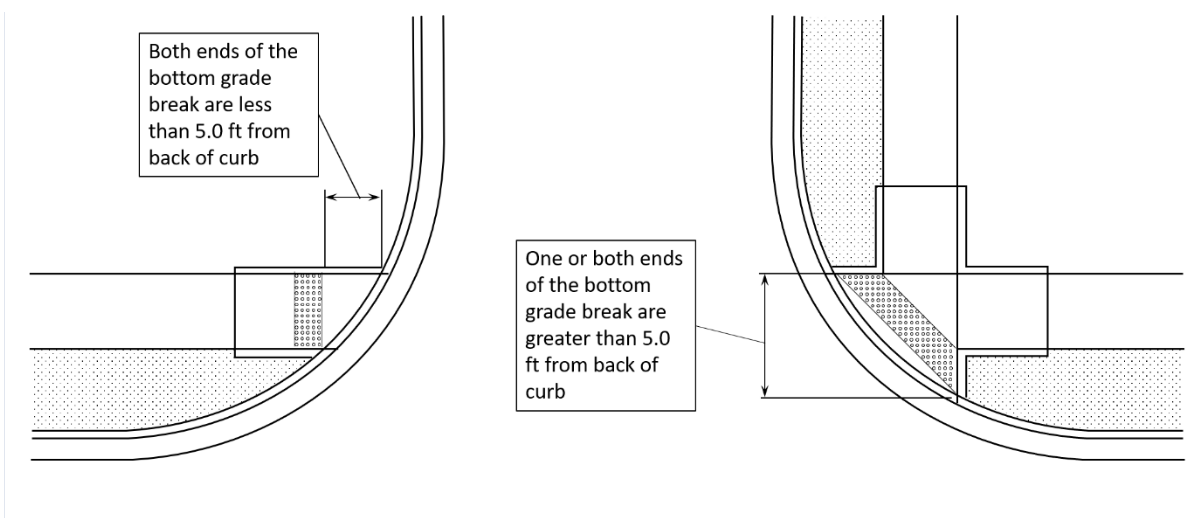
Placement and Orientation

Detectable warnings should generally be placed at back of curb, which is often where the bottom grade break of a curb ramp is found (See **Figure 17**). When perpendicular curb ramps meet curb radii, however, irregularly shaped areas often result between the bottom grade break and back of curb. The proposed Public Rights-of-Way Accessibility Guidelines (PROWAG)[1] indicates that detectable warnings should be placed at such locations, namely:

- Where the ends of the bottom grade break are in front of the back of curb, the detectable warnings should be placed at the back of curb.
- Where the ends of the bottom grade break are behind the back of curb, and both ends of the grade break are 5.0 feet (1.5m) or less from the back of curb, the detectable warnings shall be placed on the ramp run within one dome spacing of the grade break.
- Where the ends of the bottom grade break are behind the back of curb and the distance from one or both ends of the grade break are more than 5.0 feet (1.5 m) from the back of curb, the detectable warnings should be placed on the lower landing at the back of curb.

Detectable warning surfaces should be oriented such that the rows of domes are perpendicular to the grade break at the bottom of the ramp, so pedestrians in wheelchairs can more easily "track" between the domes, especially on surfaces with grades greater than 5 percent. The orientation of domes within the detectable warning strip is not intended to orient pedestrians with vision disabilities to the direction of the crossing. The domes are to be spaced not less than 1.6 in on center and not more than 2.4 in on center. Some textured surfaces intended to provide information about the location of a street or other feature are not, in fact, detectable. Grooves, crosshatching, exposed aggregate, and similar surfaces may be useful to prevent slippage, but are not detectable underfoot and not approved for this purpose, and may cause discomfort for some individuals using wheeled assistive devices.

Figure 17: Location of Detectable Warning Surfaces on Curb Ramps



1 PROWAG is currently being updated by the Access Board under the Americans with Disabilities Act (ADA) and the Architectural Barriers Act (ABA) and will address access to sidewalks and streets, crosswalks, and curb ramps. The Board is in the process of finalizing these guidelines. More can be found at access-board.gov/prowag/.

Blended Transitions

A blended transition is a raised pedestrian street crossing, depressed corner, or similar connection between the pedestrian access route made at the level of the sidewalk and crossing a street where the grade is 5 percent or less, such as on an uncurbed roadway.

Blended transitions can occur at intersection corners as well as at other street crossings. Blended transitions can be advantageous for pedestrians for several reasons. With the flat grade, no landing or turning space is needed at the top or bottom of the transition area. Maintaining the same sidewalk and ramp running slopes also simplifies the overall facility design and increases ease of use. The flatter design also eliminates sharp grade breaks between the walk and the traditional curb ramp area.

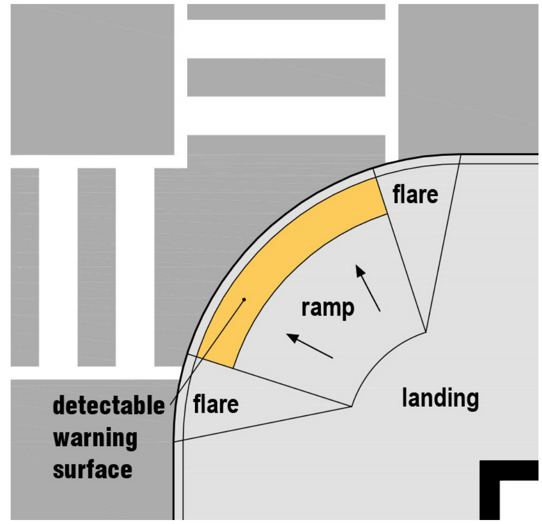
Blended transitions may also be used at raised pedestrian street crossings or raised crosswalks. To provide a clear delineation between the pedestrian walkway and the crossing or crosswalk, the detectable warning mat shall extend across the entire width of the interface between the sidewalk and the raised crossing or crosswalk.

Blended transitions may also be found at street crossings near major pedestrian generators such as sports arenas, transit hubs, convention centers, college or university campuses, or pedestrian-centric commercial areas. Blended transitions in these areas permit large volumes of pedestrians to cross roadways at a time. Similar to the raised crosswalk and intersection applications, truncated dome mats shall be placed along the full length of the transition area to delineate the boundary between pedestrian and vehicular facilities.

Design Considerations

ADA requirements for cross slopes and detectable warnings for blended transition are similar to those of a curb ramp. A landing is not required for a blended transition. Blended transitions must be wholly contained within the pedestrian street crossing served. At intersection corners, attempts to install actual curb ramps should be made before blended transition options are examined.

Figure 18: Blended Transition Example



To delineate the boundary between the pedestrian area and the vehicular area, detectable warning mats shall be placed along the entire extent of the depressed area, as shown in **Figure 18**. It is critical to ensure the detectable warning mats encompass the entire length of the area flush with the adjacent roadway so the boundary between the pedestrian area and vehicular area is clear to pedestrians with vision disabilities.

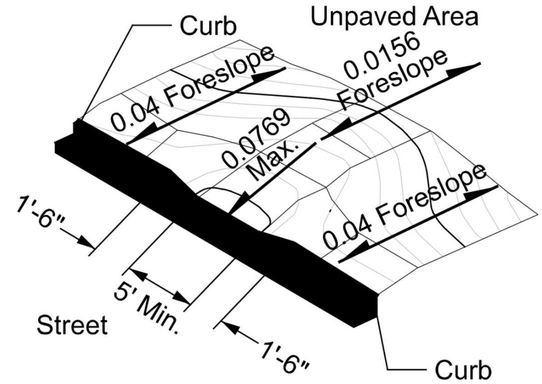
It is important to note that blended transitions between pedestrian travel ways and vehicular travel ways can create difficulties for pedestrians by providing a large area where the corner and street are at the same elevation. This can make it much more difficult to detect the boundary between the sidewalk and the street for persons with vision disabilities. Like diagonal curb ramps, depressed corners can make it more difficult for motorists to determine in which direction a pedestrian intends to cross the street.

Curb Cuts

Pedestrian curb cuts, or dropped curbs, eliminate the vertical curb face and may facilitate a pedestrian walking within the roadway to exit the roadway.

Pedestrian curb cuts should be placed where the pedestrian route is intended to continue across a roadway, but where a receiving curb ramp and sidewalk do not currently exist. This can be at the roadway edge, at a median or roundabout splitter island, or anywhere a curb presents a vertical face that is not traversable by a mobility device. **Figure 19** describes the required widths and slopes for a pedestrian curb cut.

Figure 19: Pedestrian Curb Cuts



Ramps and Landings

At times, sidewalks that are not adjacent to roadways may exceed a 5 percent longitudinal slope. Where this occurs, the pedestrian access route is treated like a ramp.

Per PROWAG R407, the maximum running slope, horizontal run, and vertical rise are summarized in **Table 6**. It is advised to provide a ramp with the least possible running slope in order to accommodate the widest possible range of users.

Landings should be clear of any obstructions, such as manholes, utility boxes, or valves, and ramps and landings should meet the surface requirements for pedestrian access routes as defined in *LCUASS* Standard Drawings.[2]

If the pedestrian access route does not have sloped grading adjacent to the ramp and has a vertical drop of more than 6 inches, a railing is required to protect pedestrians from stepping off the edge of the ramp. Dimensions for the railing can be found in PROWAG Section R-409.

Table 6: Impacts of Sidewalk Cross Slope On Pedestrian Stability

Walkway Location	Maximum Cross Slope
Within Street Crossing Without Yield or Stop Control at Intersection	5 percent
Mid-block Street Crossing	Match grade of street
All Other Pedestrian Walkways	1.56 percent

2 https://www.larimer.org/sites/default/files/uploads/2021/701-901_0.pdf

5.1.6 Bicycle Ramps

Bike ramps are used to improve bicyclist safety or comfort, to shift the elevation of a bikeway to a different elevation (e.g., from street-level to sidewalk-level), or to change the bicycle facility type (e.g., from a conventional bike lane to side path).

It is common to use bike ramps when approaching roundabouts, at interchange ramp crossings, or at high-conflict zones (such as heavy weaving areas or high turning volume intersections). In these situations, the bike ramp serves the purpose of allowing bicyclists to avoid sharing travel lanes with motorists. In some instances, it may be appropriate to provide a bike ramp that would be used by most bicyclists, but also provide an on-street option for Highly Confident and Somewhat Confident Bicyclists to allow them to ride in the shared lane environment.

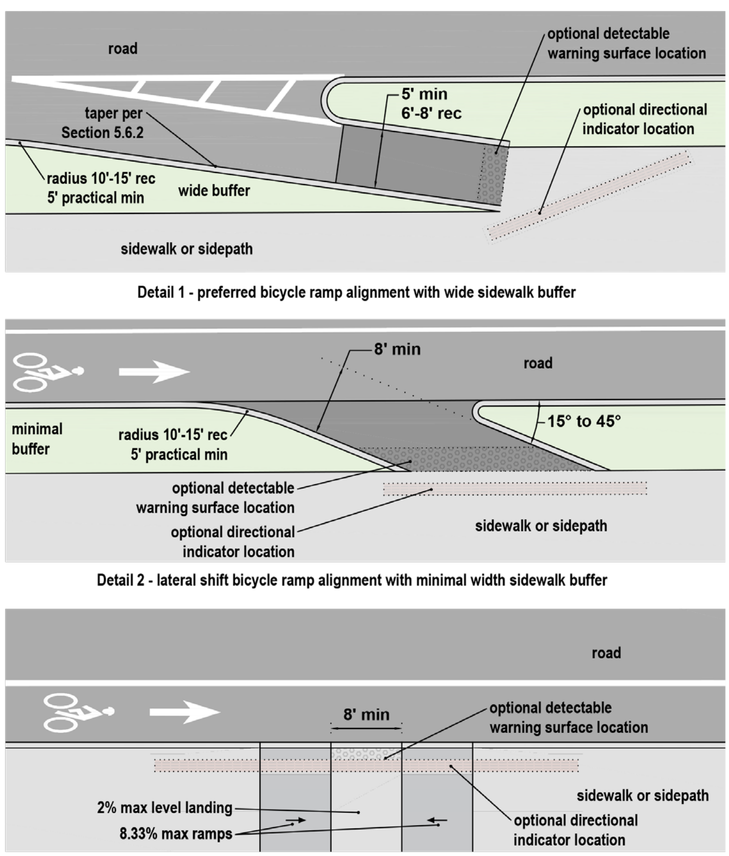
The other situation to use a bike ramp is approaching pedestrian conflict areas or raised crossings across a separated bike lane, where a change in elevation is desired to meet pedestrian accessibility guidelines, to slow bicyclists at conflicts, or to transition the bikeway elevation.

In either situation, the overall facility geometry, the extent of construction or type of project, or the types of bikeways being connected can affect the alignment of the bike ramp. **Figure 20** identifies two options for bike ramps that transition to a shared use path. Detail 1 is preferable to provide a bicyclist with a comfortable change in alignment and ensure grade breaks are parallel to the path of travel. Detail 2 should be used where there is insufficient space to provide the straight taper shown in Detail 1. Designers may encounter the following challenges with the design shown in Detail 2:

- Narrow bike ramp widths can force bicyclists to encroach on adjacent motorist travel lanes, pedestrian zones, or on-coming bicycle traffic on two-way facilities in order to access the ramp.
- If grade breaks at the top and bottom of the bike ramp are not perpendicular to the bicyclist path of travel, bicyclists with more than two wheels (e.g., adult tricycles or bikes with trailers) can experience instability or overturning.

In both situations, increasing the width of the bike ramp can help to address these issues.

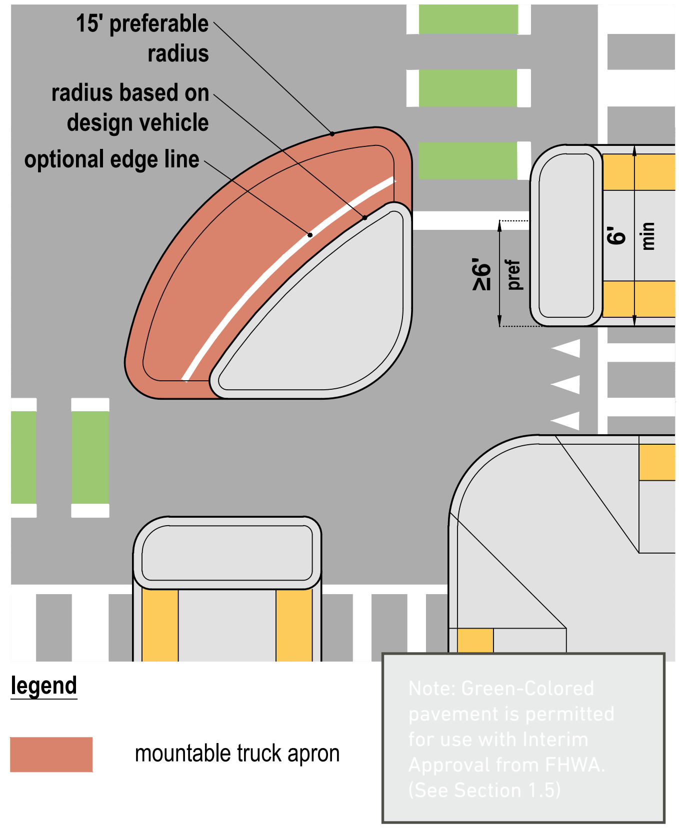
Figure 20: Bicycle Ramp to Shared Use Path or Sidewalk



5.1.7 Mountable Truck Aprons

While bicyclist and pedestrian safety is negatively impacted by wide crossings at roadway intersections, bicyclists and pedestrians are also at risk if the curb radius is too small. This can result in the rear wheels of a large vehicle tracking over queuing areas at the corner. Maintenance problems are also caused when large vehicles regularly drive over street corners to make turns. Mountable truck aprons are a solution that can reduce turning speeds for passenger vehicles while accommodating the off-tracking of larger vehicles where a larger corner radius is necessary (See **Figure 21**). Mountable truck aprons are part of the traveled way and as such should be designed to discourage pedestrians or bicyclists from using them as a safe queuing area. Bicycle stop bars, detectable warning surfaces, traffic signal equipment, and other intersection features must be located behind the mountable surface area. The mountable surface should be visually distinct from the adjacent travel lane, sidewalk, and bike facility. The heights of mountable aprons and curbs should generally be no more than 3 in. above the travel lane to accommodate.

Figure 21: Mountable Truck Apron



5.1.8 Raised Crossings (Multiple Threat Crossing Solutions)

Raised crossings are an effective strategy for reducing crashes between motorists and bicyclists because they slow the turning speed of motor vehicles, increase visibility of vulnerable street users, and increase yielding behavior of motorists. Raised crossings should be considered for crossings where motorists are required to yield the right of way to bicyclists when approaching the crossing or at a turn. However, raised crossings may not be appropriate across streets where posted speeds are over 30 mph. Designers should also consider the effects of raised crossings on drainage and pedestrian accessibility.

Raised Crossing in Commercial District

Examples where this treatment may be particularly beneficial include the following types of crossings:

- Unsignalized collector and local street crossings with side paths or separated bike lanes along arterials
- Crossings of driveways and alleys
- Crossings of channelized right turn lanes and roundabouts
- Intersections where a large corner radius is required to accommodate large vehicles

Design Considerations

Raised crossings are similar to speed tables and should have the following design characteristics (see **Figure22)**:

- They should be elevated 3 to 6 in. above the normal street elevation.
- Motor vehicle approach ramps should have a 5 to 8 percent slope (relative to the street).

Yield lines or speed hump markings should be used on uncontrolled motor vehicle approaches to indicate where motorists should yield to bicyclists and pedestrians.

The surface materials, color, and texture of the shared use path, separated bike lane, and adjacent sidewalk, if applicable, should extend through the crossing, maintaining visual continuity to encourage motorists to yield at the crossing.

Figure 22: Raised Side Street Crossing

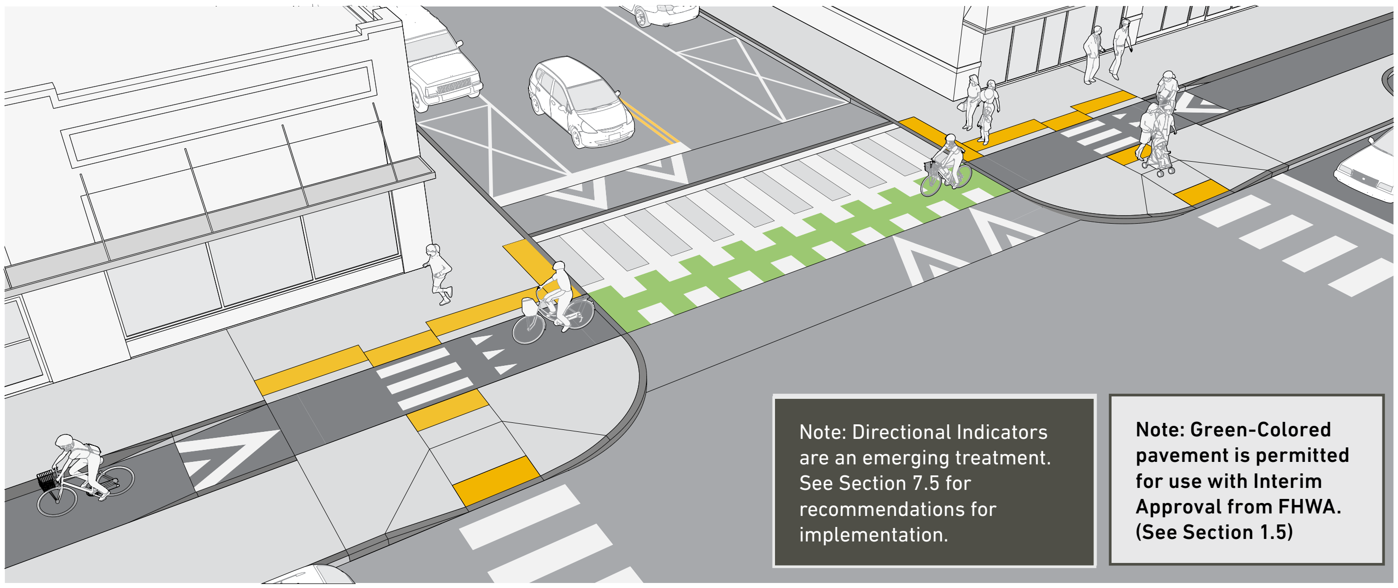
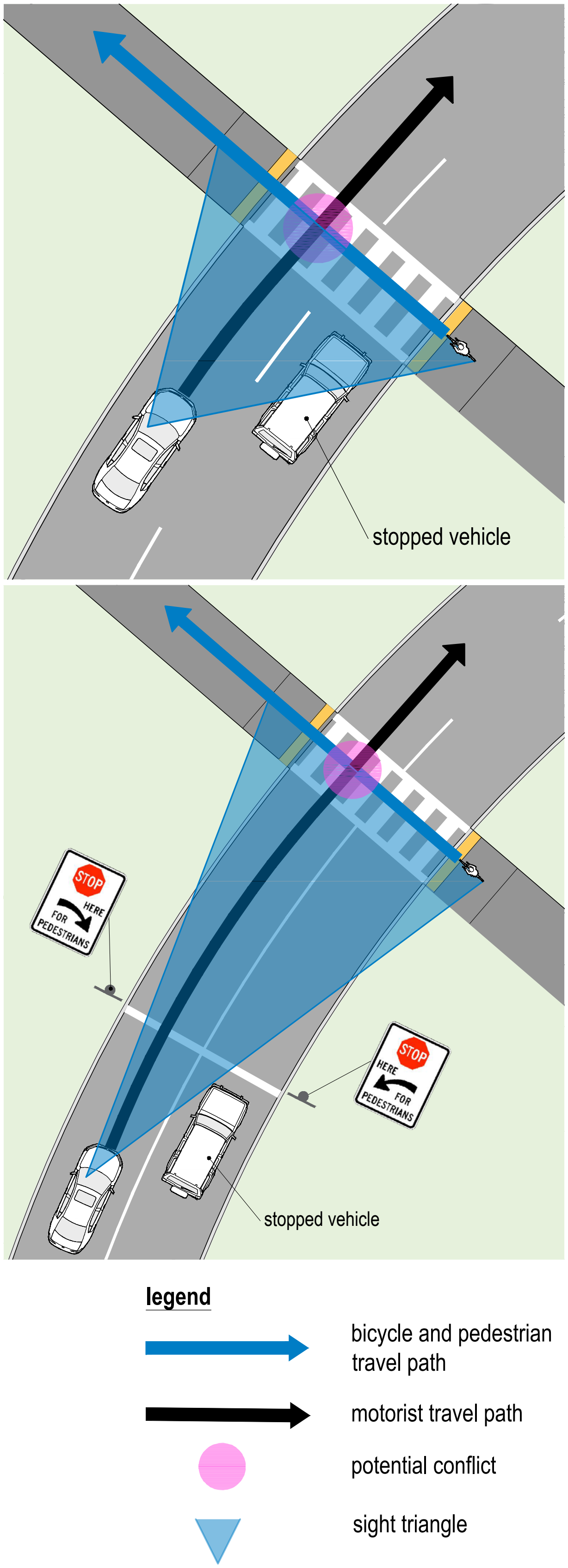


Figure 23: Multiple Threat Crash and Treatment to Address



At bicycle crossings where two or more travel lanes approach from one direction, there is increased potential for a multiple-threat crash. A multiple threat can occur when motorists yield or stop too close to crossings of uncontrolled multilane approaches, placing pedestrians and bicyclists at risk by blocking other approaching motorists' views of the crossing pedestrians or bicyclists. The stopped vehicle also blocks pedestrians' and bicyclists' views of vehicles approaching in the other lanes. Multiple threat crashes often result in severe injuries or fatalities for pedestrians and bicyclists (See **Figure 23**).

The provision of an advance stop line (or yield line) with "Stop Here For (or "Yield Here To") Bicyclists" (and Pedestrians if needed) signs can reduce the crash risk by encouraging the first stopped vehicle to yield farther from the crossing which improves the sight line between the crossing person and approaching motorists in the adjacent lanes. Solid lane line markings should be used to discourage motorists from changing lanes approaching the stop or yield line equivalent to the stopping sight distance for motorists.

The stop or yield lines should be placed 20 feet (minimum) to 50 feet (maximum) in advance of the crossing. The minimum distance should only be used where vehicle approach speeds are 30 mph or less. As speeds increase, the distance the stop or yield lines are placed from the crossing should be increased to account for the higher motorist approach speed. The roadway geometry may also justify increasing the distance between the stop or yield line and the crossing to account for motorist sight lines. This treatment should be considered at all uncontrolled, or pedestrian hybrid beacon-controlled, mid-block, or intersection crossings where a multiple threat crash could occur.

5.1.9 Neighborhood Traffic Circles

Neighborhood traffic circles are primarily used at four-leg, two-lane local streets and are installed to reduce crash severity and slow traffic speeds. Splitter islands are not required on approaches (unlike a modern roundabout), and the central island is typically raised with a mountable apron to prevent a straight-through movement of the typical design vehicle. The occasional control design vehicle should not be precluded from operating within the intersection with encroachment, if necessary, which may include going the "wrong way" to the left of the traffic circle to make a left turn. Landscaping may be planted with the center median if it does not need to be traversable. The local streets typically do not have marked centerlines.

Neighborhood traffic circles typically serve as intersections in primarily residential areas where daily motor vehicle volumes for all approaching legs of the intersection is less than 15,000 ADT, or as intersections along traffic-calmed neighborhood bikeways.

Design Considerations

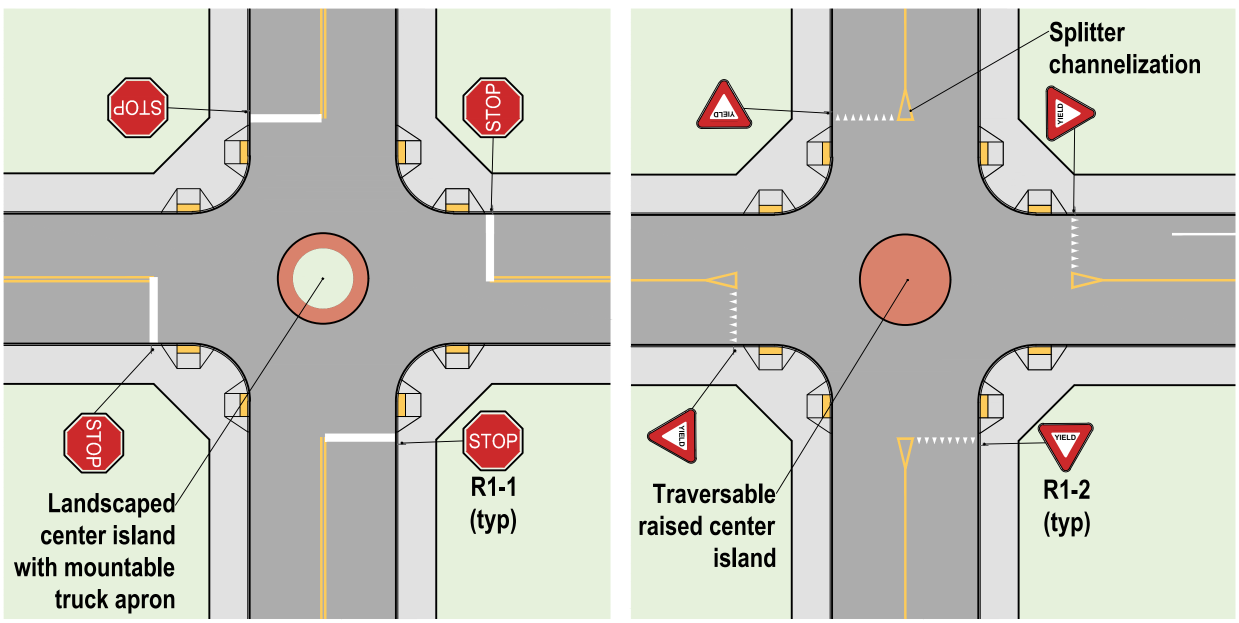
The following design standards should be followed for neighborhood traffic circle intersections:

- 15' of clearance should be provided from intersection corners to edge of traffic circle. This may include a mountable truck apron.
- Use the largest traffic circle radius possible to encourage slow speeds.
- Mark crosswalks ahead of each approach/entrance to the traffic circle.

Figure 24: Planted Neighborhood Traffic Circle

- Traffic controls may be used in addition to the traffic circle. If used, mount "Yield" (R1-2) or "Stop" (R1-1) control signs at motor vehicle approaches to the circle.
- Mount a R6-4 directional sign in the circle when possible. Mount the R6-5P on the "Stop" or "Yield" sign post if a sign can't be mounted within the circle. Use corner curb extensions or splitter islands to channelize motor vehicles and further reduce speeds.
- The aesthetic value of a traffic circle is an important part of its design. Well-designed traffic circles fit naturally into the neighborhood and can include landscaping, green street elements, or decorative pavement such as stamped concrete, pavers, etc.
- Traffic circles should be visible to street users with pavement marking, signing and reflectors used where appropriate. Regulatory and/or warning signage should be provided to advise traffic to proceed counterclockwise around the circle.
- Careful attention should be paid to the available lane widths and turning radius used with traffic circles to accommodate the design vehicles.
- Maintaining access to underground utilities must be considered

Figure 25: Schematic Examples of Mini-Roundabouts and Neighborhood Traffic Circle



Typical Neighborhood Traffic Circle with Stop Control (If Warranted)

Typical Mini-Roundabout

5.1.11 Roundabouts

Roundabouts are a popular design solution for intersections because they reduce delay for motorists and increase capacity through an intersection compared with a stop-controlled intersection, while also reducing travel speeds and the number of conflict points. While a confident bicyclist may be comfortable traversing a roundabout in a shared lane environment, many bicyclists will not feel comfortable navigating roundabouts with vehicular traffic, especially multilane roundabouts. Bike lanes are not to be located within the circulatory roadway of a roundabout per the MUTCD. For comfort and safety reasons, roundabouts may be designed to facilitate bicycle travel outside of the circular roadway on a separated bike lane or shared use path.

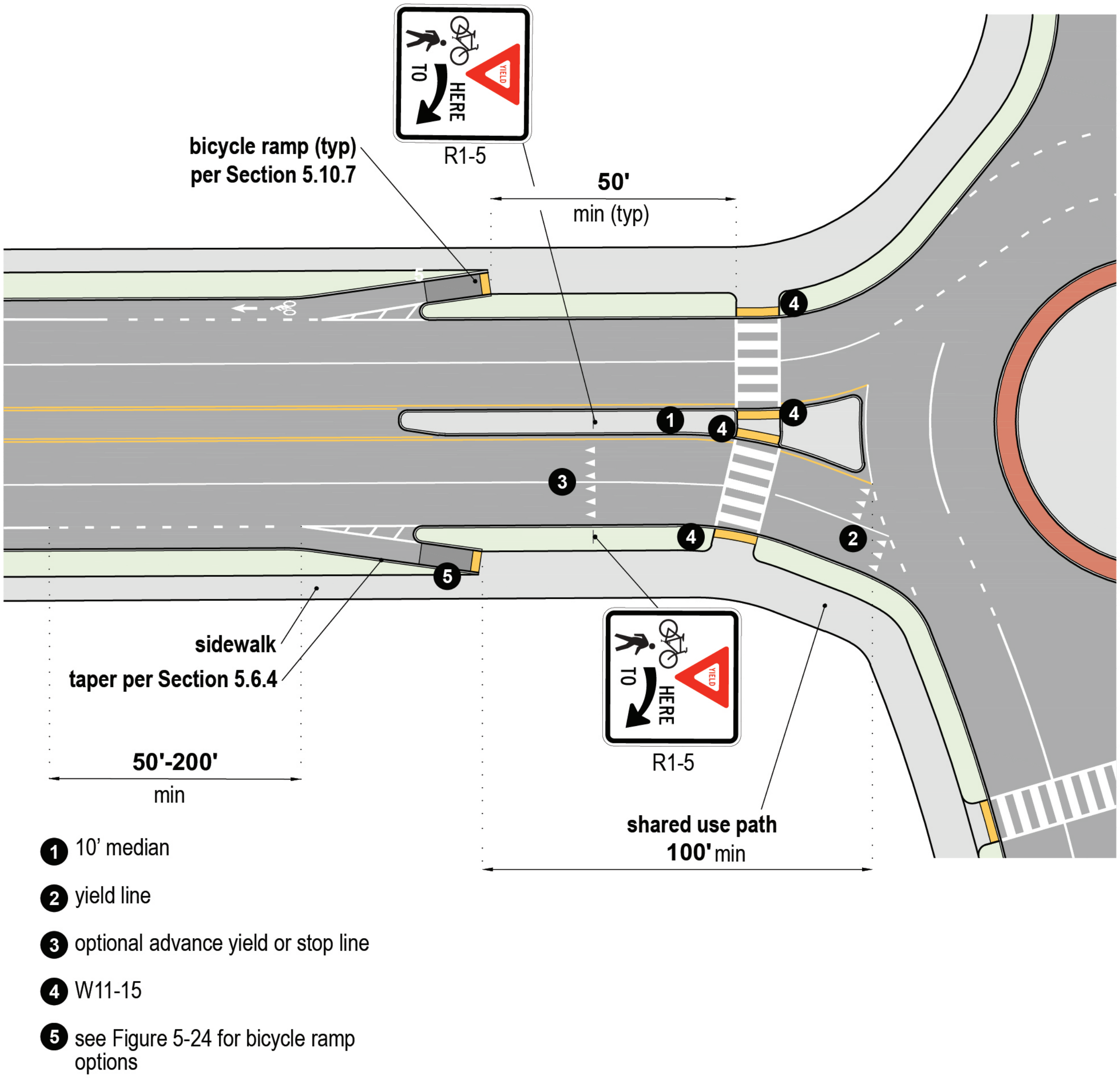
Although on-street bike lanes are to be terminated in advance of roundabouts, some bicyclists may choose to ride through the circulatory roadway as a vehicle rather than using a separated bikeway. Shared lane markings may be used within the circulatory roadway of the roundabout to indicate the preferred bicyclist position in the center of the lane.

Transitions to Separated Bikeways at Roundabouts

Accommodations should be provided to allow on-street bicyclists to move from the roadway to an adjacent separated bikeway before reaching a roundabout. The type of separated bikeway (i.e. separated bike lane or shared use path) is determined primarily by the anticipated volume of bicyclists and pedestrians. This transition from on-road to separated bikeway should be located a minimum of 100 feet from the edge of the roundabout circulatory roadway (See **Figure 26** and **Figure 27**). If on-street bike lanes are present, they should be terminated in advance of the roundabout at the transition to the separated bikeway.

As shown on **Figure 26**, if the elevation of the separated bikeway differs from the on-road facility, a bicycle ramp must be provided to transition between these facility types. An appropriate taper of the bike lane should be provided to narrow the entry width for the roundabout. The taper should end prior to the crosswalk at the roundabout, to achieve the shortest practical pedestrian crossing distance. The bike lane line should be dotted for 50 to 200 feet in advance of the taper to provide guidance to bicyclists who wish to travel the roundabout in the shared lane.

Figure 26: Typical Layout of Bike Lane Transitions to Shared Use Path at Multilane Roundabout with Bike Ramps



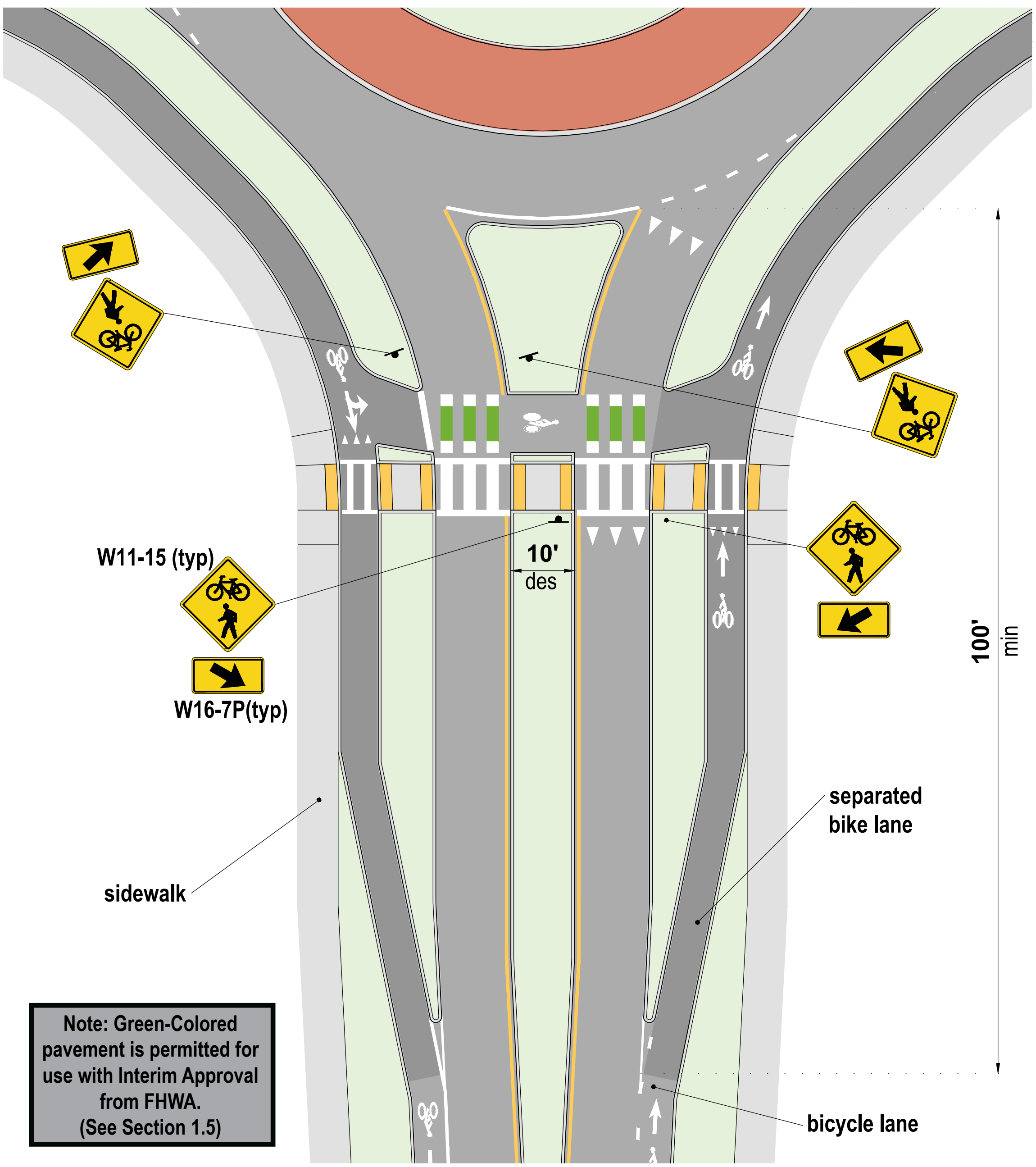
Separated Bike Lanes at Roundabouts

When separated bike lanes are provided on approaches to roundabouts, they may be continued around the intersection to maintain the continuity of the bikeway. When bike lanes are provided on approaches to roundabouts, and if it is desirable to maintain separation between bicyclists and pedestrians, the bike lanes may transition to separated bike lanes around the roundabout.

Separated bike lanes at roundabout crossings should provide the following features:

- Yield control for motorists at the bicycle crossing
- Channelizing islands or detectable surface materials to maintain separation between bicyclists and pedestrians throughout the crossings
- "Bicycle/Pedestrian Warning"signs (W11-15) at the bicycle and pedestrian crossings
- Roundabouts shall also be the preferred form of traffic control at any intersection that meets MUTCD warrants for the installation of all-way stop control

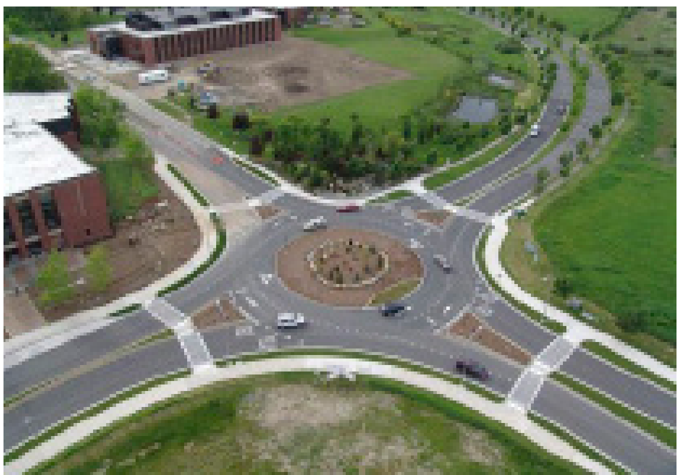
Figure 27: Typical Layout of Separated Bike Lanes at Roundabout



Shared Use Paths at Roundabouts

When shared use paths are provided approaching a roundabout, they should be continuous around the circulating roadway. Shared use path design at roundabouts is similar to separated bike lane design, and should include the following features:

- Minimum shared use path width of 10 feet
- Widened curb ramps that match the shared use path width at crosswalks to facilitate pedestrians and bicyclists at the crossings
- Supplemental yield lines for crossings at roundabout exits to reinforce motorist yielding
- "Bicycle/Pedestrian Warning" signs (W11-15) at the shared use path crossings



Shared Use Path at Roundabout

On-Street Bicycle Travel through Roundabouts

The geometric features of a roundabout (e.g., entry and exit radii, entry and exit widths, splitter islands, circulatory roadway width, and inscribed circle diameter) can combine to maintain lower desired motor vehicle speeds around a roundabout. With typical on-street bicyclists traveling between 10 and 20 mph, roundabouts that are designed to maintain similar motor vehicle speeds can be comfortable for bicyclists.

Single-lane roundabouts are much simpler for bicyclists to navigate than multilane roundabouts because bicyclists will not need to change lanes approaching the circulatory roadway and they will experience fewer conflicts with merging motorists within the roundabout. Furthermore, limiting entry and exit legs to single-lane approaches and departures reduces bicyclist and pedestrian exposure to conflicts and eliminates multiple-threat risks. Therefore, when designing and implementing roundabouts, designers should avoid implementing multilane roundabouts if existing traffic volumes do not necessitate their higher capacity.

If traffic volumes indicate the need for a multilane roundabout, but this need is not likely for several years, the roundabout can be built as a single-lane roundabout and designed so that additional lanes may be opened in the future when and if traffic volumes increase. No leg of a roundabout should be designed with more travel lanes than is necessary to accommodate the traffic volumes. This design approach can significantly reduce complexity for all users, including bicyclists. More information can be found in Appendix I, Roundabout Design Manual, of the LCUASS standards.[3]

3 https://www.larimer.org/sites/default/files/uploads/2021/appendix_i_-_roundabout_design_manual_0.pdf

5.2 Warning and Regulatory Traffic Control Devices

The following section provides guidance for warning and regulatory traffic control devices, which can improve pedestrian and bicyclists' safety and operation for all types of facilities. Ultimately, traffic controls are under the purview of the City Traffic Engineer.

5.2.1 Pedestrian Signal Phasing

Pedestrian signals are part of a system of traffic signals that control intersection operations for people walking and rolling. Pedestrian signal phasing is intended to minimize exposure of people walking and rolling to motor vehicles, minimize delay for people waiting to cross the street, reduce noncompliant and unsafe crossing behavior, and provide accessibility benefits to people with disabilities.

Pedestrian phasing falls into three categories: concurrent, exclusive, or a hybrid of the two. As much as possible, consistent approaches to pedestrian phasing should be used across the city to help make the pedestrian network predictable and consistent.

- **Concurrent phasing** refers to phasing schemes that allow people to walk across the street at the same time and in the same direction as motor vehicle traffic. Concurrent phasing minimizes delay for all users.
- **Exclusive phasing** provides a separate phase for people walking and rolling that prohibits all motor vehicle movements while people walk across the street. Exclusive phasing can provide safety benefits by eliminating conflicts with motor vehicles; however, it often creates longer delays for all modes and leads to less safe, non-compliant crossing behavior where right of way is unclear.
- **Hybrid phasing** may be beneficial at complex intersections including those with skewed intersections, multiple lanes of traffic, and leading protected left-turn phases. Hybrid pedestrian phasing uses concurrent phasing to minimize delay for people walking and rolling on those legs of the intersection where conflicts are minimal, while providing an exclusive phase for more challenging legs of the intersection.

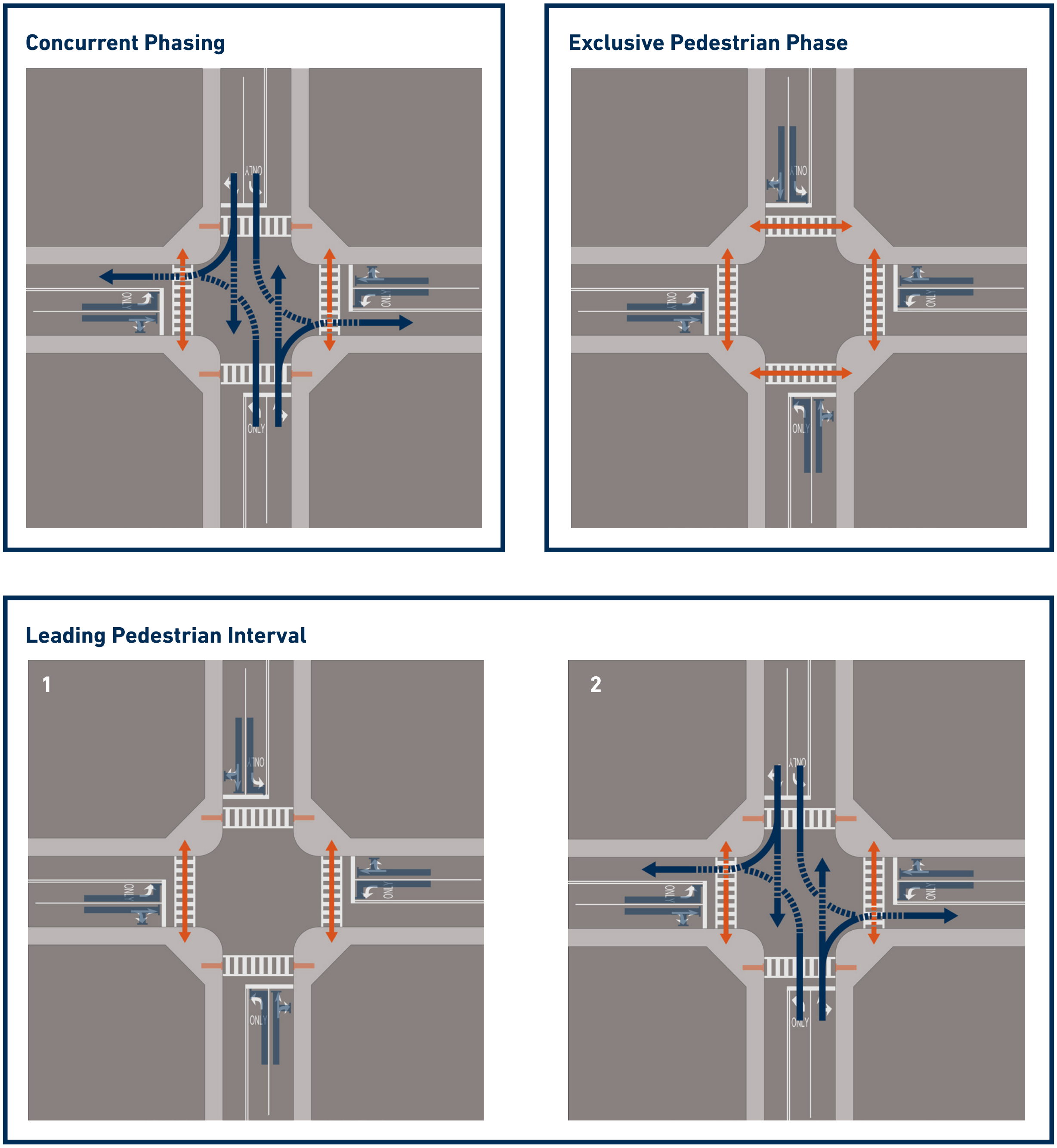
Design Considerations

The following design considerations should be used when implementing pedestrian signal phasing at intersections:

- A walking and rolling speed of 3.5 feet per second should be used to time all pedestrian phases and provide adequate time for people to cross the street. Time signal phasing so that people walking and rolling have adequate time to cross both sides of a median-divided street during a single walk phase.
- Provide accessible pedestrian signals (APS) to assist people with disabilities.
- Concurrent Phasing:
    - Use concurrent phasing at all signalized intersections, except where a strong safety concern is noted due to high turning movement volumes (250 or more turning movements per hour).
    - Leading pedestrian intervals (LPIs) should be used where concurrent phasing is applied to give people walking and rolling across the street a head start before other street users are allowed to proceed. LPIs encourage people driving to yield to pedestrians while they are turning and improve visibility between all users. Consider 'No Turn on Red' restrictions at all locations where LPIs are implemented.
    - Where concurrent phasing is used, consider placing signals on automatic pedestrian recall (parallel to the coordinated direction of traffic), particularly in high pedestrian traffic areas, such as within commercial areas and within a 10-minute walk shed of bus routes or transit stations.
    - Protected left-turn phases provide an exclusive phase for people driving to turn left and may be warranted if there is a pocket lane or center turn lane and high volumes of turning or opposing traffic on the street. In these cases, lagging left turns (left turn signal at the end of the 'green' phase) should be considered instead of leading left turns (left turn signal at the beginning of the 'green' phase) to preserve the ability to use LPIs with concurrent phasing. The lagging left turn phase should be provided for both directions of traffic to avoid conflicts between through movements and permissive left turns. Geometry may limit the ability to run concurrent left turn phases.

- Exclusive Phasing:
  - Consider use of exclusive phasing where high concentrations of people walking and rolling are present or where at least 250 motor vehicles turn right (or left on one-way streets) per hour along any approach.
  - No Turn on Red restrictions should be considered at all locations where exclusive phasing is used.
- Ensure all pedestrian signal heads are correctly oriented to be visible to all users who are directed to follow the signal indications.
- Countdowns are required for all newly installed/replaced pedestrian signals and provide a pedestrian countdown in pedestrian signal heads to assist people with street crossings.

Figure 28: Pedestrian Signal Phasing Schematics



5.2.2 No Turn on Red Restrictions

"No Turn on Red" signs are used to restrict motor vehicles from turning right or left at signalized intersections, during the red indication. Restricting this movement eliminates conflicts with bicycles and pedestrians crossing in front of motor vehicles making turns.

"No Turn on Red" signs should be considered at signalized intersections with one or more of the following features or characteristics:

- An exclusive pedestrian phase where motor vehicles are to remain stopped while pedestrian movements commence.
- A leading pedestrian interval.
- High volumes of pedestrian and turning motor vehicle conflicts.
- Poor sight distances and visibility.
- Geometry of the intersection may result in unexpected conflicts.
- More than three crashes reported in a 12-month period between pedestrians and motor vehicles where turn-on-red is permitted.
- Bicycle boxes.

Design Considerations

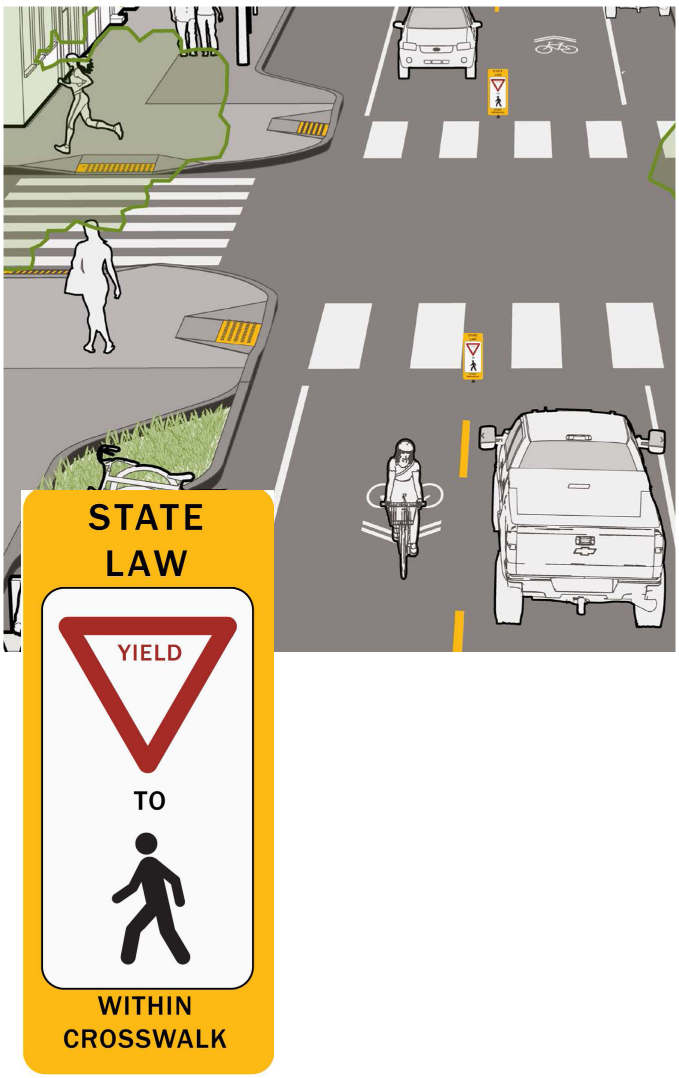
In order to implement "No Turn on Red" signs consistently, the following design considerations should be obeyed:

- "No Turn on Red" signs can be provided at all times or by a dynamic sign that changes when pedestrians are present, by time of day, by a call made by an emergency vehicle, and/or at rail or light transit crossings.
- "No Turn on Red" signs can also be used in conjunction with leading pedestrian intervals or bicycle signals that allow through movements when turning vehicular traffic is stopped.

5.2.3 In-Street Yield to Pedestrian Signs

In-street Yield to Pedestrian signs are signs placed in the roadway at crosswalk locations to remind roadway users of the laws regarding the right of way at unsignalized mid-block locations and intersections. They also increase awareness and visibility of pedestrians crossing the roadway. They are often used in busy business districts; at school crossings and other locations with vulnerable populations such as seniors and families; or where high pedestrian volumes occur in unexpected locations.

Figure 29: In-Street Yield to Pedestrian Signs



In-street signs can be used accordingly in conjunction with advanced warning signs and pedestrian crossing signs at crosswalks:

- In-street Yield to Pedestrian signs must only be used at unsignalized intersections. They are prohibited from use at signalized or all-way stop-controlled intersections.
- In-street Yield to Pedestrian signs work best on low-speed, two-lane roads. They are not recommended for roads with three or more lanes, or roads with high speeds or volumes where drivers are less likely to see them.

Design Considerations

The following design standards should be followed for In-street Yield to Pedestrian signs:

- In-street Yield to Pedestrian signs should be placed in the roadway close to the crosswalk location on the center line or on a median island, but they should not obstruct the crosswalk. In-street signs should also be placed to avoid turning motor vehicles from knocking over the sign and should be designed to bend over and bounce back when struck.
- Use MUTCD as additional guidance for sign design.
- May be permanent or temporary. It may be preferable to remove them during winter for snow removal. If there are maintenance issues, alternative treatments should be considered.
- Require regular monitoring and should be replaced when damaged. Damaged signs send the message to pedestrians that a crossing is not safe.
- Are typically not used at yield-controlled intersections and should only be installed using engineering judgment.
- May be used in combination with pedestrian warning signs. Warning signs should be placed on the right side of the road on the sidewalk or mounted on a mast arm above the crosswalk.

5.2.4 Uncontrolled Pedestrian Crossings

Uncontrolled pedestrian crossings can be found in every neighborhood in Fort Collins and are an important part of the pedestrian network. The *2011 Fort Collins Pedestrian Plan* provides detailed information for planners and engineers about uncontrolled crosswalks as well as how to determine the appropriate treatment to ensure safety and efficient movement of all users of the transportation system. This section serves as a supplement to these guidelines, and is supported by the City of Fort Collins Pedestrian Crossing Policy.

Uncontrolled crossings are typically found at intersections of lower-volume roads that do not require signalization. Several factors are used to determine whether to mark a crossing:

- Crosswalks should be considered at all signalized intersections and at all-way stop controlled intersections with centerline striping on one or both approaches and should follow guidance in the City of Fort Collins Pedestrian Plan and the Pedestrian Crossing Policy.
- At uncontrolled locations, crosswalks may be installed when they meet one or more of the following criteria:
    - Where demand requirements of 20 pedestrians/hour, applying conversion factor of 1.33 for vulnerable populations, and where the location meets sight distance requirements (AASHTO's A Policy on Geometric Design for Highways and Streets) or sight distance obstructions can be removed,
    - Where a location meets MUTCD's pedestrian signal warrant or application guidance for a pedestrian hybrid beacon, a marked crosswalk and pedestrian hybrid beacon may be installed,
    - Where pedestrian delay of LOS D or worse exist, and/or
    - At locations directly serving a school, hospital, senior center, recreation center, library, commercial district, or park.

Design Considerations

The Fort Collins Pedestrian Plan and the Pedestrian Crossing Policy should be consulted for detail on crosswalk siting, pedestrian crossing types, and treatments. In addition, uncontrolled pedestrian crossings should be designed with the following in mind:

- Crosswalks at uncontrolled intersections should have continental crosswalk markings.
- Install ADA-compliant curb ramps (or blended transitions for raised crosswalks) to connect to accessible routes when constructing new crosswalks.
- Provide yield lines and regulatory sign R1-5 in advance of uncontrolled multilane midblock crossings. Use W11-2 signs for single-lane approaches.
- Restrict on-street motor vehicle parking at least 20' in advance of the crossing to provide adequate sight distance. Depending on context, signage, paint, or curb extensions, or other strategies to daylight crosswalks may be appropriate.
- Crosswalks should be as wide or wider than the connecting sidewalk. Crosswalk markings should be a minimum of 10' in width.
- Where a protected bike lane crosses a crosswalk, yield markings on the bike lane approach can emphasize that people biking or using dockless micromobility devices must yield to pedestrians within the crosswalk. This most commonly occurs at midblock crossings, protected intersections, and transit island stops.
- Streetlights should be located to front-light crosswalks, with the light source situated in advance of the crosswalk in the direction of motor vehicle travel. For wider intersections, it may be necessary to place light poles on all four corners of each intersection to adequately light a crosswalk. See *Larimer County Urban Area Street Standards*, "Chapter 15: Street Lighting" for details.
- Use special paving or brick to match local context in historic districts. Include white striping on both sides of the special pavers or materials.

5.3 Pavement Markings

Pavement markings are used to convey messages to roadway users about what part of the roadway to use, where to pass, and what is ahead. The following sections detail various types of pavement markings and how they should be used for pedestrians and bicycles in intersections.

5.3.1 Lane Lines

Lane lines divide a roadway into sections for either the same or various modes. Solid white lane lines indicate that modes should remain in their respective areas, whereas broken lane lines can be used to show areas where modes may need to merge, either due to space or turning needs.

Broken lane lines should consist of 3-ft line segments and 9-ft gaps. They may be used to separate same direction bicyclists (or other user) travel on two-way bicycle lanes and shared use paths. Dotted lane lines should consist of 2-ft line segments and 2- to 6-ft gaps. Dotted lane lines may be used to identify where motor vehicles should merge or cross bicycle lanes on approaches to intersections, or to extend bicycle lanes through intersections. Lane line markings should not be broken for minor driveways.

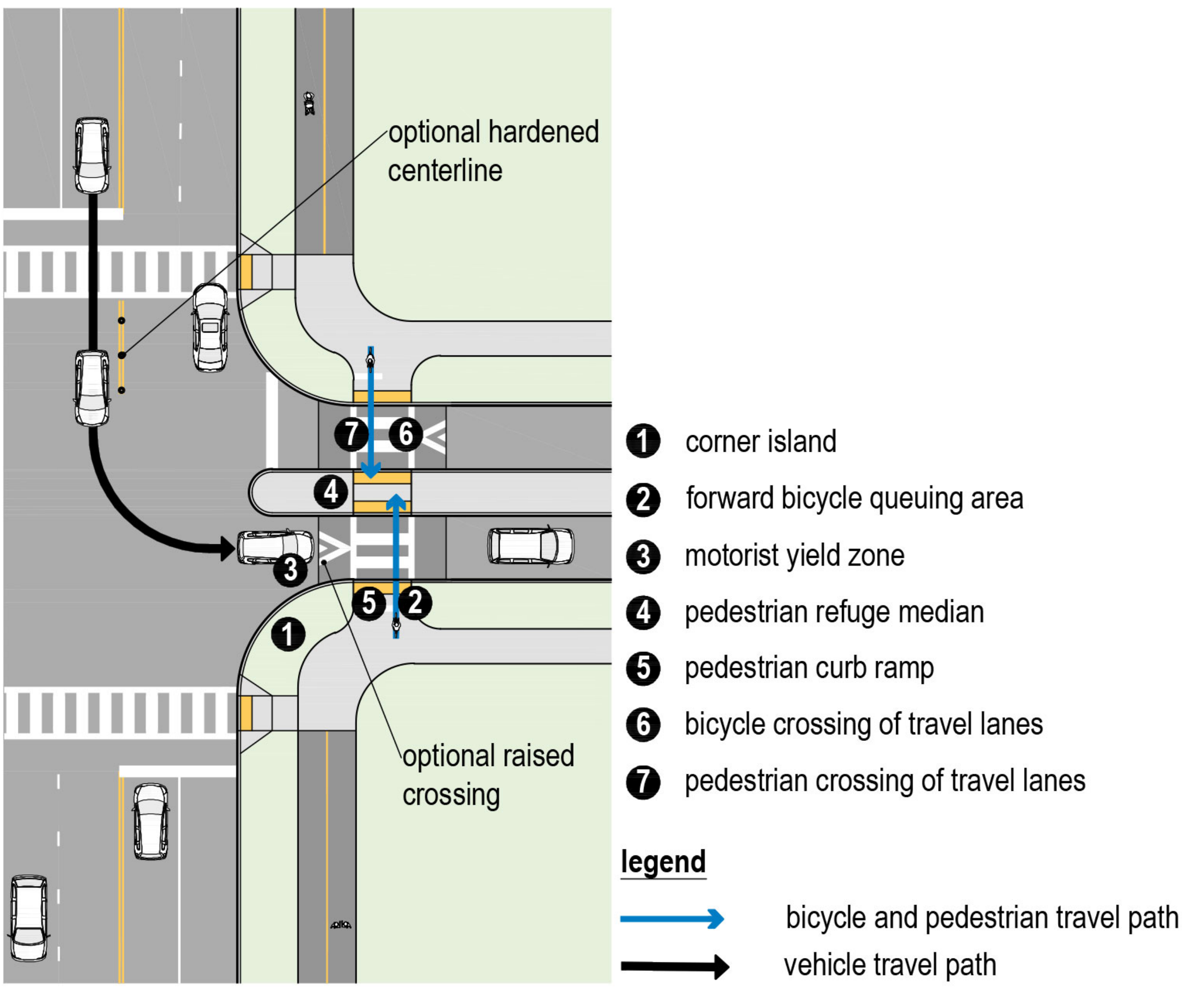
Pavement Markings Delineating Where Bicyclists Should Ride

5.3.2 Hardened Centerlines

Hardened centerlines consists of a painted center line supplemented by flexible delineators, rubber curb, In-Street Crossing Signs (Section 5.2.3), or a combination of these treatments. These treatments have been found to reduce left turn speeds of motorists and also keeps motorists from crossing the double yellow lines when making turning movements, reducing the effective turning radius of this maneuver.

The dimensions of a hardened centerline will depend on the intersection geometry and vehicle turning radius. Hardened centerlines should be considered where higher-speed left turns occur concurrent with pedestrian and/or bicyclist movements, as they have been found to reduce the speed of left turning motorists by reducing the effective turning radius. Hardened centerlines can be appropriate on both the departure roadway and the receiving roadway to control the left turning motorist path of travel. See **Figure 30** and **Figure 31**.

Figure 30: Example of Hardened Centerline Applications with Flexible Delineators on the Departure Roadway and a Pedestrian Crossing Island on the Receiving Roadway



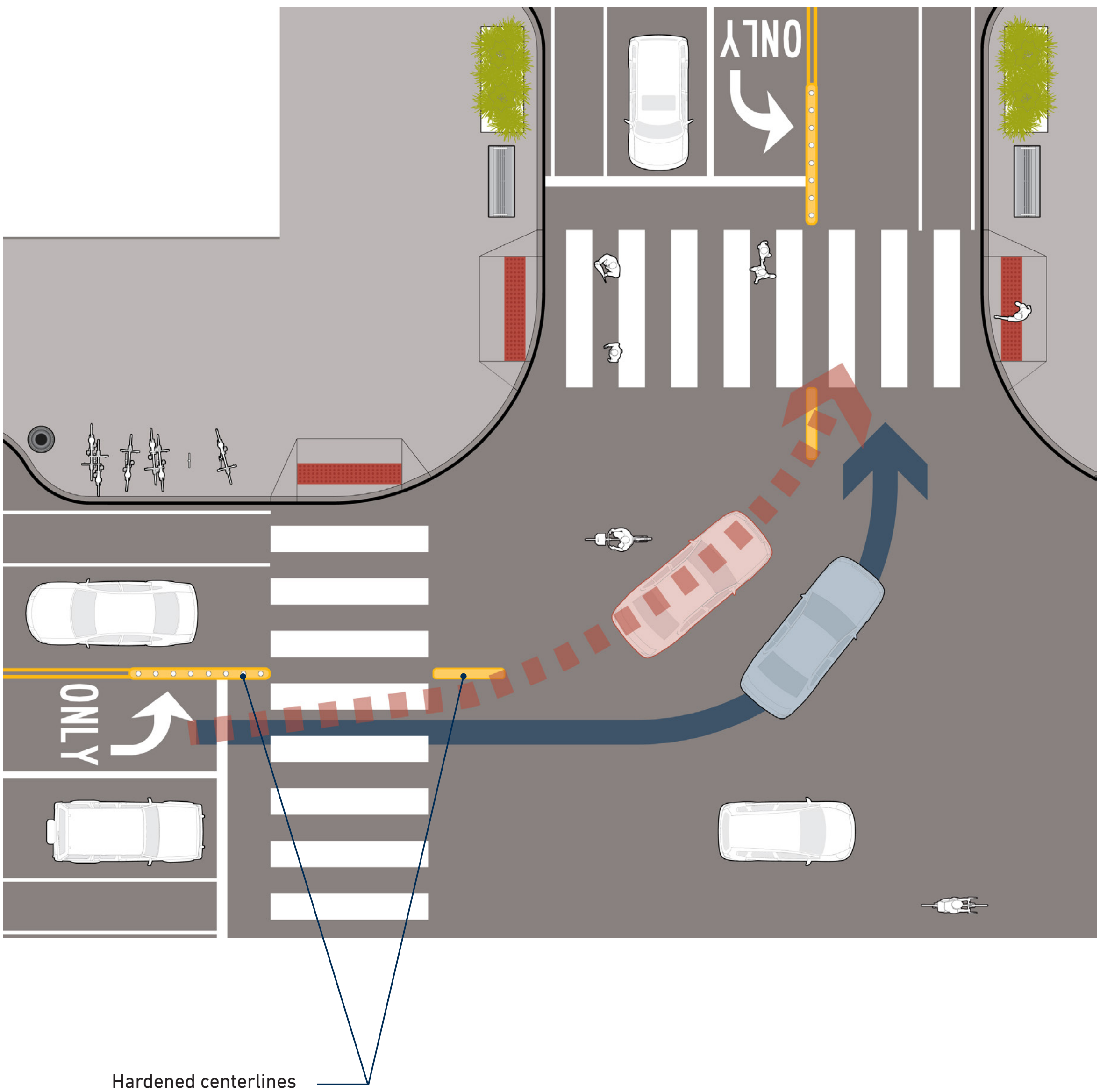
Hardened centerlines are especially useful at intersections with instances of crashes involving people walking or rolling and left-turning motor vehicles, or with high volumes of people walking, rolling, and biking crossing the street; and/or intersections where motor vehicles are frequently turning across double yellow lines at high speeds.

Design Considerations

The following design considerations should be use of hardened centerlines:

- Designs can include any combination of plastic curbing, rubber speed bumps, and flex posts, depending on turning radii, lane width, and needs to accommodate large motor vehicle turning movements.
- Where space allows, install rubber speed bump "nose" extending into the intersection.
- On roadways where trucks and emergency vehicles frequently make turning movements, consider using mountable curbs to allow larger motor vehicles to make turns while slowing smaller motor vehicles.
- Can be used in conjunction with turn wedges and at protected intersections.

Figure 31: Example of a Hardened Centerline



5.3.3 Shared Use Path and Pedestrian Crosswalks

Where bicyclist crossings of an intersection occur with pedestrians on a shared use path, crossings should be delineated with crosswalk markings. High visibility (diagonal or ladder style) marked crosswalks are recommended at uncontrolled intersections between paths and roadways. They delineate the crossing location and can help alert roadway users to the potential conflict ahead.

On roadways with low traffic volumes and speeds where sight distances are adequate, the marked crosswalk should be sufficient to accommodate pedestrians effectively. Additional crossing improvements are recommended at locations where motorists are uncontrolled and where the speed limit exceeds 40 mph and either:

- The roadway has four or more lanes of travel without a raised refuge median and an ADT of 12,000 vehicles/day or greater; or
- The roadway has four or more lanes of travel with a raised refuge median (either existing or planned) and an ADT of 15,000 vehicles/day or greater.

Shared Use Path Crossing at Intersection

Design Considerations

Locations where shared use paths intersect one another should follow similar design considerations for shared use path–roadway intersections, including:

- On a roadway approach to a shared use path crossing, placement of an intersection or advance traffic control warning sign should be at (or close to) the distance recommended for the approach speed in Table 2C-4 of the *MUTCD*. The assembly consists of a W11-15 or a W11-1 accompanied by a W16-7P (downward arrow) plaque mounted below the warning sign. This sign assembly should not be installed at the crossing if the roadway traffic is yield-, stop-, or signal-controlled. The W16-8P (shared use path name) plaque may be mounted on the sign assembly (below the W11-15 or W11-1 sign) to notify approaching roadway users of the name of the shared use path being crossed.
- At shared use path crossings that experience frequent conflicts between motorists and path users, or on multilane roadways where a sign on the right-hand side of the roadway may not be visible to all travel lanes, an additional shared use path crossing warning sign assembly should be installed on the opposite side of the road, or on the refuge median, if present.
- The Combined Bicycle-Pedestrian Warning sign (W11-15) or Bicycle Warning sign (W11-1) may be placed on the roadway in advance of a shared use path crossing. Again, this warning sign should not be used in advance of locations where the roadway is stop-, yield-, or signal-controlled. Advance warning sign assemblies may be supplemented with a W16-9p (AHEAD) plaque located below the W11-15P sign.
- The use of z-gates, bollards, or other physical obstructions within the shared use path to slow bicyclists or to force bicyclists to dismount is not appropriate approaching intersections. These treatments present a crash hazard for bicyclists and can create situations where bicyclists are forced to queue into intersections increasing their exposure to collisions with motorists while other users navigate through the obstructed area.

5.3.4 Bicycle Crossings

A bicycle crossing is any location where the bicycle enters a roadway from a dedicated bikeway within the traveled way, or a shared use path or separated bike lane outside the travel way. Bikeway crossings of roads can be broadly categorized as mid-block, intersection, or grade-separated. Some crossings may include characteristics of both midblock and intersection crossing types.

Where a bicycle lane crosses an intersection separate from a crosswalk, bicycle lane markings may be extended through the intersection to delineate the bicycle crossing) and raise awareness of the presence of bicyclists. Bike lane crossings are desirable to:

- delineate a preferred path for people bicycling through the intersection, especially a crossing of a wide or complex intersection,
- improve the legibility of the bike lane to roadway users, and
- encourage motorist yielding behavior, where motorists must merge or turn across the path of a bicyclist.

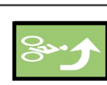
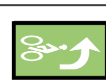
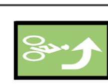
Design Considerations

For bike lanes and separated bike lane crossings at intersections, a dotted white edge line should be used to delineate the bicycle lane extension through the intersection. The dotted lines should be 2 feet in length with 6 feet gaps located on the edge of the bike lane. The width of the edge lines may vary from a minimum of 4 inches up to 2 feet The width of the crossing should match the width of the bike lane. Crossing visibility can be enhanced with green-colored pavement (or markings) and a bicycle lane symbol. The green-colored pavement should generally match the pattern of the dotted edge lines but may be solid where additional emphasis of the crossing is desired (See **Figure 32**).

Bicycle Crossing parallel to a Crosswalk

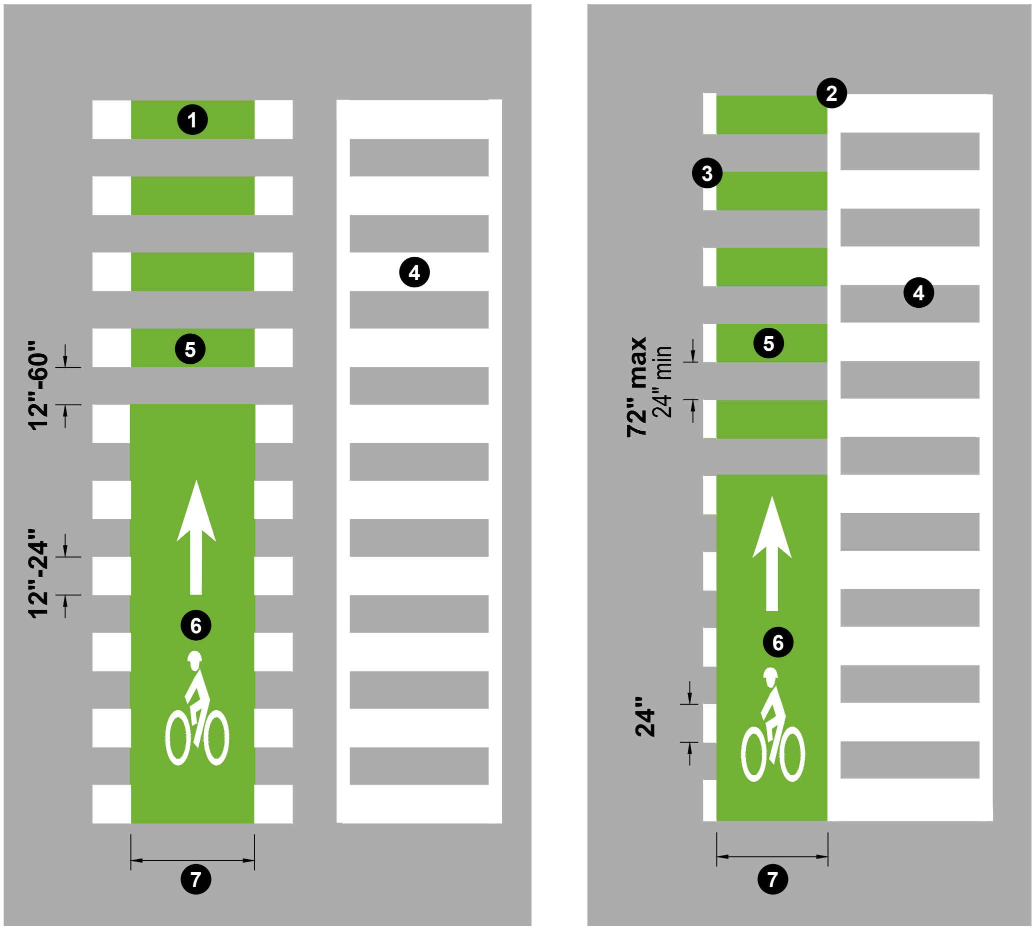
Bicycle crossings are typically parallel to pedestrian crossings. Bicycle crossings can be located directly adjacent to the pedestrian crossing (i.e., no separation between the bike crossing and pedestrian crossing). At locations where the bicycle crossing is less than 1 feet from the pedestrian crossing, the dotted edge line nearest the pedestrian crossing should not be used. Where marked bicycle crossings are parallel to and located within 4 feet of a marked pedestrian crosswalk at intersections, green-colored pavement should be used to enhance the conspicuity of the bicycle crossing and to differentiate it from the pedestrian crosswalks.

Figure 32: Bicycle Crossing Pavement Markings

Intersection Type	Condition	Separated Bicycle Lane	Conventional/ Buffered Bike Lane	Bicycle Boluevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			
Unsignalized	High Turning Volume			No Markings*
	All other conditions			No Markings
	Bikeway Corridor Turns Left			No Markings

*Additional treatment may be needed

Figure 33: Bicycle Crossing Pavement Markings

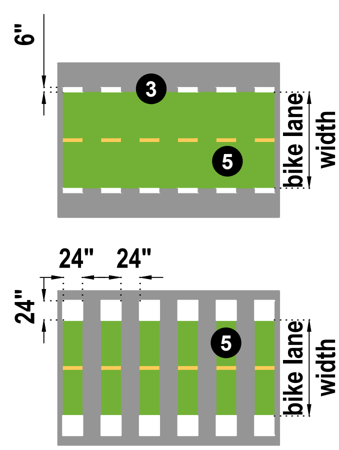


one-way bicycle crossing with 1' min offset from crosswalk

one-way bicycle crossing with no offset from crosswalk

1. 1' min offset
2. no offset
3. 6" white dashed line
4. crosswalk
5. optional green dashed or solid
6. optional bicycle symbol
7. match width of bike lane

> **Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.5)**



two-way bicycle crossing

5.3.5 Bicycle Boxes

A bicycle box is a designated area on the approach to a signalized intersection consisting of an advanced stop line and bicycle symbols. Bike boxes should be primarily considered to mitigate conflicts between through bicyclists and right-turning motorists and to reduce conflicts between motorists and bicyclists at the beginning of the green signal phase. Bike boxes should generally not be installed across more than one through travel lane. Bike boxes are limited to signalized intersections and should not be used in other locations. Bike boxes may be used with an authorized request for interim approval per FHWA Interim Approval IA-18.[4]

The bike box has the following benefits:

- Improves motorist visibility of bicyclists at intersections by placing the bicycle in front of stopped motorists, reducing conflicts which may occur on at the onset of green.
- Provides an advance queuing area to store larger numbers of bicyclists, allowing bicyclists to cross in larger groups across the intersection to increase traffic capacity at signalized intersections with higher volumes of bicyclists.
- Reduces bicyclist encroachment into crosswalks during the red signal phase.

In limited situations, bike boxes may be used to facilitate left turns for bicycles when there is an unusually heavy left turn volume, such as near the entrance to a popular shared use path. Research has shown that bicyclists' use of bike boxes to make left turns is limited in practice. The preferred treatment for left-hand turns is the two-stage bicycle turn box (See **Section 5.3.6**).

Design Considerations

At least one bicycle symbol should be placed in the box to indicate it is for bicycle use. Bike boxes should be a minimum of 10 feet in depth and may be larger depending on anticipated bicyclist volumes. The bike box should connect directly to the approaching bike lane. At least 50 feet of bike lane should be provided on the approach to a bike box so bicyclists will not need to ride between lanes to enter the box. The approaching bike lane, and the bike box, may be colored green (see **Figure 33**).

The stop bar for motorists should be moved back to coincide with the beginning of the bike box. The sign "Stop Here on Red" (R10-6 or R10-6A), aligned with the motorist stop bar, should be installed to indicate the correct stopping location for motorists, with an "Except Bicycles" (R3-7bP) word legend plaque. The sign "Stop Here on Red" (R10-6 or R10-6A) should not be used in locations with a separate turn lane where motorists are stopping in two different locations.

Where a bike box is provided across multiple lanes of an approach (e.g., a location with one through lane and a left turn only lane), countdown pedestrian signals should be provided for the crosswalk across the approach where the bike box is located to inform bicyclists whether there is adequate time remaining to cross to an adjacent lane before the onset of the green signal phase for that approach.

Turns on red should be prohibited on the approach where a bike box is placed in front of traffic that has potential to turn on red, using a "No Turn on Red" sign (R10-11 series). At intersections where a high number of collisions occur between through bicyclists and turning vehicles, alternative treatments should be considered such as a protected intersection (Section 4.7), leading or exclusive bicycle signal phases (Section 5.6), separate lanes for through and turning traffic, or a combination of these and other treatments.

4 https://mutcd.fhwa.dot.gov/resources/interim_approval/ia18/index.htm

Figure 34: Bicycle Box Configuration Across One Lane of Through Traffic

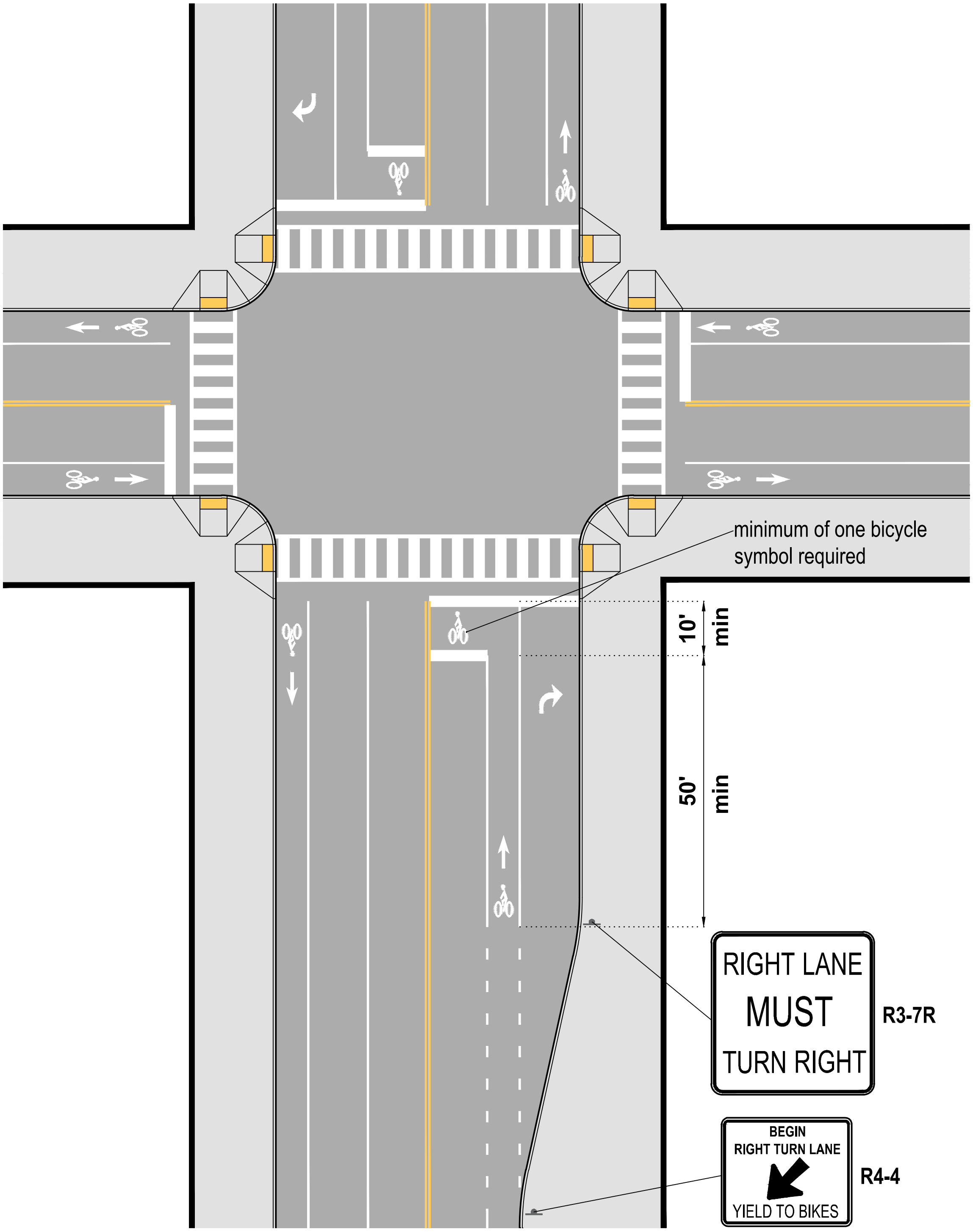
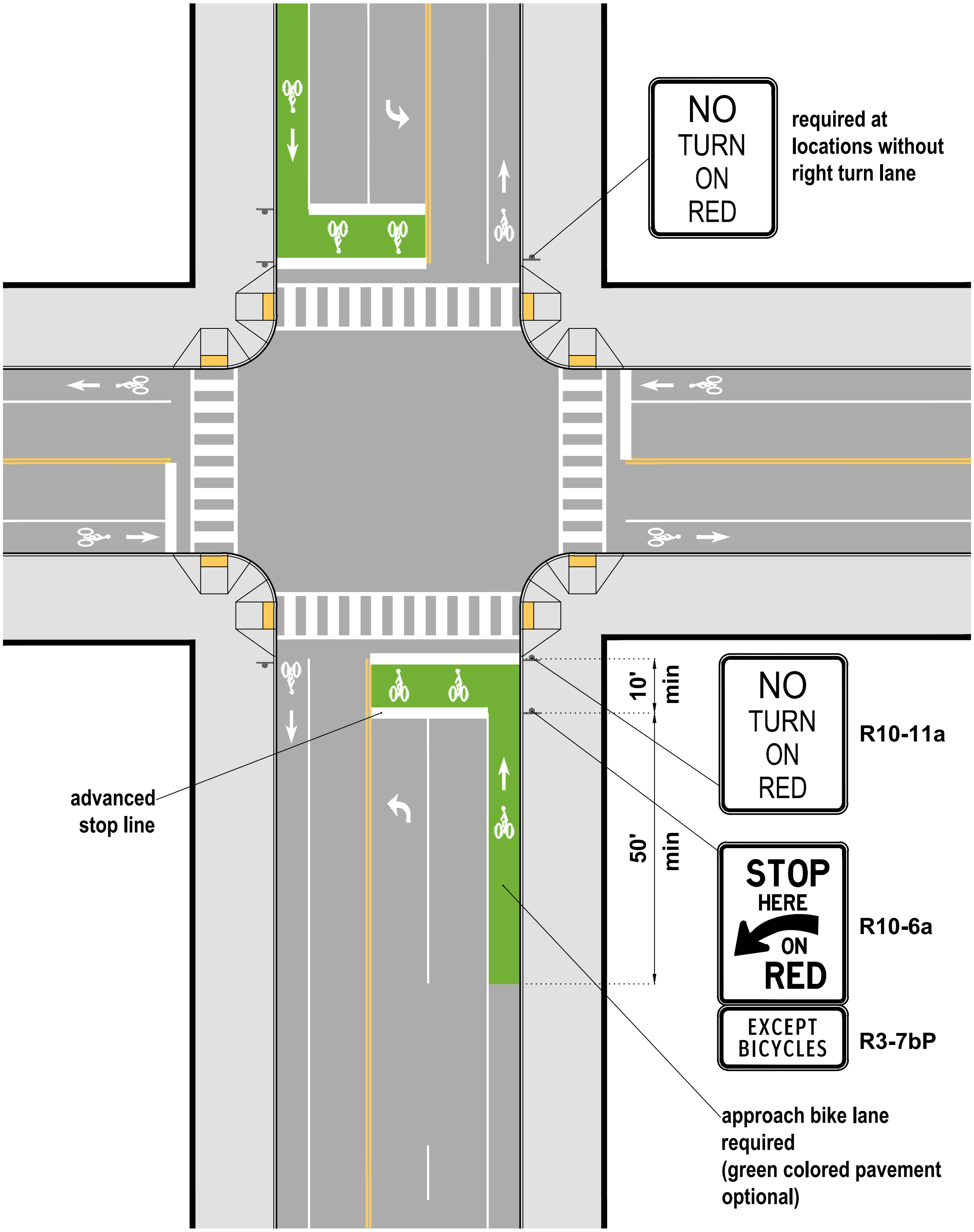


Figure 35: Bicycle Box Configuration Across Multiple Lanes of Traffic



5.3.6 Two-Stage Bicycle Turn Box

Two-stage bicycle turn boxes may be used for left or right turns, and its use is preferred for making turns instead of a bike box, particularly on higher-volume or multi-lane roads. A two-stage bike turn box may be used at signalized intersections per FHWA Interim Approval IA-20.12.[5] The use of a two-stage turn box at an unsignalized intersection is not an approved use of this treatment and would require an experimental approval from FHWA.

Design Considerations

Two-stage turn boxes should be installed where a bikeway intersects with another designated bikeway or where it would connect to a major destination, such as a school, community center, grocery store, etc. When designing a buffered or separated bike lane, designers should plan on installing two-stage turn boxes at most intersections to discourage merging with traffic to make a left turn before reaching intersections. When designing a conventional bike lane, if the volume or speed of the adjacent roadway is more than 6,000 ADT or 30 mph, designers should consider installing two-stage turn boxes at intersections.

Two-Stage Bicycle Turn Box

A two-stage bike turn box:

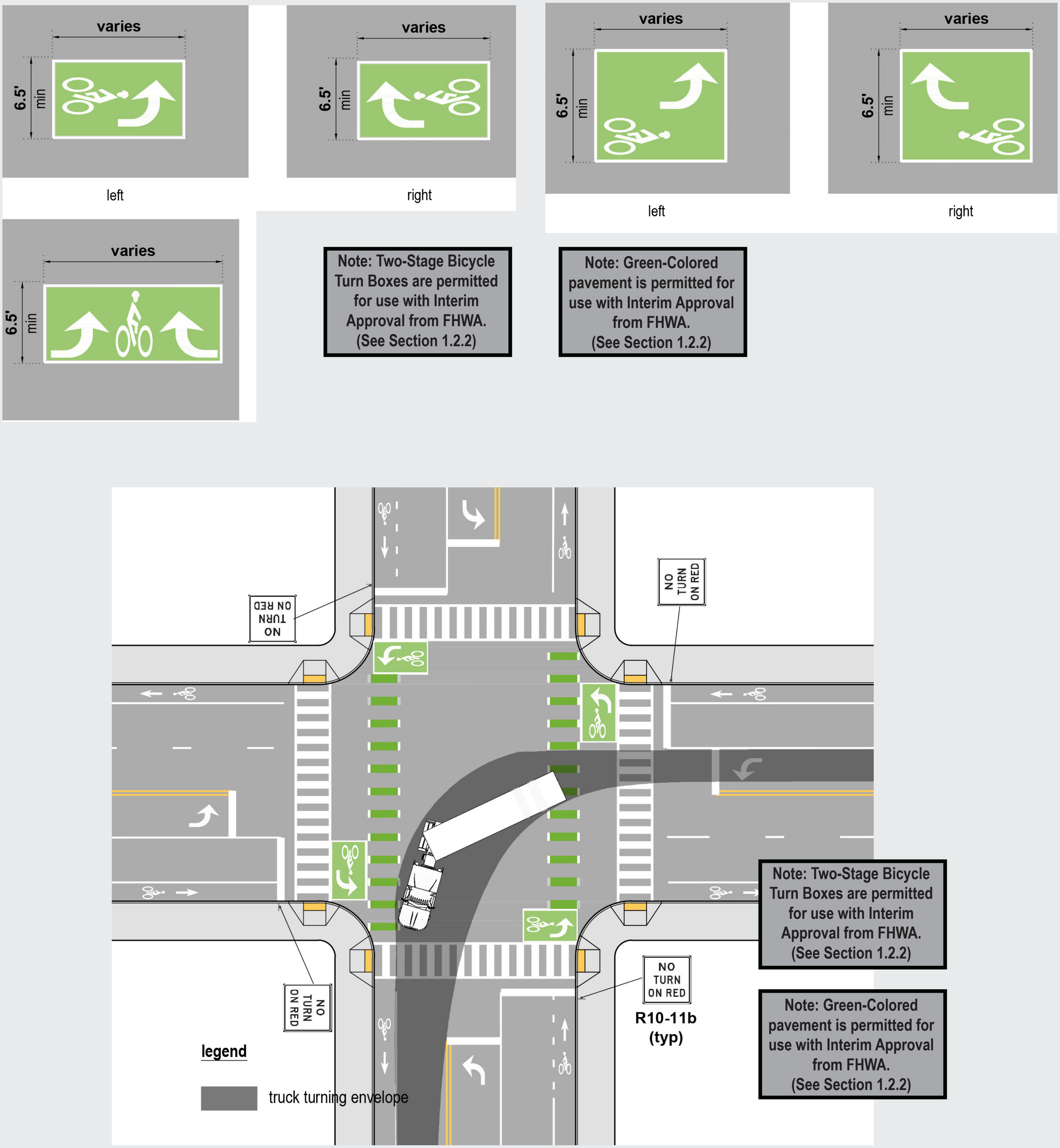
- Must be located outside of the path of through and turning traffic
- Should be located adjacent to the direct path of bicyclist travel
- Should be located downstream of the crosswalk and downstream of the stop line
- Should be located in an area clearly visible to motorists and adequately illuminated
- Must include a bicycle symbol, preferably oriented in the direction in which the bicyclists enter the box, along with an arrow showing the direction of the turn
- May include green-colored pavement or pavement markings to enhance the conspicuity of the box.

A "No Turn on Red" (R10-11) sign must be installed where a two-stage bike turn box is not located outside the path of right-turning traffic to prevent motorists from entering the bicycle queuing area. The placement must also consider left-turning traffic that may otherwise overlap with the two-stage bike turn box.

Passive detection of bicycles in the two-stage bike turn box must be provided if detection is required to actuate a traffic signal. Two-stage bicycle turn box dimensions vary based on the street operating conditions, the presence or absence of a parking lane, traffic volumes and speeds, and available street space. The queuing area should be a minimum of 6.5 feet deep measured in the longitudinal direction of bicycles sitting in the box. The box must be outlined with solid white lines.

5 https://mutcd.fhwa.dot.gov/resources/interim_approval/ia20/index.htm

Figure 36: Two-Stage Bike Turn Box Pavement Markings



5.3.7 Green-Colored Pavement

Bicycle crossings may also be supplemented with green-colored pavement to supplement other bikeway pavement markings. Green-colored pavement communicates to road users where portions of the roadway have been designated for exclusive or preferential use by bicyclists, and enhances the conspicuity of a bicycle lane, bicycle lane extension, bicycle crossing, bicycle box, or two-stage bicycle turn box at or through an intersection.

Green-Colored Pavement Used in Combination with a Crossing Diverter

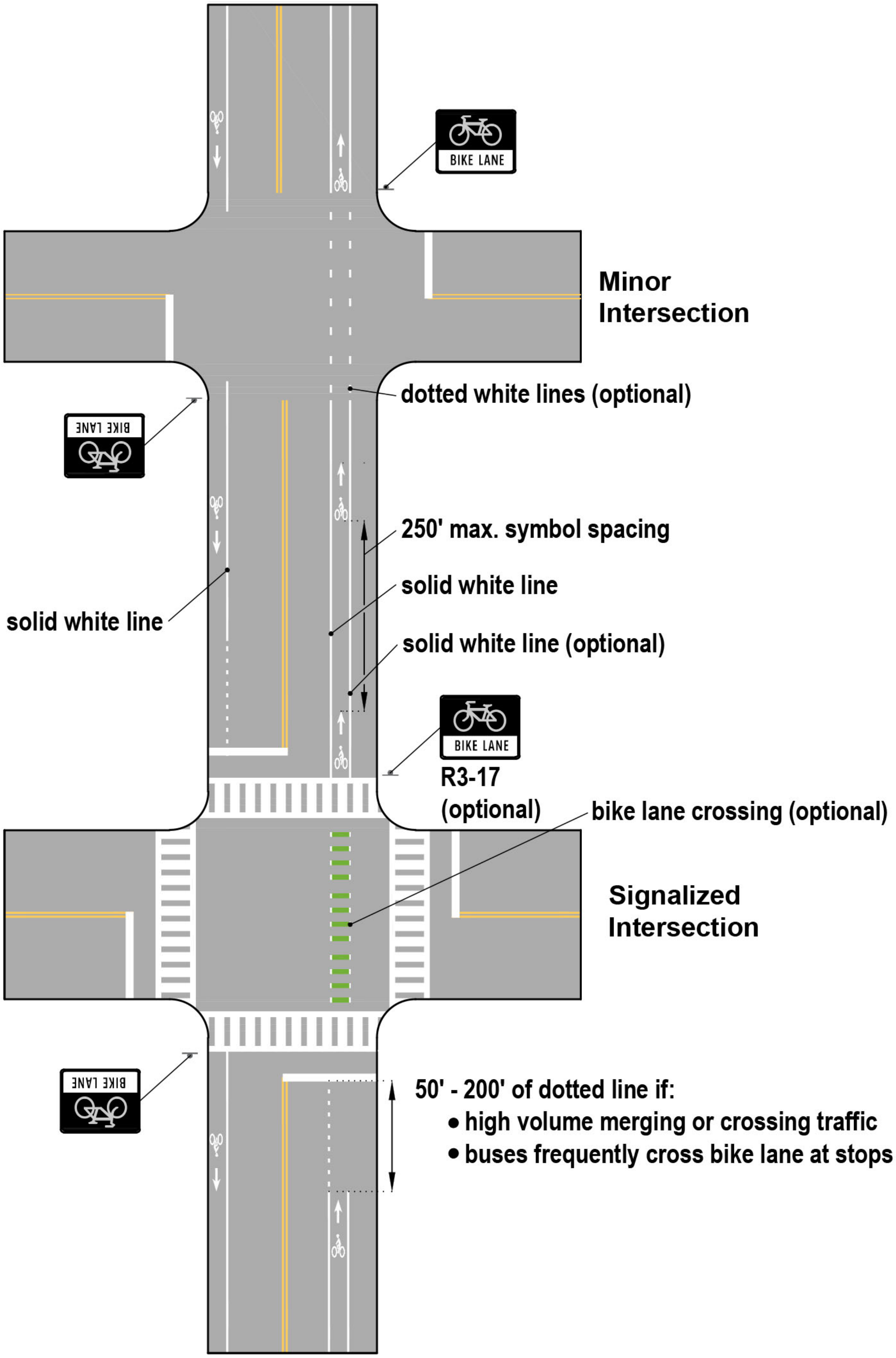
Design Considerations

If used, the green-colored pavement should align with the dotted extension line pattern of the dotted edge lines. If the green-colored bike crossings are proposed parallel to pedestrian crosswalks comprised of wide longitudinal lines (i.e., high visibility crosswalks) the dotted extension lines and green-colored pavement should align with the crosswalk markings. See **Figure 37**. This placement will reduce pavement marking clutter and ensure that the green-colored markings are spaced to avoid motorist wheel paths and improve the longevity of the markings.

Green-colored pavement is an optional treatment that may be used with an authorized request for interim approval per FHWA Interim Approval. The use of green-colored pavement should be applied consistently throughout a bicycle network and can be used to improve the legibility of a bikeway network. The use of green-colored pavement to supplement other bicycle facility pavement markings such as a shared lane marking requires experimental approval from FHWA.

If green-colored pavement is not used throughout a bikeway network, it is recommended that it be used to guide bicyclists through transition areas between bikeway types and bikeway crossings to improve the legibility of the route.

Figure 37: Typical Bike Lane Pavement Markings with Green-Colored Markings



5.3.8 Crosswalks

Crosswalk markings are a basic tool for directing pedestrians across the street and alerting motorists and bicyclists to crossing pedestrians. Engineering judgement should be used to determine when to mark a crosswalk. Marked crosswalks and other safety treatments should be prioritized at locations where pedestrians are vulnerable to conflicts with vehicles due to:

- High pedestrian and vehicle volumes, typical in town centers, at major bus stops, or near universities
- Vulnerable populations such as children, senior citizens, people with disabilities, or hospital areas
- Roadway conditions that make it difficult for pedestrians to cross, such as wide crossing distances, high traffic speeds, and/or complex intersection geometry

In some instances, crosswalk markings should be used in conjunction with other markings, signs, and warning beacons or signals.

Marked crosswalks are especially recommended for all crossings of shared use paths at roadways. At congested crossings, the shared use path can be widened on the approach to provide a separate bicycle crossing and pedestrian crosswalks to reduce conflicts and allow faster moving bicyclists to bypass pedestrians, increasing the person crossing-capacity of the crossing.

There are two types of standard crosswalks markings:

- **Standard (transverse) crosswalk markings**. A standard crosswalk consists of two transverse (parallel) lines, each a minimum of 6 inches in width.
- **High-visibility (longitudinal) crosswalk markings.** A high visibility crosswalk consists of longitudinal lines striped parallel to the direction of travel. The longitudinal lines may be used alone or in addition to the transverse lines, thus creating a ladder-style crossing.

In general, longitudinal markings are more visible to drivers and can be detected 50 to 100 percent further away than crosswalks with transverse lines. However, the increased visibility may not translate into increased driver yielding rates. Longitudinal crossings are commonly used as a safety countermeasure to alert drivers to unexpected pedestrian crossings or particularly vulnerable pedestrian users (such as school zones or transit stops). The longitudinal bar crosswalk should be used at intersections where:

1. At least one approach has a speed limit of 35 mph or higher
2. There are substantial numbers of pedestrians that cross without any other traffic control device
3. Physical conditions are such that added visibility of the crosswalk is desired
4. A pedestrian crosswalk might not be expected.

It should be noted that if crosswalks are repeatedly remarked with diagonal or longitudinal markings, they may eventually constitute surface irregularities that could inhibit those using walkers or cause vibrations for those in wheelchairs.

Design Considerations

Marked crosswalks are used to advise pedestrians where to cross the street and to send the message to motorists that they are in, or approaching, an area where people are crossing the street. The design of the crosswalk should be easily understandable, be clearly visible, and incorporate realistic crossing opportunities for all pedestrians. The following design standards should be followed across all crosswalk marking types:

- Crosswalk widths should be determined based on pedestrian volumes, pedestrian cohort, and width of approaching sidewalks.
- Marked crosswalk minimum width is 6 feet but should desirably be at least as wide as the sidewalks they connect.
- The recommended width for marked crosswalks is 10 feet, which allows for easier, bidirectional pedestrian travel and makes the marked crosswalk more visible.
- Crosswalks need to be placed so they encompass the entire curb ramp, excluding flares. At least 4 feet of clear space should be provided within the width of the crosswalk at the base of the curb ramp for the full width of the curb ramp.
- Crosswalk lines should extend the full length of the crossing. All crosswalk markings must be white, per the MUTCD.

There are several crosswalk marking options available. Common markings include bar pairs, continental, and ladder markings, and transverse markings. Bar pairs and continental markings are longitudinal and ladder markings are a mix of longitudinal and transverse. The unique design features of each alternative are:

Transverse Crosswalks—Transverse crosswalk line markings consist of solid lines not less than 6 incheswide, nor greater than 2 feet wide. There must be 6 feet clear between transverse crosswalk lines.

Longitudinal Crosswalks—Lines for longitudinal or diagonal crosswalks should be located outside of wheel paths to delay the fading of the paint and avoid frequent maintenance. Line spacing for diagonal and longitudinal markings should not exceed 2.5 times the line width. Where diagonal or longitudinal lines are used to mark a crosswalk, the transverse crosswalk lines may be omitted. If used, like on ladder crossings, longitudinal lines should be 1 to 2 feet wide and spaced 1 to 5 feet apart.

At any marked crosswalk, curb ramps and other sloped areas should be wholly contained within the crosswalk markings. The crosswalk lines should extend the full length of the crossing. Longitudinal markings require more pavement marking material than transverse markings, and as a result have higher installation costs. Staggered spacing on longitudinal markings to avoid vehicle wheel paths can, however, reduce maintenance costs.

Crosswalk on a Residential Street

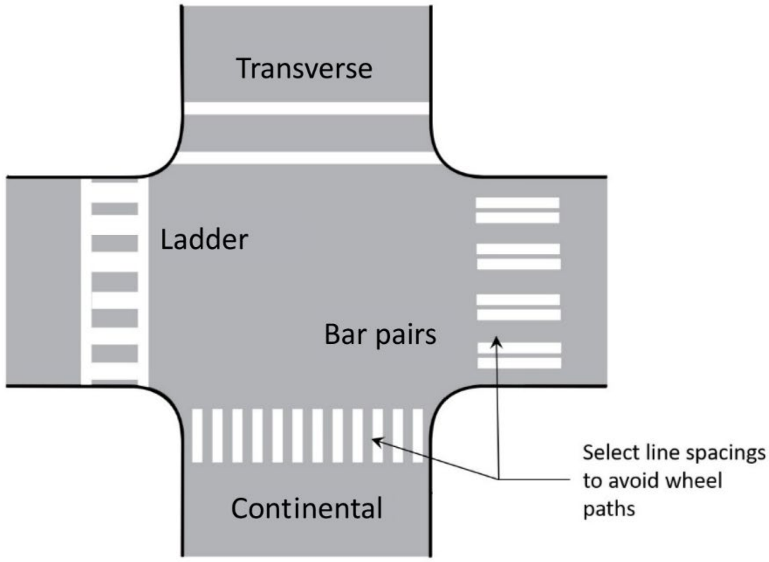
Colored and Textured Crosswalk—Sometimes used to improve aesthetics, but do not replace the need for white markings that are easier to see at night and when the surface is wet to designate a crosswalk. Where colored and/or textured crosswalk treatments are used, they should not degrade the contrast of the white crosswalk markings, nor should they be designed such that they could be mistaken by road users as a traffic control application.

Additionally, colored and textured crosswalk treatments should be designed with material that is smooth, nonslip, and visible. Textured crosswalk design treatments should not be used if there is a possibility the treatment may shift and/or settle or induce a high degree of vibration in wheelchair caster or drive wheels. If a textured crosswalk treatment is used, a 5 feet wide untextured surface should be maintained in the center of the crosswalk that connects the curb ramps on each end of the crossing. Recessed pavement markings, which enhance marking durability, may also be used.

Requirements for use of colored pavements are presented in MUTCD Section 3G. Guidance on the interpretation of the MUTCD requirements has been provided by FHWA.

Raised Crosswalks—Where raised crosswalks are used, detectable truncated dome warnings are needed at the curb lines, and pavement markings are required on the roadway approach slopes.

Figure 38: Examples of Crosswalks Markings



Considerations when determining placement of crosswalk markings include the following:

- **Access**—Assume that pedestrians want and need safe access to all destinations accessible to motorists, as well as to destinations not accessible to motorists such as trails and parks.
- **Generators and Destinations**— Pedestrians will cross streets following natural “desire lines” from generators to destinations (i.e. schools, parks, shopping, residential neighborhoods) and will not typically go out of their way to cross the street at another location, unless that location provides a safer crossing opportunity and is reasonably close by. A marked street crossing should be available near most transit stops.
- **Controlled and Uncontrolled Intersections**—All intersections that have signals, stop signs, or yield signs to facilitate motor vehicle crossings should also be designed to accommodate pedestrians with marked crosswalks. Pedestrians need safe access at many uncontrolled locations as well. See section *5.2.4 Uncontrolled Pedestrian Crossings* for more information.
- **Frequency—**Pedestrians should be able to cross streets at regular intervals and consideration should be given to facilitating crossings at key high-use locations. Unlike motor vehicles, pedestrians cannot be expected to go more than half a block out of their way to take advantage of a controlled intersection.
- **Snow Clearing**—Locations with frequent snow accumulation tend to have periods when crosswalk markings are either totally or partially obscured, making it difficult for both motorists and pedestrians to see marked crosswalks. Marked crosswalks in such locations should be supplemented with pedestrian signing for greater year-round visibility.
- **Special Paving or Brick Crosswalks** —These crosswalks often existing in historic districts, downtown areas, or Main Streets. Include white striping on both sides of the special pavers or materials.

Near schools, crosswalks aid in establishing routes and crossings to and from school for children. On established routes to a school, crosswalks should be marked and signed at all crossings where any of the following conditions are found:

- There are substantial conflicts between motorists and pedestrians (and bicyclists).
- Children are encouraged to cross between intersections.
- Children would not otherwise recognize the proper place to cross.
- Motorists (or bicyclists) may not expect children to cross.

5.3.9 Stop Bar and Yield Markings

Stop and yield lines may be used to indicate the point at which a bicyclist or motorist should yield in compliance with a stop bar, yield sign, a Yield Here to Pedestrian (R1-5 or R1-5a) sign or a or Bicycle Yield to Peds (R9-6) sign.

An advance stop or yield line can greatly reduce the likelihood of a multiple-threat crash, which occurs when a motorist stopped in one lane blocks the view of a second motorist. Advanced yield lines should be considered for any uncontrolled multi-lane crosswalk.

Design Considerations

Advance yield markings should be placed 20 to 50 feet in advance of a marked crosswalk to indicate where the vehicles are required to stop or yield and shall be paired with a Yield Here to Pedestrians (R1-5) sign. Where a protected bike lane crosses a crosswalk, yield markings on the bike lane approach can emphasize that people biking or using mobility vehicles must yield to pedestrians within the crosswalk.

At stop- or signal-controlled legs of an intersection, stop lines are solid white lines, 1-2 feet (0.3- 0.6 m) wide, extending across all approach lanes. stop lines shall be placed a minimum of 4 feet (1.2 m) in advance of, and parallel to, the nearest crosswalk line. Greater setbacks can help reduce multiple-threat crashes since the motorist's view of pedestrians within the crosswalk is less likely to be screened by vehicles in the adjacent lanes. However, stop lines should not be set too far back on the approach as to negatively affect the capacity of the intersection or the sight lines of the drivers (e.g., intersection sight distance). Stop lines set too far back will also have the potential to be ignored by drivers.

At crosswalks in uncontrolled locations on multilane roads, setbacks of 20 to 50 feet (6.1 to 15 m) are desirable for yield or stop lines to provide adequate sight distance between pedestrians and vehicles. At such locations, "Yield Here To (or Stop Here For) Pedestrians" signing must be used. Also, parking should be prohibited in the area between the yield or stop line and the crosswalk.

The MUTCD allows staggered stop lines and staggered yield markings for different lanes. For instance, setting the right-turn lane stop line forward of adjacent lanes can increase pedestrian visibility to right-turn-on-red drivers. It is desirable to set the stop line of the left-turn lane farther back than the stop line of the through lanes.

Advanced Yield Marking places in Advance of Crosswalk

When used at signalized intersections, advanced stop lines can reduce pedestrians' conflicts with motorists in the crosswalk.

Yield markings are used instead of stop lines where signs, signals, or local laws require motorists to yield instead of stop. Yield markings consist of a row of solid white isosceles triangles pointing toward approaching vehicles.

In the absence of a marked crosswalk, a stop line or yield marking should be placed at the desired stopping or yielding point not less than 4 feet (1.2 m) in advance of an unmarked crosswalk.

Design Considerations

The following design considerations should be followed when implementing stop bars or yield markings:

- At controlled intersections, provide a stop bar in advance of the crossing and consider signal timing guidance in the Pedestrian Signal Phasing section at signalized intersections. Consider location of vehicle stop bars based on design vehicle turning envelope.
- Use and design of stop and yield lines is described in Chapters 3B and 9C of the MUTCD. For shared use paths, stop or yield lines may be placed across the entire width of the path even though the shared use path is typically two-way.
- In some cases, drivers may be unable to see children, wheelchair users, or other pedestrians in the crosswalk. Locating the stop line in advance of the crosswalk by 10 feet (3.0 m) or more may be considered where there are large numbers of trucks or pedestrians at an intersection. These greater setbacks may benefit from a supplemental sign, such as "Yield Here To Pedestrians" or the in-street sign "Stop (or Yield) Here For Pedestrians Within Crosswalk" depending upon the selected design vehicle and traffic laws for a particular state.

5.4 Signals, Beacons, and Signs

5.4.1 Introduction

Traffic signals manage traffic flow by separating and allocating time to specific movements. They can reduce conflicts between motor vehicles, transit vehicles, bicyclists, and pedestrians. The decision to install a Pedestrian Hybrid Beacon (PHB) or a traffic signal involves a holistic evaluation of numerous factors at the study location and requires the use of engineering judgment to apply and evaluate the MUTCD and the Colorado Supplement to the Federal Manual on Uniform Traffic Control Devices warrant criteria.

The design guidance in this chapter covers how to design pedestrian hybrid beacons and traffic signals, including traffic signal heads, signal phasing, signal timing, signing, markings, and pedestrian/bicycle detection. It also includes ways to reduce delay and manage or eliminate conflicts between vulnerable users and motor vehicles. The design guidance provided in this chapter also supplements intersection design guidance provided in other chapters. This design guidance should be used in conjunction with the MUTCD.

5.4.2 Evaluation of a Traffic Control Signal or Pedestrian Hybrid Beacon

Traffic signals may be installed to facilitate roadway crossings by pedestrians and bicyclists. It may be necessary to consider pedestrian signal or pedestrian hybrid beacon (PHB) installation at crossing locations where one or more of the following conditions occur:

- Where one or more MUTCD traffic signal warrants or PHB guidelines are met;
- Sight distance is restricted, based on prevailing motor vehicle speeds;
- Motor vehicle approach speeds exceed 30 mph;
- There are four or more through lanes of major street traffic;
- There are insufficient crossing opportunities (including crossings of two through lanes) within about a quarter of a mile from the location in question.

Traffic control signal installation should be limited to locations where less restrictive traffic control devices do not provide adequate crossing opportunities for pedestrians and bicyclists. Even at locations where a traffic control signal is warranted, other treatments such as traffic calming, roundabouts, active beacons, or PHBs should be considered before determining a full traffic signal is appropriate. A traffic signal can increase delays, motorized traffic volumes on minor street approaches, and some types of crashes. PHBs intended specifically for bicycle use can also introduce challenges for bicyclists' timing (see Section 5.6.2.).

5.4.3 MUTCD Traffic Control Signal Warrants

The MUTCD (Chapter 4C: TRAFFIC CONTROL SIGNALS NEEDS STUDIES) provides list of nine traffic control signal warrants to help determine whether a new signal should be installed. Many of the warrants are primarily focused on vehicular traffic flow. There are separate guidelines (not warrants) for PHB installation. Some flexibility is allowed in applying warrants to determine if a traffic control signal or PHB is needed at a bicycle crossing. For example, since bicyclists may operate as vehicles or pedestrians at street crossings, they may be counted as either for a traffic signal or PHB warrant analysis.

Designers have the flexibility to estimate future demand in the absence of a signal or PHB if existing conditions limit vulnerable user crossing opportunities. In some cases, people may not be crossing a street in sufficient numbers to satisfy a warrant because there are not adequate gaps in traffic or they do not feel comfortable doing so – thus they avoid the crossing altogether. For these locations, it may be more appropriate to use an estimated crossing demand for warrant analysis that assumes better crossing protection, as experience shows once a street can be crossed more safely, people will generally cross in greater numbers compared to prior conditions. Designers may consider estimating pedestrian and bicycle volumes as part of developing signal warrant methodology. In these cases, the designer shall coordinate with the appropriate CDOT representative to identify forecasting assumptions.

Projecting volumes is an important consideration where bicycle boulevards and shared use paths are installed and are consistent with the MUTCD. In these situations, there is an implied understanding that a higher level of care has been taken to ensure bicyclists and pedestrians can safely navigate these routes, as families commonly use such facilities with children. For this reason, agencies and designers should evaluate a proposed facility using the appropriate signal warrants and, if necessary, for a reasonably anticipated volume of peak hour crossings.

The following warrants have the greatest applicability for evaluating the need to install a traffic control signal to assist pedestrians and bicyclists in crossing a street:

- **Warrant 4, Pedestrian Volume** – may be considered at locations where pedestrians experience excessive delay attempting to cross a high-volume street. Bicyclists should be considered with pedestrians in this analysis. The criterion for Warrant 4 (Pedestrian Volume) may be reduced by 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 ft per second.
- **Warrant 5, School Crossing** – may be considered at locations where there is a desire for school children to cross and there are not adequate gaps for them to do so.
- **Warrant 7, Crash Experience** – may be considered in locations where a threshold of crashes that a traffic control signal could correct has occurred during a 12-month or 3-year period. Thresholds vary depending upon number of approach lanes, type of crash and context (i.e., urban or rural).
- **Warrant 8, Roadway Network** – may be considered at locations to encourage concentration and organization of traffic flow on a roadway network. Thresholds are based on existing volumes (that meet one or more of Warrants 1, 2, and 3) and an engineering study that projects five-year traffic volumes. Using this warrant assumes it is part of a major route that either serves as a principal roadway, includes a rural or suburban highway outside or near a city, or appears on an official plan in an urban areas traffic and transportation study.
- **Pedestrian Hybrid Beacon Guidelines** – A PHB may be considered at locations that do not meet traffic control signal warrants or for locations where it might be undesirable to provide a traffic control signal. Guidelines for the PHB are included in the MUTCD (CHAPTER 4F: PEDESTRIAN HYBRID BEACONS) and suggest that PHB's may be appropriate at locations where at least 20 people cross in a peak hour. See the MUTCD for specific thresholds for speeds, pedestrian volumes, and vehicular volumes.

According to the MUTCD (Section 4C.01), with the exception of locations where an engineering study uses Warrant 8 to justify signal installation, a traffic signal installed under projected conditions should have an engineering study performed within one year of energization to determine if it is still justified. If not, the signal should be either taken out of stop-and-go operation or removed.

5.5 Signal Design Guidance for Pedestrian Facilities

Pedestrian signal heads should be provided at all signalized intersections with sidewalks and curb ramps on the approaches and at all signalized intersections where pedestrian activity may be expected or anticipated based on land uses, transit stops, or other factors likely to generate pedestrian activity, regardless of the presence of sidewalks.

5.5.1 Pedestrian Signals

The MUTCD (Section 4E.03 Application of Pedestrian Signal Heads) defines the conditions under which pedestrian signals shall be provided. At all locations where signals are newly installed, replaced, or significantly modified and pedestrian signals are provided for street crossings, countdown pedestrian displays are required. Pedestrian signals with countdown displays show the number of seconds remaining in the clearance interval and their use has been shown to reduce both pedestrian and vehicular crashes at signals[1].

Accessible pedestrian signals (APS) are devices that communicate information about pedestrian signal timing in nonvisual formats and are integrated with pedestrian pushbuttons. All intersections where pedestrians are expected, regardless of whether the pedestrian phase is automatic or requires actuation, shall be accessible for people with disabilities. This often means that accessible pushbuttons are installed in locations with automatic pedestrian phases. APS installation is required by PROWAG (R209.1) with any new traffic signal that has pedestrian signals or where there will be significant changes to an existing signal. APS guidelines include the following:

- APS should be placed in consistent locations;
- APS should be located as close as practical to the crosswalk line farthest from the center of the intersection and as close as practical to the curb ramp;

- When installed at signals or PHBs, APS pushbuttons must have both audible and vibrotactile components. Vibrotactile indications integrated into the pushbutton provides information to persons with hearing or visual disabilities;
- APS pushbuttons shall have a locator tone that operates during the DON'T WALK and the FLASHING DON'T WALK intervals only to assist those with low or no vision to find the correct device for a particular crossing;
- APS pushbuttons shall have a tactile arrow that indicates the crossing direction activated by the pushbutton;
- One post and pushbutton assembly should be provided for each crossing. Ideally, pushbuttons on the same corner should be placed a minimum of 10 ft. from each other. This helps clarify which percussive locator tone is applicable to each button for the respective crossing. In constrained areas (e.g., limited building setbacks, unusual geometric conditions), should two APS assemblies be separated by less than 10 ft., an audible walk indication shall include speech pushbutton information and walk messages. These information messages tell pedestrians the name of the street they are crossing. Braille or raised lettering on the pushbutton housing may also provide street name information;
- If an extended pushbutton press feature provides additional crossing time, then an R10-32P plaque shall be mounted adjacent to or integral with the APS pushbutton. For these locations, APS pushbuttons shall be marked with three braille dots forming an equilateral triangle in the center of the pushbutton;
- If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median to wait for the next cycle, then an additional APS pushbutton shall be provided in the median.

Some pushbutton housings include a map of the intersection in relief on the side of the housing that informs pedestrians about the number of lanes and islands they will have to cross. These should be provided at wide or complex intersections and when a two-stage crossing may be necessary. However, using a two-stage crossing where pedestrians are required to cross to a median and then to the other side of the street on separate signal phases should be discouraged where sufficient physical protection (e.g., concrete curbing, wide medians) is not included. When installed, two-stage pedestrian crossings should consider a "z"-median where pedestrians are required to traverse a short distance (10 ft. min. preferred) in a center island, facing on-coming traffic, prior to activating a second pushbutton. The center median distance may require adjustments to accommodate site specific conditions.

APS audible messages and tone volumes should be adaptive to the surrounding ambient noise. APS units produce a louder signal message when motor vehicle and other noise at a given intersection is higher. Automatic volume adjustment provides flexibility and allows APS units to adjust so they are not disturbing to neighbors at night or times of low traffic volume. This is also helpful to visually impaired pedestrians, as the APS does not drown out essential traffic sounds necessary for crossing. See Section 4E.11 of the MUTCD for volume setting requirements and guidance.

When APS and countdown pedestrian display improvements are made, all crossing associated with the system must be upgraded (see Section X for ADA requirements, standards, guidelines). Among the requirements provided in MUTCD, Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications, pedestrian signals should be placed in a conspicuous location, visible to pedestrians waiting to cross. See Section X for additional information on the placement of pedestrian pushbuttons for accessibility.

5.5.2 Pedestrian Detection

Pushbuttons

Where pushbuttons are provided for detection, they shall be accessible. Pushbutton placement must be within easy reach of a pedestrian (and bicyclist when applicable) and obvious to which crosswalk they are associated with.

In addition to standards laid out in Chapter 4E.08 of the MUTCD, and Section 5.5.1 of this guide, accessible requirements and best practices are as follows:

- Place pushbuttons so they are adjacent to curb ramp landing or similar surfaces. A level surface with a 1.56 percent cross slope (max.) in each direction shall be provided.
- Pushbuttons may be placed between 1.5 ft. and 6 ft. behind the face of curb or edge of pavement. In some cases, placement as far as 10 ft. is permissible. A distance of 6 ft. is preferable as it allows bicyclists and pedestrians pushing strollers to stop at the button

without the front end of their wheel(s) getting closer than 2 ft. from the face of curb or edge of road and provides greater physical separation from moving traffic.
- When placing pushbuttons, consider expected users and their needs. Where bicyclists are expected, a slightly taller pole can provide a surface to hold while waiting for the right of way.

Passive Detection

Passive detection devices are less common, but may be used to actuate or extend pedestrian signals in specific applications. Beacons can be outfitted with motion or break-beam sensors, though care is needed to ensure detection is for only those intending to cross. Infrared crosswalk sensors can detect the presence of slow-moving pedestrians in crosswalks and extend the clearance time.

Passive detection may be used in lieu of or in addition to pedestrian pushbuttons, though careful consideration will be necessary in doing so. Passive detection may be helpful in reducing intersection noise, though pedestrians with vision disabilities may not approach the crossing within the detection zone nor wait at the exact crossing area for activation to occur. They may also not know passive detection is present unless they are familiar with the intersection. In addition, passive detection systems need to be carefully calibrated and monitored to avoid or limit detecting something other than pedestrians.

Passive detection may be an option where compliant pushbutton placement is not feasible at a given intersection. Such factors may include lack of right-of-way, limited building setbacks, or pushbutton placement that would limit or block pedestrian access.

5.5.3 Signal Timing and Reducing Pedestrian Delay

Frequent crossings that accommodate walking speeds for people of all ages and abilities are key to creating a safe, accessible, and connected pedestrian network. Signals are typically timed to prioritize the "major" street movements which may, under certain conditions, increase delay for pedestrians and bicyclists waiting to cross the major street. In addition, when pedestrians and bicyclists are faced with long delays, they may be more likely to ignore signals entirely and cross the road when they perceive an adequate gap in traffic. When this occurs, pedestrians will sometimes choose to cross away from intersections, potentially increasing crash risks. The following section describes best practices for reducing delay and providing accessible crossings to improve safety for all users.

While there are many factors associated with signal timing as it relates to reducing pedestrian delay, corridor consideration should be a factor. Streets in lower density, suburban settings, often do not have comparable pedestrian volumes relative to more dense, urban networks. However, these corridors may have transit operation, which may make road crossing decisions challenging without appropriate crossing opportunities.

Signal Cycle Length

In some instances, where pedestrians routinely experience long delays at signals, they may elect to cross away from the crosswalk at locations where conflicts are not controlled by a signal. Therefore, strategies to reduce overall cycle length can be particularly important for pedestrian safety. Where pedestrians are expected regularly, cycle lengths greater than 60 to 90 seconds should often be discouraged. In addition to reducing cycle lengths, designers may also consider using half-cycle lengths, particularly during off-peak hours. Adaptive signal control, where employed, should have limited variation in cycle length. Operations for adaptive signal control should be confined to suburban settings and event venues where traffic patterns can be highly variable.

Designers should be aware that shortening signal cycle lengths can impact the amount of time that a pedestrian is provided in the pedestrian signal phase (see "Pedestrian Signal Phase Timing", discussed later in this section). While long cycle lengths can increase pedestrian non-compliance, at wider intersections shorter cycle lengths may not be possible without implementing two-stage pedestrian crossings which could increase pedestrian delay compared to providing a longer cycle length. Single stage crossings are preferable in most instances (see Chapter 5.3.6 for complex locations where two-stage crossings may be appropriate). Designers can also shorten crossing distances using curb extensions (see Chapter 5.1.2), eliminating the need for a longer pedestrian cycle length and potentially reducing the current cycle length.

If a two-stage crossing is provided, designers shall provide a crossing island (see Section 5.1.1) and provide a pushbutton within the crossing island.

Pedestrian Signal Phase Timing

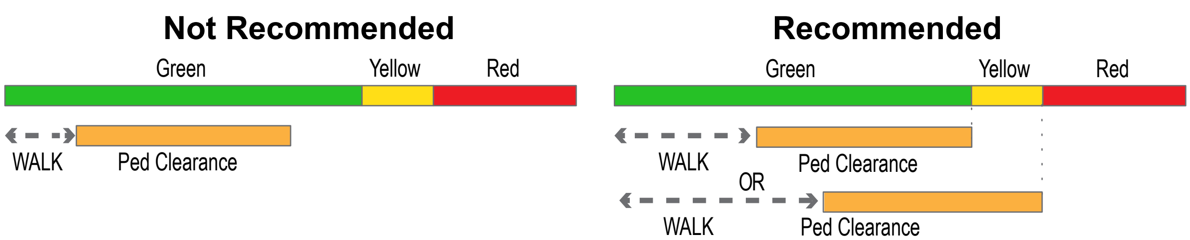
Pedestrian signals provide a WALK phase (steady white walking man symbol) followed by a FLASHING DON'T WALK clearance phase (flashing orange upraised hand symbol with integrated countdown timer). Details for programming the walk and clearance interval is provided in the MUTCD (Section 4E.06). Pedestrian signal timing shall meet the following requirements:

- The duration of the WALK indication should allow sufficient time for a pedestrian to react to the signal and enter the crosswalk. The MUTCD recommends a minimum walk interval of seven seconds, though it allows for a walk interval as low as four seconds in certain situations;
- A clearance interval based on a maximum walking speed of 3.5 ft. per second from the face of curb or edge of shoulder to the point where they have cleared the farthest lane in the crosswalk;
    - Where a crossing has a higher proportion of slow-moving pedestrians, slower walking speeds of 3.0 ft. per second or lower may be programmed. A longer clearance interval can also be requested by pedestrians using a longer push on the pushbutton.
    - Passive detection may also be considered, provided that the system can sense slower pedestrians and extend the clearance time.
- The total WALK + FLASHING DON'T WALK phase (walk plus clearance interval) shall be long enough to allow a person with a walk speed of 3.5 ft./sec. to walk from the pushbutton to the point where they have cleared the farthest lane in the crosswalk. When a pushbutton is not present, the crossing distance should be 6 ft. wider than the width of the road;
- In addition to the recommendations and guidance in the MUTCD, designers should consider a longer walk interval (e.g., sufficient for a pedestrian to react and walk to the center of the intersection) at locations where there are more than two travel lanes to be crossed or roadway posted speeds are higher than 30 mph.

Signal timing should strive to maximize the WALK + FLASHING DON'T WALK phase such that the total pedestrian time is equal to the total concurrent vehicle green and yellow timing (see Figure 39). Providing a shorter WALK phase is sometimes proposed to split the green phase between the pedestrian crossing and turning vehicles. This application is discouraged as it is an informal treatment that does not clearly convey the phasing intention; pedestrians may elect to cross anyway after observing that the concurrent through movement is still green. To address conflicts, designers should instead use one or a combination of treatments listed in Section 5.3.4.

It is typical practice is to terminate the FLASHING DON'T WALK phase at the same time as the concurrent vehicular green indication. However, the MUTCD (Section 4E.06) allows this interval to overlap with the concurrent vehicular yellow phase. See the MUTCD (Section 4E.06) for further details.

Figure 39: Maximizing the WALK Interval



Pedestrian Recall and Actuation

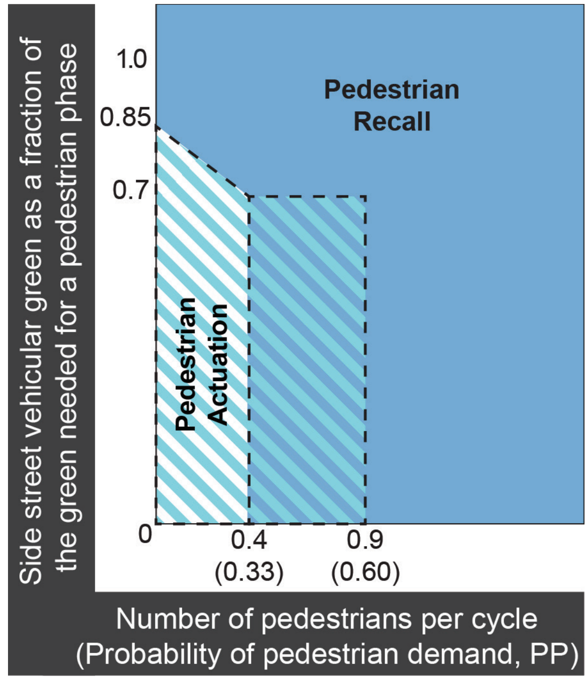
Pedestrians should not always be required to push a button to call the pedestrian phase at locations with high pedestrian volumes. This is particularly important in downtown corridors or business districts where there tends to be significant pedestrian volume and relatively short cycle lengths. In such environments, fixed time operation with time-of-day phase plans often functions more efficiently compared to actuated or semi-actuated signal timing. Fixed time operation allows for signal controllers to call pedestrian phases each cycle. In a fixed time grid, pedestrian intervals are often the maximizing factor for phase length, as the time necessary to accommodate pedestrian movements exceeds the time needed for motor vehicles. Designers should follow the guidance in Figure 40 for providing pedestrian recall or actuation. This could be accomplished based on different signal timing plans at certain times of day or day of the week.

Signal timing plans, when updated, shall provide a sufficient walk phase for all crossings. If it is determined that the pedestrian phase should switch from actuated to recall based on the time of day, designers can minimize confusion by ensuring the pushbutton includes a confirmation light. When the signal operations have switched to pedestrian recall, the detection indicator can be programmed to illuminate by default.

5.5.4 Signal Phasing for Managing or Reducing Conflicts

There are a variety of alternative signal phasing options for reducing or eliminating conflicts between motorist and pedestrians. Designers should consider both the operational and safety impacts of signal phasing changes at an intersection. Designers should also be aware that a phasing scenario may necessitate a separate motor vehicle turn lane and an additional signal phase, which may increase delay for some users, including pedestrians. Fully separated crossings may require longer cycle lengths, which may result in reduced user compliance with signal indications and increased potential for conflict. The following sections describe four major phasing scenarios, criteria, and considerations. Often, there may not be one solution, but a combination of treatments for specific periods or scenarios to address pedestrian safety.

Figure 40: Recall versus Actuated Pedestrian Phase for Coordinated-Actuated Arterials



5.5.5 Leading Pedestrian Intervals (LPIs)

Leading Pedestrian Intervals (LPIs) or Leading Through Intervals (LTIs) may be used to give pedestrians a head start (typically a minimum of three seconds) when crossing the street. LPIs are a proven safety countermeasure to reduce vehicle-pedestrian crashes at intersections. Implementation allows waiting pedestrians to enter the crosswalk where they become more visible to conflicting motorists. Both LPIs and LTIs accomplish the same goal through different strategies:

- Leading Pedestrian Intervals - With traditional signal phasing, parallel pedestrian WALK and motor-vehicle circular green indications start at the same time, immediately after the conclusion of the red clearance interval. With LPIs, the walk phase begins as usual and parallel motor vehicle circular green indications start after a brief period. Designers should provide APS units where LPI's are provided; without APS units, pedestrians with low or no vision may not be able to maximize the advantage of LPIs, as they otherwise use the noise of concurrent vehicles to determine when to begin walking.
- Delayed Turn or Leading Through Intervals -A delayed left (or right) turn or LTI provides a green signal to through movements while delaying permissive left

(or right) turns for a specific period. This delay time may vary based on site specific conditions, but (similar to an LPI) is usually between three and six seconds. This option minimizes intersection capacity impacts while providing a partially protected pedestrian phase, allowing those on foot a head start in order to establish themselves in the intersection before turning movements are allowed after the protected left (or right) turn phase.

When curb extensions or a protected intersection is provided, pedestrians can establish themselves in the crossing before vehicles due to the distance between the stop line and the edge of the curb where a pedestrian would wait.

Table 7 provides the equation for calculating the LPI interval (rounded to the nearest second) found in Ohio DOT's Signal Design Reference Packet (SDRP) (CDOT does not have an adopted formula for calculating LPIs).

An approach meeting any one of the following criteria may be a good candidate for the installation of an LPI:

- Reported crash history finds one or more crashes per year have occurred over the last three years between vehicles turning on green and pedestrians crossing the street on the associated crosswalk with the pedestrian WALK signal;
- A visibility issue exists between the driver's view of pedestrians on the crosswalk due to obstructions or poor sight distance at an intersection approach that can be improved through an LPI. LPIs by themselves don't resolve sight distance limitations, as they don't protect pedestrians who arrive at the end of the WALK phase. Physical measures to remove corner sight obstructions should be given primary consideration;
- Intersection observations reveal conflicts between crossing pedestrians and turning vehicles in which there is a risk of collision should their movements and speeds remain unchanged;
- One of the two movement volumes (turning vehicle volume (A), or pedestrian volume (B), identified below) meet at least one of the thresholds identified in Table 8 for a given warrant.

When a protected left turn phase is provided, it should occur as a lag to prevent left turning vehicles from continuing to cross during the LPI. Designers must avoid the "yellow trap".

Table 7: Formula for Leading Pedestrian Interval (LPI)

Leading Pedestrian Interval (LPI) Formula
$$\text{LPI (sec.)} = \frac{(W_1 + W_2)}{S_w}$$
Where:
LPI = Leading pedestrian interval (sec.)
W_1 = Width of first lane of moving vehicles (ft.)
W_2 = Width of shoulder, bike lane, and/or parking lane (ft.)
S_w = Walking speed (typically 3.5 ft./sec.)

Table 8: LPI Volume Warrant Thresholds

Warrant	Turning Vehicles Volume (A)	Pedestrian Volume (B)
Vehicle Peak Hour	≥130 per hour	≥25 per hour
Pedestrian Peak Hour	≥100 per hour	≥50 per hour
4-Hour Vehicular and Ped Volume	≥105 per hour	≥30 per hour
8-Hour Vehicular and Ped Volume	≥100 per hour	≥25 per hour
School Crossing	≥50 per hour	

5.5.6 Protected Pedestrian Phase and Turn Restrictions

Protected pedestrian phases or protected-only signal phasing for turn movements can significantly reduce conflicts between pedestrians and motorists. This process involves eliminating specific motor vehicle phases (e.g., left turns) that cross concurrent pedestrian phases. For example, if the permissive left turns (either green ball or flashing yellow arrow) that cross pedestrian phases is eliminated, there is no longer a turning conflict for the crossing during that phase. In these cases, pedestrian phases may occur before (lead) or after (lag) conflicting vehicular movements.

Turn restrictions or protected pedestrian phases may be considered when one or more of the following criteria are met:

- There are high conflicting turning vehicles volumes. High turning volumes are defined as equal to or exceeding:
    - 200 total right and left turning vehicles per hour;
    - 50 left turning vehicles per hour when crossing one lane of through traffic; or
    - 100 right turning vehicles per hour.
- There is a high volume of total approaching traffic (greater than 2000 vehicles per hour for all approaches);
- There are high pedestrian volumes (pedestrians are 30 percent of vehicle volumes or 300 pedestrians per hour);
- Crash patterns at the study location or nearby locations with similar geometry support the use of separating motor vehicle and pedestrian phasing. Typically, this encompasses three or more left-turn or right-turn collisions where pedestrians had the right of way over a three-year period;
- The available sight distance is less than the minimum stopping sight distance
- The intersection geometry is unusual (streets intersect at acute/obtuse angles or streets have significant curvature approaching the intersection), which may result in unexpected conflicts and/or visibility issues;
- An intersection in close proximity to senior housing, elementary schools, recreational areas, playgrounds, and/or health facilities.

Protected pedestrian phases or protected-only turn phases may be implemented on a permanent basis, during specific hours, or "on-demand" when a pedestrian is present and activates the pushbutton. If only one movement or street meets the criteria above, consider a treatment to address those specific issues before implementing an intersection-wide approach (i.e., provide protected-only turns for the major roadway and allow for permissive turns on the minor roadway, if turning volumes are low on the minor roadway).

Turn Restrictions

Permissive left turns may be prohibited on demand through programming a signal controller to display a red left arrow when a conflicting pedestrian movement is called. Such programming may require staff time on the part of the jurisdiction where the signal is located in order to maintain signal flexibility and coordination.

A (R10-11) sign may be used to prohibit right turn movements at all times, or a dynamic sign may be installed to limit turns at specific times or conditions. Motorists turning right on red tend to focus on finding a gap in cross traffic. Driver attention in these situations tends to be on conflicting traffic approaching from their left, and not necessarily a pedestrian beginning to cross from the driver's right. Drivers may also encroach into the crosswalk while waiting for a gap in traffic, effectively blocking the crosswalk. Right turn on red restrictions may be used to reduce these conflicts, though such signs may not be effective if sight distance is not limited by geometry or other roadway features (landscaping, business signs, etc.) without significant enforcement efforts. Where left turns on red are legal on one-way streets, such restrictions may be appropriate for similar reasons.

Right turn on red restrictions increase the number of turns on green, which tend to be higher speed maneuvers, particularly at intersections with larger curb radii. Consequently, such restrictions may not always improve pedestrian safety and shouldn't be used as a default treatment without an engineering study.

5.5.7 Concurrent Pedestrian Phase with Permissive Vehicle Turns

At most signals, the indication for pedestrians is displayed concurrent with the green indication for parallel through vehicular movements. Concurrent timing often allows vehicles to turn left or right across the crosswalk during the phases with change interval countdown indication (pedestrian clearance interval), provided the motorists yield to pedestrians. To mitigate conflicts and improve motorist yielding, designers may consider the following treatments:

- Regulatory signs, such as the R10-15a series "TURNING VEHICLES YIELD TO [PEDESTRIANS]" (see Section X);
- Flashing Yellow Arrows (see below);
- Geometric treatments to reduce vehicle speeds and increase sight distances such as raised pedestrian crossings and curb extensions (see Chapters X).

Flashing Yellow Arrows

Flashing yellow arrows (FYAs) may be used for left or right turning motor vehicles to emphasize that drivers may proceed after yielding to oncoming traffic and/or pedestrians in a crosswalk. FYAs allow flexibility in providing permissive turns while warning drivers of potential conflicts.

5.5.8 Exclusive Pedestrian Phases

An Exclusive Pedestrian Phase (EPP), sometimes referred to as a "Barnes Dance" or a "Ped Scramble", stops vehicular traffic in all directions, allowing pedestrians to cross the intersection in all directions, including diagonally. This treatment can produce a safer operation over conventional phasing but delay for both pedestrians and motorists can be higher than conventional signal timing.[2] Most often, a protected pedestrian phase, specific turn restrictions, or LPIs are more appropriate solutions. An EPP may be preferred over a protected pedestrian crossing for the following scenarios:

- A combination of the criteria listed in Section 5 is met and 15 percent of pedestrians desire to cross diagonally;
- During special events that occupy a substantial portion of the public right-of-way (e.g., street fairs, parades);
- The start and end of school days for major school crossings;
- Intersections where certain motor vehicle turning movements are either not permitted or not in conflict with designated pedestrian crossings.

Signs may be attached to signal poles or pedestrian pushbuttons to inform people that the intersection has an EPP and they may cross diagonally; to inform where an EPP must be actuated by a person waiting to cross; or to deter crossing against the pedestrian signal concurrently with vehicle traffic. Signals that include EPP should time pedestrian phases to accommodate the longest possible crossing.

If a diagonal crossing is employed, designers may need to consider how a person with a visual disability would know that they could cross diagonally. Such determinations need to be carefully considered along with pushbutton placement and pedestrian ramp design for accessibility. Pavement markings should be designed in accordance with the MUTCD (Figure 3B-20).

5.6 Signal Design Guidance for Bicycle Facilities

This section's design guidance covers traffic signal head options for controlling bicycles, signal phasing, signal timing, and detection. The decision to install a traffic signal or pedestrian hybrid beacon (PHB) involves a holistic evaluation of numerous factors at the study location and requires an evaluation of MUTCD warrant criteria in addition to the use of engineering judgment. Additional details on this process can be found in Section 5.8 . The design guidance provided in this chapter supplements intersection design guidance provided in other chapters.

5.6.1 Indication Options

A vehicular signal head controls a bicyclist traveling in a shared lane or adjacent bicycle lane. Where it is necessary or desirable to control a bicycle separately from a motor vehicle, a bicycle may be controlled by a traffic signal designated for bicycle use only, or by a pedestrian signal head. Traffic signal indications for a bicyclist along a corridor should be as uniform as possible.

Standard Traffic Signal Face for Motor Vehicles and Bicycles

Standard signal control is appropriate to control both motor vehicles and bicyclists riding for both shared lanes and adjacent bicycle lanes. Supplemental signage may be appropriate to instruct bicyclists to follow motor vehicle signal control in cases where applicability is ambiguous.

Pedestrian Signal Heads

Using pedestrian signals to control bicyclist movements is generally discouraged except on shared use paths, but may also be appropriate for:

- separated bikeways traveling in the same direction as the closest motor vehicle travel lane and the pedestrian signal is well oriented for bicyclists to see,
- locations where an LPI is provided and allowing bicyclists to follow the pedestrian signal means they are provided a protected time to cross without turning vehicles, and
- projects with insufficient funding to provide separate bicycle signals, such a quick-build (rapid implementation) projects or those implemented as part of a resurfacing project where signal work is not part of the project scope.

Where a bicycle is required to follow the pedestrian signal, a "[BICYCLE] USE PED SIGNAL" (R9-5) sign shall be posted and the pedestrian signal must be readily visible and discernable to bicyclists. Where a bicycle may follow the pedestrian signal but can also follow the standard traffic signal (such as locations where the LPI provides a protected phase), a "BICYCLE MAY USE PED SIGNAL" sign should be considered.

Where bicyclists are required to follow a pedestrian signal, they are only legally allowed to enter the crosswalk during the WALK phase. Research has found low bicyclist compliance rates at locations where bicyclists are directed to follow pedestrian signals.[3] Most bicyclists continue to enter crosswalks on the FLASHING DON'T WALK phase, as it is timed for a pedestrian who moves much more slowly than a bicyclist. Additionally, at locations where the WALK indication is only four to seven seconds, bicyclists who comply with the signal are likely to experience more delay than bicyclists who enter during the FLASHING DON'T WALK phase. Caution should be exercised when requiring bicyclist to use pedestrian signals, particularly at locations with long crossings or unique signal timing.

Standard Traffic Signals Designated for Bicycle Use Only

A separate standard traffic signal may provide a separate signal exclusively for bicyclist use. When used, a "[BICYCLE] SIGNAL" (R10-10b) sign shall be installed immediately adjacent to the signal. A bicycle signal is typically used in the following situations:

- Where the bikeway is a one-way or two-way separated bike lane;
- Where bicyclists' position in the bikeway does not allow them to see motor vehicle or pedestrian signals that may otherwise be able to control their movement, and;
- Where intersection complexity is such that signals may be helpful, as determined by engineering judgment.

BICYCLE SIGNAL FACES WITHOUT CONCURRENT VEHICLE TURNS (INTERIM APPROVAL)

Bicycle signals may use a [BICYCLE] symbol face when used in compliance with FHWA's Interim Approval (IA)-16. There are many benefits to using bicycle signal faces and research indicates that bicycle signals increase compliance with the traffic control and reduce bicycle crashes.

Under IA-16, [BICYCLE] faces may only be used where "bicycles moving on a green or yellow signal indication in a bicycle [symbol] signal face are not in conflict with any simultaneous motor vehicle movement at the signalized location, including right (or left) turns on red." The Interim Approval also prohibits the use of bicycle signal faces at pedestrian hybrid beacons. Situations where bicyclists follow pedestrian signals or where a standard traffic signal head is designated for bicycle use are not restricted by the provisions of the Interim Approval for bicycle signal faces.

5.6.2 Bicyclist Detection

At locations with active warning devices, pedestrian hybrid beacons, or traffic signals, there are various techniques that can be used to actively or passively detect bicyclists. Semi- or fully-actuated signals should passively detect bicycles for phases with "no recall" (i.e., to call the signal and extend the side street green) or "min recall" (i.e., to extend the green on the main street). If a signalized intersection approach cannot accommodate passive detection, a curb-side pushbutton for active detection should be provided.

Detection Technology

Passive detection equipment does not always reliably detect bicyclists. Bicycle detector installations should be tested under a variety of lighting and weather scenarios to confirm effectiveness. Below is a list of detectors commonly used to detect bicyclists at traffic signals as well as considerations for each type:

- Radar Detection System – Some radar detection can distinguish between user types. Detection systems that are not able to do so should be either replaced or supplemented if signal operations require a distinction between bicyclists and motor vehicles.
- Inductive Loop Detection - Quadrupole inductive loops, Type Q and Type D, are two options for loop detector configurations for bicycles. Powerhead loops provide better bicycle detection at stop lines while quadrupole loops are typically used for dilemma zones to extend green phases. They can be used to detect bicycles on shared use paths and bike lanes, as well as in travel lanes on roadways.
  - Type Q loops can best detect bicyclists when they are above the loop wire.
  - Type D loops have a magnetic field everywhere within the loop and thus are better for detecting bicycles within the entire loop area. Type D is also particularly effective at rejecting vehicles in the adjacent travel lane, allowing the use of a higher sensitivity setting on the detector amplifier.
- Video Detection System - Video detectors may have challenges detecting vehicles, including bicycles, due to poor streetlighting. Video detection can also be problematic when the sun is low in the sky, which can cause glare and potentially skip phases. This may also be the case during inclement weather (e.g., heavy rain, fog, or snow), though it can be somewhat mitigated by ensuring detection zones are appropriately illuminated.
- Infrared Detection – Bicyclists can be detected through fog, snow, and other environmental constraints that impair video detection.

Bicycle pushbuttons may be used to supplement passive detection. Pushbuttons may also be used where it is desirable for a bicyclist to be detected, but not a motorist (e.g., a bicycle boulevard crossing an arterial with a pedestrian hybrid beacon or a Toucan crossing). Where used, pushbuttons should be reachable by bicyclists and be accompanied by explanatory signage.

Location

Passive bicycle detection should:

- be located in the expected path of bicyclists;
- extend across most of the bicycle lane or shared roadway lane width;
- be adjacent to a curb or other type of footrest, when present.

Detection should also be included in bicycle boxes and two-stage turn queue boxes. In bicycle boxes, detection should be provided both in front of general purpose lanes and bicycle lanes. In two-stage turn queue boxes, the detection zone should include the full area of the marked queue box. Both bicycle boxes and two-stage turn queue boxes have Interim Approval from FHWA (see Section).

When used, bicycle pushbuttons should be placed within a reasonable reach from a bike lane or shared use path. They should allow bicyclists to actuate them without dismounting while satisfying lateral offset requirements from the AASHTO Roadside Design Guide. This can be accomplished by placing bicycle pushbuttons a maximum of 18" from the face of curb, which is an exception to the bikeway shy distance recommendations provided in Section 5.5.2. If there are concerns about a motor vehicle striking the pushbutton pole, bollards may be installed to protect the equipment with the understanding that this could be a hazard to turning motor vehicles. Alternatively, bike ramps should be provided so that a bicyclist can access a sidewalk or separated bike lane to actuate a pushbutton.

Pushbuttons intended both for pedestrians and bicyclists should be located and operated in accordance with accessibility guidelines. Section 5.5.2 provides guidance on the location of pushbuttons when they are on a sidewalk or shared use path. Where bicycle pushbuttons are installed, they do not have to meet accessibility guidelines or MUTCD requirements for placement. In locations where pedestrians and bicyclists have parallel crossings and pushbuttons are used to activate a warning device or other active traffic control device, pushbuttons for pedestrians and bicyclists may be placed on the same pole or separate poles. While there is a recommended minimum spacing of 10 ft. between two pedestrian pushbuttons on the same intersection corner, separate pushbuttons for bicyclists and pedestrians do not have a minimum separation recommendation. Pushbutton placement 6 ft. behind the curb is preferable to allow bicyclists and pedestrians pushing strollers to stop at the pushbutton without the front end of their wheel(s) getting closer than 2 ft. from the face of curb or edge of road.

Signs and Markings

When installed, a bicycle detection marking should indicate to bicyclists where they should position themselves to be detected. MUTCD Section 9C.05 includes bicycle detector pavement markings that can be used. The pavement marking can also be supplemented with a BICYCLE SIGNAL actuation sign (R10-22). This marking and sign can be used with any type of bicycle detection.

5.6.3 Signal Design Considerations

The MUTCD establishes requirements for the size, arrangement, number, visibility, and positioning of vehicle traffic signals at an intersection. Bicycle signal locations are guided by similar principles and FHWA's Interim Approval (IA)-16. The following guidance is intended to supplement the MUTCD. In general, designers should minimize the number of mast arms and/or pedestal poles by combining equipment where possible. This minimizes the number of fixed objects that can be damaged or cause injury and reduces clutter.

Size and Layout of Displays

All signal indications in a bicycle signal face shall be the same size, including those that display arrows and those that display bicycle symbols. The primary bicycle signal head for the bicycle movement shall use an 8 inch or 12 inch diameter lenses. When the primary bicycle signal face is located on the far-side, a 12 inch diameter bicycle signal shall be used if it is located more than 120 ft. from the stop line.

Bicycle signal faces with 4 inch diameter lenses may only be used as a supplemental, near-side signal. Near-side bicycle signal faces may alternatively be 8 inches in diameter. The smaller size allows it to be mounted at a lower height, improving visibility to approaching bicyclists.

Number of Displays

The MUTCD and the Colorado Signs, Signals, and High-Mast Lights Inventory & Inspection Manual[4] prescribe the use of two signal faces for a primary motor vehicle movement. As bicycles are rarely the primary movement, the use of one bicycle signal face is generally sufficient. A supplemental near-side signal should be considered in the following situations:

- Locations with protected bicycle phases, as bicycle crash risk is increased if the bicycle signal fails;
- Per FHWA's Interim Approval (IA)-16, if the signal head is located more than 80 ft. beyond the bicycle stop line (a supplemental near-side signal head shall be provided when the signal head is more than 120 ft. from the bicycle stop line);
- Intersections that require diagonal or unusual bicycle movement through the intersection.

An additional benefit of a second bicycle signal display is that it provides an added safety feature in case one of the displays malfunctions.

Visibility

At least one signal face should be visible a minimum of 120 ft. before the stop line based on stopping sight distance for a bicycle traveling 15 mph on a flat grade. This distance should be increased where higher bicycle speeds are expected, such as on downhill grades. Where bicyclists do not have a continuous view of the signal for the minimum sight distance, a W3-3 sign "SIGNAL AHEAD" should be installed.

Bicycle signals should be installed such that visibility is maximized for bicyclists and minimized for adjacent, conflicting motor vehicle movements. Visibility-limiting lenses may be appropriate so long as bicyclists can still see the indication, though such equipment may not effectively shield adjacent travel lanes. As such, other methods to distinguish bicycle signals may be necessary. These may include lower or pole mounted placement, use of smaller signal heads than those controlling motor vehicle traffic (e.g., 8 inch vs. 12 inch), and/or different color signal backplates and/or equipment housing. Legend use or supplemental word messages on backplates is prohibited.

Where existing vehicle traffic signal heads are anticipated to be the sole source of guidance for bicyclists, designers shall check that they are located within the cone of vision measured from the bicycle stop line, as described in the MUTCD. If bicyclists are required to follow optically programmed or shielded vehicle signals, the signals shall be visible to approaching bicyclists. If the vehicle signal faces fall outside the cone of vision, supplementary vehicular or bicycle signals should be provided.

Placement

The primary bicycle signal head should be mounted in a lateral position that reduces the potential for pedestrians, landscaping, or other signal equipment to block the view of the signal for approaching bicyclists. The recommended distance from the edge of the bikeway is 5 ft. or less. If possible, mounting bicycle signal heads overhead is preferred. If bicycle heads are side-mounted, they should be installed on the same side (i.e., left or right) of the bikeway along an entire corridor.

The spacing between bicycle signal heads and motor vehicle signal heads should be maximized. Bicycle signal heads should not be placed between two motor vehicle signal heads with the same signal face as another motor vehicle signal head. Bicycle signal heads should have a minimum separation of 3 ft., either vertically or horizontally, from other signal heads to reduce the potential for confusion. Signals are located in close proximity, it may be desirable to consider one or more of the following strategies to reduce potential for confusion:

- Provide optical programming or shielding on both signal faces;
- Mount the bike signal face at a lower height then the vehicular traffic signal faces;
- Use 8 inch signal heads for far-side signals. 8 inch signal heads should only be considered if other signal heads are 12 inches in diameter for the same direction of travel.

A BICYCLE SIGNAL sign (R10-10b) shall be placed adjacent to all bicycle signal faces.

Mounting height

When newly erecting a pole for adding a bicycle signal or adding a bicycle signal to an existing pole, the following applies:

- If a bicycle signal head is mounted on a mast arm, the bottom of the housing shall be between 15 and 25.6 ft. above the pavement;
- The bottom of the signal housing of an 8 inch or 12 inch bicycle signal face that is not located over a roadway shall be a minimum of 10 ft. and maximum of 19 ft. above the sidewalk or ground. Where supplemental signing is installed below the bicycle signal face, the minimum mounting height to the bottom of the supplemental sign should be 10 ft.;
- If a 4 inch bicycle signal face is used as a near-side supplemental signal, the bottom of the signal housing should be between 4 and 8 ft. above the ground.

When feasible, mounting bicycle signal heads at a different height than adjacent vehicle signal heads can reduce confusion.

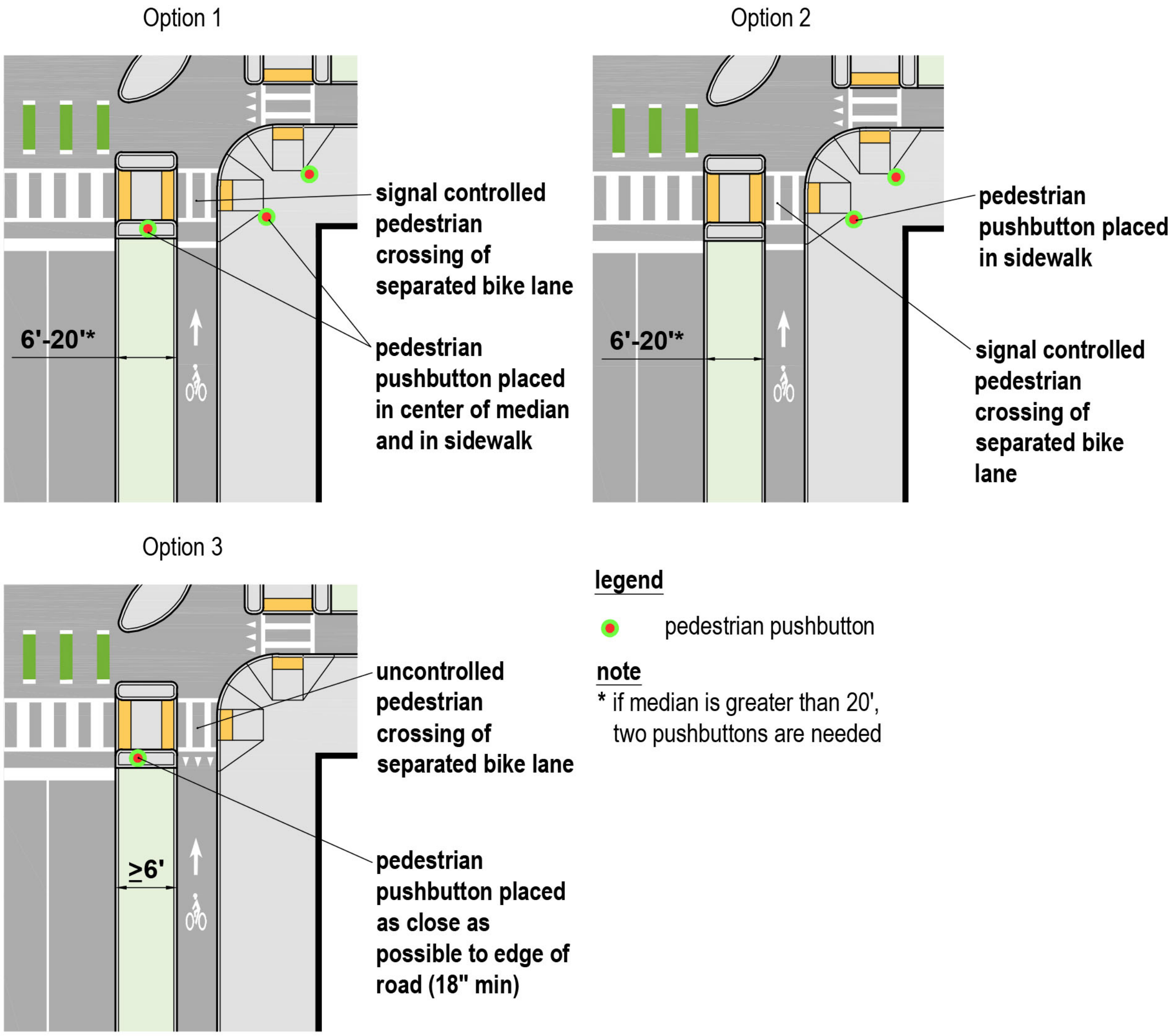
Considerations for placement with pedestrian signal equipment

Designers must determine if a pedestrian crossing of the separated bike lane should be controlled or uncontrolled at intersections with a separated bike lane and a street buffer that is 6 ft. or wider. When floating transit stops are present along a separated bike lane at a signalized intersection, the platform will serve as a pedestrian crossing island; as such, a second pushbutton must be placed in the buffer (see Chapter X for floating bus stops). The following discusses uncontrolled and controlled crossing considerations:

- **Controlled crossings** – Can be used where it is desirable to ensure bicyclists are stopped prior to the pedestrian crossing (see Option 2 and 3 in Figure 41). In these cases, the separated bike lane movement across the pedestrian crossing is signal controlled. The pedestrian clearance interval should be based on a crossing distance beginning/ending at the sidewalk, which will increase the signal cycle length and delay for all users. Additionally, the benefits of the forward queuing area to reduce bicyclist conflicts with turning traffic are diminished. If the street buffer is greater than 6 ft., an additional pushbutton may need to be placed in the median to meet pedestrian accessibility guidelines, such as where a floating transit stop is present (see Option 2 in Figure 41).
- **Uncontrolled crossings** – Can be used where it is desirable to prioritize a shorter pedestrian crossing distance and maintain the ability to allow bicyclist to wait in the forward queueing area of a protected intersection (see Option 1 in Figure 41). In this option, the separated bike lane movement across the pedestrian crossing is uncontrolled and the pedestrian clearance interval is based on a crossing distance beginning/ending at the median (i.e., street buffer).

When the buffer is less than 6 ft. wide at an intersection with a separated bike lane, the pedestrian pushbutton should not be placed in the buffer area. In these cases, pushbutton placement should follow the layout shown for Option 3. In all scenarios, designers should ensure all proposed pedestrian ramps, pushbuttons, and signals meet current accessibility guidance, see MUTCD Section 4E of this guide for additional details.

Figure 41: Accessible Pedestrian Pushbutton Locations with Separated Bike Lane



5.6.4 Signal Timing and Reducing Bicycle Delay

Existing signals are usually timed for prevailing motor vehicle speeds. Designers should evaluate minimum clearance intervals based on bicyclists' operating characteristics and make adjustments that provide the safest design for all users. Signal cycle length and signal coordination can also impact bicyclist delay, which may lead to traffic control device non-compliance. Designers should balance traffic operations and consider delay and safety impacts to all users.

A bicyclist design speed of 8 mph and acceleration of 2.5 ft/s^2, which is a typical speed and acceleration profile of a slow-moving adult bicyclist, is recommended for minimum green signal timing. A bicyclist design speed of 15 mph is recommended for red clearance interval signal timing. The designer should adjust the design speed and acceleration values as appropriate at locations where the typical bicyclist may be slower or faster moving, such as on downhill or uphill grades.

Signal Cycle Length

Signal cycle length can have a significant impact on pedestrian and bicyclist travel. Signal cycle lengths of 60 to 90 seconds are common in urban areas, as they allow frequent street crossings and can encourage more efficient street network use. In suburban areas where vehicle traffic is often consolidated on a relatively small number of arterial and collector streets, signal cycle lengths are typically longer compared to denser, urban corridors that may have a number of one-way facilities. Cycle lengths are generally between 90 and 150 seconds, though some intersections run longer cycle lengths during peak travel periods. At intersections with a longer signal cycle length, users approaching from a minor street can experience significant delays. This can result in reduced signal compliance for bicyclists where gaps are present, when bicyclists are unaware that they have been detected, or if they have not been detected at the intersection. Consideration should be given to providing shorter signal cycle lengths when feasible, or operating in "free" or fully actuated mode during off-peak periods so that the signal switches to the side street phase more quickly to minimize delays to side street users including bicyclists. However, signal cycle length reductions must not come at the cost of adequate pedestrian crossing intervals (see Section 5.5.3).

In some cases, the signal cycle length at an intersection is determined based on adjacent intersections that are part of a coordinated system described later in this section.

Bicycle Minimum Green

When an approach receives a green indication, a bicyclist waiting at the stop line needs enough time to perceive, react, accelerate, and establish themselves in the intersection before the beginning of the yellow signal indication. The recommended minimum green time for a bicyclist is long enough for a bicyclist to travel at least halfway across the intersection so that a bicyclist is visible to conflicting traffic and has established themselves in the intersection before the signal turns yellow.

Where bicyclists and motorists follow the same signal, the minimum green at an intersection should be based on the bicycle minimum green. Different minimum green time for bicyclists and motor vehicles may be established under the following scenarios:

(A) The traffic controller has the capability to set bicycle minimum green parameter;
(B) Separate detection or detection that can differentiate bicycles from motor vehicles is implemented.

When bicycle signals (either a standard traffic signal face designated for bicycle use or a bicycle signal face) are used for exclusive bicycle phases, the bicycle minimum green should be used.

Table 9 defines the bicycle minimum green time based on the distance from the stop line. At a minimum it is recommended "d" be defined as the distance from the stop line to the middle of the intersection. However, designers may choose a higher value of "d" up to the full width of the intersection. A larger "d" will enable a bicyclist to get farther through the intersection before the green indication ends, potentially improving bicyclist comfort when crossing the intersection.

Table 9: Bicycle Minimum Green Time Equation

Bicycle Minimum Green Time Equation		
$G_{min} = t + \frac{1.47v}{2a} + \frac{d+L}{1.47v}$		
Where:		
G_{min}	=	bicycle minimum green time (s)
v	=	attained bicycle crossing speed (assumed 8 mph)
t	=	perception reaction time (generally 1.5 s)
a	=	bicycle acceleration (assumed 2.5 ft/s^2)
d	=	distance from stop bar to middle of the intersection (ft)
L	=	typical length of a bicycle (6 ft)

Table 10: Total Phase Length, Minimum Green

Total Phase Length and Minimum Green		
$G_{min} + Y + R_{clear} \geq t + \frac{1.47\,v}{2a} + \frac{W+L}{1.47v}$		
Where:		
G_{min}	=	time required to attain crossing speed (s)
Y	=	yellow change interval (s)
R_{clear}	=	all-red (s)
w	=	intersection width (ft)
L	=	bicycle length (assumed 6 ft)
v	=	bicycle travel speed (assumed 8 mph)
a	=	bicycle acceleration (2.5 ft/s^2)
t	=	perception reaction time (assumed 1.5 s)

A minimum green time based on a bicyclist traveling halfway across the intersection will typically result in a phase length long enough for a bicyclist to fully clear the intersection before the conflicting approach receives the green indication. However, at some wider crossings, the total phase time may not be sufficient. Designers should also verify that the total phase time is greater than the total time for a bicyclist starting from a stop to cross the intersection (see Table 10). Designers should increase the minimum green time until the total phase time is greater than or equal to the total time for a bicyclist to cross the intersection.

Note that the assumed bicycle travel speed for both minimum green time and total phase length is 8 mph. However, a higher speed may be considered for the red clearance interval, since slow moving bicyclists are not likely to enter the intersection at the end of the yellow change interval. See the discussion of "Red Clearance Interval" below.

Yellow Change Interval

The MUTCD, Section 4D.26 states that a vehicle yellow change interval should be a minimum of three seconds, which provides sufficient reaction time for a bicyclist traveling at up to 15 mph to stop before entering the intersection. When a bicycle signal (either standard traffic signal face designated for bicycle use or a bicycle signal face) are used exclusively for bicycle phases, the minimum yellow change interval of three seconds should be used.

When bicyclists and motor vehicles follow the same signal, the yellow change interval for a motor vehicle should be used, as motor vehicles will likely be traveling at higher speeds and need additional time to react.

Red Clearance Interval

The red clearance interval allows for a roadway user that legally entered the intersection at the end of the yellow change interval additional time to complete their movement prior to crossing movements receiving a green indication. Designers should determine where a bicyclist would be positioned if they entered the intersection at the end of the yellow interval. For shorter red clearance intervals, the bicyclist may not be visible to motorist stopped on the conflicting approach waiting for a green indication. In these instances, designers should lengthen the red clearance interval so that a bicyclist will have established themselves in the intersection or traveled beyond the conflict point with a conflicting approach (see Figure 42).

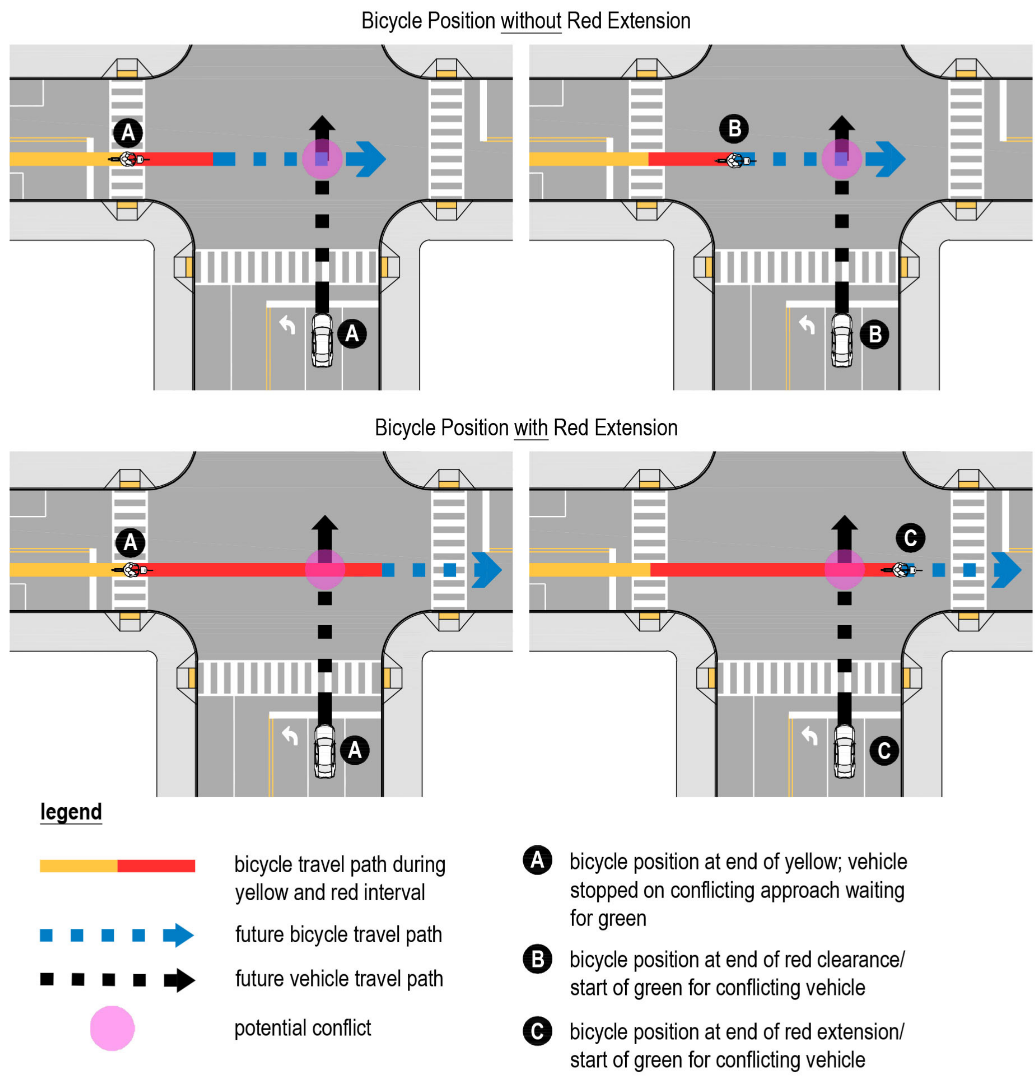
As previously mentioned in the "Bicycle Minimum Green" section, a higher design speed may be considered for the red clearance interval when taking bicycles into account. If a bicyclist determines not to stop during the yellow change interval, they are likely accelerating to clear the intersection. In this case, a higher design speed of 15 mph may be considered for the red clearance interval. Such a calculation is not likely to significantly change the overall interval if rounded to the nearest second, but it may reduce the red clearance from two seconds to one second, allowing that time to be applied elsewhere in the cycle length.

When bicyclists on the major street intend to use a two-stage bicycle turn box place in line with the lanes of the minor street approach, the designer should consider extending the red clearance interval because the bicyclist must slow to access the bicycle turn box. If the subsequent phase includes side street through traffic, a longer red clearance may be necessary to accommodate bicycle traffic entering the box. However, if the subsequent phase does not include side street through traffic (e.g., lagging left turn on the major approach), a longer red clearance would not be necessary.

Bicycle Green Extension

In locations where bicycle volumes are heavy during a particular time of day, additional green time may be needed. In these cases, the approach may include a detector at the stop line or in advance of the stop line to extend the green interval in order to allow bicycle traffic to move through the intersection. The length of the extension should be determined by the speed of bicyclists, the detector distance from the stop line, and the amount of extension time that can be provided. Once the phase has begun, each bicyclist will extend the green time for each bicycle detected up to the maximum green.

Figure 42: Bicycle Position During Red Clearance



Signal Coordination Considerations

Corridors with coordinated signals are often timed to progress motor vehicles at speeds which are significantly faster than typical bicycle travel. Consequently, in these cases, most bicyclists will not gain progression benefits.

Cycle length is usually selected based on the needs of the largest or most congested intersection. These signal cycle lengths are sometimes longer than optimal for smaller or less busy intersections and can result in higher delays for users on side streets. These side streets are often more comfortable for bicyclists, assuming they provide reasonable network connectivity and comfort for bicycles. Significant intersection delays degrade the value of these corridors and can result in reduced signal compliance when traffic gaps are available. This can be a significant barrier at bicycle boulevard crossings or shared use paths where there may be an expectation of a higher level of service for bicycle travel.

To offset these challenges, on streets that are designed to accommodate bicyclists, designers should consider the following:

- **Half signal cycle lengths or a shorter corridor-wide signal cycle length during lower volume and off-peak periods**. On coordinated corridors with semi-actuated signalized intersections (i.e., detection on the side street), signals could operate in "free," or uncoordinated mode, to reduce delays on the side streets. Designers should consider signal spacing, traffic volumes, and delay for all users when evaluating whether to run a signal in "free" or uncoordinated operation. In signal networks with fixed time operation and lower cycle lengths (90 seconds or less), it may be preferred to maintain coordination.

- **Progression speeds closer to bicycle operating speeds to support and encourage bicycle traffic on the coordinated corridor.** These are referred to as "Green Wave" progressions for bicycles. They allow bicyclists to operate at a consistent speed, reduce stopping, and improve compliance. Common green wave progression speeds are between 12 and 15 mph. This speed can vary depending on corridor geometry and geography (e.g., grade, sight distance). A "Green Wave" encourages slower travel speeds for motor vehicles, which improves safety for all roadway users. Where a "Green Wave" is provided, SIGNALS SET FOR XX MPH (I1-1) signs may be posted to advise road users of the recommended speed.

"Green Wave" progression would be most appropriate on bikeway corridors (e.g., bicycle boulevards) with reasonable volumes of bicycle activity. Lowering progression speeds could needlessly increase delay for motor vehicles and transit passengers, so the installation of "green wave" progression should consider the effects on all travel modes.

In some instances, bicycles may be traveling in the opposite direction of signal progression. For example, there may be counterflow movement of a two-way separated bike lane or side path. There may also be a designated bike lane traveling the opposite direction of motor vehicle traffic on a one-way street. These scenarios should be designed with signal progression similar to a conventional two-way street.

5.6.5 Signal Phasing for Managing or Reducing Conflicts

Traffic signal phasing is an essential tool for managing and reducing conflicts at intersections. Signal phasing should be considered in conjunction with intersection design treatments described.

Although eliminating conflicts between bicyclists and motorists provides the greatest safety benefit, signal phasing should balance delay to all users, signal cycle length, and the risk of conflicts. Designers should assess the number of right and left-turning motorists across bikeways during the peak hour to identify when a protected or partially protected bicycle phase may be considered. Table 11 identifies thresholds for when a protected phase or leading bicycle interval for a separated bike lane or side path may be appropriate to improve safety at an intersection. It may also be appropriate to reduce the threshold volumes on higher speed roads.

In addition, designers shall consider providing separate signal phases for the following situations:

- Locations with multiple left or right turn lanes;
- Where sight obstructions limit bicycle visibility;
- At locations where bicycle volumes and/or parallel pedestrian volumes are
  high and turning motorists are unable to find appropriate gaps;
- At locations where more than 5 percent of the turning traffic volume is heavy vehicles;
- Locations where motorists may turn across the bikeway at speeds over 30 mph or on roads with posted speeds of 35 mph or greater.

Table 11: Hourly Turning Traffic Thresholds for Time-Separated Bicycle Movements

Hourly Volume Thresholds for Separate Turn Phases		
	Left Turn Crossing One Oncoming Lane	Left Turn Crossing Two Oncoming Lanes
One-Way Separated Bike Lane	≥ 100 ≥ 150*	≥ 50 ≥ 150*
Two-Way Separated Bike Lane or Sidepath	≥ 50 ≥ 100*	ANY ≥ 100*

*Threshold also applies to left turns on one-way streets

Protected phases and turning restrictions may be implemented on a permanent basis, through actuation, or during specific hours. If only one approach meets the criteria above, consider a treatment to address that approach before considering an intersection-wide treatment (e.g., evaluate a protected only left-turn phase if only the left turning volume threshold is exceeded but not the right turning volume threshold).

Where Table 11 or the list of criteria indicates that one or more vehicular turning movements should be phase separated from bicyclists, but a separated phase is not feasible or desirable, designers should consider a leading bicycle interval and/or a flashing yellow arrow. Additional treatments are discussed in Section 5.5.

Conventional, buffered, and raised bike lanes will follow either traffic signals or pedestrian signals, as directed. Where right turn only lanes are present (see Section 5.3) a conventional or buffered bicycle lane cannot be placed to the right of the turn lane. If a bicycle lane must be placed to the right of a right turn lane for safety and to accommodate the design user (i.e., high volume of vehicles crossing the bicycle lane to turn right), designers shall convert the bicycle lane to a raised bike lane or separated bike lane and follow the principles set forward in this section. Phase separation is required for a raised bicycle lane located to the right of a right turn lane (see Section 5.3).

Phasing Schemes

Designers may incorporate a bicycle signal phase at a signalized intersection to reduce potential conflicts between bicyclists and motor vehicles. Designers should consider both the operational and safety impacts of signal phasing changes at an intersection. Designers should be aware that a phasing scenario may necessitate a separate motor vehicle turn lane and an additional phase, which may increase delay for some users, including bicyclists. Fully separated movements may require longer signal cycle lengths, which may result in reduced user compliance with signal indications and therefore increase potential for conflict. However, the need to protect bicyclists from turning conflicts should be considered a higher priority over reducing bicyclist delay.

Many of the signal phasing options described in Section 5.5 for pedestrians can also be adapted to eliminate or manage conflicts between bicyclists and motorists. This section describes four schemes of bicycle signal phasing that employs some of the techniques discussed in Section 5.6. There are numerous phasing options available to designers, and not all options are possible depending on the type of bikeway provided at the intersection (e.g., conventional bike lane, raised bike lane, separated bike lane). These schemes are intended to provide examples of some of the options available.

Exclusive Bicycle Phase

This phasing scheme represents a fully separated bicycle movement. All motorized vehicle movements, including conflicting vehicle turns across the bikeway, are restricted during the exclusive bicycle phase. Exclusive turn lanes for the conflicting vehicle turns are not required since all vehicle movements are stopped. Some pedestrian movements may be allowed during the exclusive bike phase.

If bicyclists move independently of pedestrians, this phasing requires the use of a standard traffic signal face designated for bicycle use or a bicycle signal face consistent with FHWA's Interim Approval (IA)-16 that is separate from the motor vehicle signal. Alternatively, bicyclists may be directed to follow pedestrian signals during a shared, protected bicycle and pedestrian phase. In this case, a [BICYCLE] USE PED SIGNAL sign (R9-5) should be installed. R9-5 sign installation should only be considered for use on shared use paths, raised bike lanes, or separated bike lanes. Right (or Left) turn on red shall be prohibited during the protected bicycle phase. Depending on the signal phasing, a blank out or static NO TURN ON RED (R10-11) sign shall be provided.

Where a pedestrian-only phase is provided, a text-based BICYCLE MAY USE PED SIGNAL sign may be used to allow bicyclists to use the pedestrian-only phase.

Depending on right and left turn volumes, the exclusive bike phasing scheme is more likely to have an impact on motor vehicle operations. To accommodate queues or an increase in signal cycle, consider extending turn lane storage lengths, if feasible.

Concurrent Protected Bicycle Phase

This phasing scheme also represents a protected-only bicycle movement. The bicycle phase runs concurrently with parallel through motor vehicle phases, but conflicting turns across the bikeway are restricted. Right and left-turn movements across the bikeway operate under a protected-only phase. Exclusive turn lanes for conflicting vehicle turns will be necessary.

In this phasing scheme, a bicycle shall be controlled by a bicycle signal head separate from the vehicle signal. Right (or left) turns on red shall be prohibited during the protected bicycle phase. Depending on the signal phasing, a blank out or static NO TURN ON RED (R10-11) sign shall be provided.

Depending on left and right turning volumes, this phasing scheme may have an impact on motor vehicle operations, especially for the turning movements across the bikeway. Turn lane storage lengths may need to be extended to accommodate queues; reducing split times for other phases or increasing signal cycle length may also be necessary. This phasing scheme can be effective for bikeways along streets with high through movement volumes and low turning volumes.

Leading Bicycle Interval

At locations where bicycle volumes and/or motor vehicle turning volumes are lower than the threshold shown in Table 11, or at locations where a bicycle protected phase is not feasible, there may be benefits to providing a leading bicycle interval (LBI) or leading through interval (LTI). For LTI, designers should refer to Section 5.6.5. This phasing scheme represents a partially separated bicycle movement. Leading intervals are typically between three and eight seconds long and occur in advance of the green indication for turning motor vehicles. For pedestrians, if a protected intersection is used and bicyclists are allowed to queue in front of the crosswalk, the leading interval may be reduced as bicyclists will be positioned ahead of adjacent motor vehicle lanes and, by design, will be able to establish themselves in the intersection sooner with a short leading interval. Because it only requires a few seconds, a leading bicycle interval may have only a minor impact on motor vehicle operations and, in general, does not require a longer signal cycle length. However, on higher travel corridors, the designer may wish to perform a microsimulation of the proposed phase plan prior to implementation to estimate the difference in travel time between scenarios.

An LBI allows a bicyclist to enter the conflict area prior to a turning motorist, improving their visibility as they cross the intersection. In some cases, an LBI may allow bicyclists to clear the conflict point before motor vehicles enter the intersection. A parallel LPI may also be considered where there is a parallel pedestrian crossing. When a protected left turn phase is provided, it should occur as a lagging phase to prevent left turning vehicles continuing to cross during the LBI. Designers should also avoid the "Yellow Trap" when providing a lagging turn phase.

In this phasing scheme, a bicycle must be controlled by a signal head that is separate from the motor vehicle signal. Any of the signal indication options from Section 5 may be used to control bicyclist movements for an LPI except for the bicycle signal face (per IA-16). Right (or left) turns on red shall be prohibited during the LBI under this scenario. At locations where additional motor vehicle capacity is desired or there are concerns about compliance with a static sign, the use of a blank out NO TURN ON RED (R10-11) sign may be considered.

LBIs only assist bicycles waiting at the stop line at the beginning of the green interval. They do not provide any protection to bicyclists who arrive after the LBI has ended. Because an LBI includes permissive turns while bicyclists may proceed through, designers should provide signing or signal indications to communicate that mutual yielding (see Section 5.6.5) conditions will apply. Designers can also consider regulatory signs, such as the R10-15 series TURNING VEHICLES YIELD TO BICYCLISTS (AND PEDESTRIANS), and warning signs stating WATCH FOR TURNING VEHICLES. Section 4D of the MUTCD provides additional signal information using protected and permissive signal design for right and left turns.

Concurrent Bicycle Phase with Permissive Vehicle Turns

This phasing option represents a common scenario at most intersections where bicyclists in a shared lane or bike lane are not provided any exclusive time in the intersection. In this case, bicyclists are crossing the intersection concurrent with parallel through motor vehicles, and motorists may make permissive turns that cross their path if separate right turn lanes are not provided. This phasing scheme has the lowest impact on motor vehicle operations but may not adequately address turning motorist/through bicyclist conflicts. Any of the signal indication options from Section 5 may be used to control bicyclist movements with concurrent bicycle phases except for the bicycle signal face (per IA-16). Designers should apply the following treatments as appropriate:

- Flashing Yellow Arrows (see Section 5.5.7);
- Regulatory signs, such as the R10-15 series TURNING VEHICLES YIELD TO BICYCLISTS (AND PEDESTRIANS);
- Warning signs for bicyclists to WATCH FOR TURNING VEHICLES;
- An offset bicycle crossing to create space for yielding;
- Geometric treatments to reduce vehicle speeds and increase sight distances (see Chapters 5.1).

5.7 Toucan Crossings with Traffic Signals

A Toucan crossing, originating from the phrase 'two can cross,' is a traffic signal complemented by a geometric design treatment that restricts some motor vehicle movements while providing a signalized bicycle and pedestrian crossing. The pedestrian crossings may be located in their traditional location, from corner-to-corner, or may be consolidated to one crossing of the roadway adjacent to the bicycle crossing (see Figure 45). A consolidated crossing may reduce conflicts with motorists, but it requires pedestrians to cross away from their traditional line of travel and require a larger central island size to accommodate them while maintaining separation from bicyclists.

This design stops motor vehicle traffic on the major street during the entirety of the bicyclist and pedestrian crossing. These intersections restrict through and left turn motor vehicle movements from the side street, creating a protected crossing for bicyclists. Motorists are permitted to make a right turn movement from the side street, thus removing it from signal control.

This design may be considered for major arterial crossings where it is not desirable to provide a PHB or a full traffic signal. A typical application for a Toucan crossing is where a bicycle boulevard crosses an arterial street. Toucan crossings may also be used at T-intersections.

5.7.1 Geometric Design Features and Signal Equipment Placement Considerations

There are several key features of this type of crossing (See Figure 45):

- Minor street center medians for bicyclist separation from motor vehicles and space for bicycle signal placement;
- Raised median or raised bike lane to create a queueing area for bicycles;
- Pedestrian crosswalks on all legs or consolidated to one crossing of the major street;
- Channelization island to restrict motorist through and left turns from minor street;
- Pedestrian signals for pedestrians crossing motor vehicle movements;
- Pedestrian signals for pedestrians crossing signalized bike lanes (if a two-stage crossing is provided);
- Bicycle signals for bicycles crossing the major street.

Figure 44: Signal Phasing Scheme with LBI and FYA

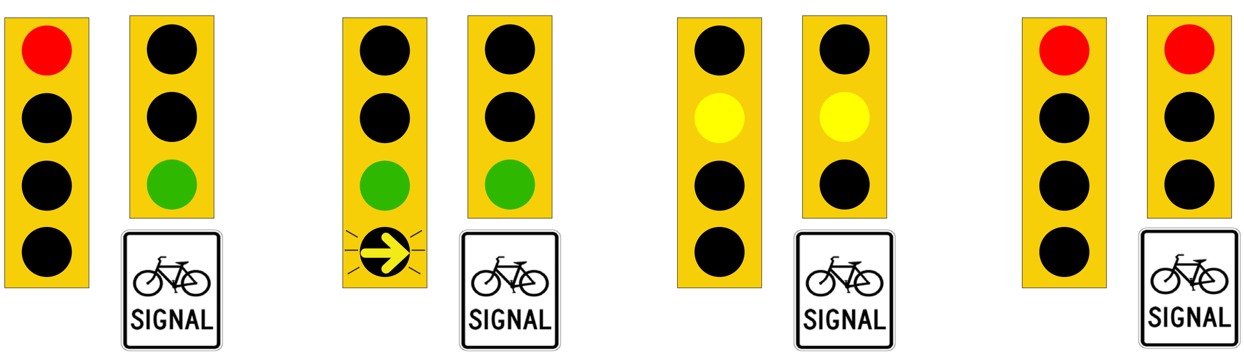
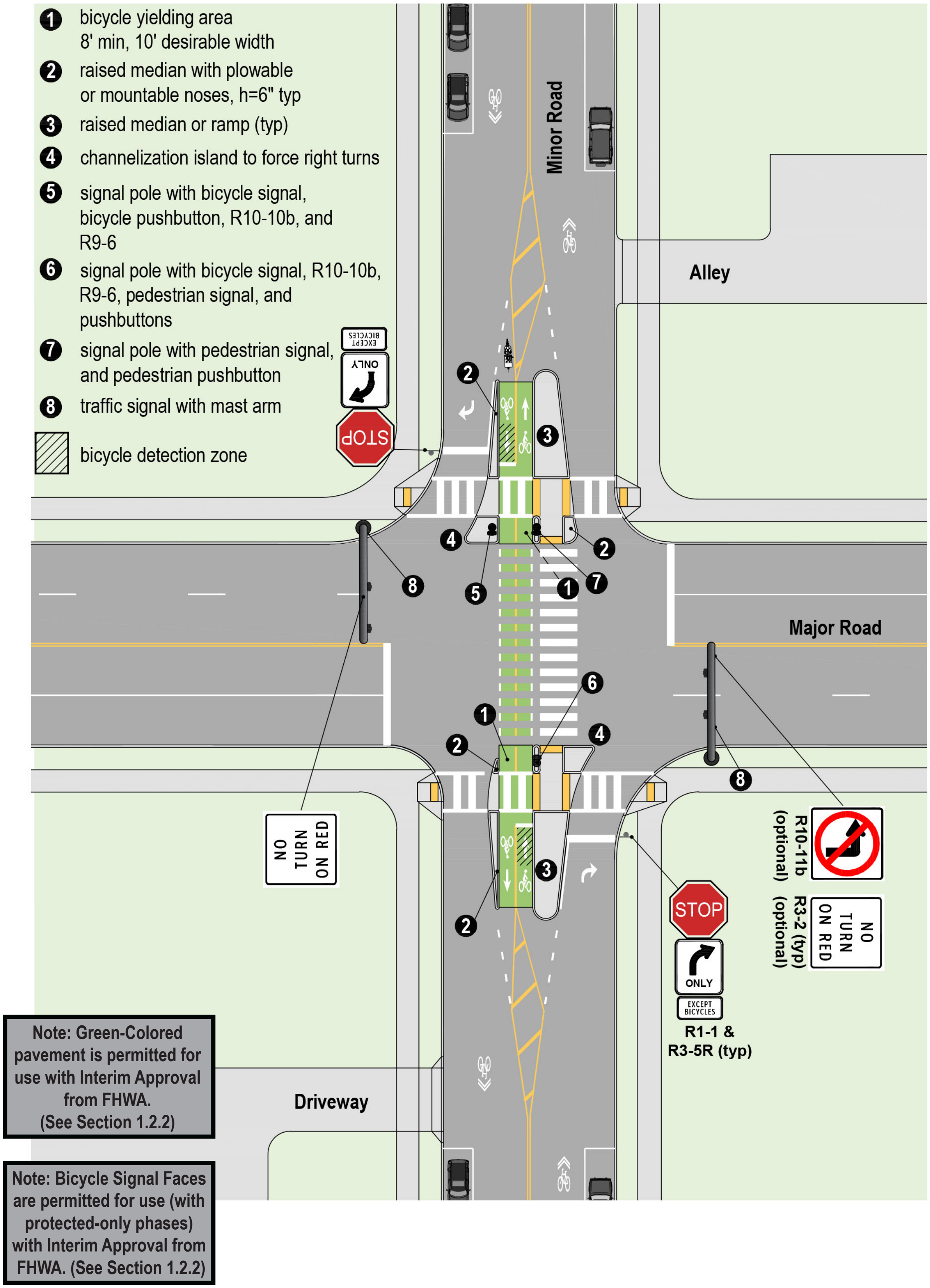


Figure 45: Toucan Crossing Example



Parking restrictions on the minor street may be necessary within 75 ft. to 100 ft. from the intersection to accommodate motorist shifting tapers and space for the bicycle queuing area and pedestrian crossing island. In addition, median noses of channelization islands should be plowable. Due to the center of the roadway alignment for the bicycle movement, green-colored pavement may be used to delineate the bicycle lane and crossings.

Where pedestrians cross from corner-to-corner, the pedestrian pushbuttons are needed for crossings from all four corners and actuation for bicyclists would be separate. Where pedestrians crossing to the center of the intersection and cross parallel to the bicycle crossing, all pedestrian and bicycle pushbutton equipment is located within the raised islands and the number of pedestrian pushbuttons is reduced.

5.7.2 Toucan Crossing Signal Timing Considerations

A Toucan crossing's signal timing should accommodate both pedestrian and bicycle crossings and their unique operating characteristics. Since the pedestrian crossing and bicycle crossings are separated, there is flexibility in how the signalized crossing is timed:

- When a bicyclist is detected, the bicycle signal should be activated, and the total phase length should be based on the signal timing guidance in Section 5.5.3;
- When a pedestrian is detected, the pedestrian signal should be activated and the total phase length (WALK and FLASHING DON'T WALK) should be based on pedestrian clearance times in the MUTCD. The bicycle signal should also be activated with the pedestrian phase since the bicycle signal phase length is less than the pedestrian phase length and there are no conflicts between the two phases in this timing plan;
- Designers have the option of activating the pedestrian signal when a bicyclist is detected to reduce potential pedestrian delay. This is a particularly important consideration if the pedestrian crossing is moved to the center of the intersection.

Designers should consider the impact of the signal activation in a coordinated signal system. The guidance in Section 5.8 for PHBs in coordinated signal systems will also apply to Toucan signals.

5.8 Pedestrian Hybrid Beacons

A Pedestrian Hybrid Beacon (PHB) is a type of traffic beacon that facilitates a roadway crossing by stopping major street traffic with a red indication. PHBs are similar to pedestrian signals and are used in variety of applications to improve crossing safety and reduce crossing delay for pedestrians and bicyclists. These devices may be used in a variety of contexts (urban, suburban, and rural).

The decision to provide a PHB at either an intersection or a mid-block crossing is discussed in the MUTCD (Section 4F.03 Operation of Pedestrian Hybrid Beacons).

5.8.1 General Design Considerations

In addition to the standards specified in the MUTCD (Sections 4F), the following design considerations may be applicable:

- Pedestrian signals shall be provided in accordance with Section 5 ;
- Pedestrian pushbuttons shall be provided in accordance with Section 5 ;
- When PHBs are installed for bicycle use, refer to guidance in Section 5 ;
- Parking and other sight obstructions should be prohibited for at least 100 ft. in advance of and at least 20 ft. beyond the marked crosswalk, or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance;
- A W11-2 (PEDESTRIAN), S1-1 (SCHOOL), or W11-15 (TRAIL) crossing warning sign should be provided on the mast arm overhead or to the right with a diagonal downward arrow (W16-7P) plaque;
- A similar sign to those listed in the previous bullet point with an "AHEAD" plaque (W16-9P) may be installed in advance of a PHB;
- Warning beacons may be installed in advance of PHBs, though if installed, they should only activate when the PHB is not in "dark" mode;
- An R10-23 (CROSSWALK, STOP ON RED) sign, mounted overhead on the PHB mast arm, shall be included for each major street approach at a PHB.

5.8.2 Pedestrian Hybrid Beacon Timing & Reducing Delay

Designers should follow the pedestrian signal phase timing guidance in Section 5.3.3 for PHBs. Designers may consider inserting a steady red clearance interval before the walk interval begins. At locations where both bicyclist and pedestrians use PHBs, the crossing interval should be timed based on pedestrian crossings design parameters and speeds. Pedestrian signal timings will most likely provide sufficient time for a bicyclist to clear the entire intersection. See Section 5.4.3 for additional design guidance for signal timing for bicyclists.

To minimize delay for both pedestrians and bicyclists and increase compliance, a PHB should operate in isolation from other intersections (i.e., in "free operation"), if possible. The maximum length of the "dark until activated" period after activation of the pushbutton should be as short as feasible (i.e., less than 30 seconds).

If a PHB is installed within a coordinated system, the designer may choose to run the timing plan in coordination. While not always desirable from a non-motorist user perspective, coordination may be necessary if a PHB is installed near the intersection of two major streets (less than 750 ft.). To mitigate potential pedestrian and bicycle non-compliance, the designer may consider using a half cycle length to reduce pedestrian and bicycle delay.

5.8.3 Considerations for Bicycle Traffic

When installed, PHBs should be located to respond to bicyclist desire lines with respect to crossing major roadways. Bicyclists should not be expected to significantly detour from their direct travel path to reach an intersection or mid-block location with a PHB, as this can create additional delay for bicyclists and may encourage unwanted crossing behaviors.

Pedestrian hybrid beacons intended for bicyclist use should provide clear and unambiguous messages to bicyclists, and beacon actuation should be accessible to bicyclists. Where PHBs are provided, side street motor vehicle traffic is stop sign controlled, pedestrian traffic is pedestrian signal controlled, and bicycle traffic may be controlled by either of the following:

- Stop sign – bicyclists cross as motorists at intersections;
- Pedestrian signal – bicyclists are directed to cross as a pedestrian.

At such intersections, bicyclists have the choice to use the stop sign if there are adequate gaps in traffic on the major road. If there are not adequate gaps or if a bicyclist would be more comfortable using the pedestrian signal, they can activate the PHB and wait for the WALK indication. The following discussion provides contextual considerations for each crossing strategy (see Section 5.4.2 for detection guidance).

Stop Sign Control

After stopping at the intersection and finding an adequate gap in traffic, the bicyclist may cross the street. This option minimizes bicyclist crossing delays during periods where there are sufficient gaps in major street traffic. During periods of higher traffic volume, bicyclists may exhibit unwanted crossing behavior if gaps in traffic are inadequate and it is not clear how to activate the PHB. For this reason, bicyclists should be given the option of using the pedestrian signal control. The PHB should be designed to clearly communicate how a bicyclist can activate the beacon, as described below.

Pedestrian Signal Control

A bicyclist should be provided with one or more of the following options to activate the beacon:

- Curbside pushbutton (this pushbutton is in addition to the pedestrian pushbutton located at or near the top back of the pedestrian ramp);
- Opportunity to exit the roadway to access the pedestrian pushbutton via a curb ramp to the sidewalk;
- Passive detection in the location where bicyclists are likely to operate.

The BIKES USE PED SIGNAL sign (MUTCD R9-5) should be mounted adjacent to the pedestrian signal heads. If passive detection is used at an intersection, the detection should be designed to discern between a bicycle and motor vehicle, or a bicycle lane or separated bike lane should be provided so a motorist does not activate the PHB. See Section 5.4.2 for additional design guidance on bicycle detection.

Pedestrians and bicyclists are not legally allowed to start crossing during FLASHING DON'T WALK. If a bicyclist perceives that they can clear the intersection, they might enter crosswalks during this phase. During FLASHING DON'T WALK at a PHB, motor vehicles typically have an alternating "wig-wag" red indication and can proceed through the intersection if it is clear. Given the higher speed of a bicyclist compared to a pedestrian, it may be difficult for a motorist to see the bicyclist. At locations with higher volumes of bicyclists. it may be desirable to consider a full traffic signal.

At a PHB, designers may consider creating a separated bicycle lane approaching an intersection and cross bicyclists parallel to the crosswalk. To minimize conflicts with merging or turning motorists near the intersection, it is recommended the bicyclists be channelized into a separated bicycle lane 50 ft. to 100 ft. in advance of the intersection (see Figure 48).

5.9 Warning Beacons

Warning Beacons are yellow flashing lights that supplement warning signs, or in some cases regulatory signs, to provide advance notification of a confined space (such as a bridge or tunnel) or shared use path crossing where bicyclists may be present. Yellow Beacons used as warning devices shall not be installed without an appropriate warning or regulatory sign. See the MUTCD (Section 4L.03) for additional details.

5.9.1 Active Warning Beacons

Active Warning Beacons are actuated yellow flashing lights that supplement warning signs to provide advance notification of a specific roadway feature (tunnel entrance, pedestrian crossing, etc.). Beacons may be activated either passively (e.g., video detection, radar detection, by time of day) or actively by using a pushbutton.

One example of this application is a bridge with limited sight distance and lacking bicycle specific infrastructure. In this scenario designers may consider a custom legend warning sign "BIKES ON BRIDGE WHEN FLASHING" with a beacon timed to flash long enough for a bicyclist to traverse the facility. Similar applications may be appropriate to warn motorists of unexpected or less visible pedestrians or bicyclists on facilities such as in tunnels or on roads with significant horizontal or vertical curvature.

When used at uncontrolled crossings, active warning beacons are most effective along streets with three or fewer travel lanes and posted speed limits at or below 35 mph. Research has found yielding rates of 45% can be achieved at locations with these characteristics.[5]

For the design of Active Warning Beacons, designers should reference the following:

- Flashing Beacons – MUTCD (Section 4L)
- Warning Signage – MUTCD (Section 2C)
- Detection – Sections 5.3.2 and 5.4.2

Figure 47: Active Warning Beacon Example

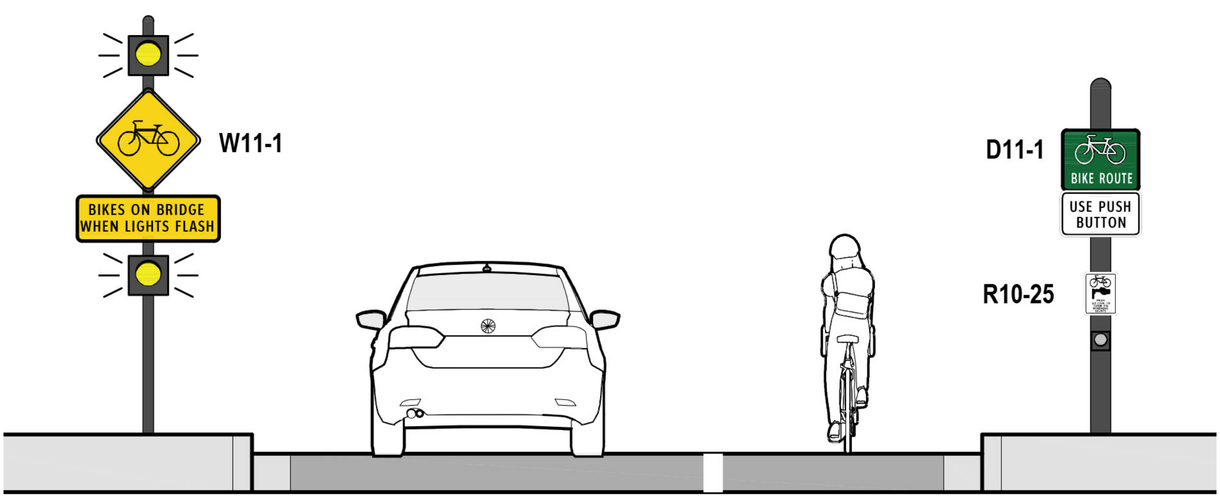
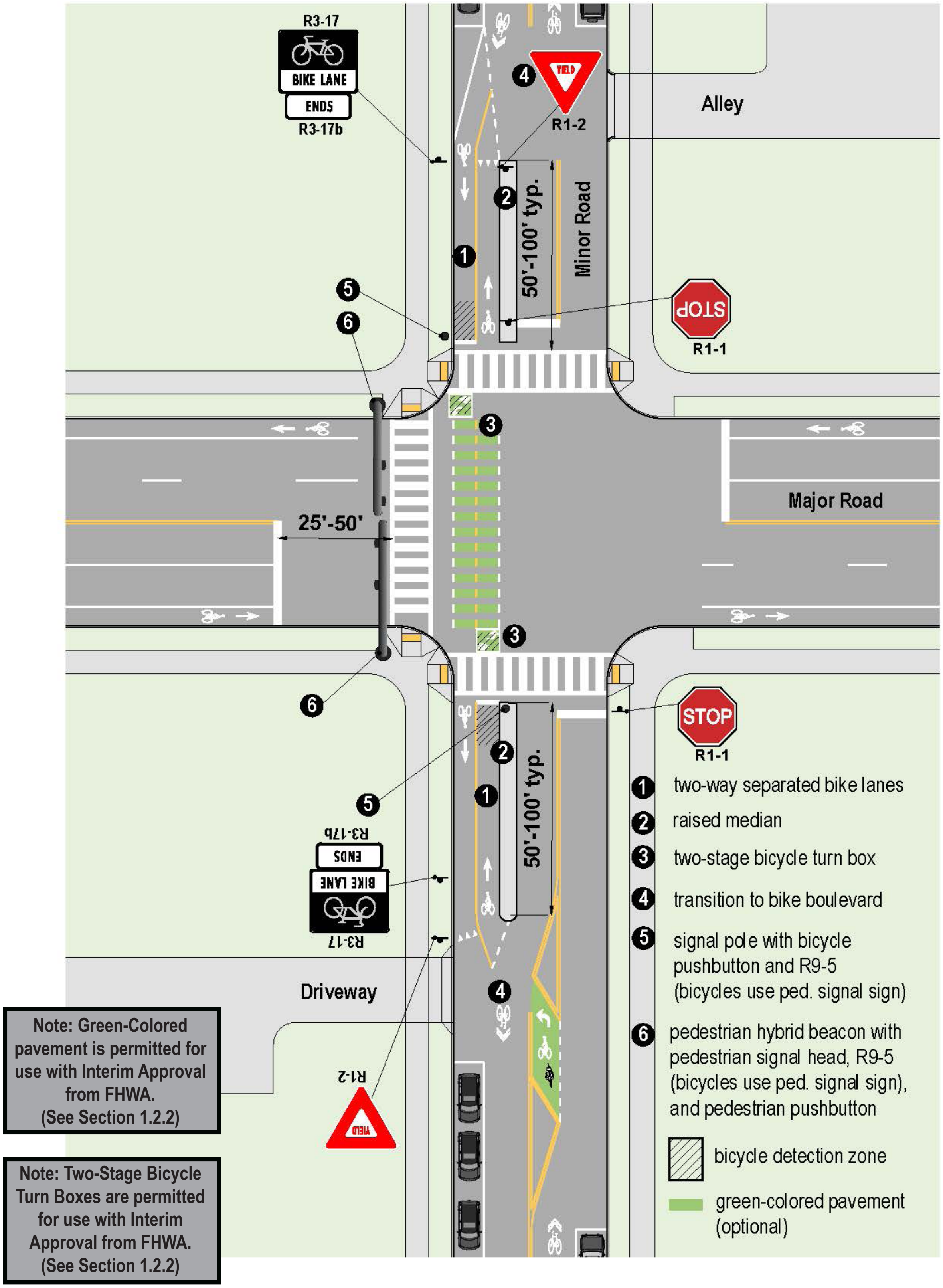


Figure 48: Pedestrian Hybrid Beacon at High Volume Major Road



Flashing beacons may be used in a number of different applications for bicycles and pedestrians. However, use of passive, continuously flashing beacons is not recommended, as indiscriminate use can degrade their effectiveness and affect the usefulness of other flasher locations.

5.9.2 Rectangular Rapid Flashing Beacons (Interim Approval)

Rectangular Rapid Flashing Beacons (RRFBs) are user-actuated, high-intensity yellow LEDs that flash in a rapidly repeating sequence. Like Active Warning Beacons, RRFBs may supplement crossing warning signs. However, RRFBs, installed at appropriate locations, can achieve high driver yielding rates. Research has shown that RRFBs can achieve motorist yielding rates between 80 and 100 percent both during the day and during periods of darkness when installed under appropriate conditions.[6]

While RRFBs have been used on roadways with posted speeds 45 mph and above and on roads with more than four travel lanes, caution should be used in these applications as driver yielding percentages may be lower compared to lower speed and volume scenarios.

RRFBs may also be beneficial at multi-lane roundabout exits where motorist yielding compliance may be poor and gaps are infrequent during peak hours. RRFBs may be used per FHWA Interim Approval 21 (IA-21).

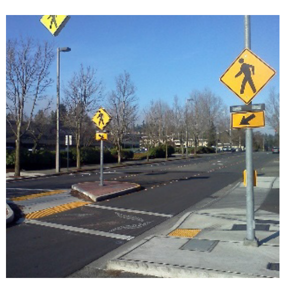
The general crossing design and standards of an RRFB will be the same as for a crossing without an RRFB (see MUTCD Section 2C for crossing sign types, sizes, and placement). In addition, the following design considerations apply to RRFB installation:

- When used, RRFBs shall supplement post-mounted W11-2 (PEDESTRIAN), S1-1 (SCHOOL), or W11-15 (TRAIL) crossing warning signs with a downward diagonal arrow (W16-7P) plaque, or an overhead-mounted W11-2, S1-1, or W11-15 crossing warning sign, located at or immediately adjacent to an uncontrolled marked crosswalk. The RRFB shall be installed on the same support as the associated crossing warning sign and plaque.
- For any approach where RRFBs are used to supplement post-mounted signs, a minimum of two (2) W11-2, S1-1, or W11-15 crossing warning signs (each with an RRFB unit and a W16-7P plaque) shall be installed at the crosswalk, one on the right-hand side of the roadway and one on the left-hand side of the roadway. On a divided highway, the left-hand side assembly should be installed on or within the median, if practical, rather than on the far left-hand side of the highway. Careful consideration needs to be given to RRFB installation with especially wide medians (20 ft. or greater) where prevailing speeds are 45 mph or greater.
- Except for crosswalks across the approach to, or egress from, a roundabout, an RRFB shall not be used for crosswalks across approaches controlled by YIELD signs, STOP signs, traffic control signals, or pedestrian hybrid beacons.
- RRFBs shall be pedestrian or bicycle actuated. Pushbuttons are the most common method, though passive detection methods such as motion or break-beam sensors may be appropriate in locations where they will not erroneously activate for those not wishing to cross the street. See Sections 5 and 5 for design guidance on pedestrian and bicycle detection, respectively.
- The RRFB unit associated with a post-mounted sign and plaque may be located between and immediately adjacent to the bottom of the crossing warning sign and the top of the supplemental plaque or within 12 inches above the crossing warning sign. If the RRFB unit is supplementing an overhead-mounted sign, the RRFB unit shall be mounted directly below the bottom of the sign.
- RRFB timing shall be based on the procedures provided in the MUTCD (Section 4E.06) for pedestrian clearance timing.
- When considering additional enhancements, such as crossing islands or additional signage, the following should be considered:
    - It is preferable to erect crosswalk signage on the far-side of crosswalks less than 20 ft. in width. This placement helps ensure that sightlines between pedestrians and motorists are not obstructed.
    - Where sight distance approaching the crosswalk where RRFBs are installed is less than deemed necessary by the engineer, an additional RRFB may be installed on that approach in advance of the crosswalk. This RRFB would supplement a W11-2 (Pedestrian), S1-1 (School), or W11-15 (Trail) crossing warning sign with an AHEAD (W16-9P) or distance (W16-2P or W16-2aP) plaque. If an additional RRFB is installed in advance of the crosswalk, it shall supplement, not replace, the RRFBs located at the crosswalk.

- If a speech pushbutton information message is used in conjunction with an RRFB: a locator tone shall be provided, the audible information device shall not use vibrotactile indications or percussive indications, and the message should say, "Yellow lights are flashing." The message should be spoken twice.
- On four or six lane streets, RRFBs produce higher driver yielding rates when mounted in the median (or overhead) as well as on the right edge of the roadway in combination with advanced stop or yield lines.
- RRFBs may be solar powered and communicate with other assemblies via radio. This may eliminate the need for a power supply and/or conduit between the units, though the designer needs to ensure proper overhead lighting is present at the crossing.
- Unless RRFBs are specifically designed as warning devices for bicycle use, flashing operation should be timed for pedestrians. The flashing operation following each actuation should be based on the MUTCD procedures for timing of pedestrian clearance times for pedestrian signals. When installed for both pedestrians and bicyclists, doing so will provide sufficient time for bicyclists to clear the roadway.

5.9.3 Signal and Beacon Summary

The prior portions of Section 5 provide specific detail and guidance for a variety of pedestrian and bicycle signals and beacons that could and should be used at intersections. The following table is a summary of some of the key guidance that can be used by practitioners to decide why and when they should use specific beacon and signal types.

	Traffic Control Signal	Warning Beacon	Pedestrian Hybrid Beacon (PHB)	Toucan Crossing
Placement	Roadway intersections or other cross-traffic locations	In combination with warning signs: in advance of shared-use crossings, confined spaces	Midblock locations where there is non-vehicular cross traffic	In combination with a traffic signal at the traditional crosswalk location, from corner-to-corner, or as one consolidated crossing
Application	Traffic control signals should be installed at locations where less restrictive traffic control devices do not provide adequate crossing opportunities for pedestrians and bicyclists.	Typical applications of Warning Beacons include providing warning or supplemental warning to regulatory signs, obstructions, or crossings	PHB installation is relevant at intersecions where it is undesirable or unwarranted to install a traffic control signal, but vehicle speeds, sight distance, number of traffic lanes, or a lack of crossing opportunities dictates the need for a traffic control device to protect non-vehicular cross traffic	This design may be considered for major arterial crossings where it is not desirable to provide a PHB or a full traffic signal. Typical applications for a Toucan crossing include where a bicycle boulevard crosses an arterial street or at T-intersections.
Legal	See MUTCD Chapter 4C for Warrants	See MUTCD Section 4L.03 for Guidance	See MUTCD Chapter 4F for Guidelines (Figure 4F-1 and 4F-2)	The guidance for PHBs in coordinated signal systems will also apply to Toucan signals
Additional Considerations	A traffic signal can increase delays, motorized traffic volumes on minor street approaches, and some types of crashes.	May be activated passively (detection) or actively (pushbutton)	Semi- or fullyactuated signals should passively detect bicycles for phases with "no recall" or "min recall". If a signalized intersection approach cannot accommodate passive detection, a curb-side pushbutton for active detection should be provided.	This design stops motor vehicle traffic on the major street during the entirety of the bicyclist and pedestrian crossing.
Image				

Endnotes

1 FHWA Tech Brief – "Safety Evaluation of Pedestrian Countdown Signals", FHWA Publication No. FHWA-HRT-19-046.

2 AASHTO Pedestrian Guide 2004, p. 103.

3 Thompson, Samson Ray Riley, "Bicyclist Compliance at Signalized Intersections" (2015). Portland State University, Dissertations and Theses. Paper 2222

4 https://www.codot.gov/library/bridge/bridge-manuals/2019-09-24_sshml_master_-_submitted.pdf

5 Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord. National Cooperative Highway Research Program Report 562: Improving Pedestrian Safety at Unsignalized Crossings. NCHRP, Transportation Research Board, Washington, DC, 2006.

6 Shurbutt, J. and R. Van Houten. Effects of Yellow Rectangular Rapid-Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalk. FHWA-HRT-10-043. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2010.


PUSH BUTTON FOR

Chapter 6. Maintenance

6. Maintenance

While the previous chapters of the Guidelines include elements of intersection design in Fort Collins, this chapter covers the process of getting street projects implemented. Partner agencies, private developers, and consultants are involved in the design and construction of streets (including intersections) but the City of Fort Collins has the primary responsibility for guiding and permitting design, and maintaining the streets and facilities on which intersections are located. Thus, the City of Fort Collins requires coordinated rules and regulations across multiple departments that are aligned with the strategies outlined in this and previously created standards and regulations for intersection development.

References in this document are relevant at the time of publication.The City will evaluate and consider updating associated rules and regulations over time based on the best practices guidance provided in this document. Rationale for not incorporating best practice guidance should be documented.

Bicycle Infrastructure Impacts from Projects

6.1 Project Types

Projects can vary in size and scope from major corridor improvements to small maintenance projects. Often, projects can be phased to deliver quick, low-cost improvements in the short term while waiting for funding and/or leveraging opportunities for major capital projects to make improvements more permanent. The following provides an overview of the types of projects that may impact intersections in For Collins.

- **Major intersection and corridor improvements** are the largest, most complicated, and most costly type of street project. These are often planned many years in advance and may rely on multiple funding sources such as state or federal funds.
- The **Community Capital Improvements Program (CIP)** was initiated in 2015 after voters passed a 10-year quarter-cent tax renewal dedicated to community improvements. This program funds all sorts of roadway projects, including intersection projects such as crosswalk enhancements, ADA updates, new sidewalks, new cycle tracks, medians and resting areas, or even a combination of these elements.
- **Private developments** do not always change the public right-of-way. However, projects that have an increased impact on the public right-of-way (such as when the new building would generate more trips than the previous structure) may require developers to perform a traffic study and make improvements to mitigate project impacts and bring the street, and therefore often the adjacent intersection, up to current standards.
- **Retrofit projects** are generally smaller in scale and address a specific issue at intersections. These projects must be designed around significant constraints to keep costs manageable while bringing streets up to current right-of-way standards.
- **Maintenance projects** are limited in their ability to significantly change the geometry of an intersection but can reallocate space through activities like restriping. Repaving projects also provide opportunities to stripe curb extensions that narrow turning radii, narrow travel lanes to recommended widths to control vehicle speeds, and stripe reverse angled parking to narrow a roadway. The City can also use a OneBuild approach to combine multiple projects into one bigger project to maximize economies of scale and minimize construction impacts. Striping and paving projects should involve coordination among appropriate City staff to ensure that these opportunities are not missed.

6.2 Organizational Responsibilities

Intersection design projects in Fort Collins are informed by the constraints and opportunities of working in a city with a mix of historic and modern construction, multiple jurisdictions and agencies, and a commitment to meaningful community and stakeholder engagement. This section outlines departmental responsibilities related to planning, design, construction, management, and maintenance of intersections.

6.2.1 City of Fort Collins Department Responsibilities

Many departments within the City of Fort Collins play a role related to design, function, and use of intersections. These departments are committed to the success of the Guide and will take the following implementation steps:

- Evaluate current standards, rules, and regulations to determine where conflicts and/or gaps with the Intersection Design Guide exist
- Revise and/or create new standards, rules, and regulations where necessary to align with the Guidelines
- Coordinate updates between departments to promote consistency and minimize conflicting direction
- Work together with partners such as Transfort and CDOT to encourage consistency and alignment with the Intersection Design Guide

The following sections outline internal departments within the City of Fort Collins and describe their roles in maintaining intersections in Fort Collins.

Traffic Operations

Traffic Operations is responsible for all traffic related needs within the City. Examples of these needs include signal systems, signs and pavement markings, traffic engineering such as speed limits, other studies, work area traffic control, safety, and pedestrian and bike innovations. The department provides support to residents who want to make community streets safer by managing the Neighborhood Traffic Mitigation Program that works to lower speeds on local streets by employing education, engineering, and enforcement solutions.

Intersection Maintenance Responsibilities:

- Signal Equipment
- Pavement Markings
- Signage

Streets Department

The City of Fort Collins Streets Department maintains a street network with 557 centerline miles. Services include street maintenance and paving, street sweeping, snow removal, and mowing. In addition, this department operates a recycling/crushing facility that processes and recycles concrete and asphalt for re-use on public and private projects.

Intersection Maintenance Responsibilities:

- Concrete Work (curb, gutter, and sidewalk)
- ADA Accommodations
- Snow Clearing
- Lighting (pedestrian lighting)
- Street Sweeping
- Resurfacing

Parks Department

The Parks Department is the City agency responsible for functions involving parks, outdoor amenities, memorials, trails, and outdoor facility rentals and reservations. They also follow an Integrated Pest Management (IPM) strategy and control pest levels in Fort Collins to prevent damage to both property and the environment. Divisions of the department include Parks, Cemeteries, Forestry and Golf.

Intersection Maintenance Responsibilities:

- Landscaping (some arterial intersections)
- Lighting (in parks and on trails)

Light and Power

Fort Collins Light & Power is a part of the City Utilities Department and provides reliable electric service to Fort Collins homes and businesses. Fort Collins Utilities receives its power supply from Platte River Power Authority, which is a wholesale electricity provider for the cities of Fort Collins, Longmont, Loveland, and Estes Park.

Intersection Maintenance Responsibilities:

- Lighting (primary contact for maintenance)

Transfort

Transfort is responsible for operating and maintaining bus services, stops, and stations. Transfort is also responsible for snow clearing of bus stops.

Intersection Maintenance Responsibilities:

- Transit stops & shelters
- Transit operations & performance data

6.2.2 City Partner Responsibilities

In addition to internal departments, the City of Fort Collins partners with the following agencies to maintain intersections throughout the city:

- **Colorado Department of Transportation (CDOT)** is responsible for operating and maintaining many state and US highway
- **Platte River Power Authority** is responsible for operating and maintaining electric services used by the Fort Collins Utilities Department

6.3 Maintenance Responsibilities

A strong systemic commitment to maintenance will ensure the longevity, dependability, and quality of intersections in Fort Collins. This section outlines maintenance considerations for seasonal maintenance, vegetation maintenance, maintenance of street amenities, and provision of temporary access during construction.

For new construction projects or retrofits, the following best practices should be followed to ensure City operational staff are adequately prepared to maintain new components of the public right of way.

- Begin developing maintenance plans during the planning and design stages of projects and coordinate with City departments and other stakeholders responsible for enforcing and carrying out maintenance practices
- Where necessary, prepare and execute maintenance agreements for elements of the public realm—such as parklets, planters, bus shelters, traffic signals—to ensure longevity and consistent quality
- Consider materials, maintenance vehicle availability, resources for upkeep, and equipment needs for snow removal, sweeping, vegetation care, and general clean-up as design decisions are made to ensure feasibility of proper maintenance
- Carefully plan for seasonal maintenance requirements to ensure year-round accessibility and safety within the public realm

The following sections detail considerations and best practices for specific pieces and parts of intersections.

6.3.1 Signal, Signing, and Pavement Markings

Signing and pavement markings along roadways approaching and crossing intersections should be maintained to be clear and legible in order for intersections to function safely and comfortably. Similarly, traffic signals, including bicyclist and pedestrian signals and beacons, shall be inspected a minimum of one time annually to ensure reliable function, and identify signals and equipment to be replaced before failure. Facilities should be inspected per this guidance and repaired or replaced when necessary.

6.3.2 Street Buffer Treatments and Sidewalk Buffer Amenities

Vertical objects, such as street buffer treatments and sidewalk buffer amenities, may be struck by motor vehicles when they are making turns at intersections. Maintenance and operation crews should plan on replacing vertical objects placed in the buffer zone, refreshing pavement markings, and trimming any adjacent vegetation at intersection corners on a regular basis. If vertical objects are struck with significant regularity, adjustments to the design should be considered.

Other elements along walkways and bikeways that might be situated at or near intersections, such as lighting, benches, trash receptacles, etc., should also be inspected on a regular basis to ensure they are in good working condition, and when appropriate these elements should be repaired and/or replaced.

6.3.3 Pavement Maintenance

As pavement section thickness decreases, the susceptibility to cracking, settlement, and root uplift increases. Eventually all streets, pedestrian facilities, and bicycle facilities must be reconstructed, but with proper maintenance techniques, reconstruction can be delayed up to 40 years. To extend the life of the pavement and maintain a smooth rideable surface in intersections, a regular maintenance schedule should be created and followed for concrete paving.

6.3.4 Snow and Ice Maintenance

Successful seasonal maintenance programs require knowledgeable staff and crews, proper equipment, and consistent procedures and preventative strategies. To achieve successful seasonal maintenance for bikeways, walkways, and streets that will result in benefits to Fort Collins intersections, the City should:

- Develop proactive maintenance strategies including regular facility inspection, repair, replacement, and clear record-keeping to ensure seasonal maintenance practices are manageable and efficient
- Develop strategic assessment, prioritization, and maintenance plans to care for all elements of the public realm, including sidewalks, roadways, catch basins, vegetation, signage, traffic signals, lighting, trash and recycling bins, street furniture, and pavement markings

Adequate snow and ice clearance is critical to maintaining accessible trails and roadways throughout the year. Except in snow emergencies or unusually heavy snowfall, Fort Collins should keep intersections including sidewalks, bicycle lanes, and roadways free of snow and ice. It is vital that Fort Collins develop a communication plan to regularly remind property owners that they are responsible for clearing snow and ice from adjacent sidewalks within 24 hours of snow event. Refer to the City of Fort Collins' Snow Routes Map for established prioritization strategies.

Prioritization

A balanced snow clearance prioritization strategy ensures that essential services—such as emergency access—are provided while also tending to the needs of the most vulnerable users of our streets. People walking and rolling through intersections—especially those with physical disabilities—require clear sidewalks, crossings, curb ramps, and transit stops in order to travel. People riding bicycles or using other mobility options are more sensitive to snowfall than people driving due to smaller, thinner wheels and the need to maintain balance on their vehicles. Fort Collins must establish a map of priority routes where emergency and multimodal access are most critical.

Clearances and Equipment

The following criteriafor clearances is necessary to consider during intersection design to ensure snow clearing equipment can reach intersections and surrounding facilities:

- Maintain a minimum clear width of 4 feet per direction on protected bike lanes and procure special snow plowing equipment for bike lanes narrower than 8 feet
- On paved trails provide a minimum clear path of 8 feet
- Maintain a minimum clear width of 3 feet per direction on sidewalks and pedestrian paths
- Procure snow throwers to push snow farther off paths than possible with snowplows, if needed
- Consider procuring specialized equipment that can be outfitted with other attachments such as brooms, plow blades, snow throwers, and loaders

The south side of east-west streets in Fort Collins (such as Mulberry St.) get minimal sun and are, therefore, difficult to keep clear of snow and ice. **Section 5.3.4 Bicycle Crossings** discusses the benefits and downsides of installing two-way protected bicycle lanes on the north side of east-west streets where facilities are easier to maintain seasonally. If the City determines that developing new two-way cycle tracks are the best option, consideration must be taken to ensure snow and ice clearing equipment can fit the width of the bicycle lane. Refer to the bulleted list above for clearance and equipment standards when designing a new two-way facility.

Snow Storage

Buffers and landscape areas should be used for snow storage while ensuring that adjacent pedestrian paths remain clear. In addition, snow storage height and placement should not impede sight lines or block curb ramps at intersections and roadway crossings. Fort Collins should also consider the impacts of melting snow and resulting drainage at intersections as part of snow storage planning.

Mini-plow Use in Separated Bike Lane

Ice Control Treatments

Ice control, such as salt and salt brine, can reduce slippery conditions, but can also be damaging on the environment, drainage, and pavement at intersections and the surrounding facilities. Environmentally friendly options for maintenance should be considered during design.

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Source: Alta Planning + Design

Chapter 7. Appendix

7. Appendix

7.1 Additional Resources

The following resources and literature were reviewed during the development of this guide and can provide further information and guidance for designing safe and comfortable intersections in Fort Collins.

2021 AASHTO Guide for the Development of Bicycle Facilities (forthcoming)

2021 AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities

Fort Collins Transportation Master Plan

2019 Fort Collins Traffic Safety Summary

2019 Fort Collins Transit Master Plan

2014 Fort Collins Bicycle Master Plan

2011 Fort Collins Pedestrian Plan

Manual on Uniform Traffic Control Devices

Larimer County Urban Area Street Standards

APPENDIX B: EXISTING CONDITIONS SUMMARY

FORT COLLINS ACTIVE MODES PLAN
EXISTING CONDITIONS REPORT

Introduction

To establish an understanding of existing conditions for bicycling and walking in Fort Collins, the planning process includes an analysis of the City's demographics, travel characteristics, land use, planning and policy context, existing transportation networks, and roadway safety.

Fort Collins Today

Fort Collins prides itself in taking action to address the needs of the community and strives to ensure that everyone can thrive. The Fort Collins Active Modes Plan (AMP) seeks to center active transportation planning around community needs. Analyzing demographics, travel characteristics, and land use is critical to identifying opportunities and challenges, establishing goals, and centering recommendations for walking and bicycling in Fort Collins.

Population and Households

Fort Collins has experienced significant population growth over the last four decades. Since 1990, Fort Collins' population has nearly doubled from 88,000 to 166,000 residents (Table 1), with another 70,000 residents expected d by 2040 (City Plan Trends and Forces Report, 2018). A mix of manufacturing businesses, the presence of Colorado State University (CSU), and a burgeoning high-tech sector have contributed to this population growth.

Fort Collins' population skews young compared to Larimer County and the State of Colorado, despite having a lower concentration of families and residents under the age of 18 (Table 2). CSU's resident student population of 28,446 students account for approximately 18 percent the City's population (ACS 2019 5-Year Estimates, Table B14004) and the neighborhoods around CSU are the densest in the city. While fewer households identify as family households in Fort Collins than in 2010, the City's growing Hispanic/Latino population indicates a shift in the racial and ethnic makeup of family households. While Hispanic/Latino's account for ~12% of the City's total population (Table 3**),** they account for over 20% of residents under the age of 18.

The high concentration of college students in Fort Collins also skews income lower and poverty higher compared with Larimer County and State of Colorado (Table 4**)**. However, when excluding college students living off-campus from poverty calculations, the poverty rate is estimated to be 10 percent, on par with County and State averages (*City Plan Trends and Forces Report*, 2018). Household income growth in Fort Collins has stagnated since 2000 when adjusted for inflation, and disparities exist along racial and ethnic lines. Nonwhite households, on average, earn between one-fifth to two-thirds the incomes of white households. Existing dynamics in the rental housing market further compound income stagnation and disparities. Between 2005 and 2017, Fort Collins' residential rental costs increased by 78 percent (*Fort Collins' Rental Market Study*, Corona Insights/City of Fort Collins, 2019), despite incomes remaining stagnant. Households experiencing rising housing costs are further burdened by transportation costs, especially lower-income households and families. Public investments in connected, comfortable, and safe facilities and amenities for active modes provide an affordable transportation option for residents to access schools, jobs, social activities, and recreation.

The racial disparities in income and poverty are also reflected geographically, The Health Equity Index (Image 1**)**, a tool developed by the Larimer County Department of Health and Environment (LCDHE) to identify potentially vulnerable areas of the community, illustrates this spatial disparity. Generally, the Health Equity Index shows that more vulnerable or disadvantaged populations are clustered along the edges of the city and north of the Poudre River, while less vulnerable populations are clustered near Downtown and within priority growth areas. With vulnerable populations spatially disconnected from activity centers, the AMP should recommend building safe active mode linkages to transit, recreation, shopping, health services, schools, and jobs.

The analysis of Fort Collins' population and households reveals the following trends to be considered by the AMP:

- Building a transportation network that accommodates future growth using existing roadways
- Balancing the needs of the student population, family households, and non-family households alike
- Preserving and expanding affordable transportation options amidst income stagnation and rising cost of living
- Applying special attention to the needs of the City's growing Hispanic/Latino population

Year	Population	10-Year Growth Rate
2019	165,609	17.9%
2010	143,986	21.4%
2000	118,652	35.2%
1990	87,758	34.8%

Table 1: Fort Collins Population Growth 1990 - 2019 (US Census; ACS, 2019 5-Year Estimates)

Age	Fort Collins	Larimer County	Colorado
Under 18	16.3%	19.3%	21.8%
18 - 24	22.1%	13.9%	9.2%
Over 65	11.6%	16.2%	14.7%
Median Age	30.6	36.4	37.1

Table 2: Fort Collins, CO Age Demographics Compared to Larimer County and Colorado. (ACS, 2019 5-Year Estimates)

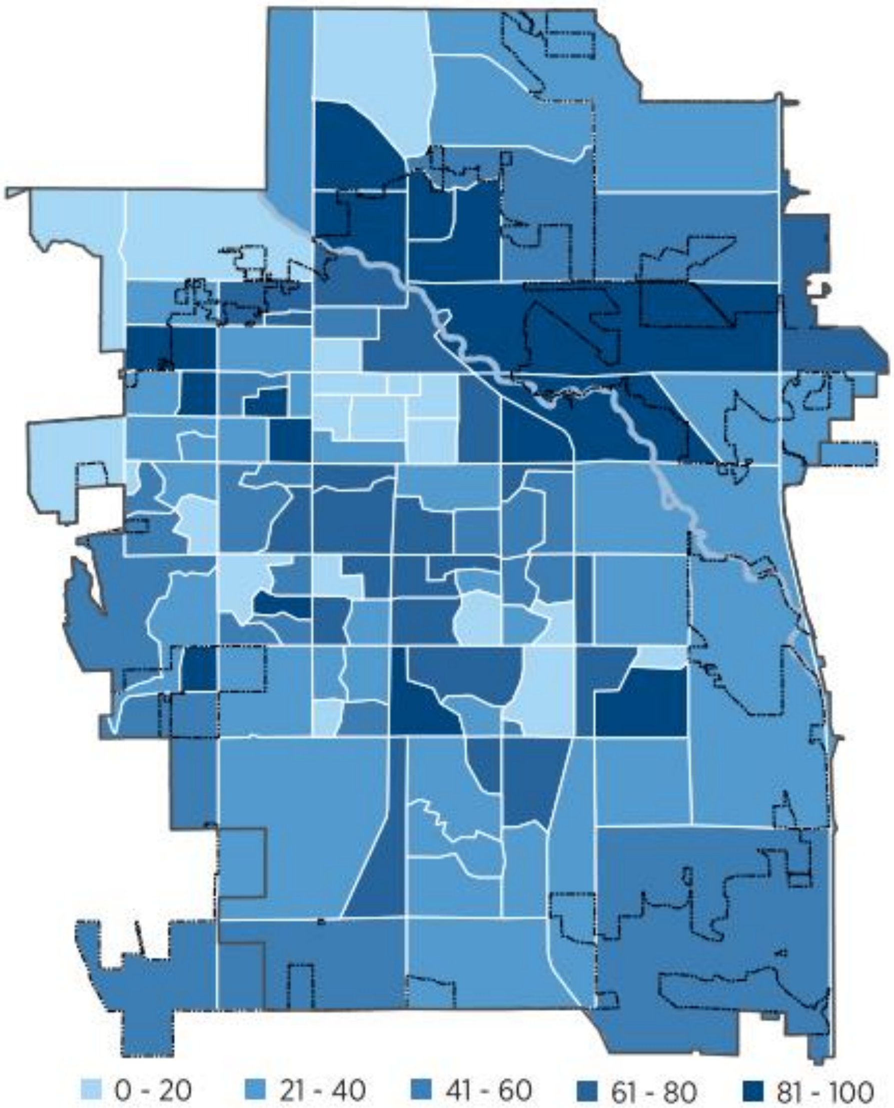
Race and Hispanic Origin	Fort Collins	Larimer County	Colorado
White alone	79.9%	82.1%	67.7%
Black or African American alone	1.6%	1.2%	4.6%
American Indian and Alaska Native alone	1.0%	1.1%	1.6%
Asian alone	3.5%	2.4%	3.5%
Native Hawaiian and Other Pacific Islander alone	0.1%	0.1%	0.2%
Two or More Races	4.0%	2.7%	3.1%
Hispanic or Latino	11.6%	11.9%	21.8%

Table 3: Fort Collins, CO Race and Hispanic Origin Compared to Larimer County and Colorado. Source: US Census Bureau (2019 5-Year Estimates)

Income and Poverty	Fort Collins	Larimer County	Colorado
Median Household Income	$65,866	$71,881	$72,331
Per capita Income	$34,482	$37,363	$38,226
Persons in Poverty	16.3%	10.3%	9.3%

Table 4: Fort Collins, CO Income and Poverty Compared to Larimer County and Colorado. Source: US Census Bureau (2019 5-Year Estimates)

HEALTH EQUITY INDEX
FORT COLLINS, 2016



Scores range from 0 to 100, with 100 indicating the highest priority.

The Health Equity Index is a composite measure of overall health equity in Fort Collins and includes the following equity and health indicators:

Equity Indicators

» Population under age 18
» Population age 65 and older
» Households at or below the Federal Poverty Level
» Hispanic/Latinx population
» Non-white (minority) population
» Households without a vehicle
» Disability status

Health Indicators

» Adult obesity
» Adults with no leisure-time physical activity
» Adults who experienced poor mental health for 14 or more days

Image 1: Health Equity Index for Fort Collins, 2016. Source: LCDHE

Travel Characteristics

Commute Modes

Fort Collins' residents are nearly five times as likely to bike to work or school ("Commute Trips") than the rest of the Colorado (Table 5). A higher bicycle commute share in Fort Collins is a testament to the City's bicycling culture. Stakeholders across Fort Collins—residents, businesses, City leaders—all recognize the economic, environmental, and social benefits of bicycling, and how building a low-stress bicycle network is critical to achieving larger citywide goals. Investments in infrastructure supporting safe and comfortable mobility for active modes contributes significantly to decisions regarding mode of travel. However, since the adoption of Fort Collins' 2014 Bicycle Plan, bicycle commuting has stagnated (ACS 5-year estimates, 2014; ACS 5-year estimates, 2019). Understanding this stagnation requires further investigation, and may be explained by changes in demographics, the housing market, and commute patterns.

Means of Transportation to Work	Fort Collins	Colorado (Statewide)
Walk	4.2%	2.8%
Bike	5.4%	1.1%
Motor Vehicle	79.1%	83.7%
Public Transit	2.3%	3.0%

Table 5: Fort Collins, CO Means of Travel to Work Compared to Colorado. Source: US Census Bureau (2019 5-Year Estimates)

Non-Commute Trips

However, commute trips only tell part of the story. Across the state of Colorado, commute trips (i.e. trips between home and place of work in either direction) account for just 14% of all trips (NHTS, 2017).

Means of Transportation for Commute Trips vs All Trips, State of Colorado	% of Commuting Trips (2017)	% of All Trips (2017)
Walk	3.0%	11.7%
Bike	1.2%	2.6%
Motor Vehicle	91.1%	84.3%
Public Transit	3.5%	1.5%

Table 6: State of Colorado Means of Travel for Commute Trips vs All Trips. Source: National Household Travel Survey (2017) and US Census Bureau (2017 5-Year Estimates, Commute Trips exclude 8.5% who work from home)

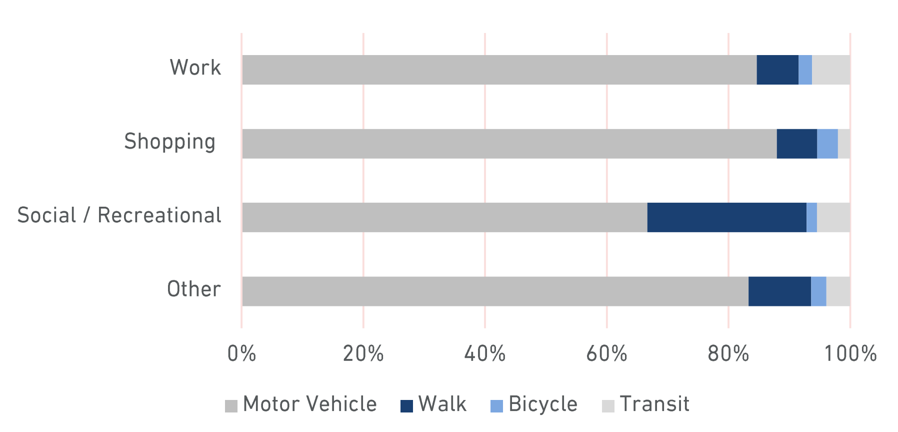
Additionally, commute trips are generally longer distances than other types of trips that people take. To unlock walking and bicycling for more people and more trips, the City of Fort Collins may focus its efforts on shifting short trips—specifically those less than 15 minutes by any travel mode—to active transportation. For instance, errands and shopping trips, social or recreational trips, medical appointments, and other activities may be within a comfortable walking or bicycling distance if the infrastructure provides comfortable and low-stress conditions.

Due to the sample size of the National Household Travel Survey—a large diary-based study conducted every eight years—this report uses the State of Colorado to understand travel patterns for all trips. When looking statewide—which includes both urban and rural contexts— nearly 12% of all trips are pedestrian trips, and 2.6% are by bike, compared with 3% and 1% of commute trips done by walking or biking (Table 6). Statewide data indicates that the percentage of trips done by biking increases for shopping activities and the percentage of trips done by walking increases for social/recreational activities (Table 7). Moreover, as the distance of trips decreases, the likelihood of walking and biking increases (Table 8).

National Household Travel Survey data at the state-level indicates that trips done by walking and biking are more likely for non-commute trips and for short-range trips. Activating greater use of active modes for those trip types and short distances can be enabled through investments in infrastructure that is safe and comfortable for people walking and biking.

Means of Transportation by Trip Purpose	Work	Shopping	Social/ Recreational	Other*
% of all Person Trips	**14%**	**19%**	**14%**	**53%**
% of all Walking Trips	*8%*	*11%*	*33%*	*47%*
% of all Bicycling Trips	*12%*	*26%*	*10%*	*52%*
% of all Motor Vehicle Trips	*14%*	*21%*	*12%*	*54%*
% of all Public Transit Trips	*21%*	*9%*	*19%*	*50%*

Table 7: State of Colorado Means of Travel by Trip Type. Source: National Household Travel Survey (2017) and US Census Bureau (2019 5-Year Estimates)



Means of Transportation by Distance	Walk	Bike	Motor Vehicle	Public Transit
% of all Person Trips	**12%**	**3%**	**84%**	**1.5%**
% of Trips < 0.5 miles	61%	4%	35%	0.0%
% of Trips < 2.5 miles	25%	5%	69%	0.8%
% of Trips < 3.5 miles	21%	4%	74%	1.2%
% of Trips ≥ 3.5 miles	0.3%	0.4%	97%	1.7%

Table 8: State of Colorado Means of Travel by Distance. Source: National Household Travel Survey (2017)

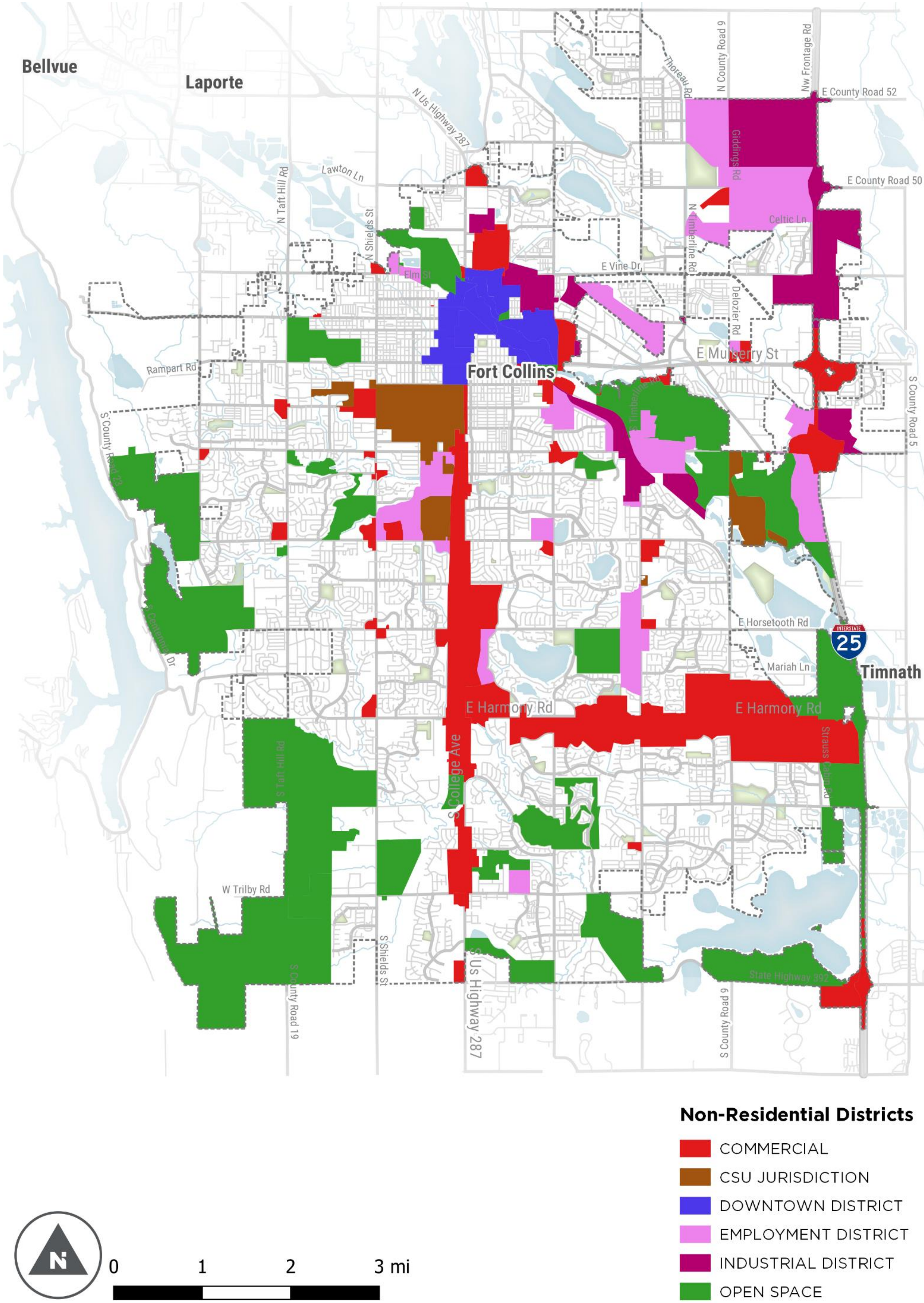
Land Use & Urban Form

Fort Collins has a relatively dense grid of streets in Old Town and the surrounding neighborhoods. However, the street network in most of the city is curvilinear and not well connected, and the land uses have been developed at a suburban scale. Nearly sixty percent of land area within Fort Collins city limits is single-family residential (29%) and open space (30%). Non-residential land uses, such as industrial, employment, and commercial districts, are concentrated along College Avenue, E Harmony Road, the Poudre River, and Interstate 25 (Figure 1). The suburban nature of much of Fort Collins is reflected in many of the current transportation issues and policies, impacting how well the bicycle facilities function.

However, as the city's population grows and diversifies, the city's land use and urban landscape is becoming denser and more diverse. The City Plan (2019) identifies the following five priority place types for infill and redevelopment over the next 10-20 years:

- Mixed-Neighborhoods
- Neighborhood Mixed Use
- Suburban Mixed-Use
- Urban Mixed Use
- Mixed-Employment

The City Plan provides mobility considerations for each of the place types, including traffic circulation, active transportation infrastructure and amenities, and transit access. The AMP will be critical to achieving the envisioned character for each of the five place types and gracefully managing higher densities in Fort Collins by linking transportation planning with land use decisions. These place types and the accompanying considerations will inform project recommendations and priorities.


Bellvue
Laporte
Fort Collins
Timnath
N Us Highway 287
Lawton Ln
N Taft Hill Rd
N Shields St
Rampart Rd
Elm St
E Vine Dr
E Mulberry St
N Timberline Rd
Delozier Rd
Thoreau Rd
N County Road 9
Nw Frontage Rd
E County Road 52
E County Road 50
Giddings Rd
Celtic Ln
S County Road 5
E Horsetooth Rd
Mariah Ln
E Harmony Rd
S College Ave
Strauss Cabin Rd
W Trilby Rd
S Taft Hill Rd
S County Road 19
S Shields St
S Us Highway 287
S County Road 9
State Highway 392
S Centennial Dr
25
Non-Residential Districts
COMMERCIAL
CSU JURISDICTION
DOWNTOWN DISTRICT
EMPLOYMENT DISTRICT
INDUSTRIAL DISTRICT
OPEN SPACE
0
1
2
3 mi

Plan and Policy Review

The State, Region, and City have adopted numerous plans that have helped create and support the current bicycling environment. The section that follows discusses existing plan recommendations that will inform the 2021 AMP.

Regional and Statewide Planning Context

The North Front Range Metropolitan Planning Organization (NFRMPO), which includes the City of Fort Collins, is currently updating their shared vision for improved bicycle and pedestrian transportation within and between communities. The adoption of this Plan will be monitored for regional projects and programs identified within Fort Collins by the Regional Active Transportation Plan. According to the Plan's webpage, the Regional ATP will include the following:

- A consolidated summary of the existing bicycle and pedestrian infrastructure, data, and design standards throughout the region
- Segment by segment analysis of each Regional Non-Motorized Corridor, including important local connections and critical gaps, and major barriers and opportunities for completion
- Best practices and policy recommendations for emerging micro-mobility solutions (electric bikes, scooters, and skateboards, etc.)
- Updated tools, analysis, and guidance supporting local and regional planning and funding efforts

The Colorado Department of Transportation's (CODOT) Statewide Bicycle and Pedestrian Plan, updated in 2015, outlines an approach to deciding which bicycle and pedestrian projects to fund based on the following goals:

- Enhance safety
- Increase bicycling and walking activity
- Expand recreational opportunities and enhance quality of life
- Improve public health Appendix B: State of Bicycling in Fort Collins Aug. 2014
- Improve the environment, air quality, and fossil fuel dependence
- Provide transportation equity
- Maximize transportation investments
- Improve statewide and regional economy

The Statewide Bicycle and Pedestrian Plan focuses on what CODOT has jurisdiction over and therefore, does not make specific recommendations for facilities or programs in Fort Collins.

Triple Bottom Line

To promote sustainability, the City's Triple Bottom Line policy seeks to institutionalize environmental sustainability and social equity, along with economic health, in evaluating proposed policies, infrastructure investments, and development projects. This means that projects are evaluated based on their social, economic, and environmental impacts rather than profit-making alone.

The 2014 Bicycle Master Plan identified the triple bottom line for bicycling. Economically, a bicycle-friendly community attracts residents and businesses, supports tourism, and is a low-cost investment. Environmentally, bicycling can reduce single-vehicle occupancy trips and greenhouse gas emissions, along with having a relatively low construction footprint. Socially, bicycling provides an affordable transportation option, improves personal health, and increases quality of life for communities.

Equity Indicators

In 2019, Fort Collins initiated a process to identify equity indicators that inform critical decisions about the allocation of resources and policy development. The equity indicators reveal disparities using 114 measures across 10 domains, including transportation. One of the indicators evaluating active transportation equity is *Reported Ease of Biking*. The 2021 Equity Indicators Report reveals that Fort Collins residents find it easy to travel by bicycle, giving the City a rating of 81 out of 100. However, residents of color reported that it was somewhat more difficult to travel by bicycle than their white counterparts. This disparity indicates that the

AMP should apply special attention to improving the comfort, safety, and connectivity of bicycling in Fort Collins' non-white neighborhoods and for the City's non-white population.

Building on Previous Efforts

This AMP builds off the vision and recommendations from the 2014 Bicycle Master Plan, which identified a connected network of low-stress bicycle facilities. The 2011 Pedestrian Plan devises a methodology for determining Pedestrian Level of Service, Crosswalk Identification Policy, and Pedestrian Priority Areas. The infrastructure and programming recommendations from these efforts will be integrated and expanded upon as part of the AMP process.

Plan	Description	Active Transportation Related Goals	Relevant Policy/Project Recommendations
Fort Collins City Plan (2019)	City Plan is the comprehensive plan for the City of Fort Collins. It articulates the community's vision and core values, and establishes the overall policy foundation that will be used by the City of Fort Collins organization	Outcome Area 2: Culture & Recreation Outcome Area 5: Safe Community Outcome Area 6: Transportation	*Policy CR 2.2 – Interconnected System* *Policy SC 4.1 – Active Transportation*
Fort Collins Strategic Plan (2020)	The 2020 Strategic Plan outlines key objectives and strategies that link City Plan and the City's organizational priorities.	Goal 2: Multimodal Transportation & Public Transit Goal 4: Environmental Sustainability Goal 5: Community Vibrancy .	2.2 Address critical park, recreation equipment and trail lifecycle and maintenance needs and continue the planned buildout of the system. 2.5 Ensure safety and welfare in City parks, natural areas, trails, and cultural and recreation facilities for visitors and employees. 6.1 Improve safety for people using all modes of travel 6.3 Ensure equitable access to and expansion of all sustainable modes of travel, with emphasis on growing transit ridership.

Transportation Master Plan (2019)	The Transportation Master Plan (TMP) articulates a vision and core values for growth and policies. The TMP focuses on Transportation Infrastructure, Mobility and Travel Choices, Health and Equity, Innovation, Safety, and Sustainability and Resiliency.	Goal 2: Build and maintain high-quality infrastructure that supports all modes of travel. Goal 6: Support Bicycling as a safe, affordable, efficient, convenient travel option for all ages and abilities by building a connected network of facilities. Goal 7: Support walking as a safe, easy, and convenient travel option for all ages and abilities by building a connected network of sidewalks, paths and trails. Goal 9: Utilize the transportation system to support a healthy and equitable community. Goal 10: Support and enhance safety for all modes	» Developing a neighborhood greenway program in connection with the low-stress bike routes » Continuing the protected bike lane pilot program with new project locations » Developing best practice policies for bikeway maintenance » Sidewalk and ramp improvements to meet ADA standards » Proposed pedestrian priority project list consisting of items identified by citizens through a pedestrian survey, public comments and remaining Capital Improvement Program projects from 2004 » Pedestrian projects as identified in the most recent CIP. » Expanding the bicycle wayfinding system with walking routes and distances to make the program more relevant to pedestrians as well » Launching a pedestrian safety outreach campaign that is tailored to specific audiences and behaviors » Identifying and improving pedestrian crossings of arterials » Conducting targeted yielding and speed enforcement operations; use a data-driven approach and crash analyses to inform the best locations to conduct these targeted efforts, including school crossing guard placement » Performing regular evaluations of safety improvements by performing an evaluation before and after a pedestrian project is implemented.

Transit Master Plan (2019)	The Fort Collins Transit Master Plan provides a vision, guidance, and strategic actions to improve and expand transit-service in Fort Collins between now and 2040. This Plan serves as a resource to City staff, the public and the development community on how transit-service may expand and what transit in Fort Collins will look such as in 2040.	None.	Policy 5.8: Connect Transit to Other Modes
Our Climate Future Plan (2021)	The OCF comprehensive plan to simultaneously address climate, energy and waste goals while improving our community's equity and resilience. OCF articulates an unwavering commitment to mitigating and adapting to climate change with a people-first systems-approach.	Goal 1: Reduce 2030 Greenhouse Gas Emissions by 80% below 2005 baseline levels	CTC 1: Continue to build bicycle facilities as identified in the Bicycle Master Plan CTC 2: Create mobility hubs to support convenient transportation connection options CTC 4: Provide travel trainings program
Wayfinding Plan (2015)	The Fort Collins Wayfinding Plan provides a summary of sign design and guidelines for sign placement.	Goal #2: Program system of routes that builds on the Low Stress Bicycle Route network identified in the 2014 Bicycle Master Plan and seamlessly connects to the multi-use trail network	None.

Table 9: Related Plans

Existing Multimodal Network

Functional Classification

Functional Roadway Classifications distinguish roads based on their level of mobility and access. Highways and Arterials function around mobility, serving a high volume of vehicles traveling at high speeds while Collectors and Local Streets provide access to destinations, carrying a lower volume of vehicles traveling at lower speeds (Figure 1). On high-volume, high-speed roadways, the AMP will consider bicycle facilities providing physical separation from vehicles to improve safety and mobility. On low-volume, low-speed roadways, the AMP will consider strategic infrastructure investments to improve comfort and ease of access for people biking and walking.

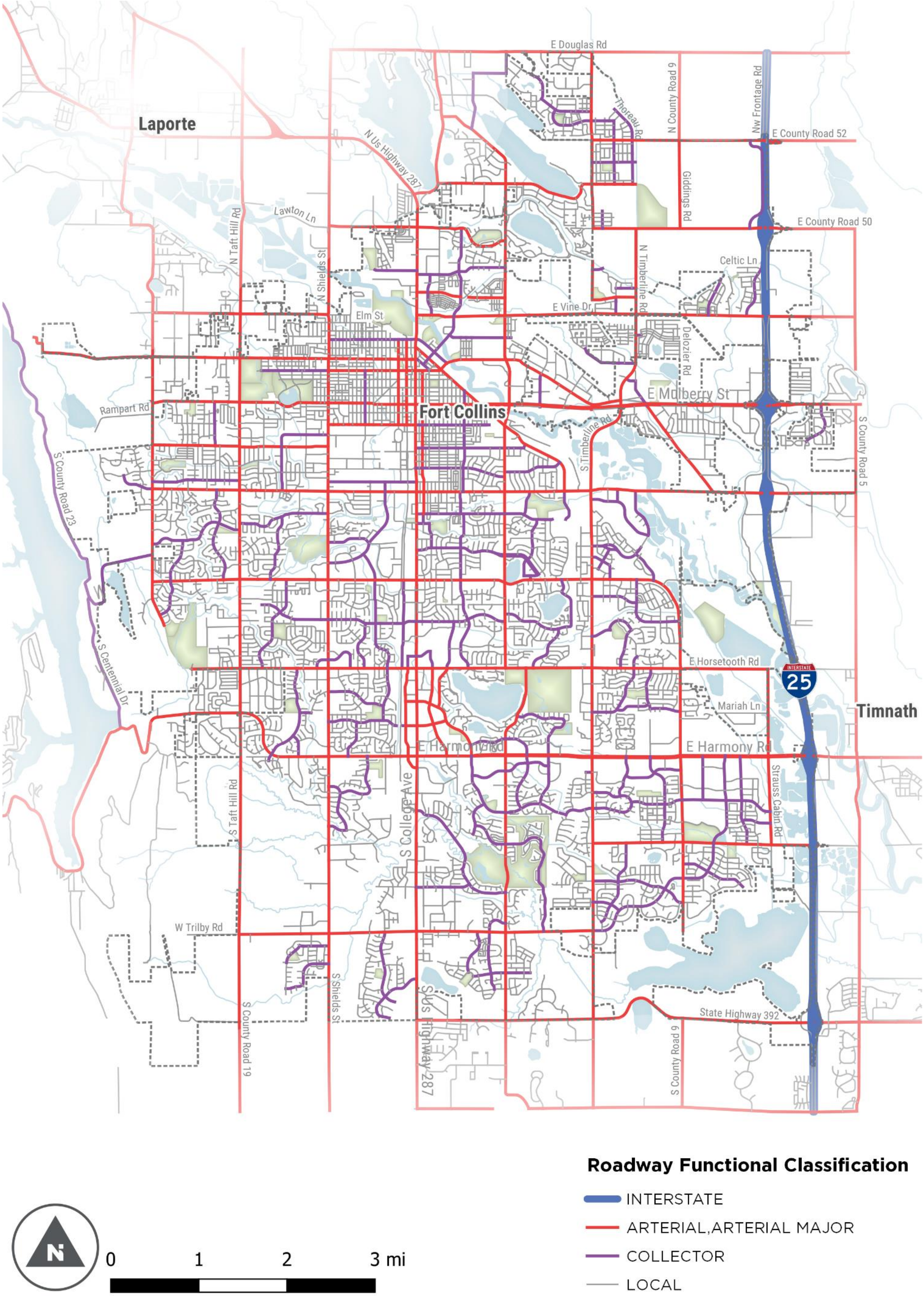


Figure 1: Functional Roadway Classifications. Source: City of Fort Collins

Sidewalks

While most of Fort Collins has sidewalk coverage (Figure 2), there are pockets of missing and inadequate sidewalks across the City. According to the City Plan, there are 221 miles of missing sidewalk in the City and 217 miles of sidewalks that are not ADA compliant.

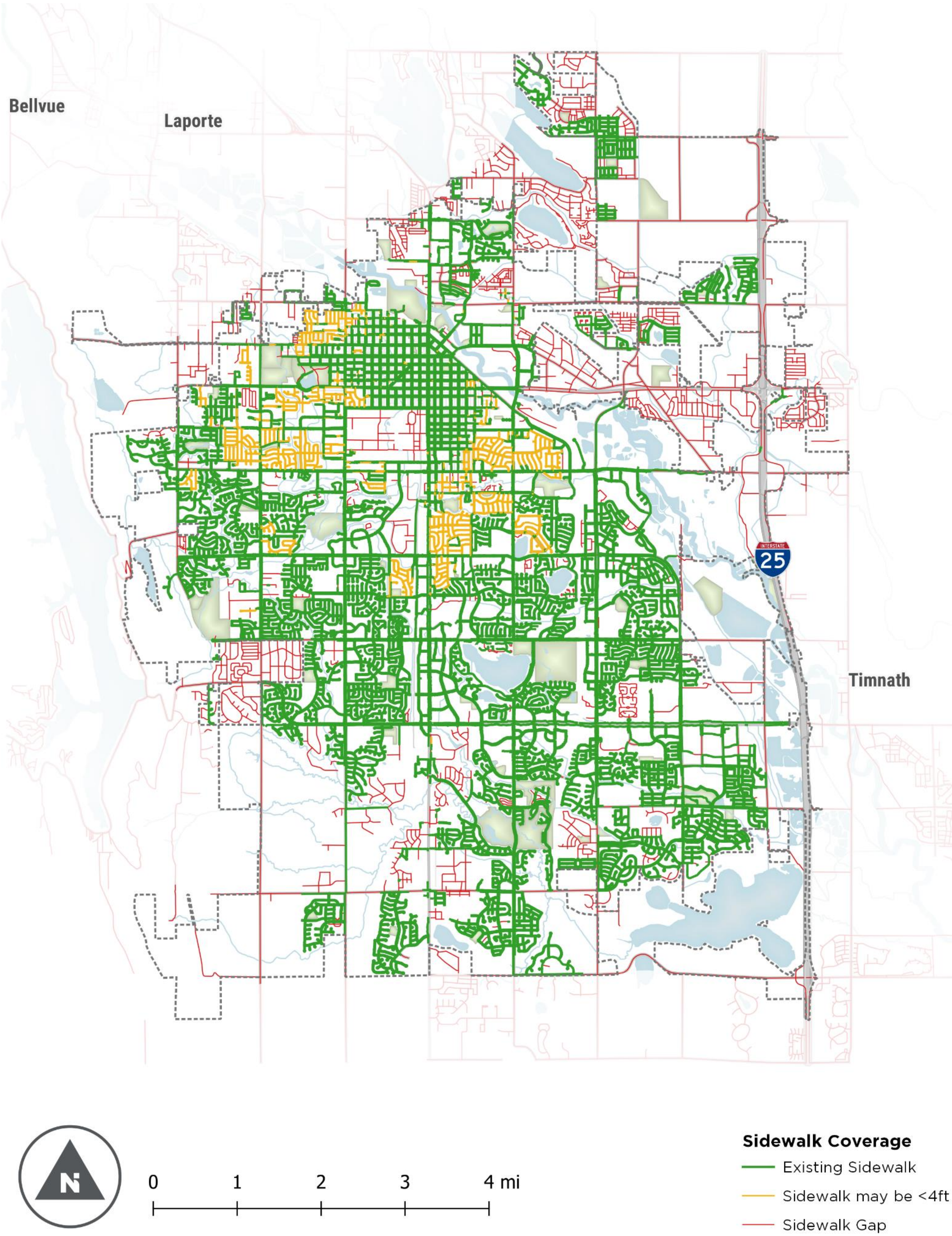


Figure 2: Sidewalk Coverage. Source: City of Fort Collins

Bikeways

The 2014 Bicycle Master Plan introduced the 2020 Low-Stress Bicycle Network, The Low-Stress Bicycle Network feature “High-Comfort” bicycle facilities (figure 3)—bikeways with a dedicated path for people on bikes to travel along on a street that provides a buffer of protection between them and passing traffic. “High-Comfort” bikeways minimize conflict between bikers and vehicles, encouraging the “Interested but Concerned” bicycle commuters. “Interested but Concerned” bicyclists have a desire to bike more but are concerned about their safety on existing facilities. Fort Collins’ success designing for this population group contributes the higher share of bicycle commuters in the City relative to other places.

Figure 4 shows Fort Collins boasts over 266 miles of on-street facilities, including 148 miles of “High Comfort” facilities and 121 miles of “Low Comfort” facilities (City Plan, 2019). In addition to on-street facilities, Fort Collins is home to 97 miles of off-street paved trails. Figures 5, 6, and 7 illustrate the progress made on constructing both the short-term and long-term visions of the 2020 Low-Stress Bicycle Network. The AMP will update the existing Low-Stress Network and consider strategies to improve project delivery ability and capacity.

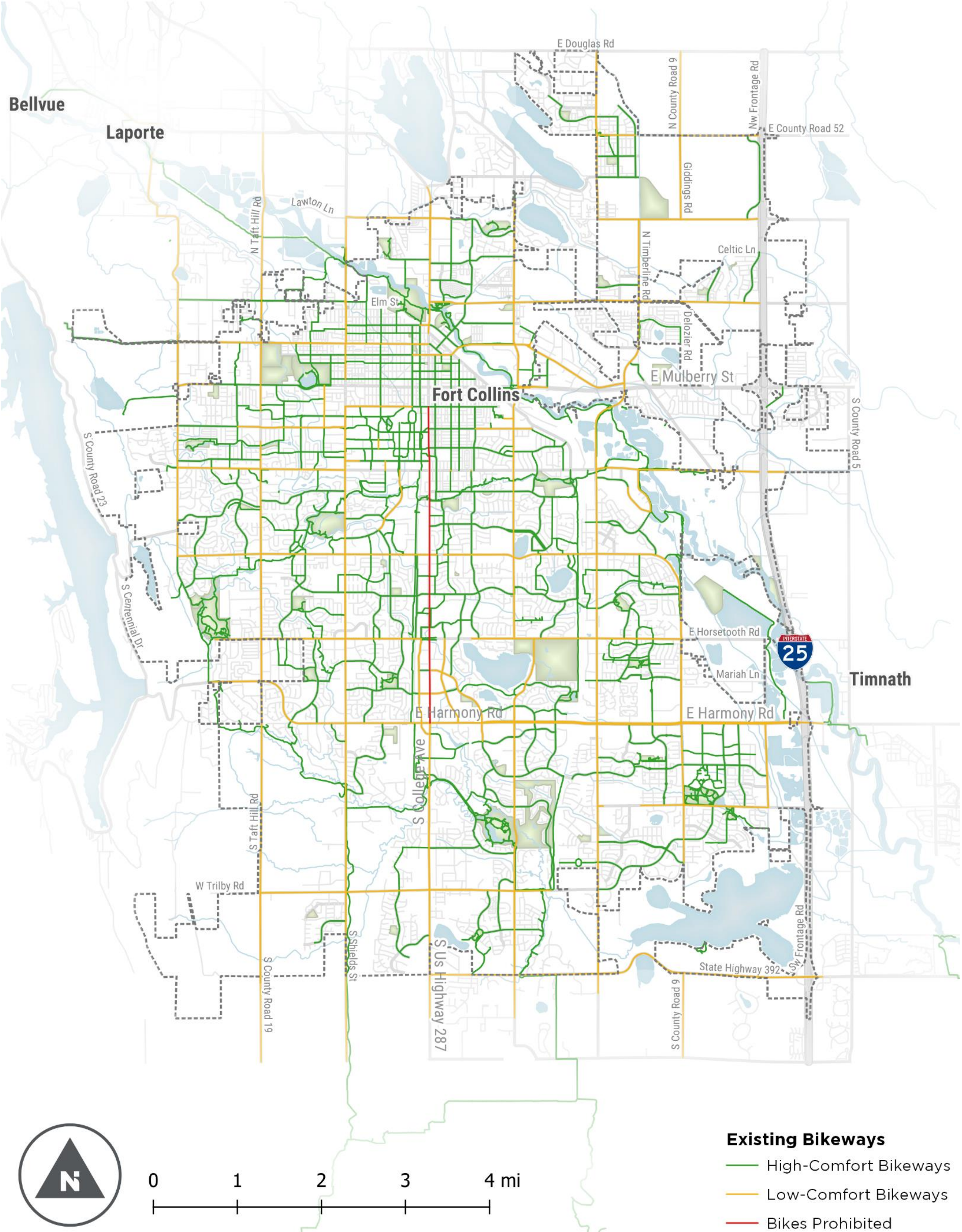


Figure 3: High and Low Comfort Bicycle Facilities. Source: City of Fort Collins

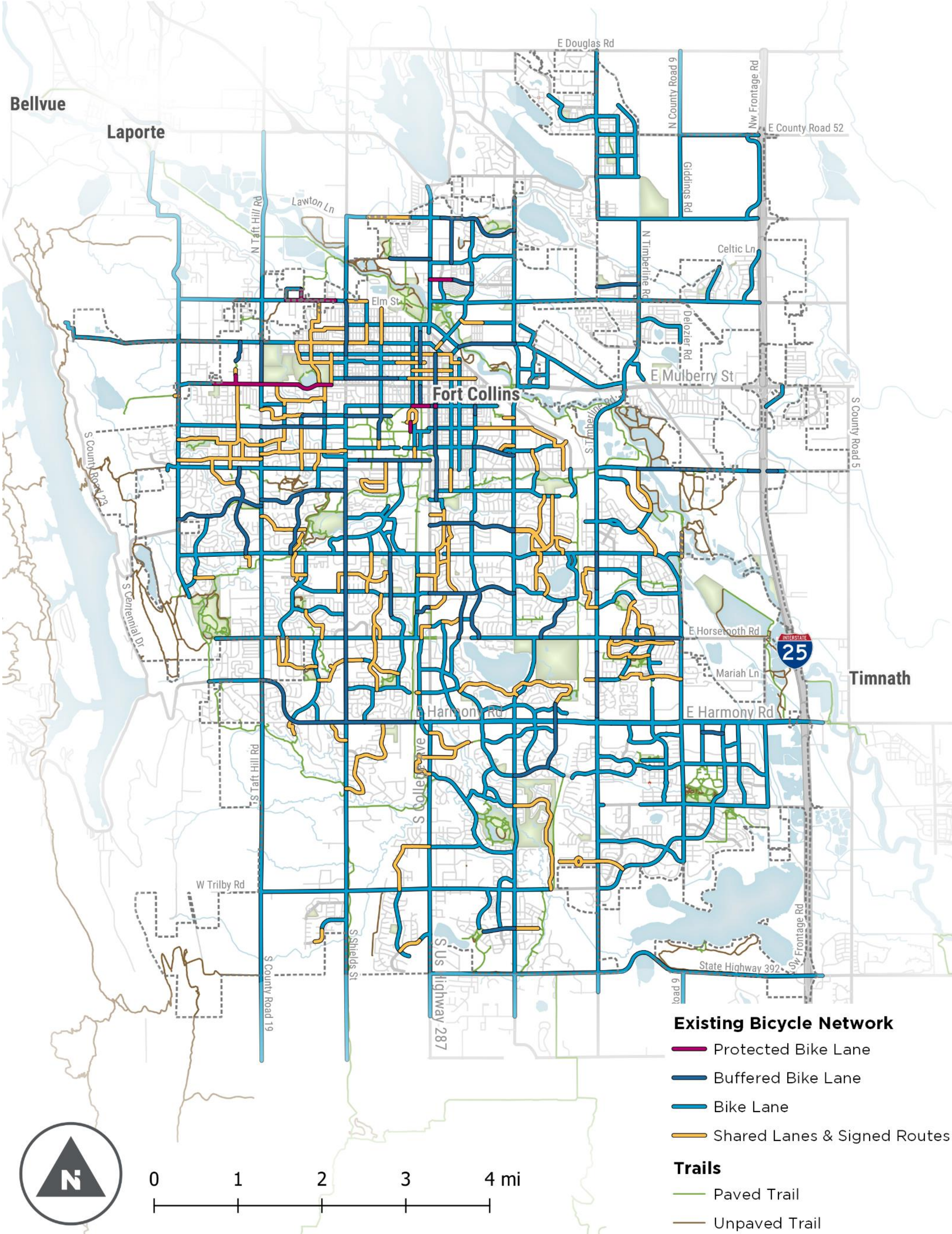


Figure 4: Existing Bicycle Network. Source: City of Fort Collins

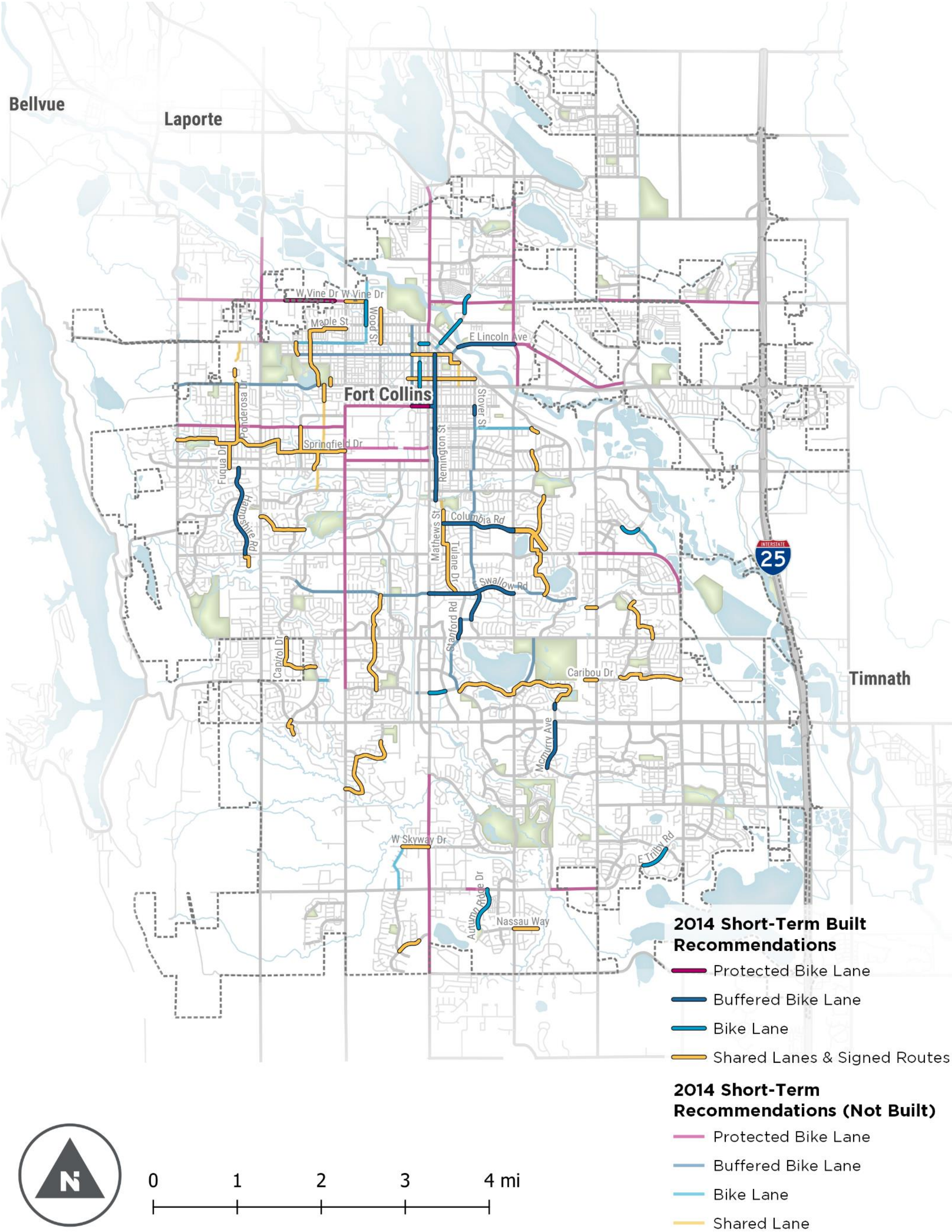


Figure 5: Implemented Short-Term Recommendations from the *2014 Bicycle Plan*. Source: City of Fort Collins

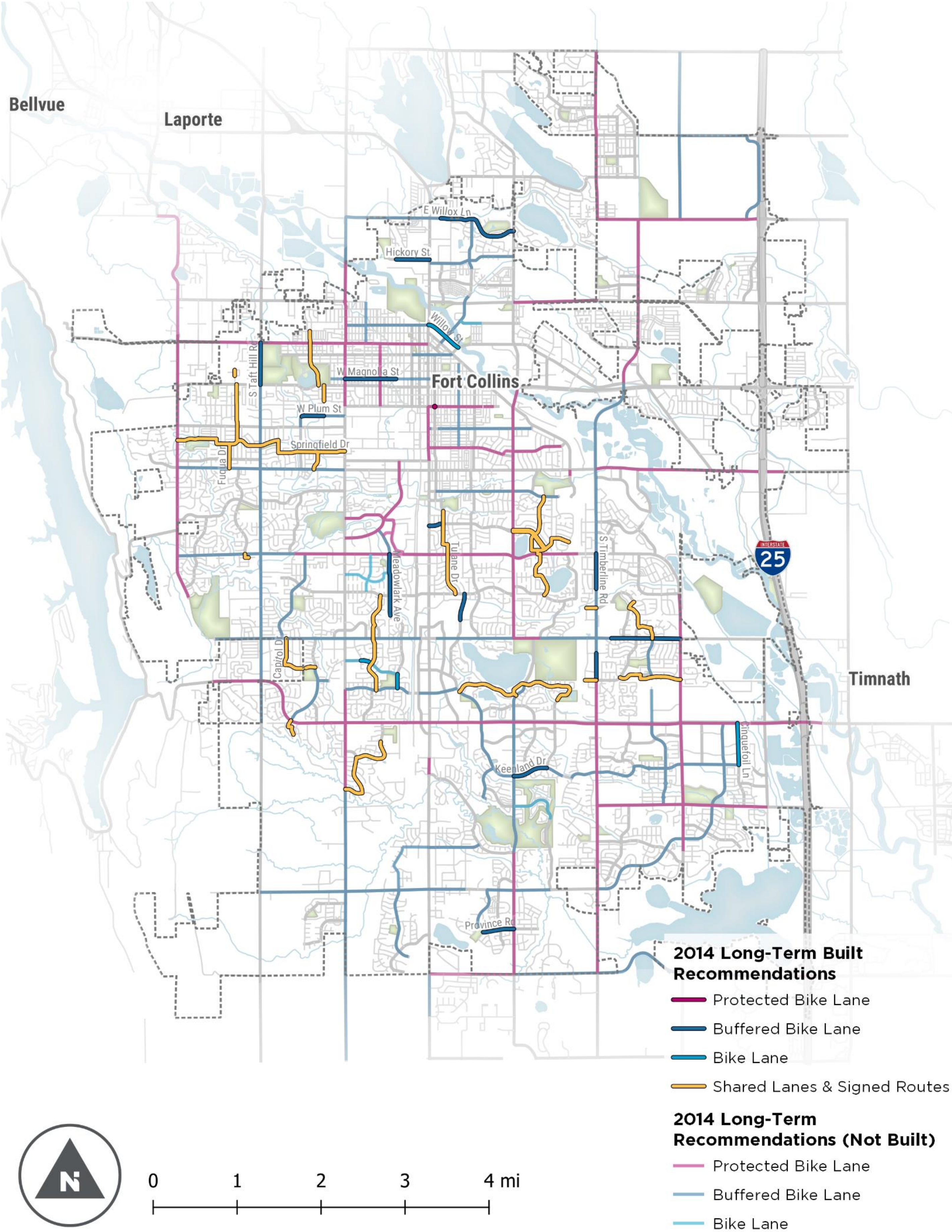


Figure 6: Implemented Long-Term Recommendations from the *2014 Bicycle Plan*. Source: City of Fort Collins

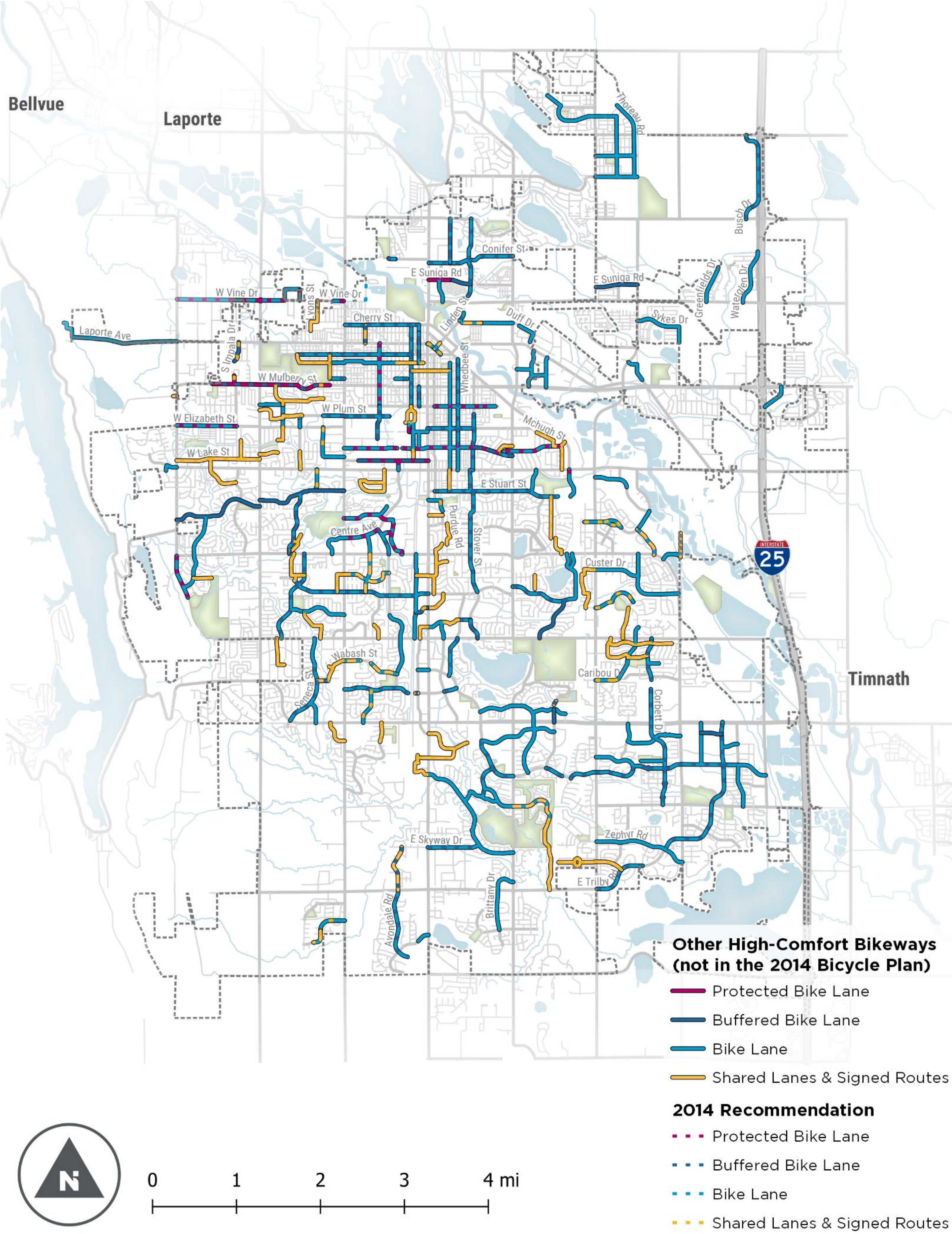


Figure 7: Existing High-Comfort Bikeways that differ from the *2014 Bicycle Plan* recommendations. Source: City of Fort Collins

Transit

Fort Collins is served by Bus Rapid Transit, High Frequency routes, several Local Routes, and a Regional line (Figure 8). Prior to the Covid-19 pandemic, Fort Collins had seen transit ridership increase from 2.5 million annual riders in 2014 to 4.4 million riders in 2018. Recent ridership growth can be attributed in part to the implementation of the highly successful MAX Bus Rapid Transit (BRT) line along the Mason Street corridor in 2014 and strategic investments in services catered to Colorado State University students and staff (Transit Master Plan, 2019). Public comments received during the Transit Master Plan planning process indicated a desire among residents to expand the BRT to additional corridors. However, improving access and safety for active modes along arterial roadways will be critical to expanding the BRT system. Public transit and active transportation are complimentary; people who commute by biking or walking are more likely to use transit for a part of their trip.

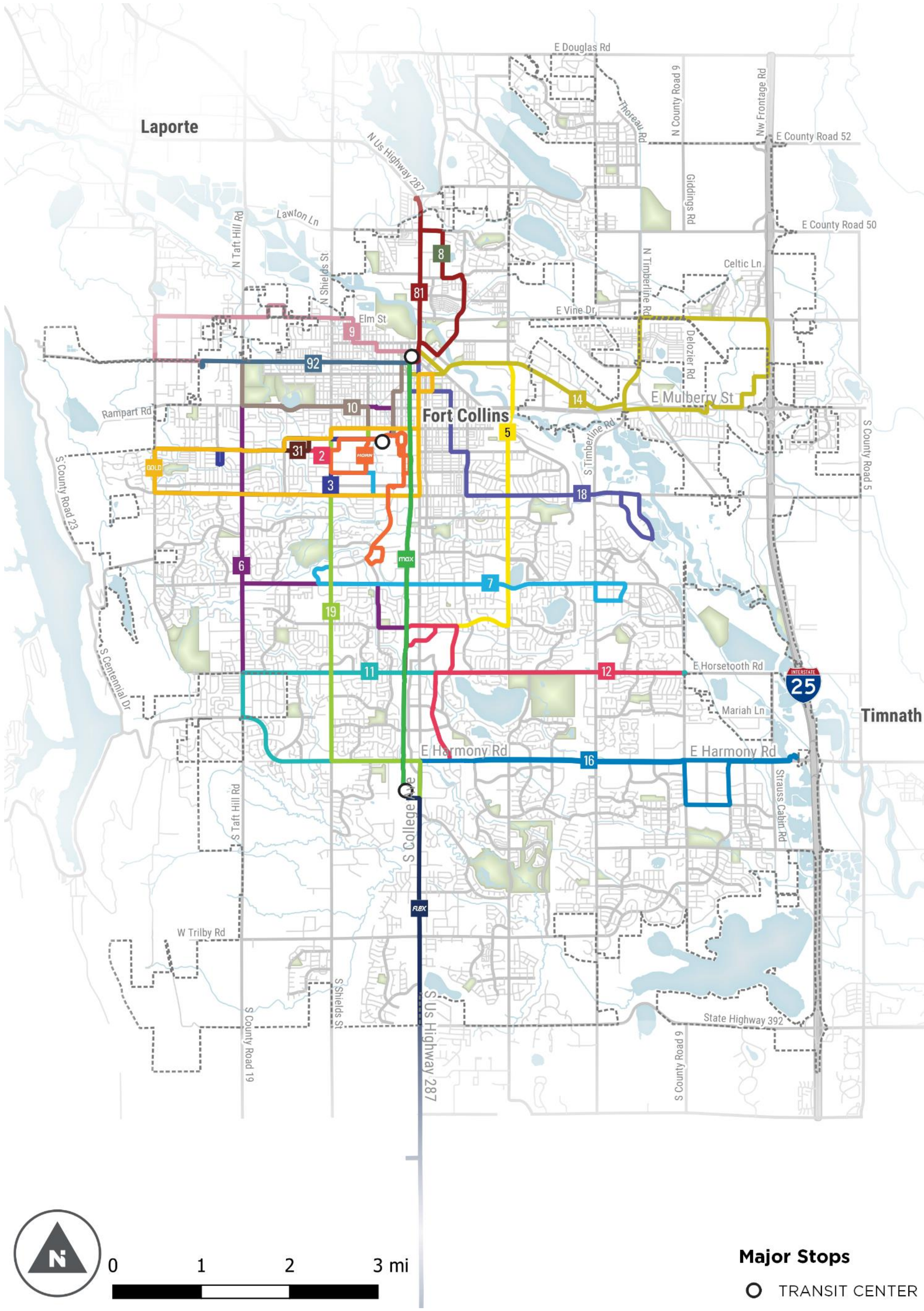


Figure 8: Bus Transit Routes. Source: City of Fort Collins

Safety Analysis

In 2016, Fort Collins became the first public local entity to join the Colorado Department of Transportation (CODOT) Moving Towards Zero Deaths initiative. This commitment signifies Fort Collins' vision for providing a safe and efficient transportation system for people using all modes of travel. Between 2015 and 2020, there were 18,422 total crashes in Fort Collins, including 817 (4.4%) involving people walking and biking (CODOT, 2021). Of the 18,422 crashes, 171 resulted in a fatality or serious injury collision (CODOT, 2021). Fatal and Serious Injury Collisions (KSIs) occurred at or near intersections, and along high-volume, high-speed roadways (Figure 7). Despite only accounting for 4% of total collisions, people walking and biking account for one-third of KSI collisions. Combined, this data indicates the high-risk of death or serious injury people walking and biking face when traveling along arterial roadways.

Hot spot locations for bicycle and pedestrian collisions include the northern part of the City (North of Drake Avenue) and Arterial Roadways such as College Avenue, Mulberry Avenue, and Prospect Road (Figure 8). Two-thirds of collisions involving people walking and biking occur during mid-day and evening peak commutes (12 pm – 7 pm) and between April and October. Primary collision factors include failure of vehicles to yield at crosswalks, high vehicle speeds, vehicles making right-turns on red-lights, and inconsistency between facility placement of traveler desire lines. This data indicates that the collision risk is greater for people walking and biking where and when there are more vehicles on roadways. Based on this data, the AMP will focus on opportunities to reduce conflicts between modes traveling at different rates of speed and mass through facility recommendation and traffic calming measures.

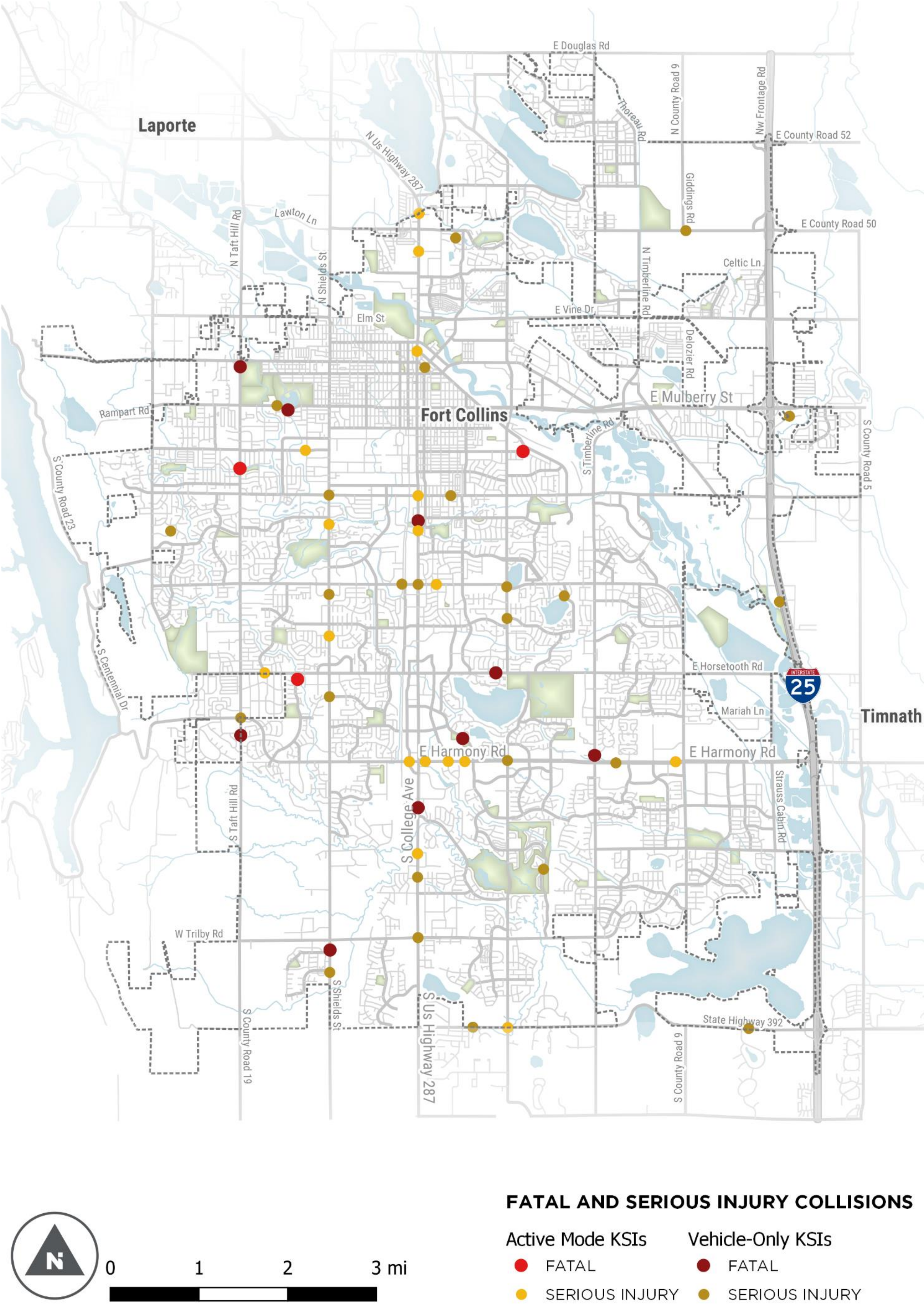


Figure 7: KSI Collisions. Source: City of Fort Collins

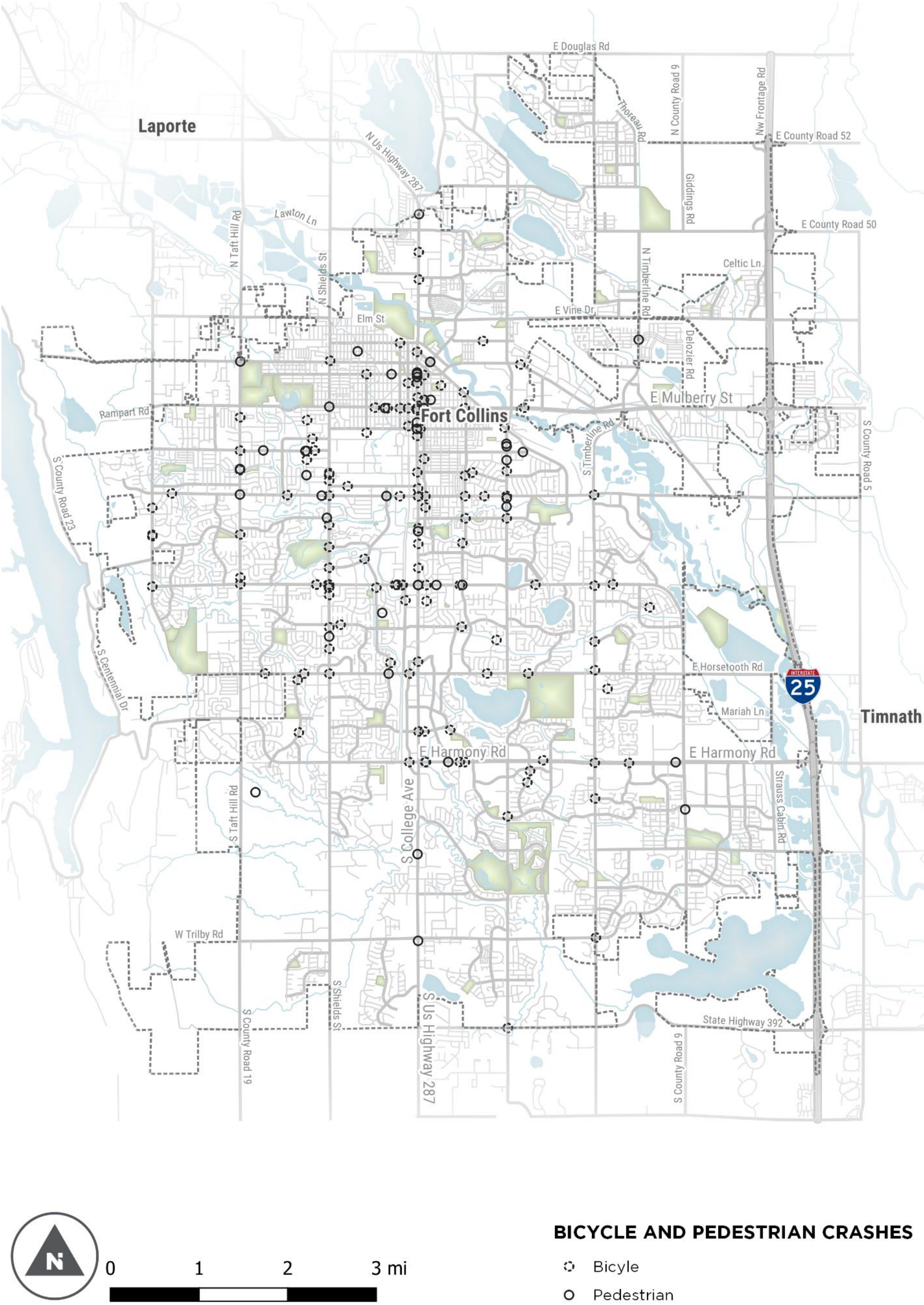


Figure 8: Bicycle and Pedestrian Crashes. Source: City of Fort Collins

APPENDIX C: COMMUNITY ENGAGEMENT SUMMARY

City of Fort Collins FC Moves

walk. bike. roll.

ACTIVE MODES PLAN

Community Engagement Summary

2021-2022

Engagement Overview

1

Visioning Questionnaire

2 workshops

3 pop-up events

239 responses online

Active Oct. 2021

2

2 Community Surveys

Online and Print

1,680 online survey submissions

Active Nov. 2021 and Feb. 2022

3

2 Mapping Exercises

16+ virtual & in person focus groups

2,620 people engaged

Active Nov. 2021 and Feb. 2022

Who has provided feedback?

	STAKEHOLDER REPRESENTATIVES / ORGANIZATIONS
Technical Advisory Committee (TAC)	FC Core Staff: FC Moves, Engineering, Traffic Operations, Parks Planning & Development, CSU Other FC Staff & Agencies: Streets, City Planning, Parks, Economic Health, Community Development & Neighborhood Services, Environmental Services, Police Services, Natural Areas, Transfort, Parking Services, Utilities, DDA, CDOT, Larimer County, PSD, North Front Range MPO
Community Advisory Committee (CAC)	BIPOC Alliance, NCIPA, Fuerza Latina, person who has experienced homelessness, Overland MTB Association, Bike Fort Collins, Youth Advisory Board, CSU CBAC, Partnership for Age-Friendly Communities, NoCo Splash, NoCo Equality, DARTAC
Focus Groups	Educational Institutions, Health Organizations, Business Organizations, Bike Organizations, Pedestrian Organizations, Accessibility/Disability Community
Internal (City)	City Council, Transportation Board, Bicycle Advisory Committee, other interested Boards & Commissions

1

Community Survey #1

Demographic Information

Overview of Survey Responses and Respondents

Gender, Race, and Ethnicity

Age, City Council District, and Disability Status

Income

Responses Overview

477
Total English Responses

375 Completed
102 Partially Completed

294
Total Spanish Responses

264 Completed
30 Partially Completed

90%
Live in Fort Collins

33%
Work in Fort Collins

9%
Go to School in Fort Collins

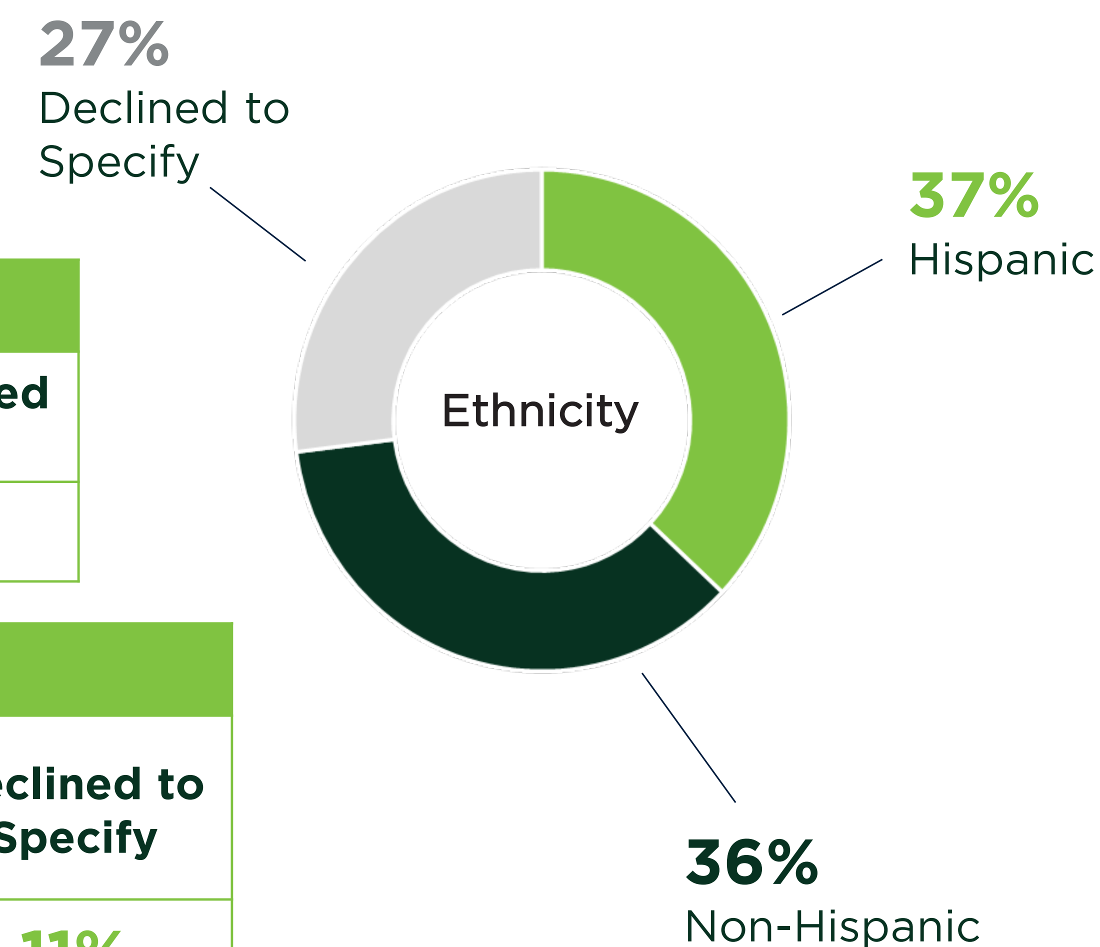
4%
Visit Fort Collins Often

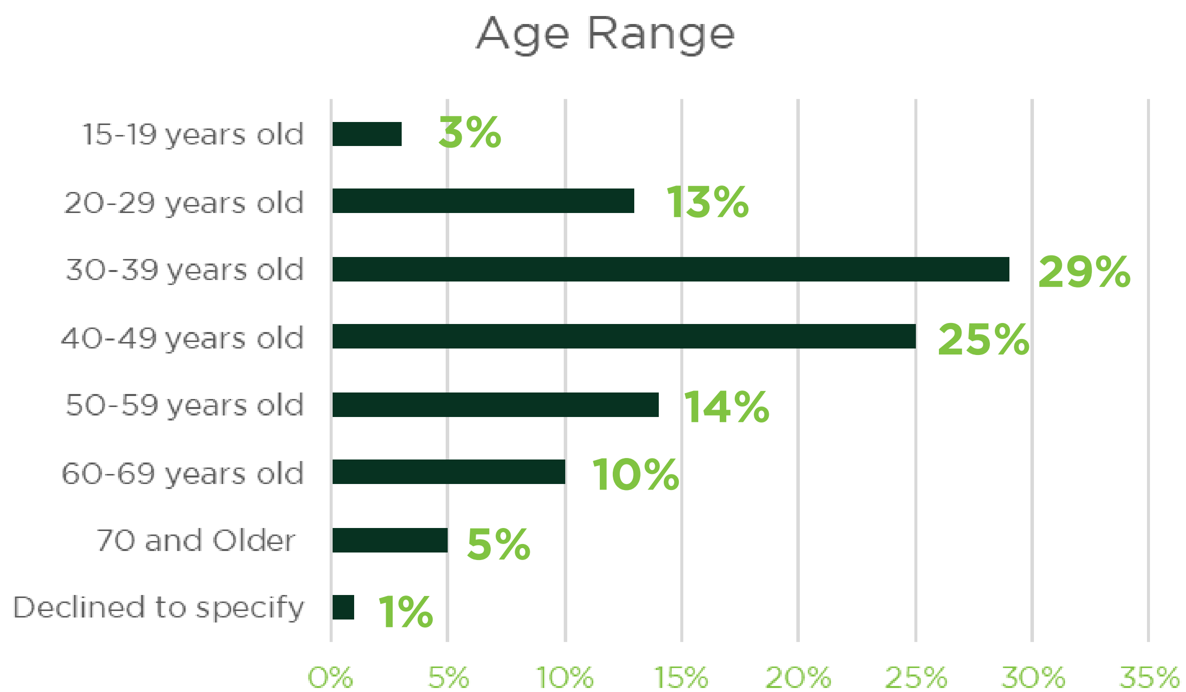
3%
Other

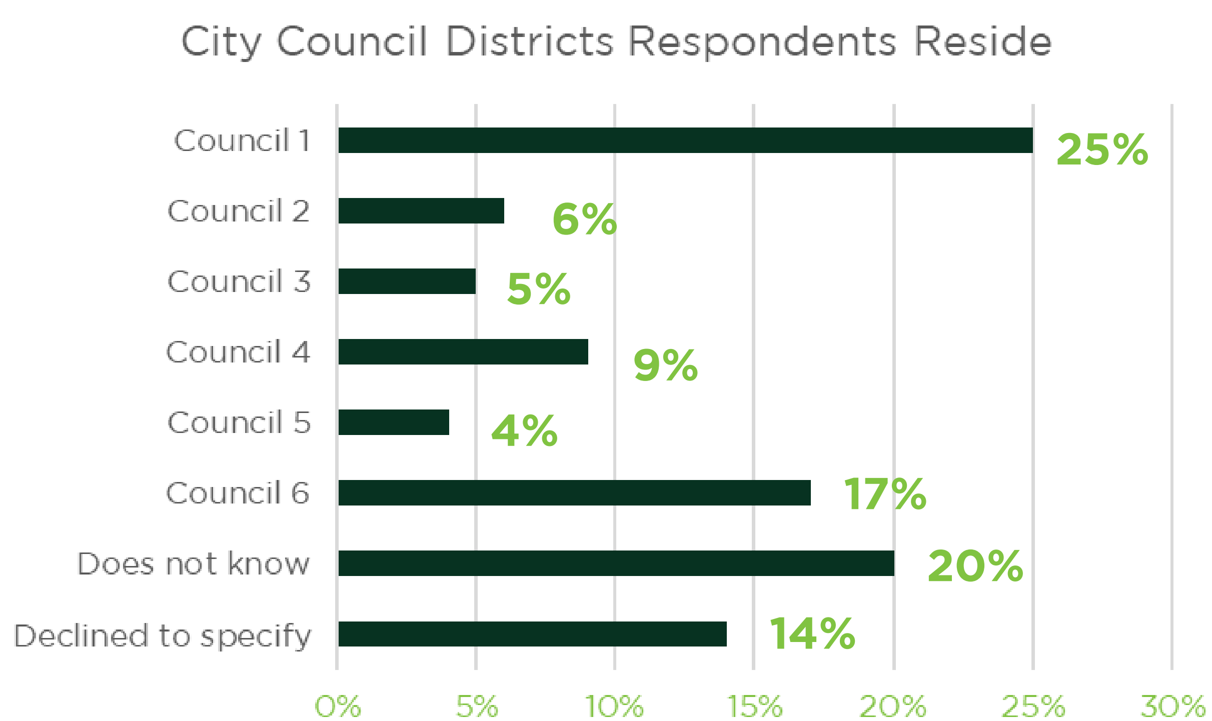
Survey Demographics

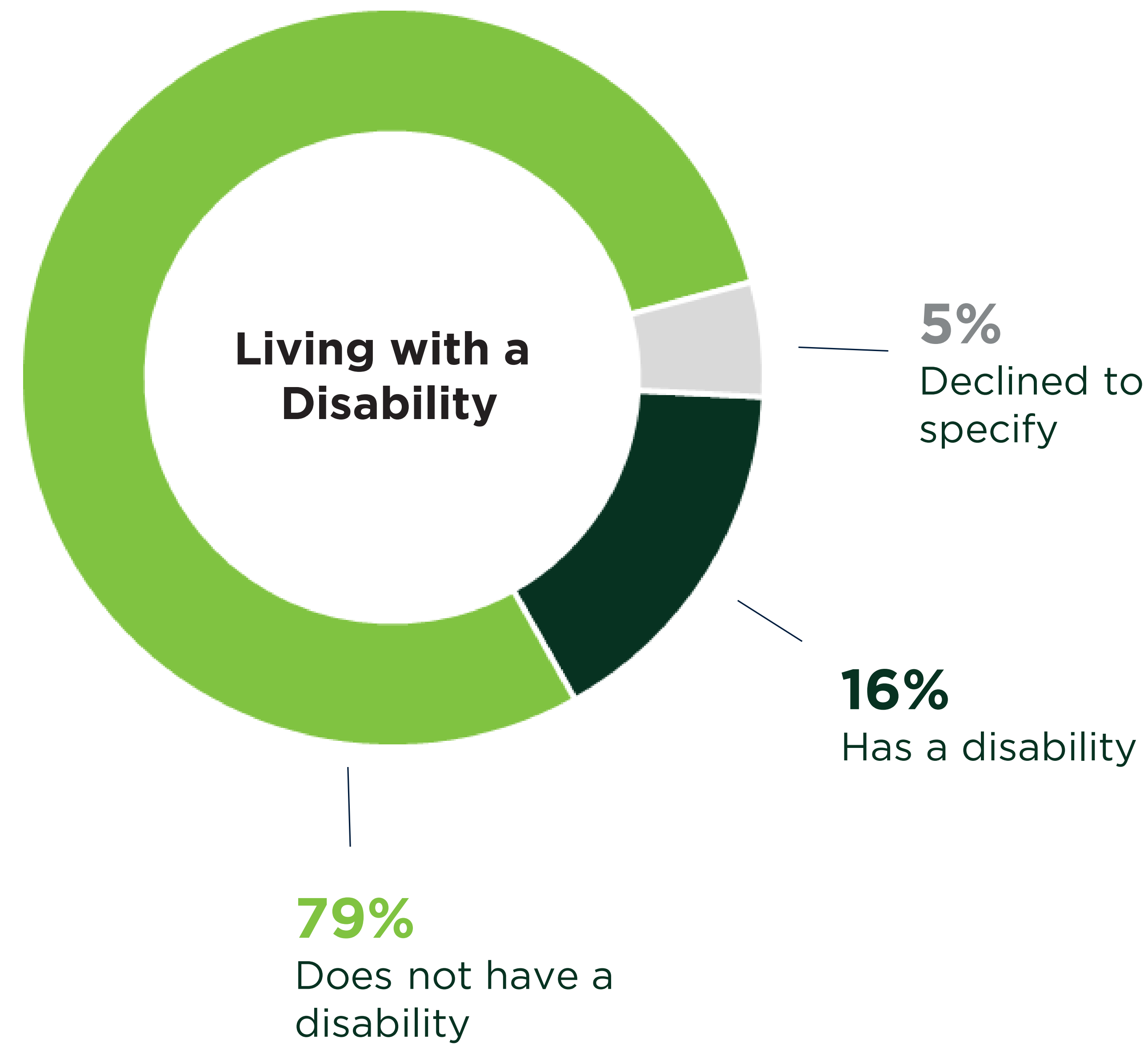
Gender of Respondents				
Female	**Male**	**Non-Binary**	**Transgender**	**Other/Declined to Specify**
59%	36%	1%	<1%	4%

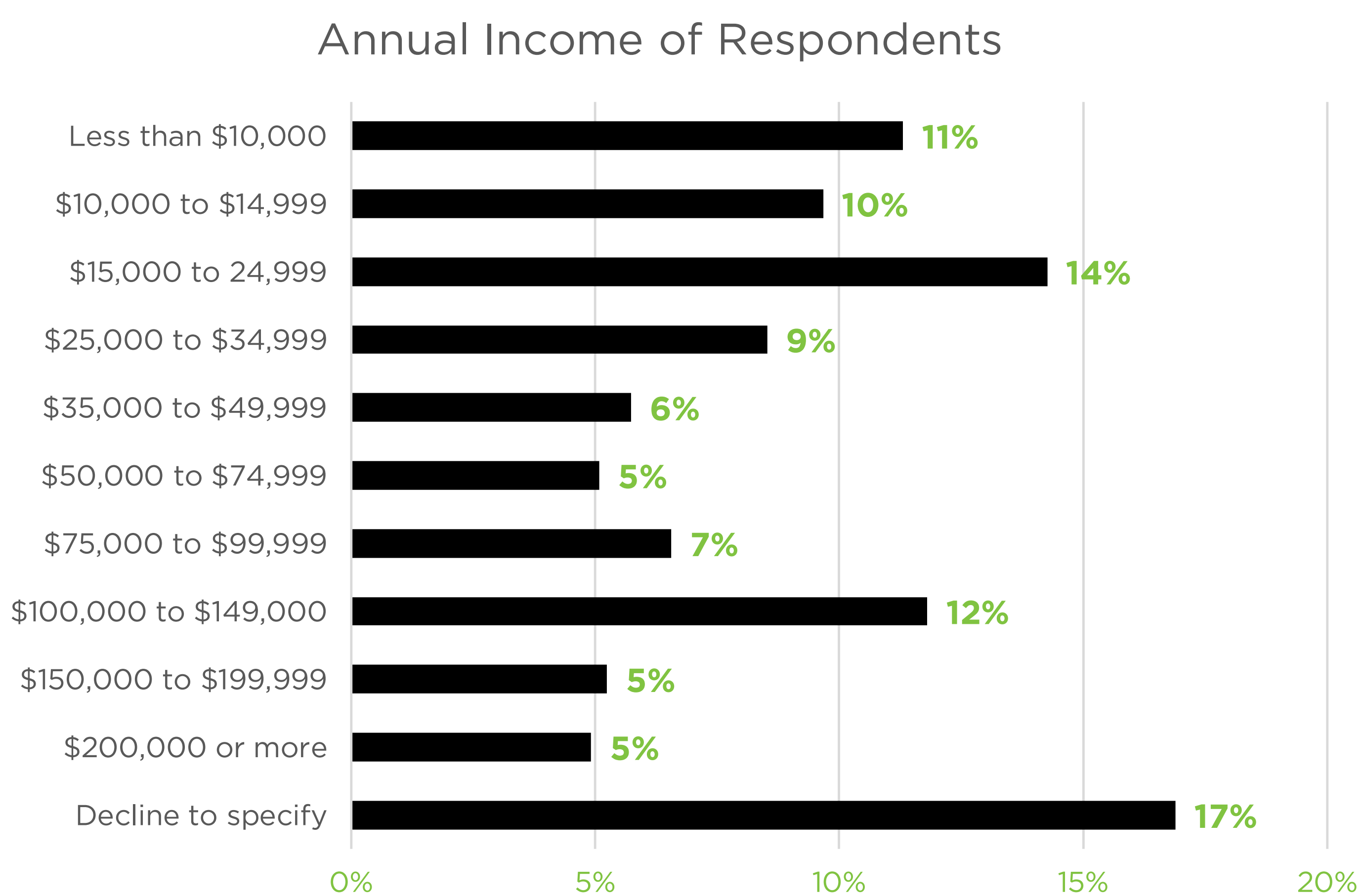
Race of Respondents					
White	**American Indian/Alaska Native**	**Two or More Races**	**Asian**	**Black or African American**	**Declined to Specify**
77%	5%	4%	1%	1%	11%




Age Range
15-19 years old
3%
20-29 years old
13%
30-39 years old
29%
40-49 years old
25%
50-59 years old
14%
60-69 years old
10%
70 and Older
5%
Declined to specify
1%
0%
5%
10%
15%
20%
25%
30%
35%


City Council Districts Respondents Reside
Council 1
25%
Council 2
6%
Council 3
5%
Council 4
9%
Council 5
4%
Council 6
17%
Does not know
20%
Declined to specify
14%
0%
5%
10%
15%
20%
25%
30%


Living with a Disability
5%
Declined to specify
16%
Has a disability
79%
Does not have a disability



14%

Earn $15,000-$24,9999 annually

Majority of Respondents Declined to Specify

Trip Frequency and Patterns

Frequency of Mode Use

COVID-19 Impacts on Transportation Patterns

How Often Respondents Use Various Modes of Transportation

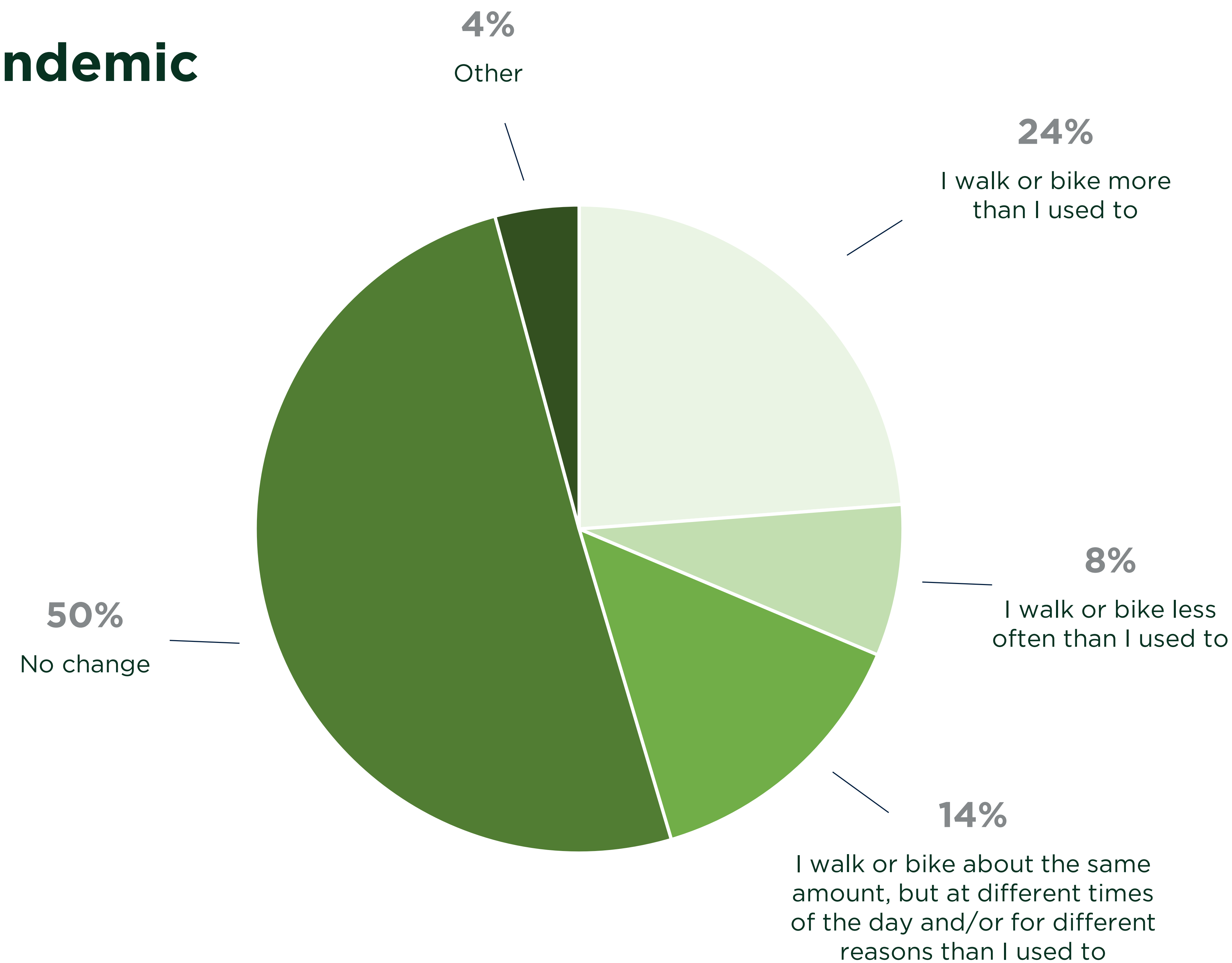
	Daily/almost every day	Once or twice a week	At least once a month	Less than once a month	Never	Total Responses
Walk	330 45%	158 22%	68 9%	61 8%	101 14%	728
Bike	150 21%	138 19%	107 15%	89 12%	243 33%	727
Electric Bike	18 3%	31 4%	13 2%	25 4%	606 87%	693
Electric Scooter	7 1%	8 1%	19 3%	31 4%	625 91%	689
Bus / Transit	34 5%	39 6%	53 8%	123 18%	446 64%	695
Drive (carpool)	173 25%	144 21%	66 9%	69 10%	248 35%	700
Drive (alone)	417 57%	159 22%	38 5%	23 3%	90 12%	727
Rideshare (e.g. Uber, Lyft)	5 1%	15 2%	45 7%	156 23%	470 68%	691
Telecommute / Work from Home	138 20%	69 10%	32 5%	35 5%	425 61%	699

% of Responses

- <10%
- 10% - 19%
- 20% - 29%
- 30% - 39%
- 40% - 59%
- 60% - 80%
- >80%

How has the COVID-19 pandemic changed travel patterns?

740
Total Responses
740 out of 771 total survey respondents answered this question.



The next set of questions were specific to walking and bicycling:

36%

Chose to answer questions ONLY about **walking**

252 Total Responses

21%

Chose to answer questions ONLY about **bicycling**

142 Total Responses

43%

Chose to answer questions about BOTH **walking and bicycling**

299 Total Responses

78 respondents skipped these questions entirely

Walking Responses

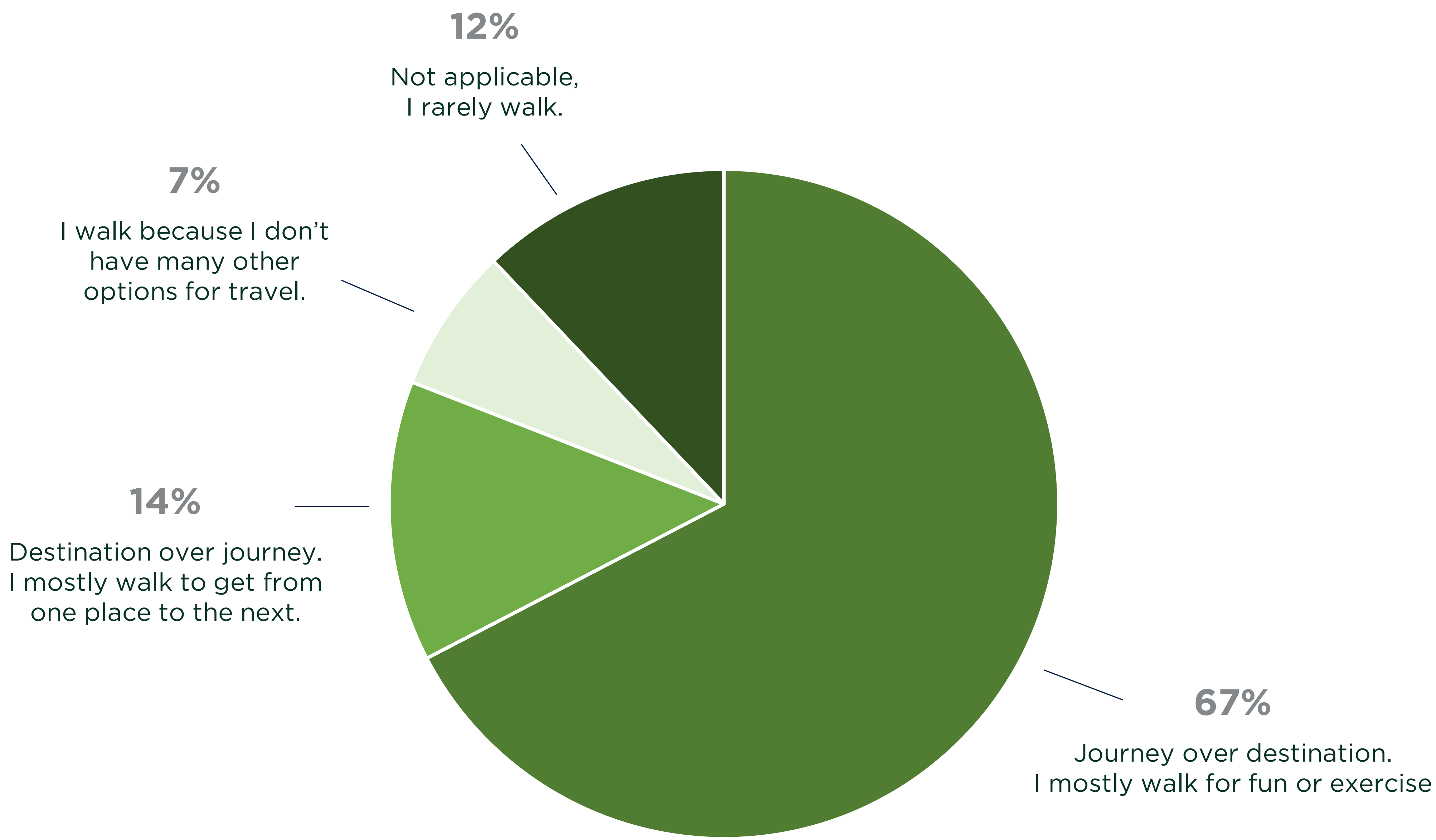
Why Respondents Walk

Frequency and Purpose of Walking

Top Challenges for Walking in Fort Collins

Top Priorities to Improve the Pedestrian Experience

Why do survey respondents choose to walk?



472
Total Responses

How often do respondents walk for the following purposes?

	Daily/almost every day	Once or twice a week	At least once a month	Less than once a month	Never	Total Responses
To get to work or school	71 15%	48 10%	20 4%	52 11%	298 61%	489
For fun or exercise (e.g. walking my dog)	231 46%	139 28%	53 11%	47 9%	27 5%	497
To visit friends/social/entertainment	62 13%	110 22%	100 20%	91 19%	127 26%	490
To shop or run errands	42 8%	93 19%	79 16%	69 14%	213 43%	496
To get to or from public transit	31 6%	23 5%	48 10%	67 14%	318 65%	487
To get to or from personal vehicle	64 25%	37 14%	19 7%	15 6%	121 47%	256
Other	23 17%	13 9%	4 3%	8 6%	91 65%	139

% of Responses

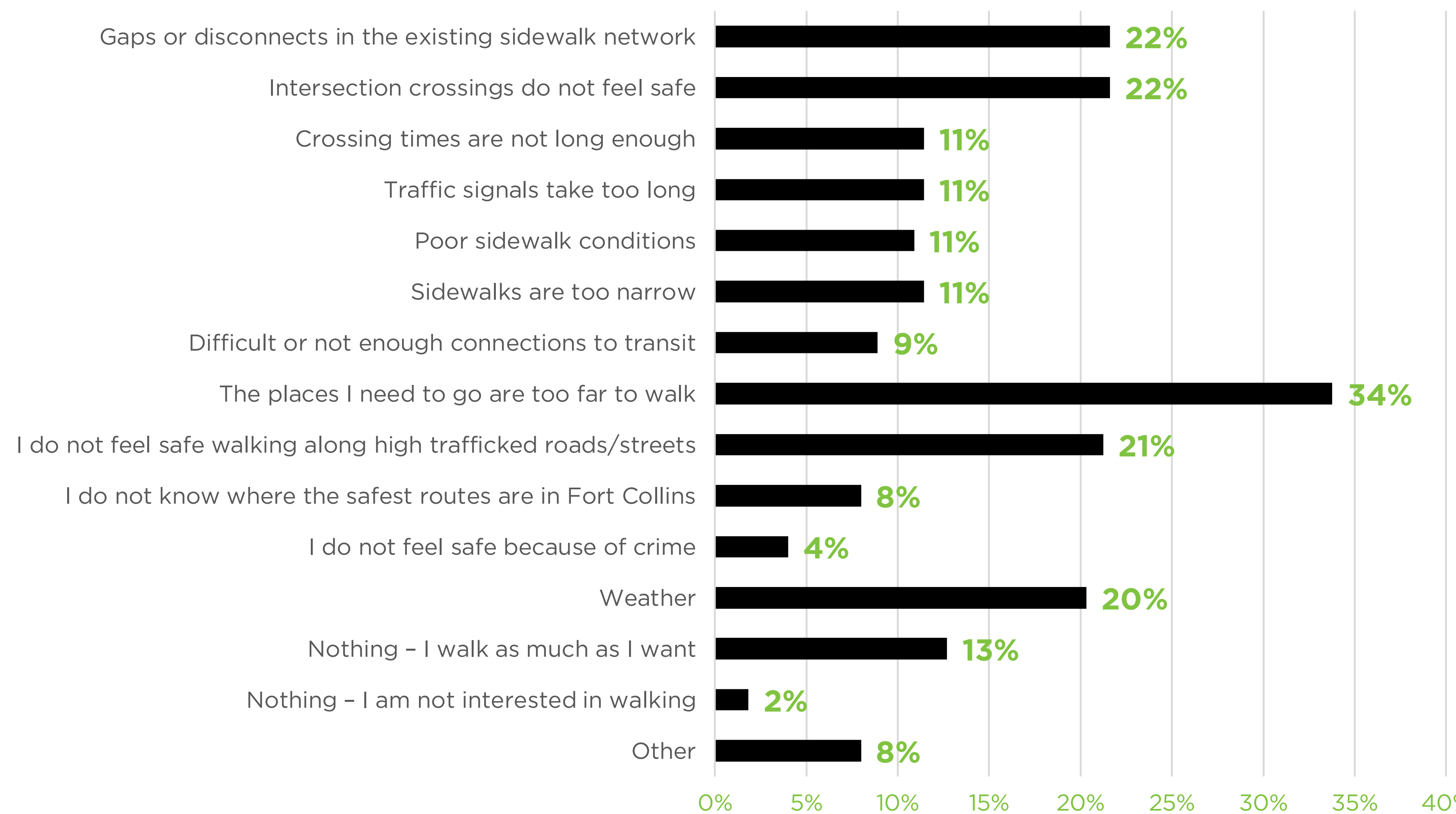
<10%
10% - 19%
20% - 29%
30% - 39%
40% - 59%
60% - 80%
>80%

Challenges that Prevent Respondents from Walking

(respondents selected top 3 answers)

Most common response:

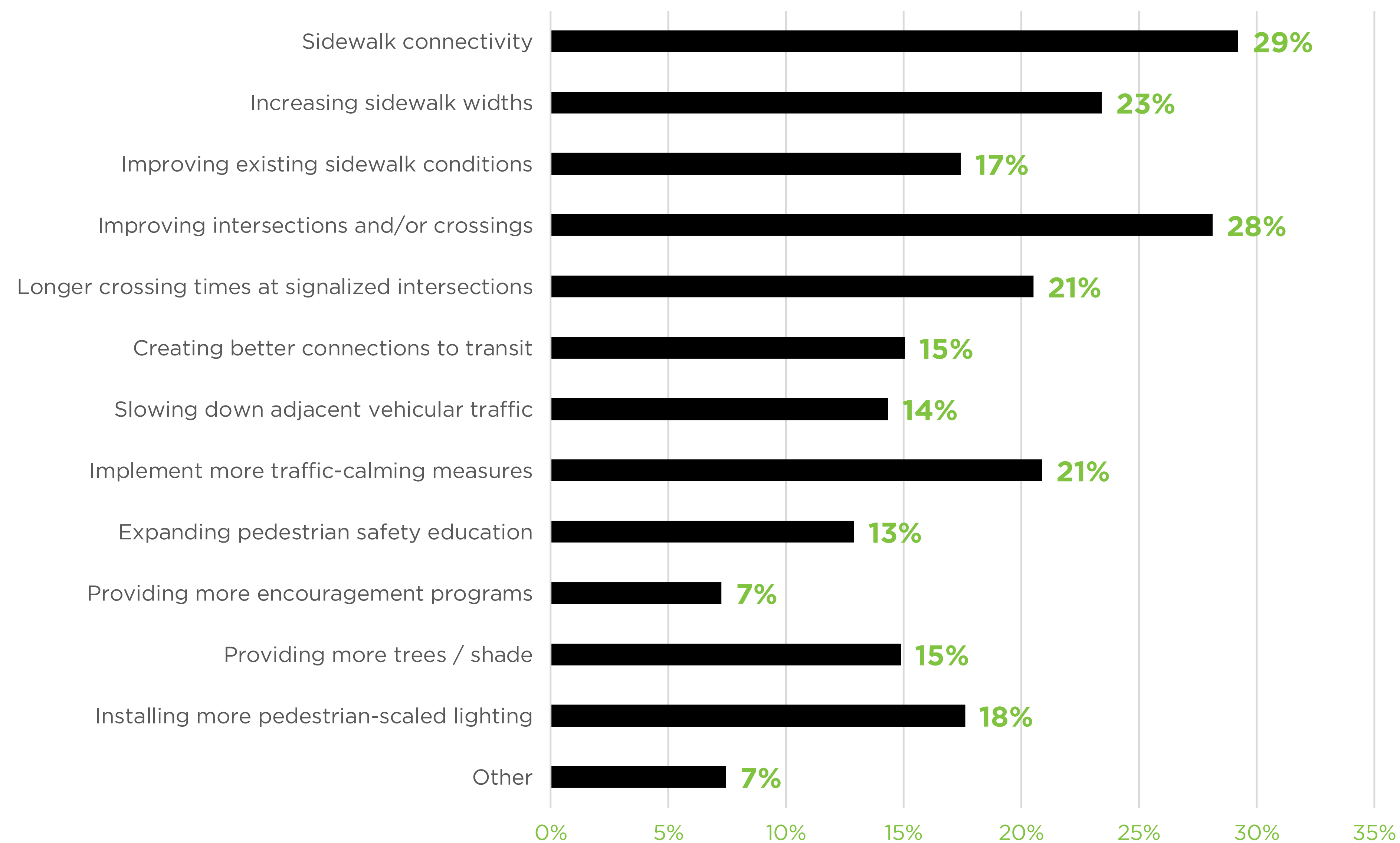
34% said they don't walk because the places they need to go are **too far to walk**.



Priorities Respondents Want the City to Focus on to Improve the Pedestrian Experience in Fort Collins (respondents selected top 3 answers)

Top Priorities:

1. Sidewalk Connectivity **(29%)**
2. Improving Intersections and/or crossings **(28%)**
3. Increasing sidewalk widths **(23%)**



Walking Responses Summary

75%
Want to walk more than they currently do

67%
Mostly walk for fun or exercise

46%
Walk for fun or exercise daily or almost every day

Top Challenges for Walking in Fort Collins

34%	Places I want to go are too far away
22%	Gaps or disconnects in the existing sidewalk network
22%	Intersections and crossings don't feel safe
21%	Weather
12%	I don't know where the safest routes are

Top Priorities for Improvement

1. Sidewalk Connectivity
2. Improving intersections and crossings
3. Increasing sidewalk widths

Bicycling Responses

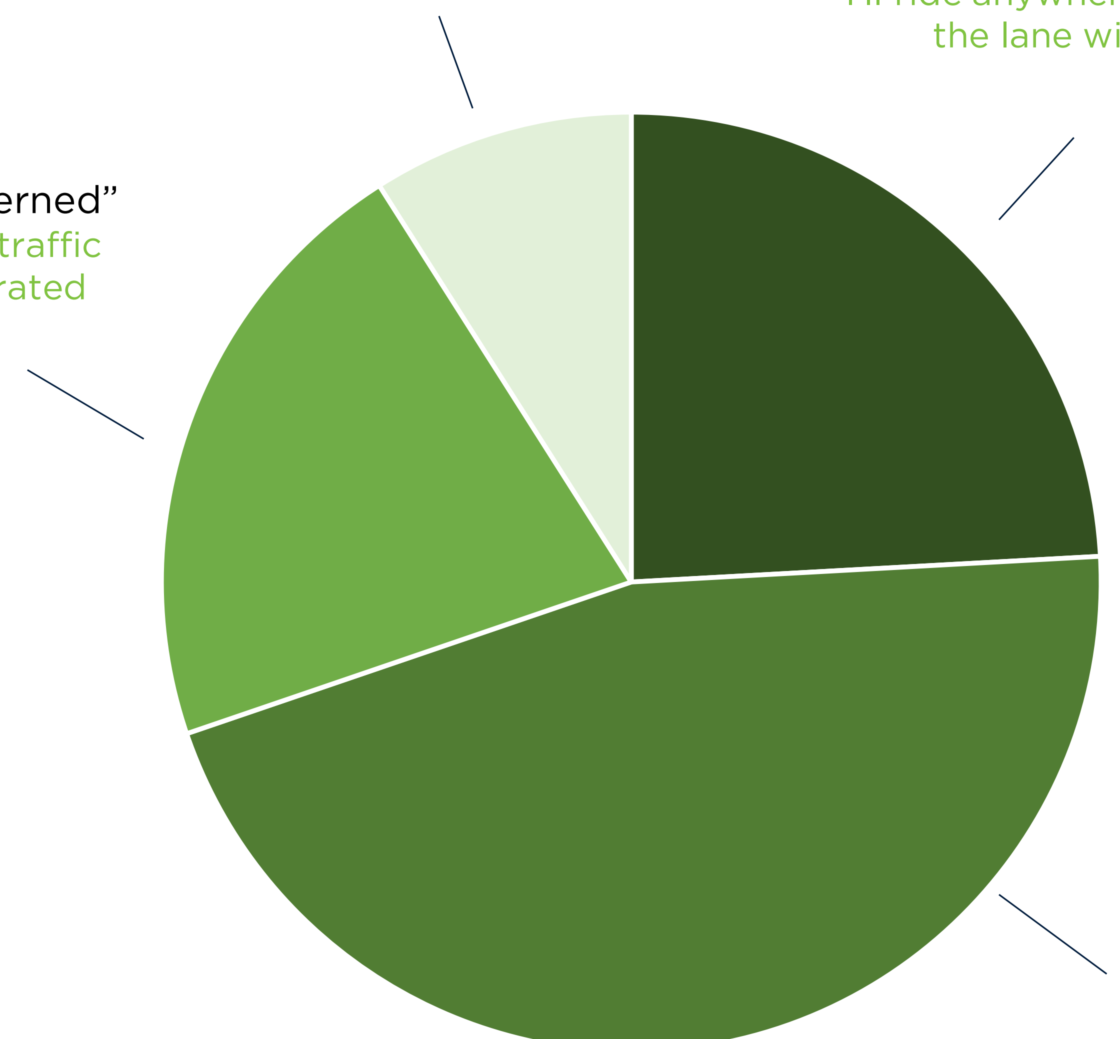
Bicycling Level of Comfort

Frequency and Purpose of Bicycling

Top Challenges for Bicycling in Fort Collins

Top Priorities to Improve the Bicycling Experience

Bicycling Habits and Comfort Level of Respondents



344
Total Responses

How often do respondents bike for the following purposes?

	Daily/almost every day	Once or twice a week	At least once a month	Less than once a month	Never	Total Responses
To get to work or school	68 18%	56 15%	37 10%	47 12%	170 45%	378
For fun or exercise	91 24%	139 36%	67 17%	45 12%	43 11%	385
To visit friends/social/entertainment	33 9%	101 27%	88 23%	76 20%	82 22%	380
To shop or run errands	29 8%	90 24%	65 17%	71 19%	125 33%	380
To get to or from public transit	13 4%	7 2%	18 5%	45 12%	282 77%	365

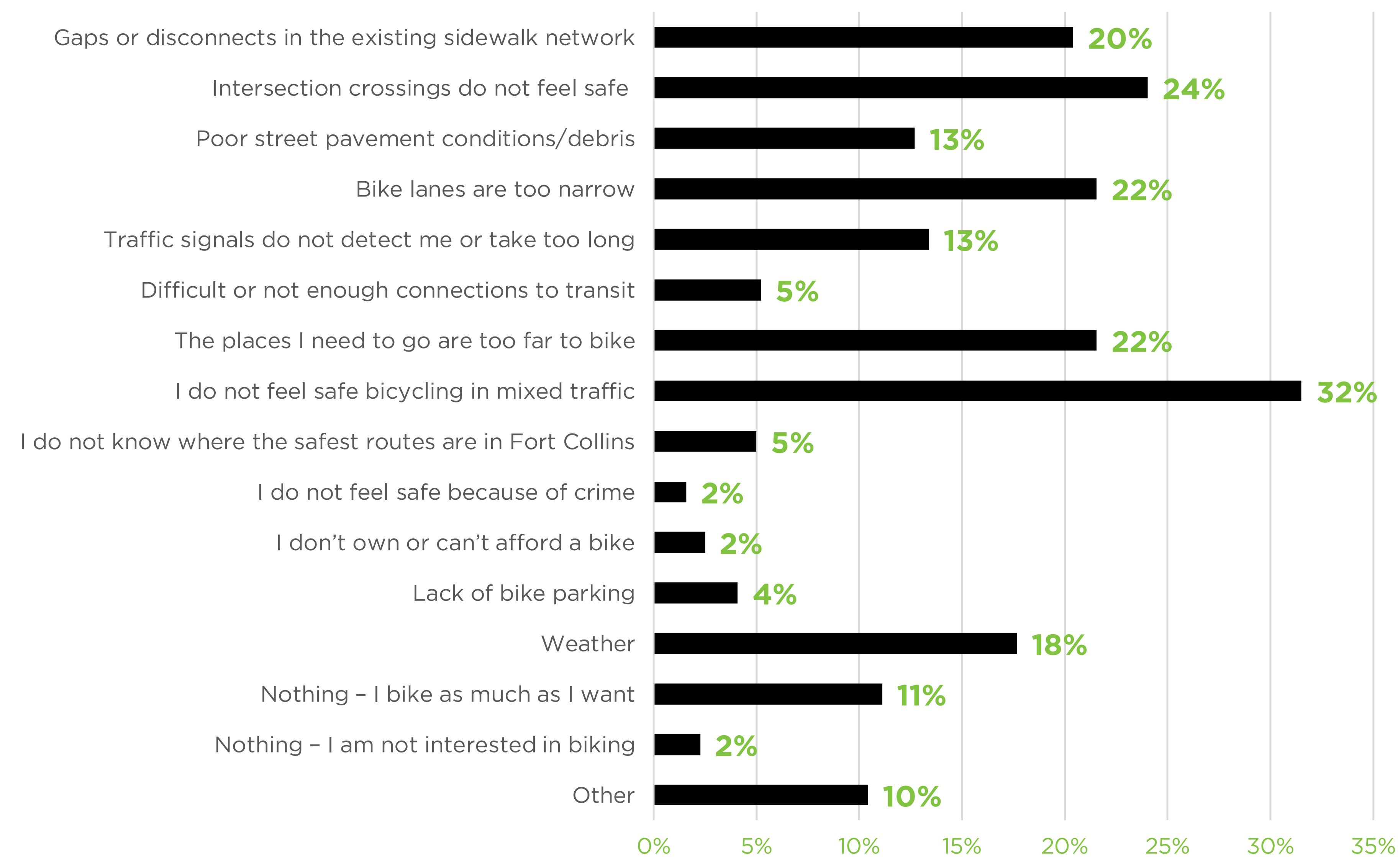
% of Responses
<10%
10% - 19%
20% - 29%
30% - 39%
40% - 59%
60% - 80%
>80%

Challenges that Prevent Respondents from Bicycling

(respondents selected top 3 answers)

Most common response:

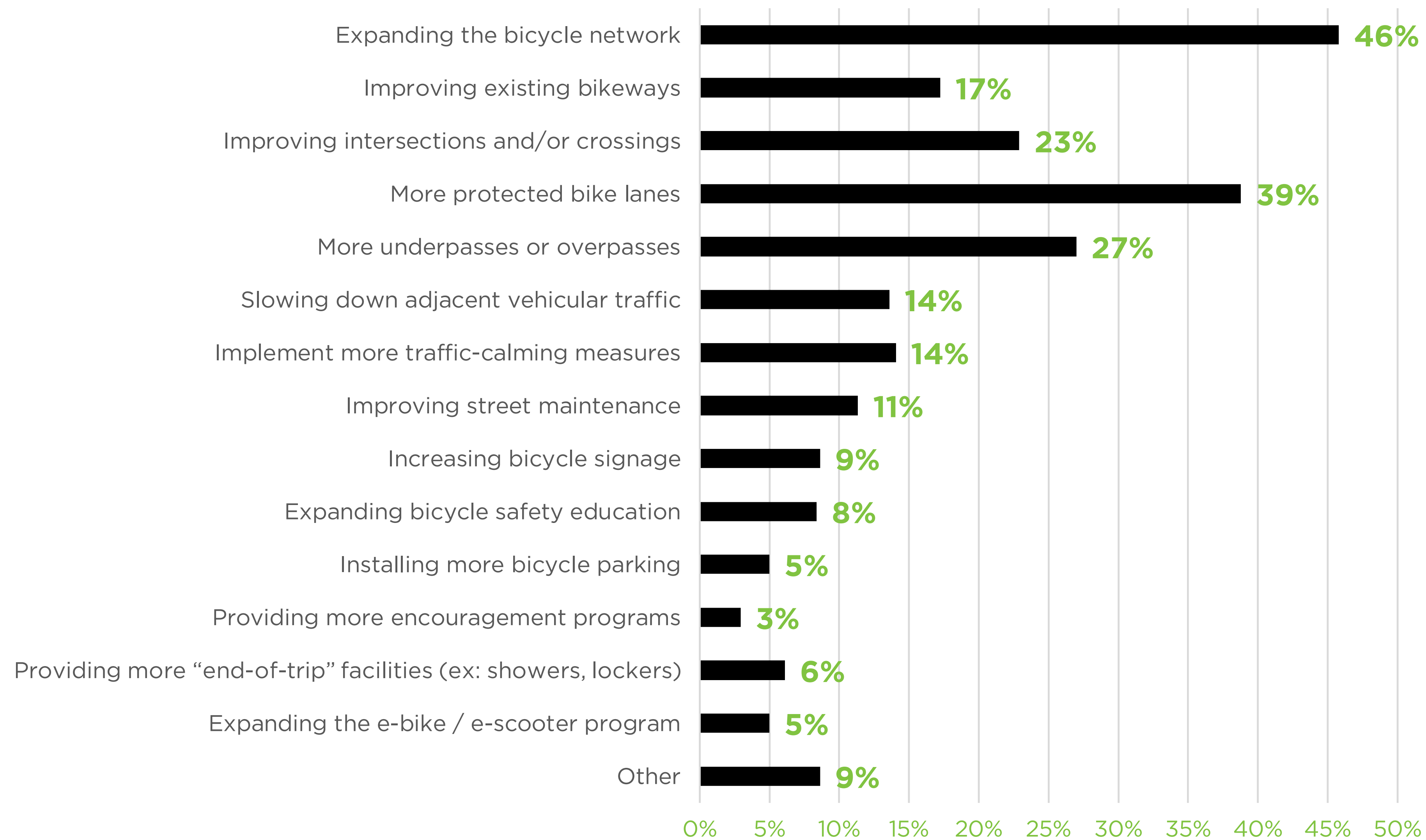
32% said they **do not feel safe** bicycling in **mixed traffic**.



Priorities Respondents Want the City to Focus on to Improve the Bicycling Experience in Fort Collins (respondents selected top 3 answers)

Top Priorities:

1. Expanding the Bicycle Network **(48%)**
2. More protected bike lanes **(39%)**
3. More underpasses or overpasses **(27%)**



Bicycling Responses Summary

76%
Participants want to bike more than they currently do

46%
Identify as “enthused and confident” bike riders

Respondent's bike most frequently for **fun and exercise** or to **visit friends, for social purposes, and to get to entertainment**

Top Challenges for Bicycling in Fort Collins

32% Don't feel safe bicycling in mixed-traffic

24% Intersections and crossings don't feel safe

22% Bike lanes are too narrow

22% Destinations are too far to bike

20% Gaps or disconnects in the existing bicycle network

Top Priorities for Improvement

1. Expanding bicycle network
2. More protected bike lanes
3. More underpasses/overpasses

Questions for Respondents with K-12 Students

Walking and Bicycling to School

Top Challenges for Students in Fort Collins

Walking and Bicycling to School

Do you have a K-12 Student?

41%
of respondents **have** a K-12 Student

280 Total Responses

59%
of respondents **do not have** a K-12 Student

408 Total Responses

Respondents with a K-12 Student

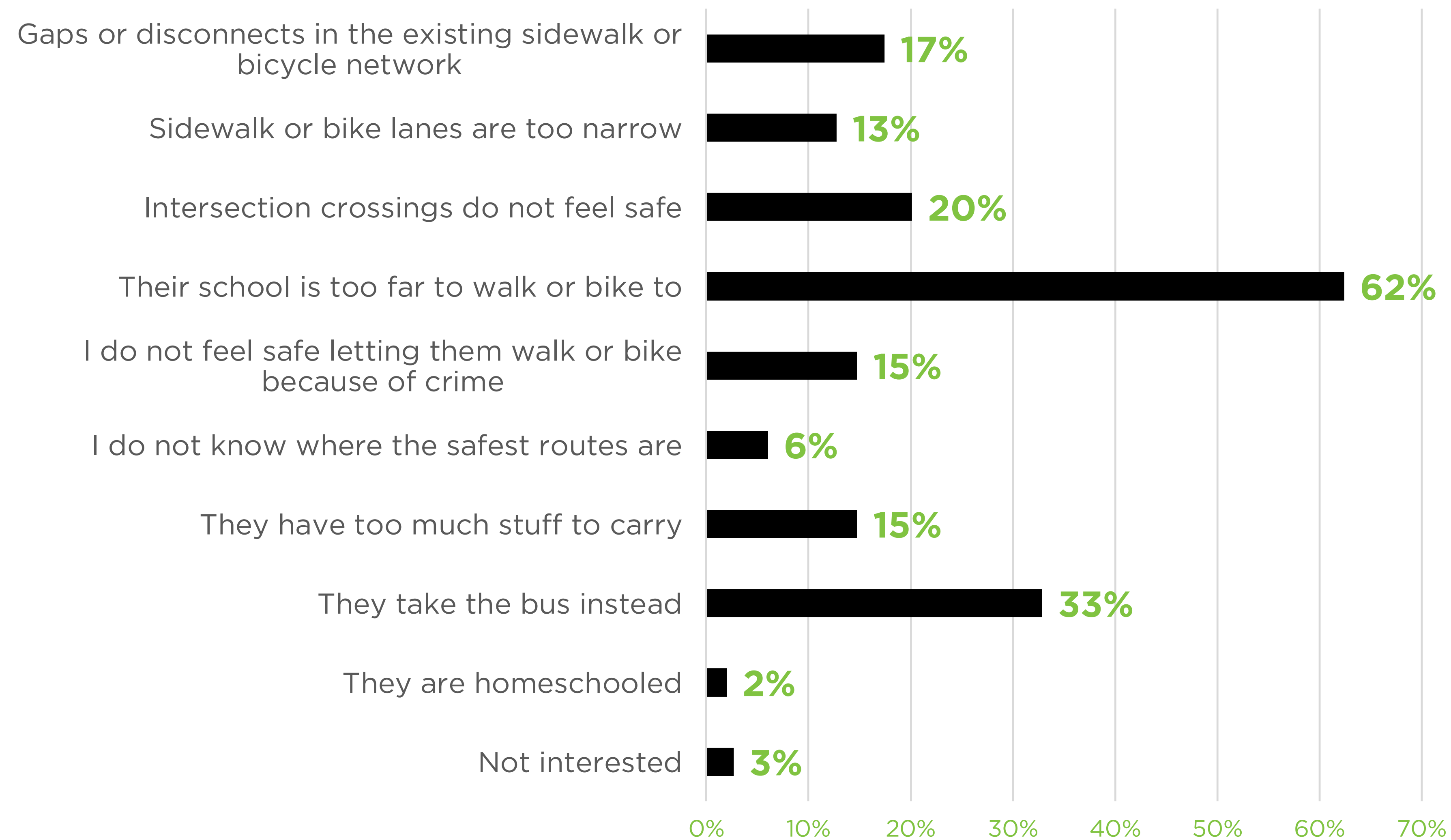
47%
of students **do** walk, bike, or use other active modes of transportation to get to school

53%
of students **do not** walk, bike, or use other active modes of transportation to get to school

Top Challenges that Prevent Students from Walking, Bicycling, and Using Other Active Modes to Get to School (respondents selected all that apply)

Most common response:

62% said their school is **too far** to walk or bike to.

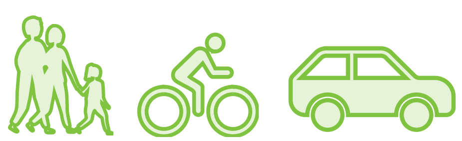


Commuting Trends

Commuting Travel Distance

Employer and School Programs to Promote Active Modes

Distance Respondents Travel to Get to Work or School



Commuting Distance

14%	< 0.5 miles
8%	0.6 to 1 mile
10%	1 - 1.5 miles
9%	1.6 to 2 miles
9%	2 to 3 miles
10%	3 to 4 miles
9%	4 to 5 miles
31%	More than 5 miles

Most respondents indicated that their commutes are **more than 5 miles**.

The **second most common** commute distance amongst respondents is **less than 0.5 miles.**

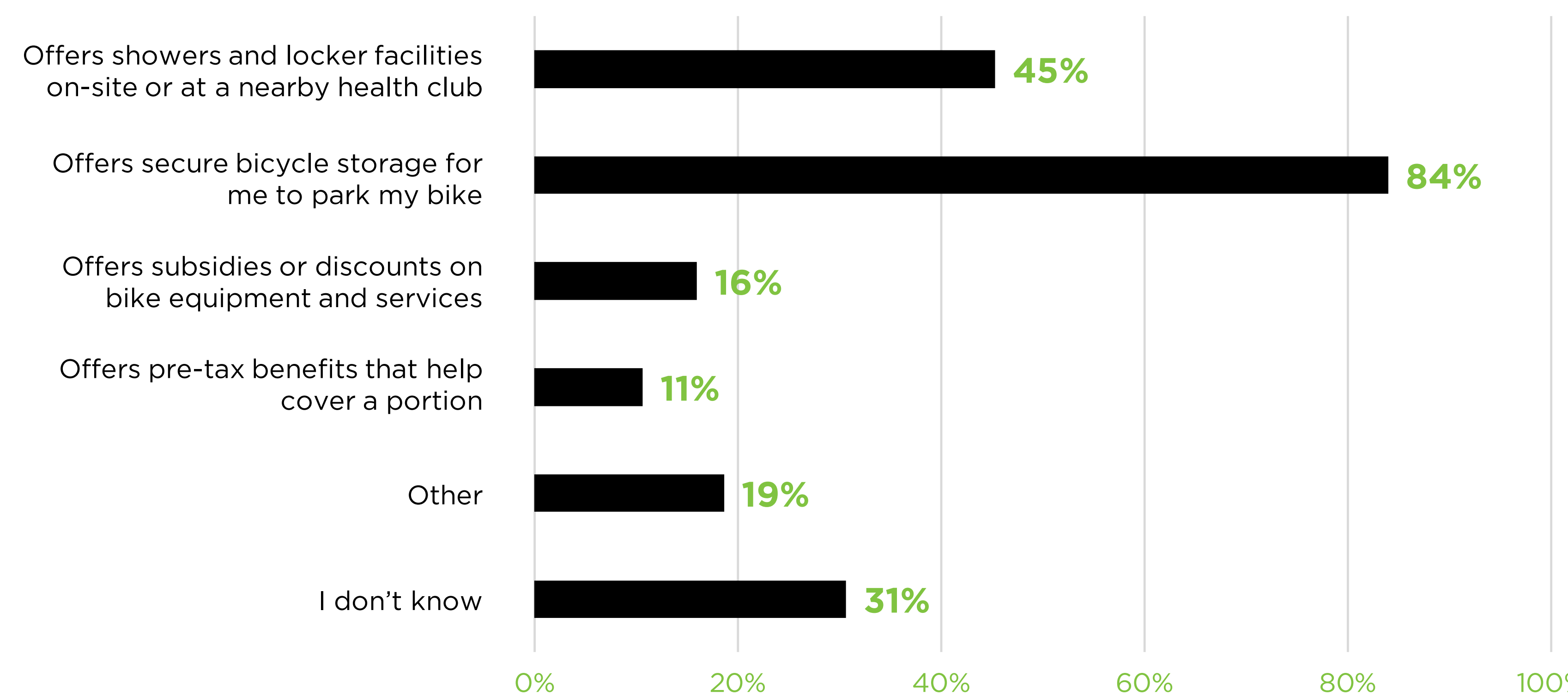
Awareness of Employer and School Programs

36%

of respondents are aware that their employers or schools have programs that support or encourage walking and bicycling commuting.

13% do not know if programs are offered

The 75 respondents who are aware of these programs identified the ways in which their employers and schools support and encourage walking and bicycle commuting:



English vs Spanish Responses

English and Spanish Responses: Key Differences

Spanish respondents are more likely to **drive (alone) daily/almost every day** to reach their destinations.

71% ES

49% EN

English respondents are more likely to **walk or bike daily/almost every day** to reach their destinations

walk/bike

24% / 4% ES

59% / 31% EN

ENGLISH	SPANISH
Top Walking Challenges	
Gaps or disconnects in the existing sidewalk network	I do not know where the safest routes are in Fort Collins
Top Priorities for Improvement	
Sidewalk connectivity	Longer crossing times at signalized intersections

ENGLISH	SPANISH
Top Bicycling Challenges	
Intersection crossings do not feel safe	The places I need to go are too far to bike
Top Priorities for Improvement	
More underpasses or overpasses	Increasing bicycle signage and expanding bicycle education

2

Online Map #1

Online Map #1 Recap

1

Concerns

Where do people not feel safe walking/bicycling/scooting/skating?

Where is there a disconnect in the sidewalk/bicycle network?

2

Destinations

What types of destinations do people currently walk/bike/scoot/skate to or would want to if improved?

3

Open response comment

Who participated?

Active Modes Plan Mapping Events

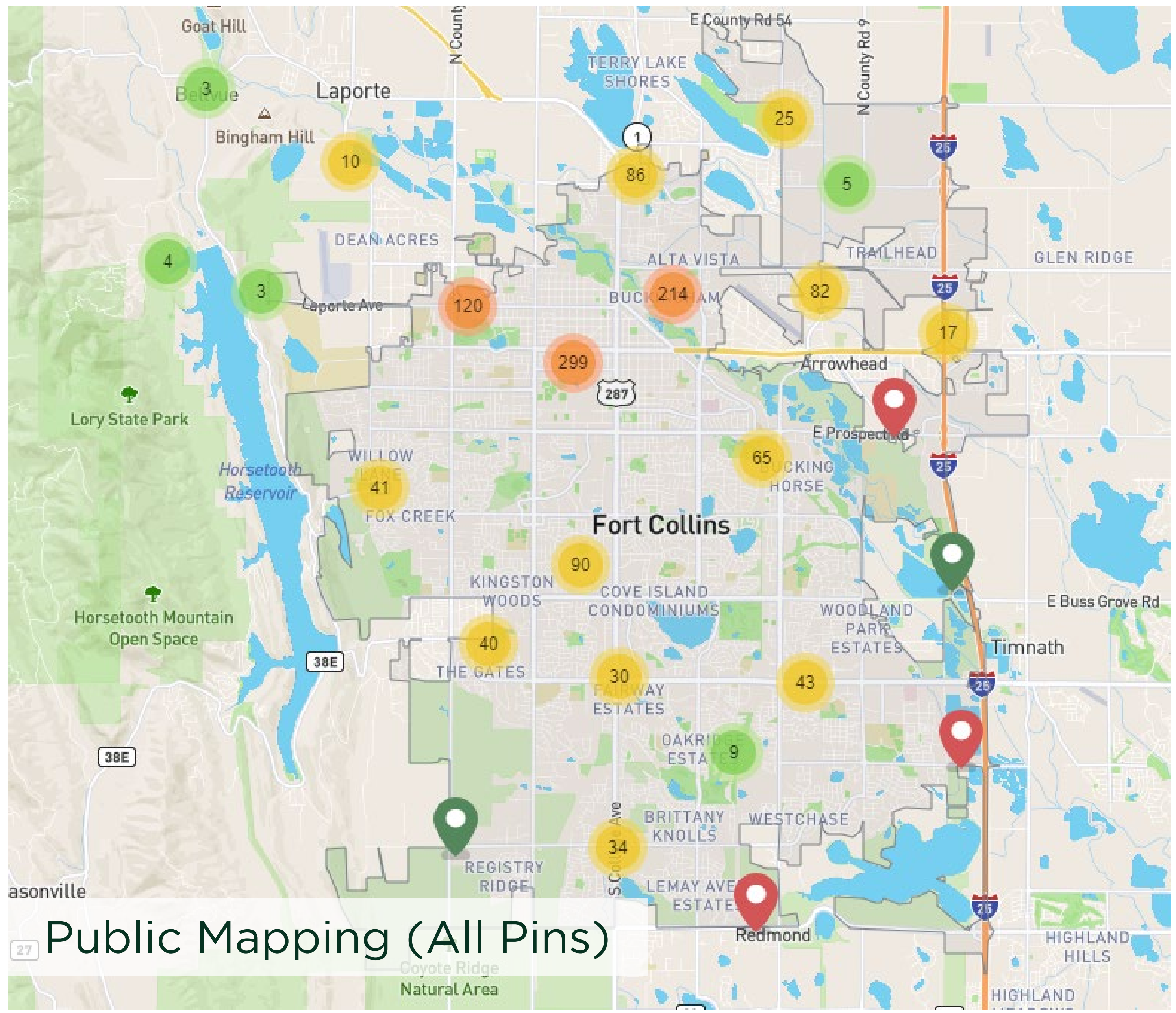
Event	Contributors	Submissions
Public Online Map November 6th – November 30th	846 Contributors	1,215 Submissions
Focus Group* November 3rd	8 Contributors	45 Submissions
TAC Meeting November 3rd	22 Contributors	99 Submissions
CAC Meeting November 3rd	3 Contributors	17 Submissions

879 Total contributors

1,376 Total submissions

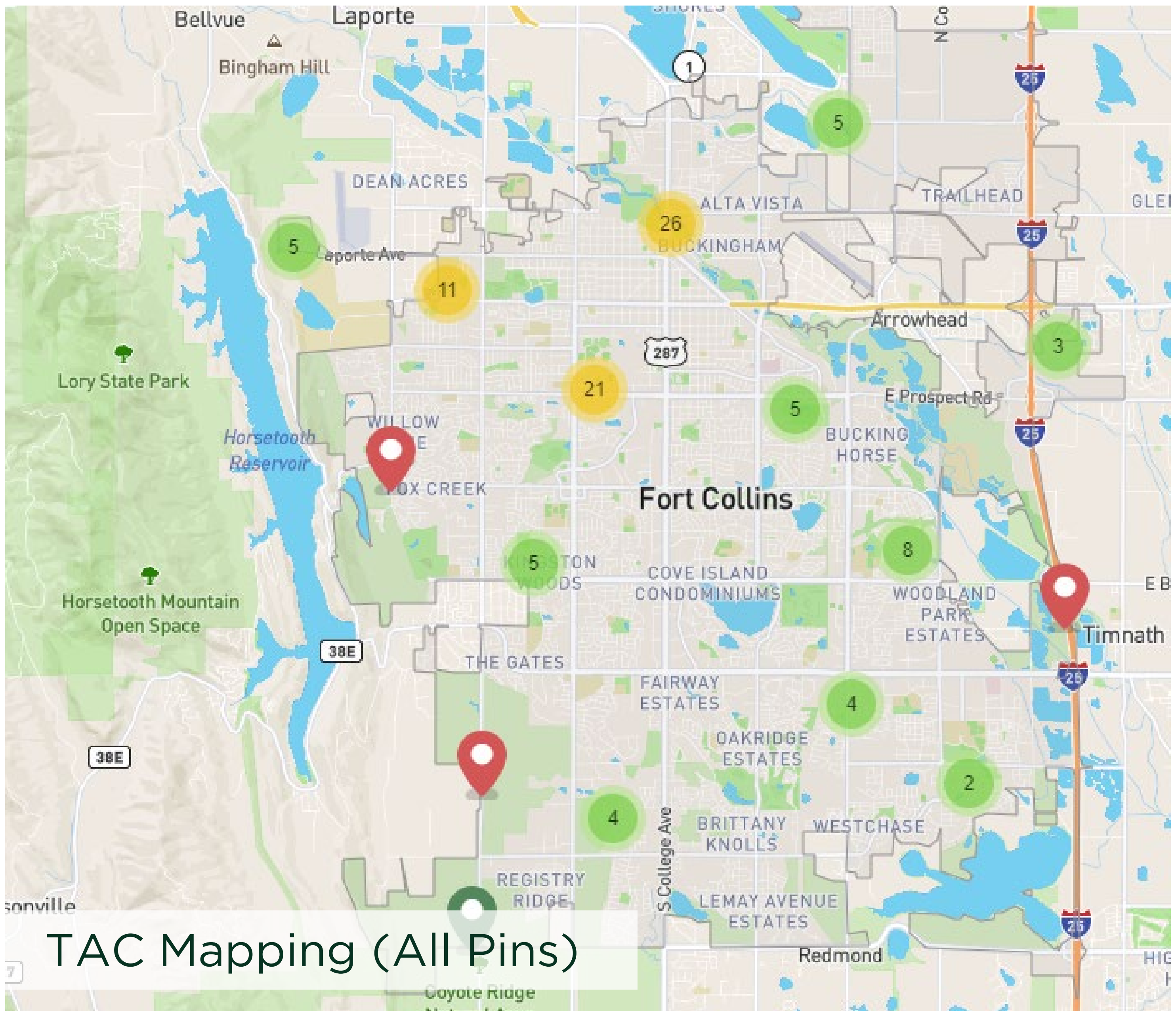
Note: Subsequent focus group feedback was incorporated directly into the public online map

Mapping Results Overview

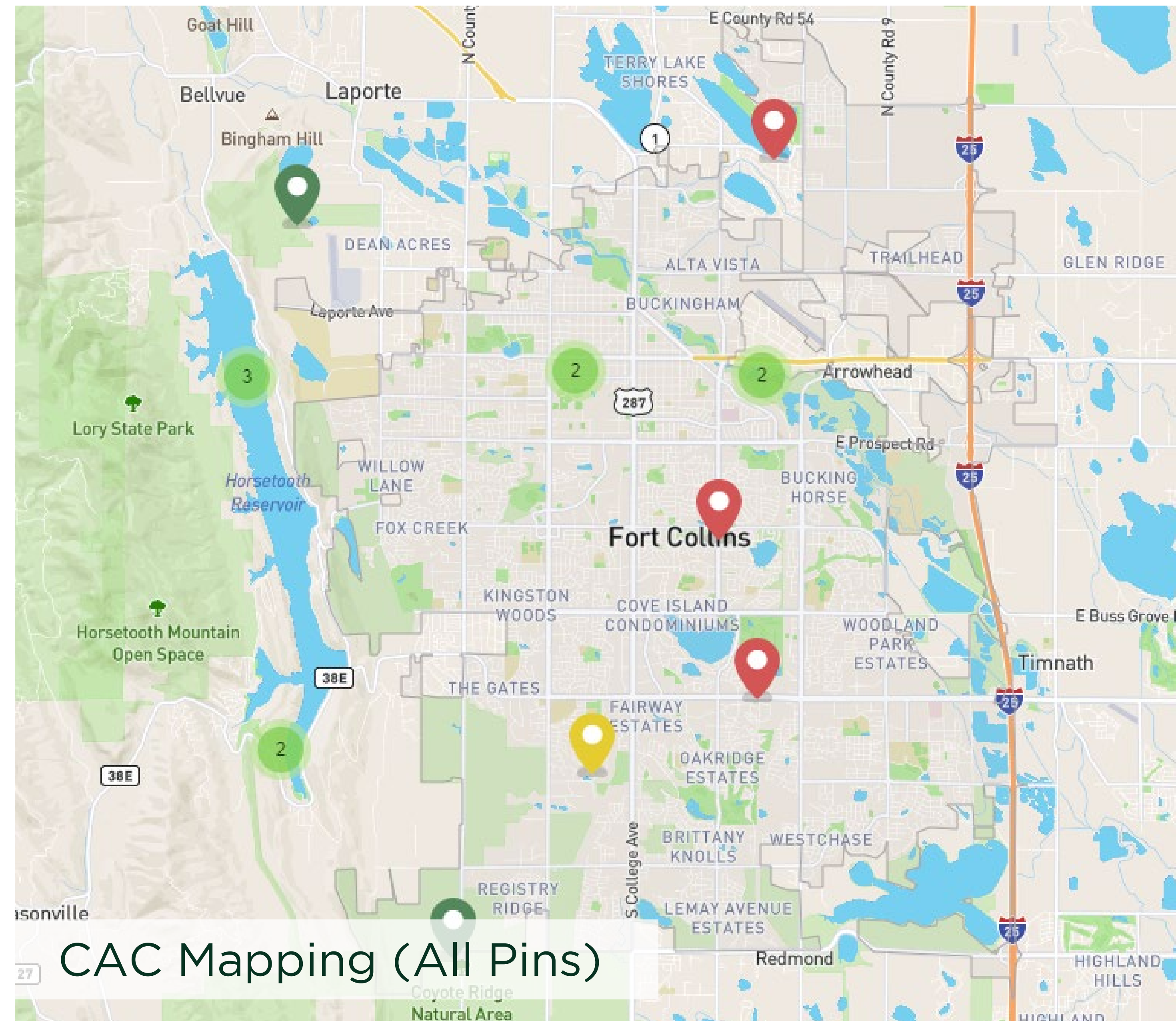


Public Mapping (All Pins)

Mapping Results Overview



TAC Mapping (All Pins)



CAC Mapping (All Pins)

Top Bicycling Concerns

924 Bicycling Related Pins

Places where bicycling is most difficult:

- Northwest Fort Collins
- East/Northeast Fort Collins
- Central Fort Collins

What is the concern related to?

28%
I do not feel safe bicycling here

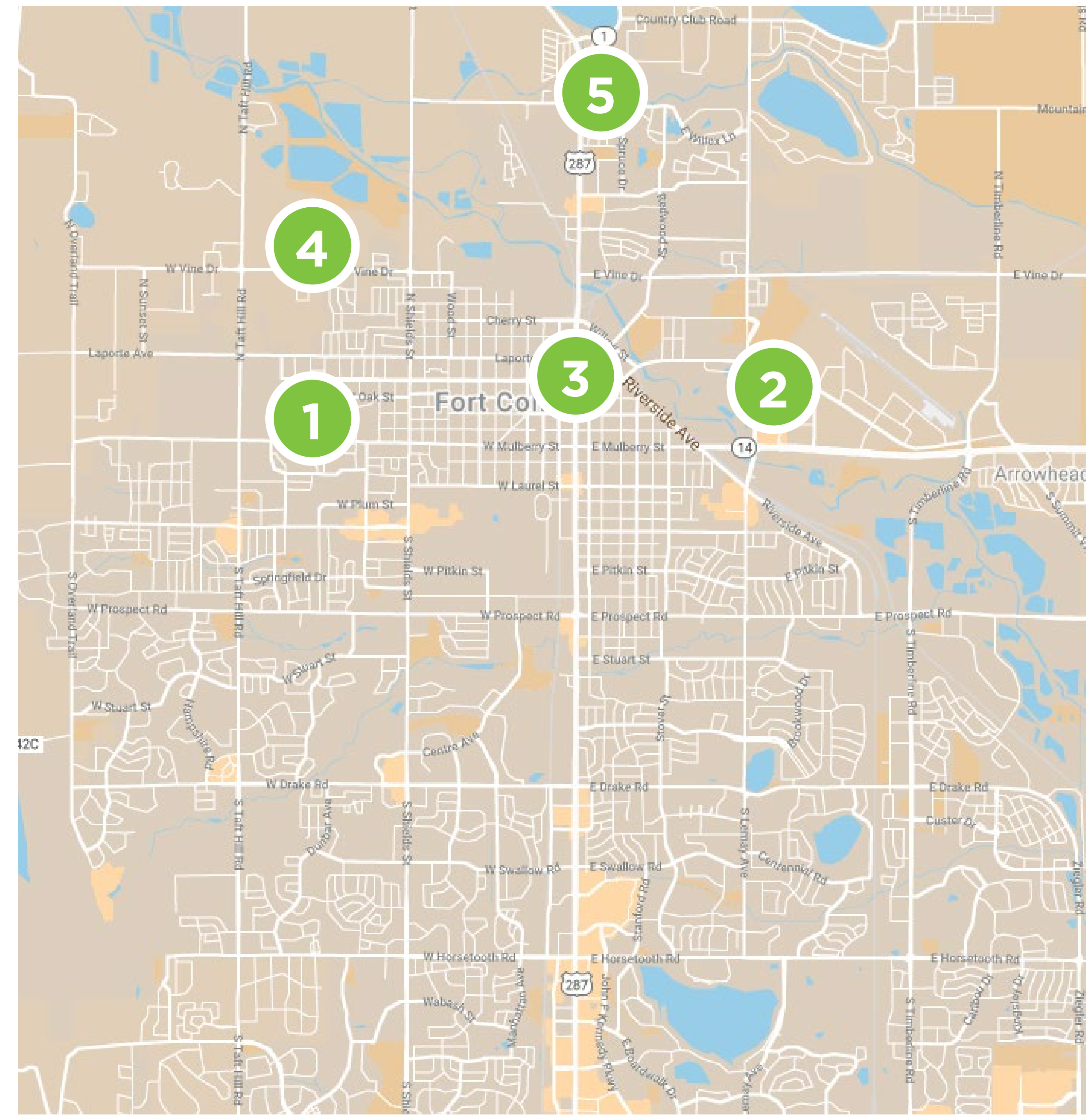
16%
There is a gap or disconnect in the bicycle network here

21%
Other

- Bike parking
- Dangerous intersections
- Lack of signage on trails
- Short cyclist lights
- Uneven pavement
- Poor connections to neighborhoods and trails
- Knowledge of routes

Top Bicycling Destinations

1. Fort Collins City Park
2. Walmart Supercenter near South Lemay
3. North College Ave and E Mountain Ave
4. Lincoln Middle School
5. King Soopers near North College Ave



Top Walking Concerns

329 Walking Related Pins

Places where walking is most difficult:

North Fort Collins

Northeast Fort Collins

Central/South Fort Collins

What is the concern related to?

24%
I do not feel safe walking here

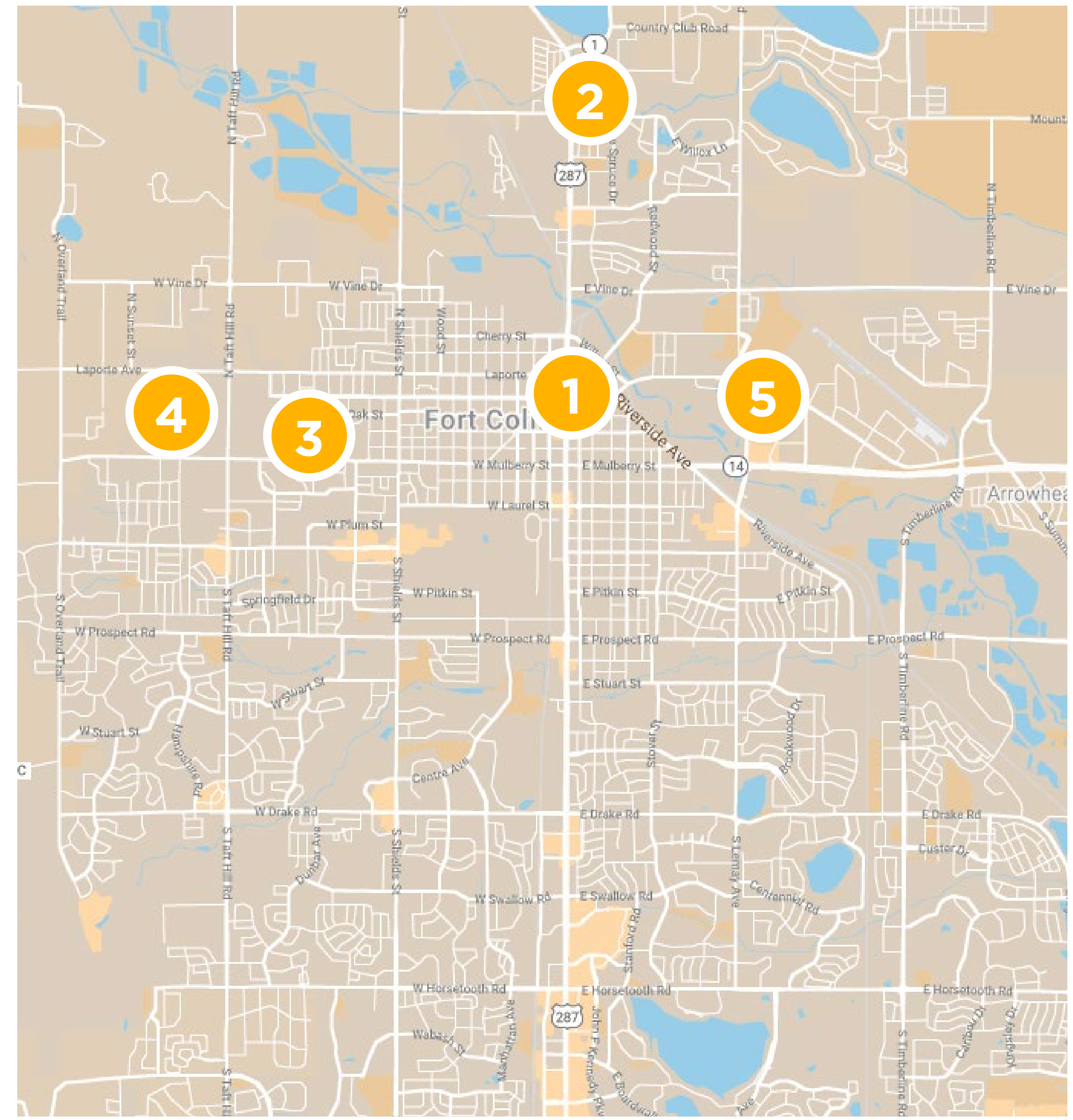
12%
There is a gap or disconnect in the sidewalk network here

11%
Other

Missing crosswalks
Unsafe and confusing crossings
Barriers in sidewalks (scooters)
Accessible parking for wheelchair users
Sidewalks that turn into unpaved paths
Lack of lighting

Top Walking Destinations

1. North College Ave and E Mountain Ave
2. Area around King Soopers near North College Ave
3. Fort Collins City Park
4. Area around Poudre High School
5. Area around Walmart Supercenter near South Lemay



Top Skating/Scootering Concerns

104 Skating/Scootering Related Pins

Places where skating/scootering is most difficult:

- Northwest Fort Collins
- North Fort Collins
- South Fort Collins

What is the concern related to?

8%
I do not feel safe skating/scootering here

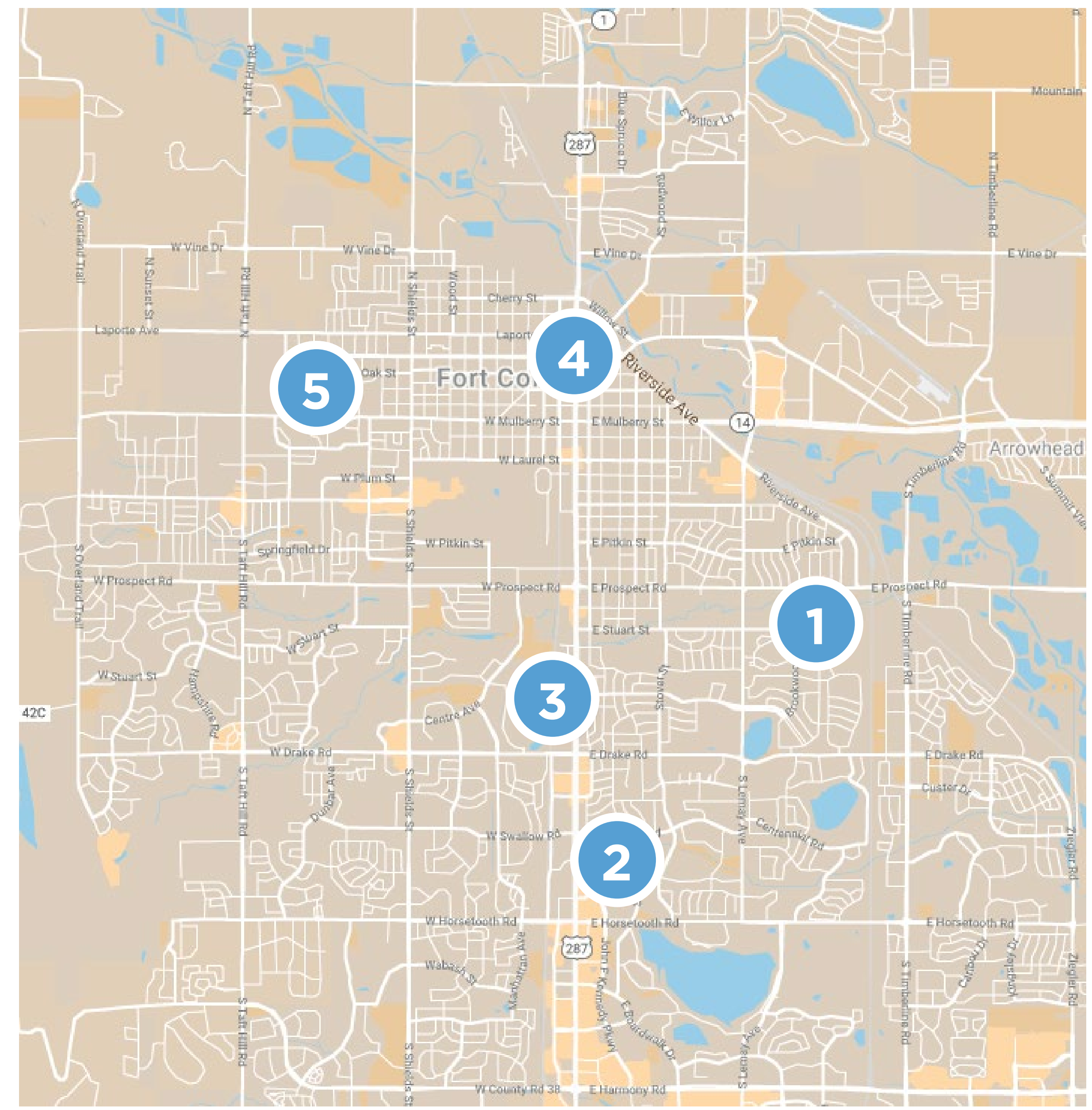
6%
There is a gap or disconnect in the sidewalk/ bicycle network here

16%
Other

Knowledge of routes
Gravel paths that are difficult to skate on
Placement of available bikeshares/micromobility

Top Skating/Scootering Destinations

1. Edora Park
2. Foothills Shopping Mall
3. King Soopers near North College Ave
4. North College Ave and E Mountain Ave
5. Fort Collins City Park



3

Survey and Online Map #2

Survey and Online Map #2 Recap

Goals of Mapping Exercise and Survey

Better understand what **strategies and factors best meet the community's priorities** for improving active modes in Fort Collins.

Explore how to better **expand the Fort Collins bicycle network**.

Determine **additional necessary improvements we have not identified** that are important to the community.

Survey Questions We Asked

Demographics

About the participant: What is your city council district, age, race, gender, income range, and bicycling comfort level?

Strategies

What strategies would have the biggest impact on achieving the vision for active modes in Fort Collins?

Prioritization

What factors are most important to consider when prioritizing new active modes projects?

Responses Overview

Source	Number of People Engaged	Number of Relevant Submissions
Middle School Focus Groups	291	176
Community Connector Surveys	273	269
Online Survey	909	909
Pop-Up Events	80	75
Online map Entries	188	1198

1,741
People Engaged

1,429
Submissions

Additional Data Included in Analysis

AMP Pop-Ups Survey data

Transportation Capitol Projects

Prioritization Study (TCPPS) data

City of Fort Collins Service Request data

CDOT Region 4 Bike/Ped Study

Survey Results

Which two strategies are most important in achieving the vision for active modes in Fort Collins?				
Prioritizing active modes projects, programs, and funding	**Updating land use policies to support active modes**	**Aligning standards with active mode goals**	**Expanding and creating community programs that support active modes**	**Engaging communities authentically around active modes**
Strategy #1	Strategy #2	Strategy #3	Strategy #4	Strategy #5

When prioritizing new active modes projects, how important are the following factors? (1 = not as important to 4 = most important)			
Network Connectivity	**Access**	**Safety and Comfort**	**Health and Equity**
Priority #2	Priority #3	Priority #1	Priority #4

Weighted Ranking

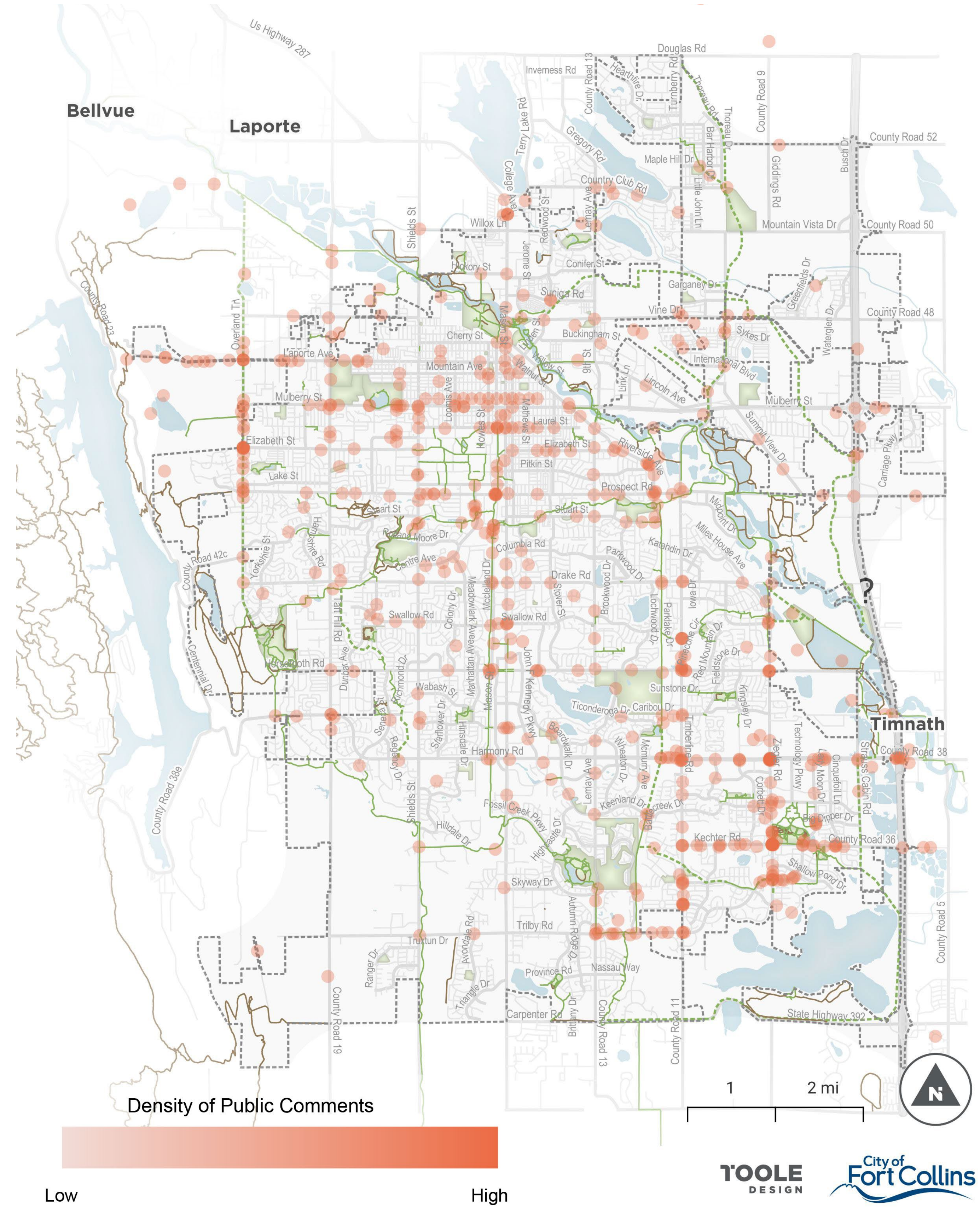
Mapping Results

Participants...

Left feedback on proposed spot improvements and recommended bicycle facilities.

Commented on whether they support or disagree with the recommended improvements.

Were invited to provide ideas for additional recommendations.



Online Map Key Takeaways

1 Streets with the Most Pedestrian-Related Comments

Centre Ave

City Park Ave

College Ave

Drake Rd

Harmony Rd

Mason Tr

Mulberry St

Prospect Rd

S Taft Hill Rd

Willox Ln

2 Streets with the Most Bicycling-Related Comments

College Ave

Drake Rd

E Laurel St

E Prospect Rd

Harmony Rd

Horsetooth Rd

Mulberry St

N Timberline Rd

Overland Tr

Riverside Ave

3 Intersections with the Most Crossing-Related Comments

Conifer St and N College Ave

S Overland Tr and W Mulberry St

S Overland Trail and W Lake St

S Howes St and W Laurel St

E Vine Dr andJerome St

S Shields St and W Prospect Rd

Sheely Dr and W Prospect Rd

APPENDIX D: CSU CORRIDOR CONCEPTS

Complete Street Design Concepts

August 2022

Colorado State University

W Plum St

Spot Treatments

A Add flexible delineators to bike lane on west leg of W Plum St at S Shields St intersection, 50 ft in advance of bike box, to prevent right turning traffic from encroaching.

B Add flexible delineators to bike lane on east leg of W Plum St at S Shields St intersection, on through-traffic side, to prevent late cut-over by right-turning traffic.

C Remove Plum Street stop signs at parking lot entrances.

D Add curb cut at Aggie Trail on the south side of W Plum St to match curb cut on north side.

E Reconfigure diagonal trail north of Moby Pool to circumscribe area where pool building will be expanded.

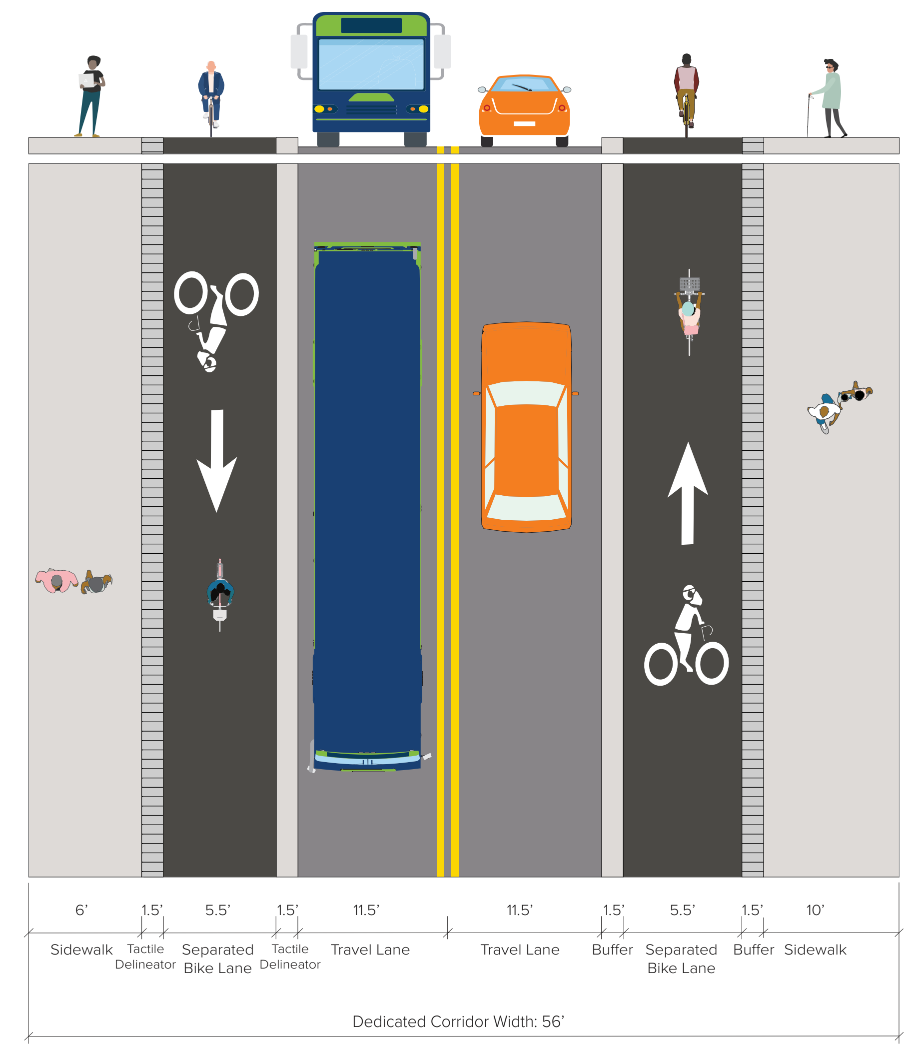
F Build a raised intersection at Meridian Ave and retain existing stop signs. Refer to Meridian Street for additional design details.

Cross Section
(Looking East)

S Shields St to CSU Transit Center

Convert existing buffered bike lane to a sidewalk-level separated bike lane.

Retain current sidewalk, bike lane, and travel lane measurements.



W Pitkin St

Spot Treatments

A At the S Shields Intersection east of the median, paint the existing left-turn lane directing bicyclists onto the off-street trail green to resemble a two-stage bicycle turn box.

B Add a speed hump adjacent to Summit Hall to mitigate vehicle speeding. Throughout the corridor a crossing or traffic calming treatment should be placed roughly every 500 feet to attenuate opportunities to speed.

C Install a transit boarding island at the Horn bus stop adjacent to Canvas Stadium parking entrance. Relocate the crosswalk from Aspen Hall to match the trail crossing and improve visbility by having pedestrians cross in front of the bus stop (rather than behind).

D Build high visibility decorative crosswalks at the entrance to Meridian Ave and install curb ramps north of the Stadium to provide accessible pedestrian crossing.

E Build a roundabout at Meridian Village just east of the Stadium. Close east leg of intersection to vehicles, and move Braiden Hall parking entrance to new Meridian Street.

F Remove marked crosswalks across portion closed to cars. This is funded to become a bicycle and pedestrian roundabout and crossing.

G Improve signage for pick-up and drop-off.

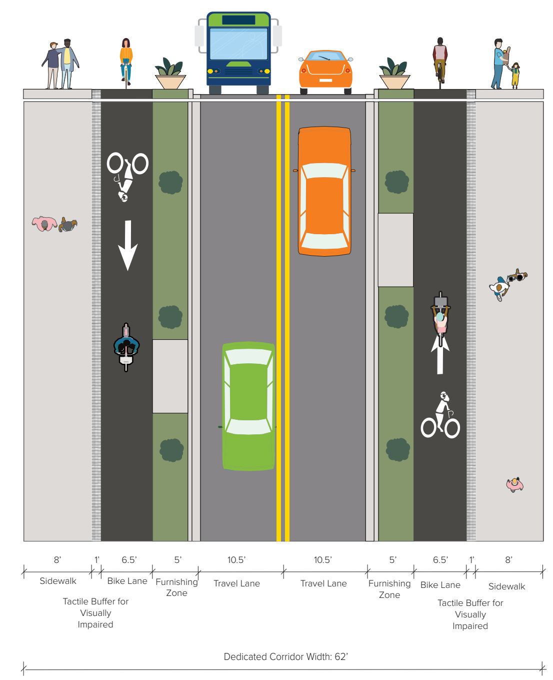
H Ramp the existing separated bike lane on the south side of W Pitkin onto a 4 ft wide sidewalk extension to facilitate bicyclists turning left onto Campus Loop Trail.

Cross Sections
Hughes Way to W Plum St
(Looking East)

S Shields St to Closure East of Meridian Ave

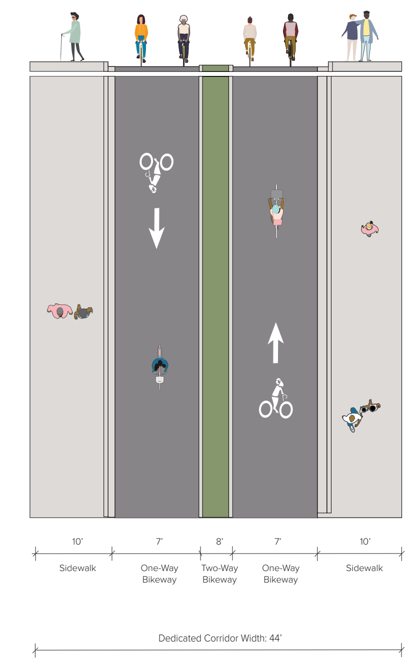
Build a sidewalk-level separated bike lane, separated from vehicle traffic by a furnishing zone with planters and benches.

Add intermittent concrete in the furnishing zone to allow for access to the curb and accomodate drop-offs.



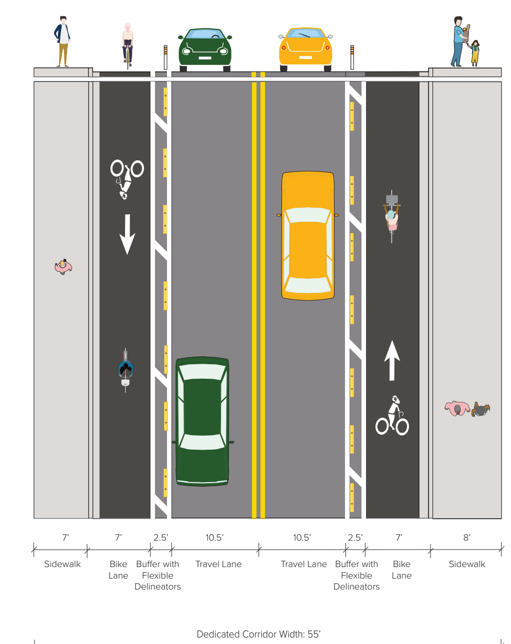
Meridian Ave to Newton Memorial

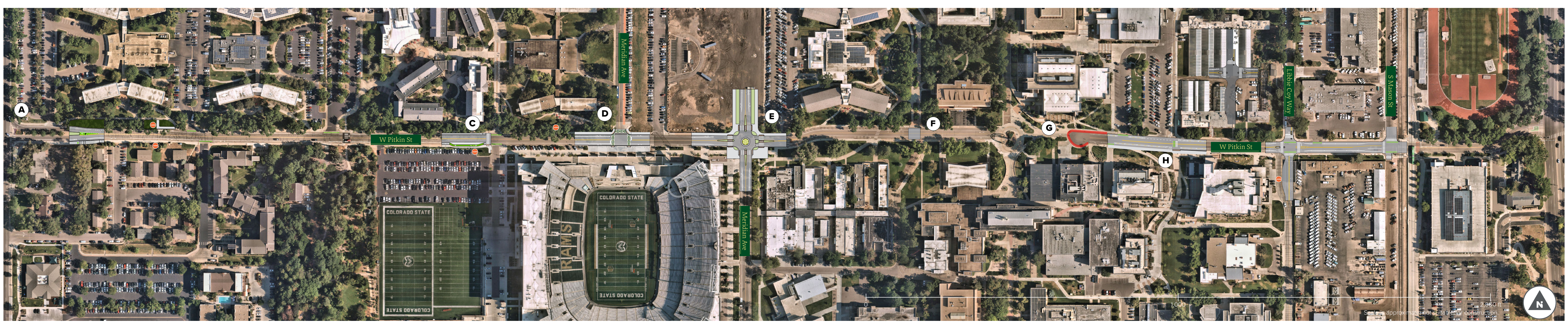
Build a center-running median with one-way bikeways and pedestrian walkways on edges, all at street grade.



Newton Memorial to S College Ave

Build a separated bike lane while maintaining existing curbline.





Meridian Ave

Spot Treatments

A Build a raised intersection at Meridian Ave and retain existing stop signs. Contruct a refuge island between the bikeway and transit lanes on Meridian to create an aperture for buses and discourage cars from entering.

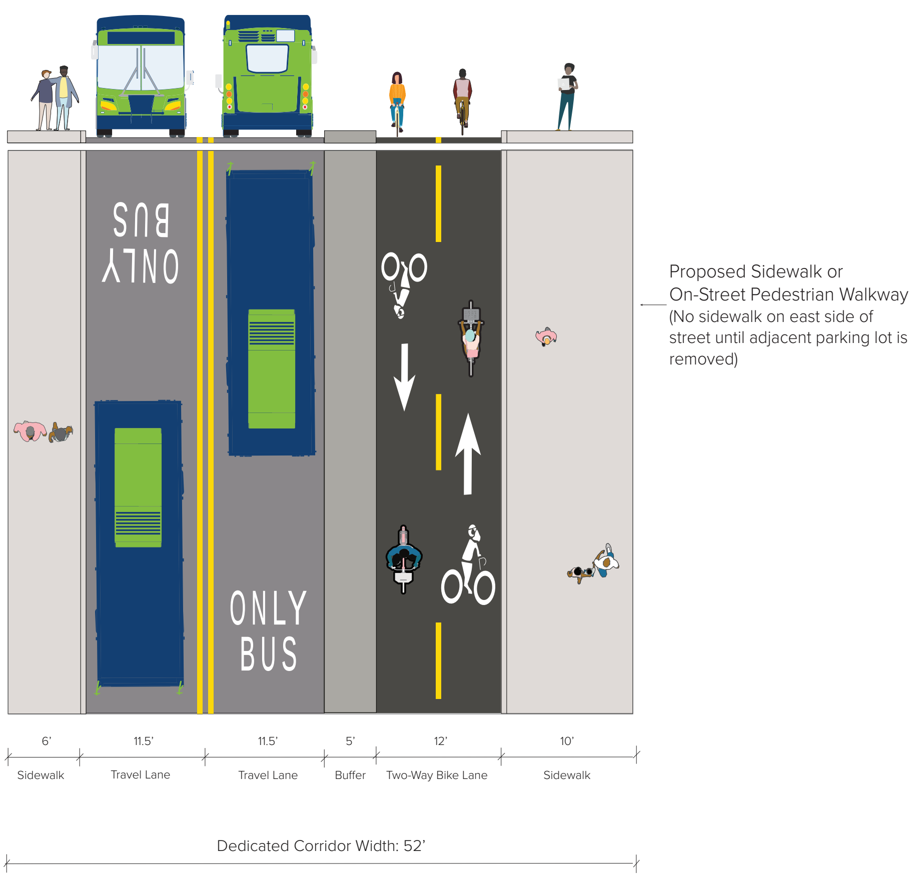
B Construct traffic circle to direct traffic that accomodates bus and bike facilities, including two-way bikeway proposed on the east side of Meridian Ave.

C Construct traffic circle to direct traffic that accomodates bus bike facilities, including two-way bikeway proposed on the east side of Meridian Ave.

D Build pedestrian gateway at the entrance to Meridian Ave and install curb ramps north of the Stadium to provide accessible pedestrian crossing across Pitkin.

Cross Section
Hughes Way to W Plum St
(Looking North)

Add a two=way separated bike lane and a sidewalk to the east side of Meridian Ave.



Libbie Coy Way

Spot Treatments

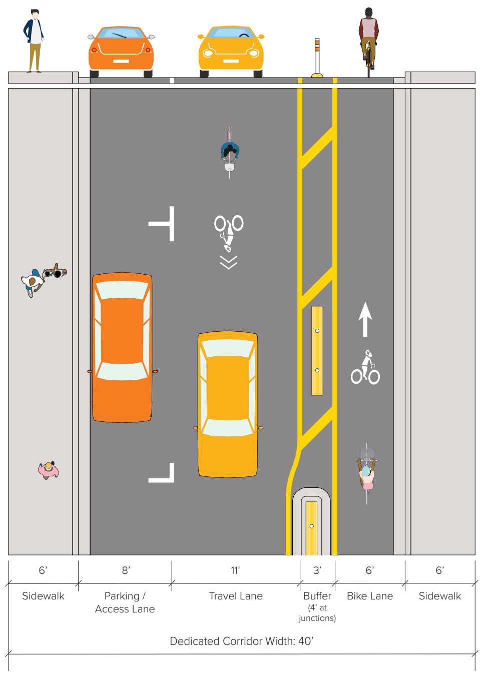
A Add mountable raised islands with flexible delineators at W Pitkin St to emphasize one-way restriction and mitigate wrong-way turns onto Libbie Coy Way.

B Install vertical delineators at A Street to discourage wrong-way turns onto Libbie Coy Way and reinforce contraflow bicycle lane.

Cross Sections
(Looking North)

W Pitkin St to University Blvd

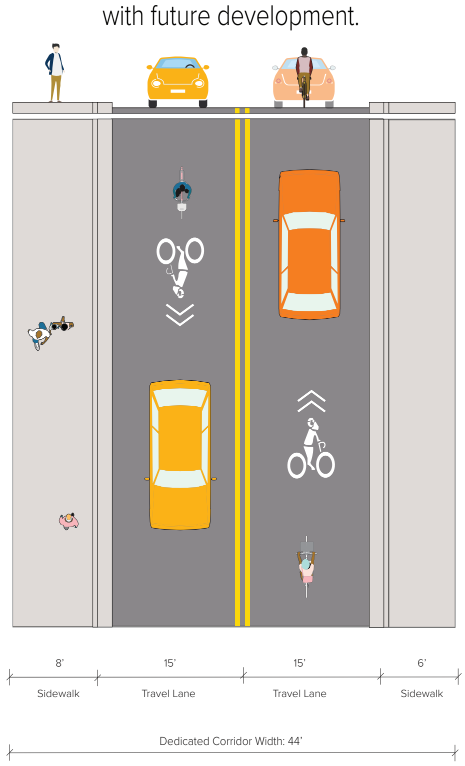
Add raised islands to buffer at intersections



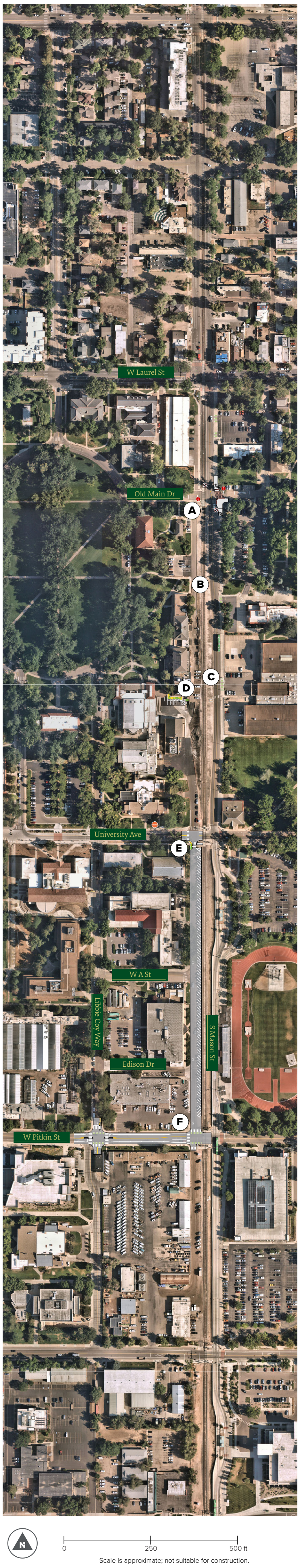
W Lake St to W Pitkin St

Move sharrows to the middle of the lane.

Add 6 ft sidewalk to the east side of Libbie Coy Way with future development.



S Mason St



Spot Treatments

A At the Old Main Dr intersection, extend the southeast curb and straigten the northeast curb line to widen the curb ramp onto the crosswalk. Remove north- and southbound stop signs.

B Remove the stairs that cross over the railroad tracks as well as the crosswalk leading to them.

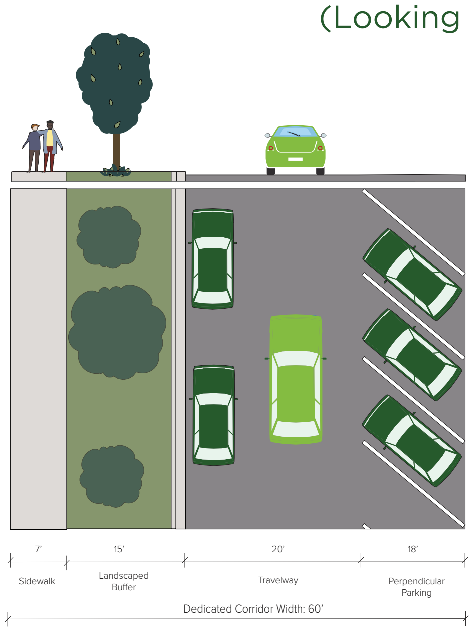
C Add green conflict markings across driveways from University Ave to W Laurel St.

D At the west railroad crossing tunnel exit, eliminate the three easternmost parking spaces and stripe a walkway through the parking lot to the trail that connects to Oval Dr.

E Reconfigure angled parking to back-in angled parking along east side of Mason St. At intersection with University Ave, extend curb (optionally with paint-and-post treatment) to narrow crossing distance to less than 15 feet; design curb radius to accommodate bus left turn. Move crosswalk and stop bar on Mason forward to mitigate sightline issue.

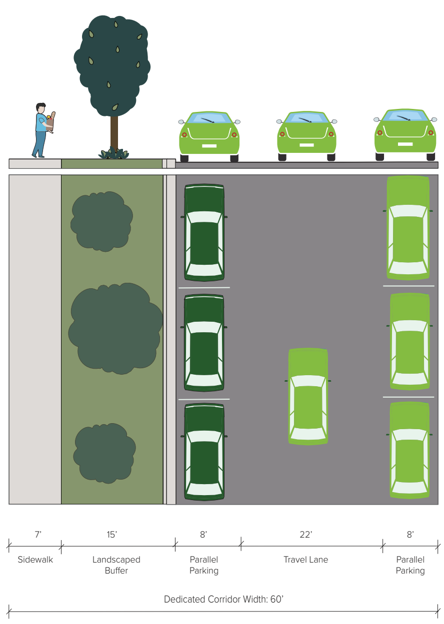
F Add green conflict markings across on Pitkin St to guide bicycles through the rail and busway crossings.

Cross Section Alternatives
University Ave to W Pitkin St
(Looking North)



Various options presented for parking solutions:

1) Back-in angled parking on the east side of S Mason St with no designated bikeway. Because of the width of the roadway, parallel parking is recommended to be permitted on the west side of Mason St.



2) Parallel Parking is formalized on both sides of Mason St.

Rampart Road

Spot Treatments

A Build bus bulb outs and landing pads at all Foothill Shuttle bus stops. See FOOTHILLS SHUTTLE for existing bus stop locations

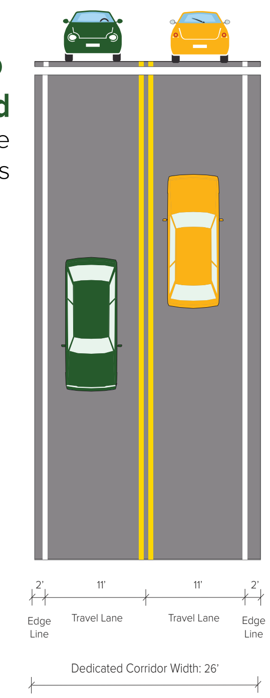
B Add speed limit signs across corridor every 0.25 - 0.5 miles. See SPEED LIMIT 20 for location suggestions.

C Implement access control by closing redundant driveways to improve corridor safety. See ⛔ for driveway closure suggestions

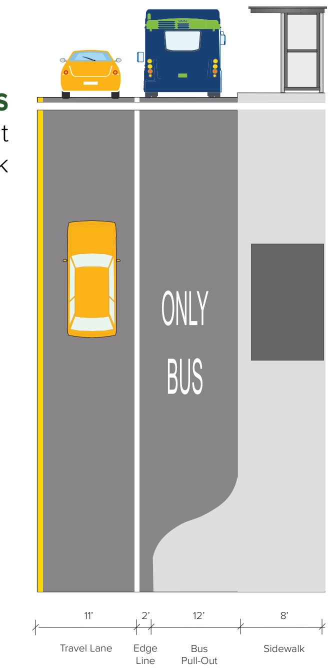
D Build raised crosswalk to support future parking lot.

Cross Sections
(Looking West)

S Overland to end of Rampart Rd
Add centerline and edge lines



Bus Stop Locations
Add 12 ft bus pull-out and 8 - 10 ft sidewalk



APPENDIX E: PRIORITIZATION SCORING

Additional details from Chapter 7: Implementing the Vision

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Pedestrian	7	Drake	Timberline	Signal Operations	Spot	*5*	*5*	*5*	*5*	*3*	*3*	**44**	*2*	*2*	*2*	*2*	**8**	52	High	1
			Lemay	Geometric Redesign	Spot															
			Shields	Signal Operations	Spot															
		Shields	Casa Grande	Signal Operations	Spot															
Pedestrian	46	Harmony	Mason	Signal Operations	Spot	*5*	*5*	*5*	*5*	*1*	*4*	**44**	*2*	*2*	*2*	*2*	**8**	52	High	2
			Boardwalk	Signal Operations	Spot															
			Lemay	Signal Operations	Spot															
			Starflower	Geometric Redesign	Spot															
Pedestrian	1	College Ave	Willow	Signal Operations	Spot	*5*	*5*	*5*	*5*	*1*	*4*	**44**	*2*	*2*	*1*	*2*	**7**	51	High	3
			Laporte	Signal Operations	Spot															
			Mountain	Signal Operations	Spot															
			Olive	Signal Operations	Spot															
			Magnolia	Signal Operations	Spot															
Pedestrian	4	Mulberry St	College	Signal Operations	Spot	*5*	*5*	*5*	*5*	*1*	*4*	**44**	*1*	*2*	*2*	*2*	**7**	51	High	4
			Mason	Signal Operations	Spot															
			Loomis	Geometric Redesign	Spot															
			Shields	Signal Operations	Spot															
			Taft Hill	Signal Operations	Spot															
			Whitcomb / Canyon	Geometric Redesign	Spot															
Pedestrian	11	Willow	Jefferson	High-Visibility Crosswalk	Spot	*5*	*5*	*5*	*5*	*1*	*5*	**46**	*0*	*1*	*2*	*0*	**3**	49	High	5
			Lincoln	Beacon / RRFB	Spot															
Pedestrian	29	Taft Hill	Prospect	Signal Operations	Spot	*5*	*4*	*4*	*5*	*1*	*4*	**40**	*2*	*2*	*2*	*2*	**8**	48	High	6
			Valley Forge	Geometric Redesign	Spot															
Pedestrian	3	College Ave	Monroe	Signal Operations	Spot	*5*	*5*	*4*	*5*	*1*	*4*	**42**	*2*	*2*	*1*	*1*	**6**	48	High	7
			Rutgers	Geometric Redesign	Spot															

Project Focus	PID	Street	Extents	Facility	Length	Connect: Network	Connect: Destinations	Transit Access	Safety: HIN	Safety: Comfort	Health-Equity	Outcomes Score (normalized)	Cost	Readiness	MM Benefit	Synergy	Implementation Score	Combined Score	Term	Rank
			Columbia	Geometric Redesign	Spot															
Pedestrian	9	Shields	Plum	Geometric Redesign	Spot	*5*	*5*	*5*	*5*	*1*	*4*	**44**	*0*	*1*	*2*	*1*	**4**	48	High	8
			Shields	Geometric Redesign	Spot															
		Elizabeth	Taft Hill	Geometric Redesign	Spot															
			Constitution	Geometric Redesign	Spot															
Bicycle	61	Taft Hill Rd	Glenmoor	Signals	Spot	*4*	*5*	*5*	*5*	*2*	*5*	**45**	*0*	*0*	*2*	*0*	**2**	47	High	9
Pedestrian	2	College Ave	Laurel	Signal Operations	Spot	*5*	*4*	*5*	*5*	*1*	*5*	**44**	*0*	*1*	*1*	*1*	**3**	47	High	10
			Prospect	Geometric Redesign	Spot															
		Mason Trail		Geometric Redesign	Spot															
Pedestrian	10	Mason	Mountain	Signal Operations	Spot	*3*	*4*	*5*	*5*	*1*	*4*	**38**	*2*	*2*	*1*	*2*	**7**	45	High	11
			Olive	Signal Operations	Spot															
Bicycle	51	W Prospect Rd	Sheely Dr	Signals	Spot	*5*	*3*	*4*	*5*	*1*	*5*	**40**	*0*	*1*	*1*	*2*	**5**	45	High	12
Bicycle	33	E Magnolia St	Remington St	Signs & Markings	Spot	*3*	*5*	*5*	*5*	*1*	*4*	**40**	*2*	*1*	*1*	*0*	**4**	44	High	13
Pedestrian	5	Mulberry St	Stover	Beacon / RRFB	Spot	*4*	*4*	*5*	*5*	*1*	*4*	**40**	*0*	*1*	*2*	*1*	**4**	44	High	14
			Remington	Median Refuge / Diverter	Spot															
			Peterson	New Crossing	Spot															
Bicycle	30	Mountain Ave, Lincoln Ave	N Howes St - Willow St	Buffered Bike Lane, Separated Bike Lane	0.5	*4*	*1*	*5*	*5*	*5*	*4*	**38**	*2*	*1*	*2*	*1*	**6**	44	High	15
Pedestrian	31	Harmony	Corbett	Geometric Redesign	Spot	*2*	*4*	*4*	*5*	*4*	*4*	**37**	*2*	*2*	*2*	*1*	**7**	44	High	16
			Timberline	Signal Operations	Spot															
Bicycle	52	W Lake St	S Shields St - S Mason St	Separated Bike Lane	1.2	*5*	*3*	*5*	*5*	*0*	*4*	**39**	*2*	*2*	*1*	*0*	**5**	44	High	17
Bicycle	50	E Vine Dr	Jerome St	Signals	Spot	*5*	*5*	*3*	*5*	*1*	*5*	**42**	*0*	*0*	*1*	*0*	**2**	44	High	18
Pedestrian	22	Lemay Ave	Prospect	Signal Operations	Spot	*4*	*3*	*4*	*5*	*1*	*4*	**36**	*2*	*2*	*2*	*1*	**7**	43	High	19
			Stuart	Signal Operations	Spot															

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Bicycle	39	S Shields St	W Mulberry St - Davidson Dr	Separated Bike Lane	1.6	*3*	*3*	*4*	*5*	*5*	*4*	**38**	*1*	*1*	*2*	*1*	**5**	43	High	20
Bicycle	32	Magnolia St	S Sherwood St - Whedbee St	Bike Boulevard	0.8	*4*	*3*	*5*	*5*	*0*	*4*	**37**	*2*	*1*	*1*	*1*	**5**	42	High	21
Bicycle	41	S Shields St	W Lake St	Two-way sidepath	Spot	*2*	*3*	*5*	*5*	*1*	*4*	**34**	*2*	*2*	*2*	*2*	**8**	42	High	22
Pedestrian	21	Lemay Ave	Mulberry	Geometric Redesign	Spot							**39**	*0*	*1*	*1*	*1*	**3**	42	High	23
Bicycle	2	E Elizabeth St	S College Ave	Intersection redesign	Spot	*4*	*4*	*5*	*5*	*2*	*2*	**37**	*0*	*2*	*2*	*0*	**4**	41	High	24
Bicycle	7	S Taft Hill Rd	W Elizabeth St - W Horsetooth Rd	Separated Bike Lane	2.5	*2*	*4*	*3*	*5*	*5*	*3*	**34**	*2*	*2*	*2*	*1*	**7**	41	High	25
Bicycle	52	City Park Ave	W Mulberry St	Signals	Spot	*4*	*5*	*3*	*0*	*1*	*5*	**35**	*0*	*2*	*1*	*2*	**6**	41	High	26
Bicycle	6	S Taft Hill Rd	Laporte Ave - W Elizabeth St	Separated Bike Lane	1.1	*2*	*3*	*4*	*5*	*5*	*3*	**34**	*2*	*2*	*2*	*0*	**6**	40	High	27
Bicycle	12	Birch St	S Shields St	Signs & Markings	Spot	*3*	*2*	*5*	*5*	*1*	*4*	**34**	*2*	*1*	*1*	*2*	**6**	40	High	28
Bicycle	28	Jefferson St	N College Ave - E Mountain Ave	Separated Bike Lane	0.5	*5*	*1*	*5*	*5*	*0*	*4*	**35**	*2*	*1*	*1*	*1*	**5**	40	High	29
Pedestrian	40	Shields	Stuart	Geometric Redesign	Spot	*4*	*4*	*3*	*5*	*1*	*4*	**36**	*0*	*1*	*2*	*1*	**4**	40	High	30
Pedestrian	15	Mason	Maple	Geometric Redesign	Spot	*3*	*5*	*4*	*5*	*1*	*4*	**38**	*0*	*1*	*1*	*0*	**2**	40	High	31
Bicycle	35	Birch St, Crestmore Pl, Skyline Dr	Orchard Pl - City Park Ave	Bike Boulevard	1.4	*4*	*2*	*5*	*0*	*0*	*5*	**32**	*2*	*2*	*2*	*1*	**7**	39	High	32
Bicycle	36	Glenmoor Dr, W Plum St	S Taft Hill Rd - Skyline Dr	Bike Boulevard	1.1	*5*	*1*	*5*	*0*	*0*	*5*	**32**	*2*	*2*	*2*	*1*	**7**	39	High	33
Bicycle	50	Springfield Dr	Castlerock Dr - S Shields St	Bike Boulevard	0.6	*4*	*4*	*4*	*0*	*0*	*4*	**32**	*2*	*2*	*2*	*1*	**7**	39	High	34
Bicycle	12	S Shields St	W Mountain Ave - W Mulberry St	Separated Bike Lane	2.2	*5*	*3*	*4*	*0*	*5*	*1*	**31**	*2*	*1*	*2*	*2*	**7**	38	High	35
Pedestrian	67	Horsetooth	Platte Auntie Stone	Median Refuge / Diverter Median Refuge / Diverter	Spot Spot	*5*	*5*	*1*	*0*	*1*	*5*	**33**	*1*	*1*	*2*	*2*	**6**	39	High	36

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Bicycle	47	Castlerock Dr, Lake St, Skyline Dr, Clearview Ave	S Taft Hill Rd - W Elizabeth St	Bike Boulevard	3.5	*5*	*3*	*5*	*0*	*0*	*4*	**34**	*2*	*2*	*1*	*0*	**5**	39	High	38
Bicycle	58	Gillette Dr	Phemister Rd - W Drake Rd	Separated Bike Lane	3.0	*4*	*3*	*5*	*0*	*0*	*5*	**34**	*2*	*1*	*2*	*0*	**5**	39	High	39
Bicycle	76	E Horsetooth Rd	S Lemay Ave - Ziegler Rd	Separated Bike Lane	0.7	*2*	*5*	*2*	*5*	*5*	*3*	**34**	*2*	*1*	*2*	*0*	**5**	39	High	40
Bicycle	11	Conifer St	N College Ave	Intersection redesign	Spot	*3*	*2*	*2*	*5*	*5*	*5*	**34**	*2*	*2*	*1*	*0*	**5**	39	High	41
Bicycle	57	Centre Ave	S Shields St - Phemister Rd	Separated Bike Lane	1.0	*4*	*2*	*4*	*5*	*0*	*5*	**35**	*2*	*1*	*0*	*1*	**4**	39	High	42
Bicycle	40	S Shields St	Davidson Dr - Hilldale Dr	Separated Bike Lane	0.1	*2*	*4*	*3*	*5*	*5*	*2*	**32**	*2*	*1*	*2*	*1*	**6**	38	High	43
Bicycle	11	Laporte Ave	Fishback Ave - N Washington Ave	Bike Lane	1.7	*5*	*3*	*4*	*0*	*5*	*2*	**33**	*2*	*1*	*2*	*0*	**5**	38	High	44
Bicycle	104	Boardwalk Dr	JFK - Harmony	Buffered Bike Lane	0.3	*4*	*3*	*3*	*0*	*5*	*4*	**33**	*2*	*1*	*2*	*0*	**5**	38	High	45
Pedestrian	72	Riverside Ave	Prospect Rd	Geometric Redesign	Spot							**33**	*1*	*0*	*2*	*2*	**5**	38	High	46
Bicycle	64	Drake Rd	S Taft Hill Rd - Tulane Dr	Separated Bike Lane	0.3	*3*	*2*	*4*	*5*	*5*	*3*	**34**	*0*	*0*	*1*	*2*	**3**	37	High	47
Bicycle	74	W Horsetooth Rd	Richmond Dr - S Mason St	Sidepath (both sides)	0.8	*3*	*2*	*4*	*5*	*5*	*3*	**34**	*0*	*0*	*2*	*1*	**3**	37	High	48
Bicycle	51	W Pitkin St	S Shields St - S College Ave	Separated Bike Lane	0.7	*5*	*2*	*5*	*5*	*0*	*2*	**33**	*0*	*0*	*2*	*1*	**4**	37	High	49
Pedestrian	13	Magnolia	Sherwood Loomis Meldrum Washington	Geometric Redesign Geometric Redesign Geometric Redesign High-Visibility Crosswalk	Spot Spot Spot Spot	*4*	*3*	*5*	*0*	*1*	*4*	**33**	*0*	*1*	*1*	*1*	**3**	36	High	50
Pedestrian	12	Olive	Remington Mathews	Geometric Redesign Geometric Redesign	Spot Spot	*2*	*3*	*5*	*5*	*1*	*4*	**34**	*0*	*1*	*1*	*0*	**2**	36	High	54

Project Focus	PID	Street	Extents	Facility	Length	Connect: Network	Connect: Destinations	Transit Access	Safety: HIN	Safety: Comfort	Health-Equity	Outcomes Score (normalized)	Cost	Readiness	MM Benefit	Synergy	Implementation Score	Combined Score	Term	Rank
Bicycle	40	N Roosevelt Ave	Laporte Ave	Signals	Spot	5	2	4	0	2	3	**30**	2	1	2	0	**5**	35	High	56
Pedestrian	60	Ziegler	Saber Cat	Beacon / RRFB	Spot	5	5	1	0	1	3	**29**	1	2	2	1	**6**	35	High	57
Bicycle	44	Centre Ave	W Lake St	Intersection redesign	Spot	3	4	5	0	1	5	**35**	0	0	0	0	**0**	35	High	58
Bicycle	59	Booth Rd	Tietz Dr - Bay Rd	Sidepath (one side)	0.5	5	1	5	0	0	5	**32**	2	0	1	0	**3**	35	High	59
Bicycle	62	S Lemay Ave	E Stuart St - E Horsetooth Rd	Sidepath (both sides)	0.2	1	4	3	5	5	3	**32**	0	0	2	1	**3**	35	High	60
Bicycle	62	Spring Creek Trail	Taft Hill Rd	New connection	Spot	5	5	4	0	0	2	**32**	1	0	1	1	**3**	35	High	61
Pedestrian	30	Taft Hill	Lake	New Crossing	Spot	3	3	3	5	1	4	**32**	0	0	1	1	**2**	34	High	62
Bicycle	7	E Horsetooth Rd	Kingsley Dr	Signals	Spot	5	1	4	0	3	2	**27**	0	2	1	2	**6**	33	High	63
Bicycle	1	E Prospect St	Stover St	Two-way sidepath	Spot	4	4	1	0	1	4	**27**	2	1	1	2	**6**	33	High	64
Bicycle	48	S Howes St	W Laurel St	Signs & Markings	Spot	4	3	5	0	1	2	**29**	2	1	1	0	**4**	33	High	65
Bicycle	39	S College Ave	Rutgers Ave	New connection	Spot	5	5	2	0	0	4	**32**	1	0	0	0	**1**	33	High	66
Bicycle	26	W Stuart St	S Taft Hill Rd (Project #1)	Two-way sidepath	Spot	5	2	1	0	2	4	**26**	2	1	0	2	**5**	31	High	67
Bicycle	34	Riverside Ave	E Mulberry St	Intersection redesign	Spot	4	5	0	0	5	3	**29**	0	1	1	0	**2**	31	High	68
Bicycle	46	Jackson Ave	W Mulberry St	Two-way sidepath	Spot	4	4	2	0	1	1	**23**	2	1	1	2	**6**	29	High	69
Pedestrian	48	Cinquefoil	Kechter	Median Refuge / Diverter	Spot	5	4	0	0	1	1	**21**	0	2	1	1	**4**	25	High	70
Bicycle	20	S Timberline Rd	E Lincoln Ave	Intersection redesign	Spot	2	1	2	0	1	5	**21**	0	2	0	0	**2**	23	High	71
Pedestrian	25	Frey	Laporte	Geometric Redesign	Spot	1	2	3	5	2	1	**21**	0	1	1	0	**2**	23	High	72
Pedestrian	75	Mason Trail	Prospect Rd	Beacon / RRFB	Spot	1	2	1	0	2	4	**18**	1	0	1	0	**3**	21	High	73
Pedestrian	34	Timberline	Horsetooth	Geometric Redesign	Spot	2	1	3	0	1	2	**17**	0	1	2	0	**3**	20	High	74
Bicycle	8	E Horsetooth Rd	Caribou Dr	Signals	Spot	3	0	3	0	2	2	**18**	0	0	1	0	**2**	20	High	75
Bicycle	24	Timberline Rd	Annabel Ave - E Prospect Rd	Separated Bike Lane	1.8	3	4	1	0	5	5	**31**	2	1	2	1	**6**	37	Medium	76
Bicycle	65	E Drake Rd	Tulane Dr - Rigden Pkwy	Sidepath (both sides)	0.5	2	4	3	5	5	3	**34**	1	0	1	0	**2**	36	Medium	77

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Bicycle	75	E Horsetooth Rd	Mitchell Dr - S Lemay Ave	Sidepath (both sides)	0.3	*2*	*3*	*3*	*5*	*5*	*4*	**34**	*0*	*0*	*2*	*0*	**2**	36	Medium	78
Bicycle	46	Clearview Ave	Ponderosa Dr - Skyline Dr	Bike Boulevard	1.0	*5*	*2*	*4*	*0*	*0*	*4*	**30**	*2*	*2*	*2*	*0*	**6**	36	Medium	79
Bicycle	48	W Lake St	S Overland Tr - S Taft Hill Rd	Bike Boulevard	1.1	*4*	*3*	*4*	*0*	*0*	*4*	**30**	*2*	*2*	*2*	*0*	**6**	36	Medium	80
Bicycle	69	Worthington Ave	W Drake Rd - W Swallow Rd	Bike Boulevard	1.6	*4*	*4*	*4*	*0*	*0*	*3*	**30**	*2*	*2*	*2*	*0*	**6**	36	Medium	81
Pedestrian	19	3rd	Lincoln	Beacon / RRFB	Spot	*3*	*4*	*2*	*0*	*2*	*5*	**30**	*2*	*2*	*2*	*0*	**6**	36	Medium	82
Pedestrian	20	Riverside	Lemay	Geometric Redesign	Spot	*4*	*5*	*3*	*0*	*1*	*3*	**31**	*0*	*1*	*2*	*2*	**5**	36	Medium	83
Bicycle	67	Water Blossom Ln, Willow Fern Way	W Drake Rd - Marshwood Dr	Bike Boulevard	1.0	*5*	*1*	*5*	*0*	*0*	*3*	**28**	*2*	*2*	*2*	*1*	**7**	35	Medium	84
Bicycle	56	Rolland Moore Dr, Phemister Rd	S Shields St - Bay Rd	Separated Bike Lane, Bike Lane	1.7	*4*	*2*	*4*	*0*	*0*	*5*	**30**	*2*	*1*	*2*	*0*	**5**	35	Medium	85
Bicycle	85	Harmony Rd	S Taft Hill Rd - S Lemay Ave	Separated Bike Lane	2.6	*1*	*4*	*2*	*5*	*5*	*3*	**30**	*1*	*1*	*2*	*1*	**5**	35	Medium	86
Bicycle	29	Linden St	Walnut St - Jefferson St	Bike Route	1.0	*5*	*1*	*5*	*0*	*0*	*4*	**30**	*2*	*2*	*1*	*0*	**5**	35	Medium	87
Bicycle	80	John F Kennedy Pkwy, E Troutman Pkwy	E Horsetooth Rd - E Harmony Rd	Separated Bike Lane, Buffered Bike Lane	1.2	*3*	*3*	*3*	*0*	*0*	*4*	**26**	*2*	*2*	*2*	*2*	**8**	34	Medium	88
Bicycle	66	E Drake Rd, Ziegler Rd	Rigden Pkwy - William Neal Pkwy	Separated Bike Lane	1.4	*3*	*4*	*1*	*0*	*5*	*3*	**27**	*2*	*2*	*2*	*1*	**7**	34	Medium	89
Bicycle	38	Laurel St	S Shields St - S Howes St	Separated Bike Lane, Buffered Bike Lane	0.2	*3*	*3*	*5*	*0*	*0*	*3*	**28**	*2*	*1*	*2*	*1*	**6**	34	Medium	90
Bicycle	42	Pennock Pl	all	Bike Boulevard	1.4	*5*	*1*	*5*	*0*	*0*	*3*	**28**	*2*	*2*	*2*	*0*	**6**	34	Medium	91
Pedestrian	65	Center	Phemister	Beacon / RRFB	Spot	*1*	*2*	*3*	*5*	*1*	*5*	**28**	*0*	*2*	*2*	*2*	**6**	34	Medium	92
Bicycle	99	Howes St	W Mountain Ave - W Laurel St	Buffered Bike Lane	0.5	*5*	*2*	*5*	*0*	*0*	*3*	**30**	*2*	*2*	*0*	*0*	**4**	34	Medium	93
Bicycle	14	Mcmurry Ave	E Harmony Rd	Intersection redesign	Spot	*2*	*5*	*2*	*5*	*5*	*1*	**30**	*0*	*1*	*1*	*2*	**4**	34	Medium	94

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Bicycle	60	East Spring Creek Trail	Lemay Ave	Two-way sidepath	Spot	*4*	*5*	*3*	*0*	*0*	*3*	**30**	*2*	*1*	*1*	*0*	**4**	34	Medium	95
Bicycle	54	E Suniga Rd	Jerome St	Signs & Markings	Spot	*5*	*1*	*3*	*0*	*5*	*4*	**31**	*2*	*0*	*1*	*0*	**3**	34	Medium	96
Bicycle	2	N Shields St	W Willox Ln - W Mountain Ave	Separated Bike Lane	0.9	*3*	*3*	*2*	*0*	*5*	*3*	**27**	*2*	*2*	*2*	*0*	**6**	33	Medium	97
Bicycle	26	S Timberline Rd	Vermont Dr - Battlecreek Dr	Separated Bike Lane	2.0	*2*	*4*	*2*	*0*	*5*	*3*	**27**	*2*	*1*	*2*	*1*	**6**	33	Medium	98
Bicycle	63	W Drake Rd	S Overland Tr - S Taft Hill Rd	Separated Bike Lane	1.1	*3*	*4*	*1*	*0*	*5*	*3*	**27**	*2*	*1*	*2*	*1*	**6**	33	Medium	99
Bicycle	27	Skyline Dr	W Prospect Rd	Signals	Spot	*2*	*5*	*2*	*0*	*2*	*4*	**28**	*0*	*1*	*1*	*2*	**5**	33	Medium	100
Pedestrian	16	College	Myrtle	Geometric Redesign	Spot	*2*	*3*	*4*	*5*	*1*	*3*	**30**	*0*	*1*	*1*	*1*	**3**	33	Medium	101
Pedestrian	43	College	Willox	Signal Operations	Spot	*1*	*2*	*4*	*5*	*1*	*5*	**30**	*0*	*2*	*1*	*0*	**3**	33	Medium	102
Bicycle	25	S Timberline Rd	E Prospect Rd - Vermont Dr	Separated Bike Lane	0.4	*3*	*3*	*1*	*0*	*5*	*3*	**25**	*2*	*2*	*2*	*1*	**7**	32	Medium	103
Bicycle	10	West St, Maple St	N Roosevelt Ave - N Shields St	Bike Boulevard	0.5	*4*	*3*	*4*	*0*	*0*	*2*	**26**	*2*	*2*	*2*	*0*	**6**	32	Medium	104
Bicycle	21	Redwood St, Linden St	Conifer St - Linden Center Dr	Buffered Bike Lane	0.8	*4*	*2*	*3*	*0*	*0*	*4*	**26**	*2*	*2*	*2*	*0*	**6**	32	Medium	105
Bicycle	60	Purdue Rd, Tulane Dr, Mathews St, Rutgers Ave	S College Ave - E Swallow Rd	Bike Boulevard	0.6	*3*	*2*	*4*	*0*	*0*	*4*	**26**	*2*	*2*	*2*	*0*	**6**	32	Medium	106
Pedestrian	55	Redwood	Conifer Suniga	High-Visibility Crosswalk High-Visibility Crosswalk	Spot Spot	*4*	*2*	*3*	*0*	*1*	*4*	**27**	*1*	*2*	*2*	*0*	**5**	32	Medium	107
Bicycle	37	W Elizabeth St	S Overland Tr - CSU Transit Center	Separated Bike Lane	6.8	*3*	*3*	*4*	*0*	*0*	*4*	**28**	*1*	*1*	*2*	*0*	**4**	32	Medium	109
Bicycle	28	Heatheridge Rd	W Prospect Rd	Signals	Spot	*2*	*3*	*4*	*5*	*1*	*2*	**28**	*0*	*0*	*1*	*2*	**4**	32	Medium	110

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Pedestrian	14	Sherwood	Cherry Maple	High-Visibility Crosswalk Geometric Redesign	Spot Spot	*3*	*4*	*4*	*5*	*1*	*1*	**30**	*0*	*1*	*1*	*0*	**2**	32	Medium	111
Bicycle	58	Willox Ln	Blue Spruce	Signals	Spot	*2*	*4*	*4*	*0*	*1*	*5*	**31**	*0*	*0*	*1*	*0*	**1**	32	Medium	113
Pedestrian	41	Timberline	Mulberry	Geometric Redesign	Spot	*3*	*3*	*2*	*0*	*5*	*5*	**31**	*0*	*1*	*0*	*0*	**1**	32	Medium	114
Bicycle	44	S Lemay Ave	Riverside Ave - E Stuart St	Separated Bike Lane	1.6	*3*	*1*	*3*	*0*	*5*	*3*	**25**	*2*	*1*	*2*	*1*	**6**	31	Medium	115
Bicycle	45	E Elizabeth St	S College Ave - S Lemay Ave	Buffered Bike Lane, Bike Lane	1.9	*4*	*2*	*4*	*0*	*0*	*3*	**26**	*2*	*1*	*2*	*0*	**5**	31	Medium	116
Bicycle	98	Loomis Ave	Laporte Ave - W Mulberry St	Buffered Bike Lane	0.6	*4*	*2*	*5*	*0*	*0*	*2*	**26**	*2*	*2*	*1*	*0*	**5**	31	Medium	117
Pedestrian	61	Timberline	International Sykes	New Crossing Beacon / RRFB	Spot Spot	*3*	*2*	*2*	*0*	*2*	*5*	**26**	*1*	*0*	*2*	*2*	**5**	31	Medium	118
Pedestrian	56	Willox	Bramblebush	Beacon / RRFB	Spot	*4*	*3*	*0*	*0*	*5*	*4*	**27**	*2*	*1*	*1*	*0*	**4**	31	Medium	120
Bicycle	43	Phemister Rd	Mason Trail	New connection	Spot	*3*	*4*	*2*	*0*	*0*	*5*	**28**	*1*	*1*	*1*	*0*	**3**	31	Medium	121
Bicycle	103	E Lincoln Ave	Lemay - Timberline	Separated Bike Lane	0.9	*2*	*5*	*3*	*0*	*0*	*5*	**30**	*0*	*1*	*0*	*0*	**1**	31	Medium	122
Bicycle	27	N Loomis Ave	Cherry St - Laporte Ave	Bike Boulevard	1.0	*5*	*1*	*5*	*0*	*0*	*1*	**24**	*2*	*2*	*2*	*0*	**6**	30	Medium	123
Bicycle	34	Ponderosa Dr, Fuqua Dr, Clearview Ave	W Mulberry St - W Prospect Rd	Bike Boulevard	0.6	*3*	*2*	*2*	*0*	*0*	*5*	**24**	*2*	*2*	*2*	*0*	**6**	30	Medium	124
Bicycle	49	Underhill Dr, Skyline Dr	Springfield Dr - Westbridge Dr	Bike Boulevard	1.4	*5*	*1*	*3*	*0*	*0*	*3*	**24**	*2*	*2*	*2*	*0*	**6**	30	Medium	125
Bicycle	53	Emigh St, McHugh St, Welch St	E Elizabeth St - E Prospect Rd	Bike Boulevard	1.0	*4*	*2*	*3*	*0*	*0*	*3*	**24**	*2*	*2*	*2*	*0*	**6**	30	Medium	126
Bicycle	61	Brookwood Dr, Rollingwood Ln, Silverwood Dr, Oxborough Ln	E Stuart St - Centennial Rd	Bike Boulevard	3.1	*2*	*5*	*2*	*0*	*0*	*3*	**24**	*2*	*2*	*2*	*0*	**6**	30	Medium	127

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Bicycle	89	S Lemay Ave	E Harmony Rd - Carpenter Rd	Separated Bike Lane	1.1	*2*	*4*	*1*	*0*	*5*	*3*	**25**	*1*	*1*	*2*	*1*	**5**	30	Medium	128
Bicycle	49	S College Ave	W/E Swallow Rd	Signs & Markings	Spot	*2*	*2*	*4*	*0*	*1*	*4*	**25**	*2*	*2*	*1*	*0*	**5**	30	Medium	129
Bicycle	41	Meridian Ave	W Plum St - Hughes Way	Separated Bike Lane	2.5	*5*	*1*	*5*	*0*	*0*	*2*	**26**	*2*	*0*	*2*	*0*	**4**	30	Medium	130
Pedestrian	53	JFK	Monroe	Geometric Redesign	Spot	*2*	*3*	*4*	*0*	*0*	*4*	**26**	*0*	*1*	*2*	*1*	**4**	30	Medium	131
Pedestrian	74	Troutman Pkwy	Boardwalk	Geometric Redesign	Spot	*2*	*2*	*2*	*5*	*1*	*4*	**26**	*1*	*0*	*2*	*1*	**4**	30	Medium	132
Bicycle	73	W Horsetooth Rd	Horsetooth Ct - Richmond Dr	Sidepath (both sides)	3.6	*3*	*2*	*2*	*5*	*5*	*2*	**28**	*0*	*0*	*2*	*0*	**2**	30	Medium	133
Bicycle	20	Conifer St	N College Ave - N Lemay Ave	Buffered Bike Lane	0.4	*2*	*4*	*2*	*0*	*0*	*4*	**24**	*2*	*1*	*2*	*0*	**5**	29	Medium	134
Bicycle	18	Turnberry Rd	Country Club Rd - Mountain Vista Dr	Separated Bike Lane	0.9	*1*	*5*	*0*	*0*	*5*	*4*	**25**	*2*	*0*	*2*	*0*	**4**	29	Medium	135
Pedestrian	63	Lake	West of Whitcomb	Beacon / RRFB	Spot	*2*	*1*	*4*	*0*	*1*	*5*	**25**	*1*	*1*	*2*	*0*	**4**	29	Medium	136
Pedestrian	66	Prospect	Whedbee	New Crossing	Spot	*3*	*3*	*2*	*0*	*1*	*4*	**25**	*0*	*0*	*2*	*2*	**4**	29	Medium	137
Bicycle	23	E Vine Dr	Linden St - I-25	Sidepath (one side)	0.1	*1*	*5*	*1*	*0*	*5*	*4*	**27**	*0*	*0*	*2*	*0*	**2**	29	Medium	138
Bicycle	83	S Lemay Ave	E Horsetooth Rd - E Harmony Rd	Sidepath (both sides)	3.0	*4*	*4*	*1*	*0*	*5*	*2*	**27**	*0*	*0*	*2*	*0*	**2**	29	Medium	139
Pedestrian	44	College	Palmer	Beacon / RRFB	Spot	*4*	*3*	*4*	*0*	*1*	*2*	**27**	*0*	*1*	*1*	*0*	**2**	29	Medium	140
Pedestrian	44		Saturn	Beacon / RRFB	Spot	*4*	*3*	*4*	*0*	*1*	*2*	**27**	*0*	*1*	*1*	*0*	**2**	29	Medium	141
Bicycle	45	Red St	Canal Crossing	New connection	Spot	*4*	*2*	*3*	*0*	*0*	*5*	**28**	*1*	*0*	*0*	*0*	**1**	29	Medium	142
Bicycle	56	Horsetooth	Seneca	Signals	Spot	*3*	*3*	*1*	*5*	*1*	*2*	**24**	*2*	*0*	*1*	*1*	**4**	28	Medium	143
Pedestrian	69	Mason	Boardwalk	High-Visibility Crosswalk	Spot	*3*	*2*	*1*	*0*	*2*	*5*	**24**	*2*	*0*	*0*	*2*	**4**	28	Medium	144
Bicycle	81	W County Road 38E	Red Fox Rd - S Taft Hill Rd	Sidepath (both sides)	0.4	*2*	*4*	*1*	*0*	*5*	*3*	**25**	*1*	*0*	*2*	*0*	**3**	28	Medium	145

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Bicycle	97	Overland Trail	W Vine Dr - W Drake Rd	Separated Bike Lane	0.3	*1*	*5*	*2*	*0*	*5*	*2*	**25**	*0*	*1*	*1*	*1*	**3**	28	Medium	146
Pedestrian	71	JFK Pkwy	Pavilion	New Crossing	Spot	*1*	*2*	*3*	*0*	*1*	*5*	**23**	*0*	*0*	*2*	*2*	**4**	27	Medium	147
Pedestrian	45	College	Fossil Creek	Geometric Redesign	Spot	*4*	*4*	*2*	*0*	*1*	*2*	**25**	*0*	*1*	*1*	*0*	**2**	27	Medium	148
Bicycle	64	Willox Ln	Lemay Ave	Intersection redesign	Spot	*5*	*2*	*0*	*0*	*4*	*4*	**26**	*0*	*0*	*1*	*0*	**1**	27	Medium	149
Pedestrian	62	Shields	Laurel	Beacon / RRFB	Spot	*2*	*2*	*4*	*0*	*1*	*2*	**21**	*0*	*1*	*2*	*2*	**5**	26	Medium	150
Pedestrian	6	Shields	Laporte	Geometric Redesign	Spot	*2*	*2*	*3*	*0*	*1*	*1*	**17**	*2*	*2*	*2*	*2*	**8**	25	Medium	151
Pedestrian	33	Timberline	Vermont	Geometric Redesign	Spot	*3*	*4*	*0*	*0*	*1*	*2*	**19**	*2*	*2*	*2*	*0*	**6**	25	Medium	152
Pedestrian	52	Harmony	Silvergate	Beacon / RRFB	Spot	*2*	*2*	*1*	*0*	*5*	*3*	**21**	*2*	*2*	*0*	*0*	**4**	25	Medium	153
Pedestrian	59	Laporte	Impala	High-Visibility Crosswalk	Spot	*1*	*1*	*1*	*5*	*2*	*3*	**19**	*2*	*2*	*1*	*0*	**5**	24	Medium	154
Pedestrian	42	Airpark	Lincoln	New Crossing	Spot	*0*	*1*	*3*	*0*	*2*	*5*	**20**	*0*	*0*	*1*	*0*	**1**	21	Medium	155
Pedestrian	27	Overland Trail	Mulberry Rampart	Beacon / RRFB New Crossing	Spot Spot	*3*	*1*	*1*	*0*	*4*	*1*	**16**	*0*	*1*	*2*	*1*	**4**	20	Medium	156
Pedestrian	35	Miles House	Drake	New Crossing	Spot	*1*	*1*	*0*	*0*	*5*	*1*	**11**	*2*	*2*	*1*	*1*	**6**	17	Medium	158
Pedestrian	49	Lemay Trilby	Brittany	New Crossing Beacon / RRFB	Spot Spot	*4*	*2*	*0*	*0*	*1*	*2*	**17**	*0*	*0*	*1*	*1*	**2**	19	Medium	159
Bicycle	90	Southridge Greens Blvd	S Lemay Ave - Center Greens Blvd	Bike Route	0.6	*2*	*3*	*0*	*0*	*0*	*3*	**16**	*2*	*2*	*2*	*1*	**7**	23	Low	161
Bicycle	94	Nassau Way	S Lemay Ave - Barbuda Dr	Bike Boulevard	3.0	*4*	*1*	*0*	*0*	*0*	*2*	**14**	*2*	*2*	*2*	*1*	**7**	21	Low	162
Bicycle	17	Turnberry Rd, Richards Lake Rd	Serramonte Dr - Country Club Rd	Separated Bike Lane	0.8	*1*	*5*	*0*	*0*	*5*	*3*	**23**	*2*	*2*	*2*	*0*	**6**	29	Low	163
Bicycle	9	Lyons St, Roosevelt Ave, Cherry St, Maple St	W Vine Dr - W Oak St	Bike Boulevard	0.6	*3*	*3*	*3*	*0*	*0*	*2*	**22**	*2*	*2*	*2*	*0*	**6**	28	Low	164
Bicycle	14	W Magnolia St, Jackson Ave	W Mulberry St - S Shields St	Buffered Bike Lane, Bike Boulevard	2.3	*5*	*1*	*4*	*0*	*0*	*1*	**22**	*2*	*2*	*2*	*0*	**6**	28	Low	165

Project Focus	PID	Street	Extents	Facility	Length	Connect: Network	Connect: Destinations	Transit Access	Safety: HIN	Safety: Comfort	Health-Equity	Outcomes Score (normalized)	Cost	Readiness	MM Benefit	Synergy	Implementation Score	Combined Score	Term	Rank
Bicycle	72	Red Mountain Dr, Fieldston Dr, Kingsley Dr, Creekstone Dr	Pinecone Cir - E Horsetooth Rd	Bike Boulevard	1.2	3	4	2	0	0	2	**22**	2	2	2	0	**6**	28	Low	166
Bicycle	42	S Overland Trail	W Lake St	Two-way sidepath	Spot	1	2	3	0	1	4	**21**	0	2	1	2	**6**	27	Low	167
Bicycle	88	Fossil Blvd, Cameron Dr, Conejos Rd	W Fairway Ln - S College Ave	Bike Boulevard	1.3	4	1	3	0	0	2	**20**	2	2	2	0	**6**	26	Low	168
Bicycle	77	Ziegler Rd	Percheron Dr - Rock Park Dr	Separated Bike Lane, Sidepath (one side), Bike Lane	0.3	2	2	1	0	5	2	**19**	1	1	2	2	**6**	25	Low	169
Bicycle	5	W Vine Dr	N Overland Tr - Lancer Dr	Separated Bike Lane	0.4	1	5	2	0	0	1	**18**	2	2	2	0	**6**	24	Low	170
Bicycle	43	Riverside Ave	S Lemay Ave - E Prospect Rd	Separated Bike Lane	0.8	3	1	2	0	0	3	**18**	2	1	2	1	**6**	24	Low	171
Bicycle	55	Midpoint Dr	Prospect Park Way - Sharp Point Dr	Bike Lane	0.3	4	1	3	0	0	1	**18**	2	1	2	1	**6**	24	Low	172
Pedestrian	26	Impala	Mulberry	Geometric Redesign	Spot	1	4	0	0	1	3	**17**	2	2	1	1	**6**	23	Low	173
Bicycle	68	Claremont Dr, Hull St, Hanover Dr	W Drake Rd - W Swallow Rd	Bike Boulevard	5.4	4	1	1	0	0	2	**16**	2	2	2	0	**6**	22	Low	174
Pedestrian	70	Kechter	Old Mill	Beacon / RRFB	Spot	1	0	0	0	3	3	**11**	1	2	2	1	**6**	17	Low	175
Pedestrian	57	Taft Hill	Bronson Imperial Brixton	Beacon / RRFB Beacon / RRFB Beacon / RRFB	Spot Spot Spot	3	3	2	0	1	3	**23**	0	1	2	2	**5**	28	Low	176
Bicycle	22	William Neal Pkwy	Ziegler Rd	Intersection redesign	Spot	2	4	0	0	5	3	**23**	0	2	1	2	**5**	28	Low	179
Bicycle	31	W Mulberry St	S Overland Tr - Tyler St	Separated Bike Lane	0.1	2	3	0	0	5	4	**23**	2	0	2	1	**5**	28	Low	180
Bicycle	86	E Harmony Rd, CR 38	S Lemay Ave - Weitzel St	Separated Bike Lane, Sidepath (both sides)	2.2	1	5	1	0	5	2	**23**	1	1	2	1	**5**	28	Low	181
Pedestrian	50	Cunningham	Richmond	High-Visibility Crosswalk	Spot	1	2	3	0	1	3	**19**	2	2	1	0	**5**	24	Low	182

Project Focus	PID	Street	Extents	Facility	Length	*Connect: Network*	*Connect: Destinations*	*Transit Access*	*Safety: HIN*	*Safety: Comfort*	*Health-Equity*	Outcomes Score (normalized)	*Cost*	*Readiness*	*MM Benefit*	*Synergy*	Implementation Score	Combined Score	Term	Rank
Pedestrian	64	Lake	Stover	Median Refuge / Diverter	Spot	2	1	1	0	1	3	**15**	1	2	1	1	**5**	20	Low	183
Bicycle	59	Lemay Ave	Ticonderoga	Signs & Markings	Spot	2	1	0	0	1	1	**9**	2	2	0	1	**5**	14	Low	184
Bicycle	24	Hampshire Rd	W Prospect Rd	Two-way sidepath	Spot	3	3	1	0	1	4	**23**	2	1	1	0	**4**	27	Low	185
Bicycle	4	N Taft Hill Rd	Stonecrest Dr - Laporte Ave	Separated Bike Lane	0.7	1	5	2	0	5	1	**23**	2	0	2	0	**4**	27	Low	186
Pedestrian	73	Washington Ave	Mulberry	New Crossing	Spot	3	1	1	0	2	5	**22**	0	0	2	2	**4**	26	Low	187
Bicycle	13	Sheldon Dr	W Oak St - W Mulberry St	Bike Boulevard	1.0	5	1	4	0	0	1	**22**	2	0	2	0	**4**	26	Low	188
Bicycle	57	Vine	East of Timberline	Signs & Markings	Spot	5	0	0	0	1	5	**21**	2	2	0	0	**4**	25	Low	189
Pedestrian	68	Sharp Point	March	Beacon / RRFB	Spot	4	3	2	0	1	1	**21**	2	1	1	0	**4**	25	Low	190
Bicycle	70	Moss Creek Dr, Colony Dr, Tradition Dr	W Swallow Rd - W Troutman Pkwy	Bike Boulevard	0.6	2	3	2	0	0	3	**20**	2	2	0	0	**4**	24	Low	191
Bicycle	79	Troutman Pkwy (planned extension)	Seneca St - S Shields St	Bike Lane	0.4	5	1	2	0	0	2	**20**	2	0	2	0	**4**	24	Low	192
Bicycle	87	Fossil Blvd, Fairway Ln, Palmer Dr	Fossil Blvd - Hogan Dr	Bike Boulevard	2.9	3	2	2	0	0	3	**20**	2	2	0	0	**4**	24	Low	193
Bicycle	95	Kechter Rd, CR 36	Timberline Rd - CR 5	Separated Bike Lane	0.6	1	2	0	5	5	2	**20**	1	1	2	0	**4**	24	Low	194
Bicycle	78	Westfield Dr, Capitol Dr	W Horsetooth Rd - Seneca St	Bike Boulevard	2.9	3	2	1	0	0	3	**18**	2	2	0	0	**4**	22	Low	195
Bicycle	82	Harbor Walk Dr, Breakwater Dr, Ticonderoga Dr, McMurry Ave	Boardwalk Dr - Monte Carlo Dr	Bike Boulevard	0.8	2	4	1	0	0	2	**18**	2	2	0	0	**4**	22	Low	196
Bicycle	96	Laporte Ave	City Line - N Overland Tr	Buffered Bike Lane	4.2	1	5	2	0	0	1	**18**	2	2	0	0	**4**	22	Low	197
Bicycle	32	Kecther	Tilden	Two-way sidepath	Spot	4	0	0	0	2	3	**16**	2	2	0	0	**4**	20	Low	198
Bicycle	71	Vermont Dr	Eastbrook Dr - S Timberline Rd	Bike Boulevard	7.1	5	1	0	0	0	2	**16**	2	2	0	0	**4**	20	Low	199

Project Focus	PID	Street	Extents	Facility	Length	Connect: Network	Connect: Destinations	Transit Access	Safety: HIN	Safety: Comfort	Health-Equity	Outcomes Score (normalized)	Cost	Readiness	MM Benefit	Synergy	Implementation Score	Combined Score	Term	Rank
Bicycle	84	Paddington Rd, Sunstone Dr, Sunstone Way	Caribou Dr - Ziegler Rd	Bike Boulevard	1.0	3	1	0	0	0	4	**16**	2	2	0	0	**4**	20	Low	200
Bicycle	91	W Skyway Dr, Constellation Dr	W Trilby Rd - S College Ave	Bike Boulevard	0.7	1	4	1	0	0	2	**16**	2	2	0	0	**4**	20	Low	201
Pedestrian	32	Ziegler	Harmony	Geometric Redesign	Spot	1	1	2	0	5	1	**15**	0	1	2	1	**4**	19	Low	202
Bicycle	13	Ziegler	Paddington	Signals	Spot	2	1	0	0	5	1	**13**	0	2	1	0	**4**	17	Low	203
Pedestrian	37	Creekwood Dr	north of Kirkwood	High-Visibility Crosswalk	Spot	2	1	0	0	0	3	**12**	2	2	0	0	**4**	16	Low	204
Bicycle	5	Lemay	Nassau	Signals	Spot	1	1	0	0	2	2	**10**	0	1	0	2	**4**	14	Low	205
Pedestrian	54	Vine	Irish	Beacon / RRFB	Spot	1	1	1	0	1	1	**9**	2	1	0	1	**4**	13	Low	206
Bicycle	25	W Stuart St	S Taft Hill Rd (Project #2)	Signals	Spot	4	4	1	0	2	2	**24**	0	0	0	2	**3**	27	Low	207
Bicycle	47	Overland	Laporte	Signs & Markings	Spot	4	0	3	0	1	3	**21**	2	1	0	0	**3**	24	Low	208
Pedestrian	17	Grant	Mountain	Geometric Redesign	Spot	2	1	3	5	1	1	**20**	0	1	1	1	**3**	23	Low	209
Bicycle	3	N Shields St	US 287 - W Willox Ln	Buffered Bike Lane	2.1	1	5	0	0	0	4	**20**	1	0	2	0	**3**	23	Low	210
Bicycle	54	Prospect Rd	Mason Trail - Sharp Point Dr	Sidepath (one side)	0.5	2	2	3	0	0	3	**20**	0	0	2	1	**3**	23	Low	211
Bicycle	53	Suniga	Blue Spruce	Signs & Markings	Spot	2	1	0	0	5	4	**19**	2	1	0	0	**3**	22	Low	212
Bicycle	6	Trilby	Avondale	Signals	Spot	3	3	0	0	2	2	**18**	0	1	1	0	**3**	21	Low	213
Bicycle	8	S Taft Hill Rd	W Horsetooth Rd - W Trilby Rd	Sidepath (one side), Separated Bike Lane	1.0	1	5	1	0	0	2	**18**	0	0	2	1	**3**	21	Low	214
Bicycle	100	Lemay Ave	Country Club Rd - Lowell Ln	Sidepath (one side)	0.1	1	4	0	0	0	4	**18**	0	0	2	1	**3**	21	Low	215
Bicycle	9	Dunbar	Capitol	Two-way sidepath	Spot	3	1	1	0	1	2	**15**	2	0	1	0	**3**	18	Low	216
Bicycle	67	Prospect Rd	Welch	Signals	Spot	1	4	1	0	1	5	**23**	0	0	2	0	**2**	25	Low	217
Bicycle	93	Trilby Rd	Taft Hill Rd - Timberline Rd	Sidepath (one side & both sides)	1.5	1	5	1	0	5	2	**23**	0	0	2	0	**2**	25	Low	218

Project Focus	PID	Street	Extents	Facility	Length	Connect: Network	Connect: Destinations	Transit Access	Safety: HIN	Safety: Comfort	Health-Equity	Outcomes Score (normalized)	Cost	Readiness	MM Benefit	Synergy	Implementation Score	Combined Score	Term	Rank
Bicycle	30	Skyline Dr	Clearview	New connection	Spot	3	2	2	0	0	4	**22**	1	1	0	0	**2**	24	Low	219
Bicycle	1	N College Ave, Bristlecone Dr, Blue Spruce Dr	Terry Lake Rd - Willow St	Sidepath (both sides), Buffered Bicycle Lanes	0.9	1	2	3	0	0	5	**22**	0	0	2	0	**2**	24	Low	220
Pedestrian	47	Wheaton	Harmony	New Crossing	Spot	1	3	1	5	3	1	**20**	0	0	1	1	**2**	22	Low	221
Bicycle	19	Mountain Vista Dr, Richards Lake Rd	Turnberry Rd - I-25	Sidepath (both sides)	0.8	1	5	0	0	0	3	**18**	0	0	2	0	**2**	20	Low	222
Bicycle	92	Zephyr Rd (Planned)	Red Willow Dr - S Timberline Rd	Bike Lane	1.9	2	5	0	0	0	2	**18**	2	0	0	0	**2**	20	Low	223
Bicycle	4	Horsetooth	Lemay	Two-way sidepath	Spot	1	3	1	0	0	3	**16**	2	0	0	0	**2**	18	Low	224
Bicycle	10	Power Trail	Nancy Gray	New connection	Spot	3	2	0	0	0	3	**16**	1	1	0	0	**2**	18	Low	225
Pedestrian	24	Lancer	Vine	Geometric Redesign	Spot	1	1	1	0	1	1	**9**	0	1	1	0	**2**	11	Low	226
Bicycle	18	Ziegler	Lady Moon	Signs & Markings	Spot	1	1	0	0	1	1	**7**	2	0	0	0	**2**	9	Low	227
Bicycle	33	E Mulberry St	S Lemay Ave - I-25	Sidepath (both sides)	3.7	1	5	1	0	0	5	**24**	0	0	0	1	**1**	25	Low	228
Pedestrian	51	Wabash	Benthaven	Geometric Redesign	Spot	4	4	0	0	1	2	**21**	0	1	0	0	**1**	22	Low	229
Bicycle	65	Canal Access Road	Trail Head / Waterglen neighborhoods	New connection	Spot	5	1	0	0	0	4	**20**	1	0	0	0	**1**	21	Low	230
Bicycle	15	Power Trail	Caribou Dr	New connection	Spot	1	3	0	0	0	5	**18**	1	0	0	0	**1**	19	Low	231
Bicycle	37	Power Trail	Keenland	New connection	Spot	5	1	0	0	0	2	**16**	1	0	0	0	**1**	17	Low	232
Bicycle	66	Southridge Greens Blvd	Trilby Rd	Intersection redesign	Spot	1	4	0	0	2	2	**16**	0	0	0	1	**1**	17	Low	233
Bicycle	63	Fossil Creek Trail	County Road 38-E	New connection	Spot	2	3	0	0	2	1	**14**	1	0	0	0	**1**	15	Low	234
Bicycle	16	Country Club Rd, Terry Lake Rd	N College Ave - Turnberry Rd	Sidepath (one side)	0.7	1	5	1	0	0	3	**20**	0	0	0	0	**0**	20	Low	235

APPENDIX F: OPINIONS OF PROBABLE COST

Below are the facility unit opinions of probable cost use for calculation in **Chapter 7: Implementing the Vision**. Opinions of probable cost were developed by identifying major pay items and establishing rough quantities to determine a rough order of magnitude cost. Additional pay items have been assigned approximate lump sum prices based on a percentage of the anticipated construction cost. Planning-level cost opinions include a contingency to cover items that are undefined or are typically unknown early in the planning phase of a project. Unit costs are based on 2022 dollars and were assigned based on historical cost data from City of Fort Collins and Colorado Department of Transportation. Cost opinions do not include easement and right-of-way acquisition; permitting or inspection; engineering, surveying, geotechnical investigation, environmental documentation, special site remediation, escalation, or the cost for ongoing maintenance. A cost range has been assigned to certain general categories such as utility relocations; however, these costs can vary widely depending on the exact details and nature of the work. The overall cost opinions are intended to be general and used only for planning purposes. Toole Design Group, LLC makes no guarantees or warranties regarding the cost estimate herein. Construction costs will vary based on the ultimate project scope, actual site conditions and constraints, schedule, and economic conditions at the time of construction.

Pedestrian Projects

Treatments	Cost / Spot
Signal Operations	$ 3,000
Geometric Redesign	$ 150,000
Beacon / RRFB	$ 600,000
Median Refuge / Diverter	$ 116,830
High-Visibility Crosswalk	$ 17,550
New Crossing	$ 585,000

Bicycle Spot Projects

Treatments	Cost / Spot
Intersection redesign	$ 585,000
Signals	$ 600,000
Signs & Markings	$ 3,000
Two-way sidepath	$ 29,000
New connection	$ 320,000

Bicycle Network Projects

Facility	Implementation Action	Cost/Mi
Bike Route	Add Wayfinding	$ 7,000
Bike Route	Design Refinement	$ 68,000
Bike Boulevard	Add Wayfinding	$ 7,000
Bike Boulevard	Design Refinement	$ 68,000
Bike Lane	Traffic Calming	$ 30,000
Bike Lane	Lane Diet	$ 42,000
Bike Lane	1 Side Parking Removal	$ 83,000
Bike Lane	2 Side Parking Removal	$ 83,000
Bike Lane	Construct New	$ 1,821,000
Buffered Bike Lane	Add Wayfinding	$ 7,000
Buffered Bike Lane	Lane Diet	$ 61,000
Buffered Bike Lane	Road Diet	$ 94,000
Buffered Bike Lane	1 Side Parking Removal	$ 94,000
Buffered Bike Lane	Design Refinement	$ 570,000
Buffered Bike Lane	Widen Roadway	$ 570,000
Buffered Bike Lane	Construct New	$ 570,000
Separated Bike Lane	Add Separator	$ 250,000
Separated Bike Lane	Lane Diet	$ 250,000
Separated Bike Lane	Road Diet	$ 302,000
Separated Bike Lane	1 Side Parking Removal	$ 302,000
Separated Bike Lane	Adjust Median	$ 526,000
Separated Bike Lane	Adjust Curb LIne	$ 526,000
Separated Bike Lane	Design Refinement	$ 738,000
Separated Bike Lane	Widen Roadway	$ 738,000
Separated Bike Lane	Construct New	$ 2,497,000
Sidepath 1 Side	Construct New	$ 1,268,000
Sidepath 2 Sides	Construct New	$ 2,536,000

APPENDIX H:
MULTIMODAL LEVEL OF SERVICE RECOMMENDATIONS

TOOLE DESIGN

1801 BROADWAY
SUITE 1204
DENVER, CO 80202

720.204.7061
TOOLEDESIGN.COM

MEMORANDUM

September 7, 2022

To: Cortney Geary, City of Fort Collins
From: Sagar Onta and Trung Vo
Project: Fort Collins Actives Modes Plan

MMLOS Draft Revisions and Next Steps

As part of Task 7 of the Fort Collins Active Modes Plan (AMP), Toole Design provided recommendations for how the City of Fort Collins can update their Multimodal Transportation Level of Service (MMLOS) Manual. This memo summarizes the current MMLOS procedure and short-term, mid-term, and long-term steps for the City to update the MMLOS procedure.

Current Procedure

Any development proposal in Fort Collins must follow the latest version of the Larimer County Urban Area Street Standards (LCUASS). Chapter 4 of the document specifically lays out the procedure to prepare a Transportation Impact Study (TIS) for developments within the Larimer County. Furthermore, Appendix H of LCUASS defines the requirements specific to development in Fort Collins. One of the outcomes of the procedure is for the developers to pay a Transportation Capital Expansion Fee (TCEF) to mitigate the impact of their development.

Toole Design reviewed Appendix H of LCUASS and offered recommendations to make it more effective. These comments are in pdf form and are attached to this memo.

Toole Design met with City staff to discuss and identify the following key challenges of the current MMLOS procedure:

- Lack of clear steps and authority to require developments to either implement multimodal improvements or contribute to planned multimodal improvements in/and around the development.
- Lack of coordination between the improvements implemented by the development and the previously planned or approved projects and planning initiatives conducted by the City or other entities.

Draft Recommendation

To address these challenges, Toole Design generated ideas to improve the procedure, shown Figure 1.

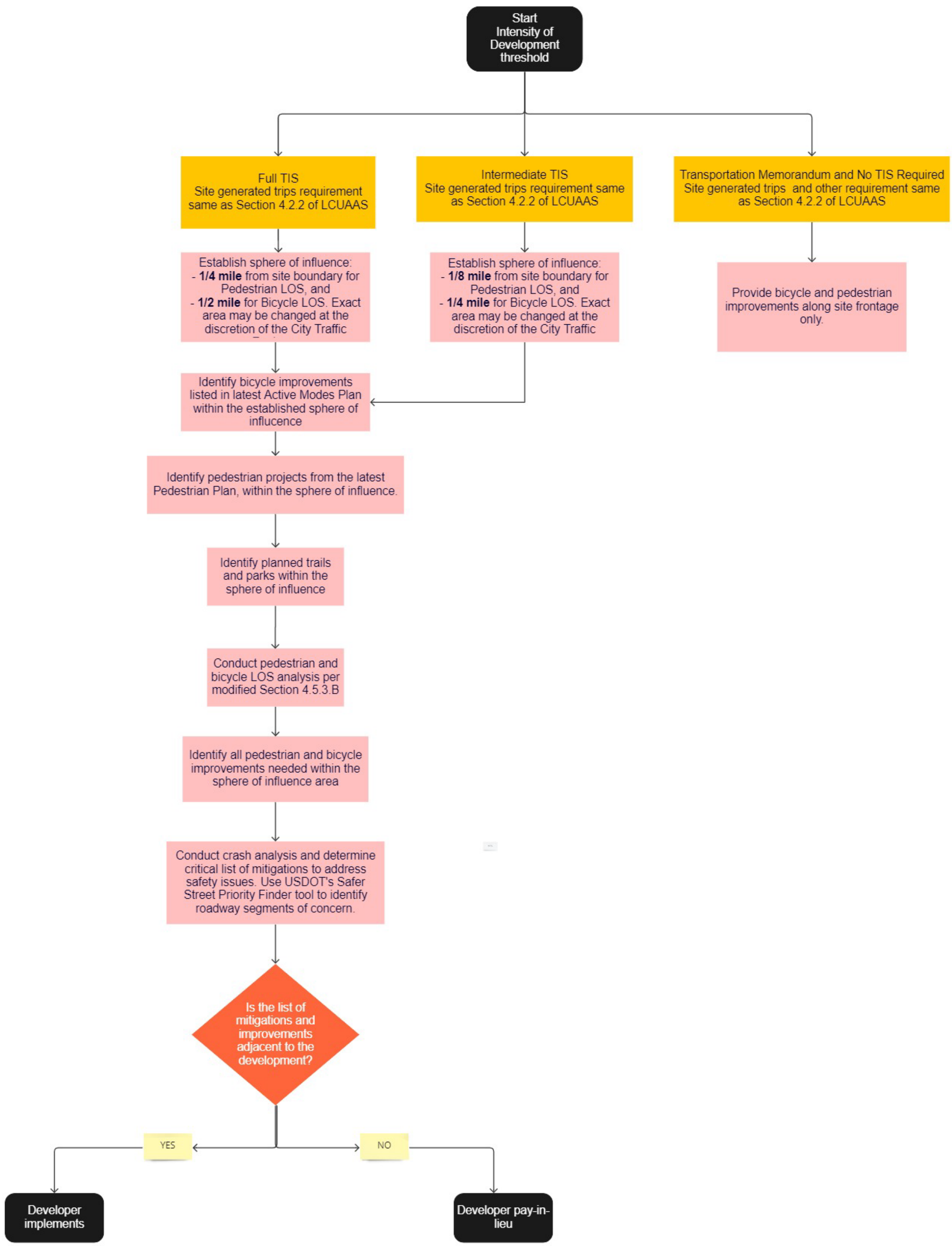

Figure 1. Draft MMLOS Procedure Recommendation

The draft MMLOS procedure accomplishes the following:

- Maintains the three existing types of TIS outlined in LCUASS based on the size of the proposed development: Full TIS, Intermediate TIS, and Transportation Memorandum.
- Clearly defines the study area by establishing sphere of influence for bicycle and pedestrian modes.
- Requires the developer to list the approved multimodal projects in the site's vicinity to assist City staff in making decisions.
- Recommends a new PLOS and BLOS analysis method as outlined below.

Draft MMLOS Analysis Update

One of the challenges of the existing MMLOS procedure is the inability to dictate physical multimodal improvements on the ground. The existing procedure aims to provide connections to bicycle and pedestrian destinations in the vicinity of the proposed development,. However, in practice, the procedure is not able to identify streets that need multimodal improvements. The procedure outlined below aims to rectify the deficiency and provide a comprehensive MMLOS analysis method.

During the Initial Scoping Meeting:

- Identify street segments and intersections within the sphere of influence to analyze.
- Discuss the scope of work, which should include:
    - Identifying previously approved projects impacting study streets and intersections (see Figure 1),
    - Collecting screenline daily traffic volumes on study street segments and peak hour turning movement counts at study intersections,
    - Gathering 5-year crash data for the study street segments and intersections, and
    - Identifying existing deficiencies in bicycle/pedestrian infrastructure, when compared against the bike and pedestrian standards, using Bicycle and Pedestrian LOS, as described below.

Bicycle LOS Analysis:

- Refer to the Active Modes Plan to determine the preferred bicycle facility for the study street segments.
- Identify the curb-to-curb and ROW widths for the study segments.
- Identify constraints to implement preferred bicycle facility for the study street segments
- Develop a cost estimate to mitigate the impacts within the bicycle sphere of influence.
- Develop bicycle trip generation for the development based on the approved Transportation Demand Management (TDM) plan.
- Use the TDM plan to determine the percent of vehicular trip generation anticipated to be converted to bicycle trips. See Table 1 below.
- Determine bike trip distribution using availability of bicycle infrastructure, level of traffic stress, and location of key destinations such as schools, retail hubs, and employment centers.
- Assign bike trips to the bike network within the sphere of influence.
- For each bike network segment, conduct bicycle level of service analysis using following methods.
    - Determine the existing peak hour bike volume for each bike network segment within the sphere of influence.

  - Calculate existing bike lane volume-to-capacity ratio using Desired Bike Flow rate in Table 2 below.
  - Estimate bike trip assignment on the segment, using the above method.
  - Calculate the proposed bike lane volume-to-capacity ratio.
  - Calculate the bike impact proportion by calculating the difference between existing and proposed bike lane capacity. See Table 3 below.

Pedestrian LOS Analysis

- Assess the existing pedestrian condition on study roadways within the sphere of influence. This includes:
  - Presence or lack of sidewalk
  - Quality of sidewalk
  - Location of or lack of safe pedestrian crossings using Fort Collins Crossing Standards
- Determine minimum LOS based on Figure 5 of the LOS Manual.
- Determine actual LOS based on existing conditions.
- Determine proposed LOS based on proposed improvements on the study roadway.
- Determine total cost of improvements for the proposed improvement.
- Determine project proportional cost based on following process:
  - Calculate the percentage of the total cost that is anticipated to be paid by private developments.
  - Identify undeveloped parcels within sphere of influence of the project.
  - Estimate the development potential of undeveloped parcels using existing zoning.
  - Project proportional cost = average of proposed development size for each type of development / development potential of undeveloped parcels for the type of development

Table 1. Bicycle Trip Generation Criteria, Peak Hour Bicycle Trip – Draft Proposal

Infrastructure Criteria	No approved TDM Plan	With <5 TDM points	With >5 TDM points
There are no existing bicycle facilities connecting to the development	2% of vehicular trips	3% of vehicular trips	5% of vehicular trips
There are existing but deficient bicycle facilities (do not meet AMP standard), without key destinations within sphere of influence	4% of vehicular trips	6% of vehicular trips	8% of vehicular trips
There are existing but deficient bike facilities and key destinations within sphere of influence	6% of vehicular trips	8% of vehicular trips	12% of vehicular trips
There are existing bicycle facilities	8% of vehicular trips	12% of vehicular trips	18% of vehicular trips

Table 2. Bicycle Desired Flow Rate

Bike Lane Width (ft)	Peak Hour Directional Volume
One-way PBL	
5.5 - 8.5	150
8.5 - 10	750
Two-way PBL	
9 - 12	150
12 - 16	350

Table 3. Bike Impact Fee Calculation Example – Draft Proposal

Desired Bike Flow Rate / hr	150	From Draft AASHTO Bike Guide Table 7.3 and 7.4
Existing Bike Volume / hr	130	From counts
Threshold for bike fee contribution	80%	Determine by local jurisdiction
Existing Bike Lane Capacity Ratio	0.87	
Site Gen Bike Trip	25	From bike trip generation table
Total Bike Volume	155	
Proposed Bike Lane Capacity Ratio	1.03	
Bike Impact Proportion	17%	Difference between existing and proposed ratio
Cost of Bike Improvement	$ 2,500,000	Random example
Length of project	5	mile
Cost / mile	$ 500,000	
Segment in bike influence area	0.5	mile
Total cost in influence area	$ 250,000	
Bike Impact Fee	$ 41,666.67	

Next Steps

Toole Design presented the above draft revisions to City staff on July 26, 2022. The meeting illustrated that a wholesale effort to update the City's MMLOS procedure would require effort beyond the contract of the Active Modes Plan. The City of Fort Collins can take the steps below to advance this effort.

Short-Term Steps

1. Update TCEP procedure / guidance to allow the use of the funds collected for specific multimodal project within the sphere of influence of the proposed development.

Mid-Term Steps

1. Finalize the proposed MMLOS procedure recommendation (Figure 1), including the proposed BLOS, PLOS, and Bike Impact Fee calculation procedure.
2. Resolve how this new process will align with existing TIS guidelines.

Long-Term Steps

1. Update the TIS guidelines to focus on person trips rather than vehicular trips. This will require substantial effort and coordination with various departments.