Guidance for Pedestrian and Bicycle Facilities at Expressway Interchanges in Southeastern Pennsylvania

DECEMBER 2019

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PLANNING COMMISSION

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CHAPTER 1: INTRODUCTION

Introduction

The development of safe bicycle and pedestrian facilities along arterial roads is critical to improving local mobility in dense urban areas and suburban centers. Arterials often have the right-of-way width needed to include pedestrian and bicycle facilities but can be difficult to safely retrofit due to complex highway intersections and interchanges. Interchanges are often designed without pedestrians or bicyclists in mind and tend to prioritize vehicular speeds and volumes, making them difficult and dangerous for pedestrians and bicyclists to cross.

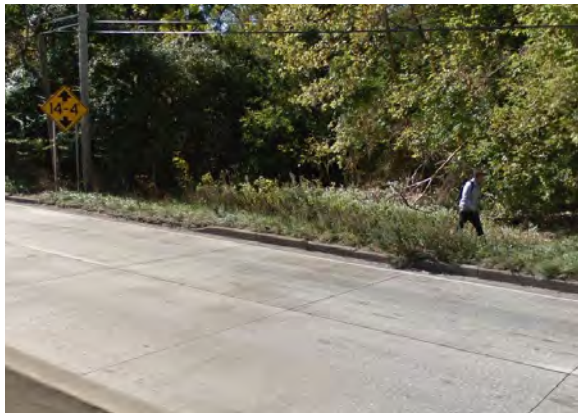
Where feasible, new or reconstructed interchanges should be designed to include high-quality bicycle and pedestrian facilities to link existing networks. With funding opportunities at a premium, retrofitting existing interchanges using the approaches detailed in this report can improve comfort and provide safety benefits for cyclists and pedestrians. Funding mechanisms emphasizing low-cost, fast-turnaround improvements, such as our region's Pennsylvania Department of Transportation (PennDOT) Connects Bike-Friendly Resurfacing initiative, can be leveraged to improve interchanges when a full redesign is not possible.

This report used state and national best practice guidance to develop guiding principles, a safety research overview, common issues, best practice treatments, and local conceptual design at sites in Bucks, Chester, Delaware, and Montgomery counties, and the City of Philadelphia.

Problem Statement

Why is it so difficult to construct bicycle and pedestrian facilities at interchanges?

Historically, the design of interchanges at arterials has prioritized ease of access for vehicular traffic onto highways over local connections made by non-motorized users. The typical result is a wide roadway with high speeds, high traffic volumes, wide crossings, free-flow ramps, and little or no right-of-way reserved for non-motorized users. These engineering decisions tend to increase speeds, meaning that vehicles are less likely to stop or slow down. This creates a high-stress and potentially dangerous condition that can increase exposure to crashes for non-motorized users.



A pedestrian walking along Pottstown Pike near the Exton Bypass interchange in East Whiteland Township, Pennsylvania.

Source: Google, 2017

Why are bike and pedestrian facilities important to include at interchanges?

1. Building high-quality bicycle and pedestrian facilities on arterials through interchanges can provide better local mobility and mode choice and provide safer conditions for vulnerable users that do not have other transportation options. In the past, expressway and interchange construction introduced barriers to local connectivity, and it is important to mitigate those outcomes where possible.

2. Using separated facilities and high-visibility crossings can reduce exposure to crashes and create a lower-stress environment for bicycle and pedestrian users.

3. Giving users the more attractive option to traverse the interchange on foot or by bike can reduce the number of local trips made by car and better connect existing land uses.

4. Bicycle and pedestrian facilities can also help drivers recognize that they have left the limited access environment of a highway and entered an area in which they should lower their speed and be alert for pedestrians and bicyclists.

Stakeholder Collaboration

A steering committee of officials from Bucks, Chester, Delaware, and Montgomery Counties, the City of Philadelphia, the Bicycle Coalition of Greater Philadelphia, and PennDOT, were brought together to provide feedback on contents of this guide. Smaller meetings with each of the counties, as well as local stakeholders, informed the case study designs found in Chapter 4.

How to Use This Guide

This guide is a reference for planners, engineers, officials, and community members to understand the best practices in building bicycle and pedestrian facilities on arterials through interchanges.

County officials and PennDOT should look to the guidance to help inform their preliminary designs, their outreach to communities, and to advocate for bicycle and pedestrian facilities along PennDOT roadways where appropriate.

Analysis and discussion with PennDOT will be required to determine the feasibility of a design for a state route. This guide provides conceptual guidance and case studies that include best practice treatments found in the United States.

Other Guidance

This document relies on the following published design guides to inform its designs. They should be considered supplementary material for designers.

- ***Roundabouts: An Informational Guide***, U.S. Department of Transportation (2000);
- ***Manual on Uniform Traffic Control Devices for Streets and Highways*** *(MUTCD)*, Federal Highway Administration (FHWA) (2009);
- ***Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians***, California Department of Transportation (2010);
- ***Guide for the Development of Bicycle Facilities***, *Fourth Edition*, American Association of State Highway and Transportation Officials (2012);
- ***Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges***, Institute of Transportation Engineers/ Fehr and Peers (2016);
- ***Design Manual***, Washington State Department of Transportation (2015).
- ***Small Town and Rural Multimodal Networks***, Federal Highway Administration (2016);
- ***Bicycle Facility Design Toolkit***, Montgomery County Maryland Planning Department (2019); and
- ***Don't Give Up at the Intersection: Designing All Ages and Abilities Crossings***, National Association of City Transportation Officials (NACTO) (2019);

CHAPTER 2: BICYCLE AND PEDESTRIAN TREATMENTS AT INTERCHANGES

Introduction

Every interchange has its own set of challenges related to its context, users, speeds, and vehicle volumes. With this in mind, there are a variety of treatments that can be used to assure that bicycle and pedestrian facilities are highly recognizable, easy to understand, and safe and comfortable to use. The following chapter discusses important considerations when designing and describes treatments that can be used together to create high-quality facilities.

Intersection Signal Control

In high-speed environments, such as interchanges, the preferred intersection control method for accommodating pedestrians and bicyclists is signal control. Signals provide maximum separation between highway-bound vehicles and pedestrians and cyclists crossing highway ramps. Signal control clarifies spatial and temporal right-of-way, and opens the opportunity for dedicated phasing to protect pedestrians and cyclists from turning vehicles. If signal control is not possible, stop control provides some of the same benefits to pedestrians and cyclists.

However, by bringing vehicles to a complete stop rather than allowing them to merge with oncoming traffic at high speeds, signal and stop control create additional delay for drivers. Because most interchanges are designed with minimal driver delay as a priority, many interchanges consist entirely of yield-controlled ramps. Signalized interchanges often include yield-controlled slip ramps for right-turning vehicles.

The prevalence of yield-controlled ramps at interchanges minimizes delay for drivers but creates safety issues for non-motorized uses. To successfully merge, drivers must accelerate to highway speeds on on-ramps and maintain arterial speeds on off-ramps. Drivers are disincentivized from yielding to non-motorized users because it makes the downstream merge more difficult. Further, trailing drivers do not expect other drivers to suddenly slow down or stop, creating rear-end crash risk for drivers who do yield to pedestrians or cyclists. For these reasons, a fully signalized interchange with right-angle approaches is preferred for accommodating non-motorized users. When possible, unsignalized interchanges should be redesigned to include right-angle geometry and traffic signals. The following section describes strategies that can be used to improve non-motorized movement through interchanges with signalized intersections.

Signal Phasing

Signal phasing is an important tool for designing bicycle- and pedestrian-friendly interchanges. Existing pedestrian signals at interchanges may require long waits for non-motorized users due to high volumes of turning vehicles and, in many cases, may not provide enough time for users to fully cross a roadway before the phase ends. Adequate crossing time based on roadway width should be provided for all crossings with marked crosswalks. A common benchmark to calculate crossing time is 3.5 feet per second, but additional time should be provided when feasible to accommodate slower walkers. Additionally, the following phasing strategies can be used to create a more comfortable crossing experience for users.

The I-5 interchange at N. Rosa Parks Way in Portland, Oregon, has ramps that meet the intersections at near 90-degree angles, allowing for easier bicycle and pedestrian crossings.

Source: Google, 2019

Protected Bike Phase with Bike Signal

A protected bike phase allows parallel through movements for vehicular traffic during the bicycle phase but provides a red arrow for conflicting turning movements (Figure 1). Bicyclists are given a red signal when conflicting vehicle turns are allowed. This phasing strategy fully separates through bicycle movements from turning vehicles, and is most appropriate at intersections with high turning volumes (over 150 turns per hour, where vehicle speeds exceed 30 miles per hour, where vehicle yielding rates are low, or where multiple turning lanes cross the bike lane).

A protected bike phase is communicated to cyclists and drivers through the use of a bike signal. Protected bike signals have interim approval in the MUTCD.

The addition of a protected bike phase may result in delay and impact capacity. At interchanges with lower bicycle volumes, it may be beneficial to install a bicycle detector to enable bike-actuated phasing (see page 11).

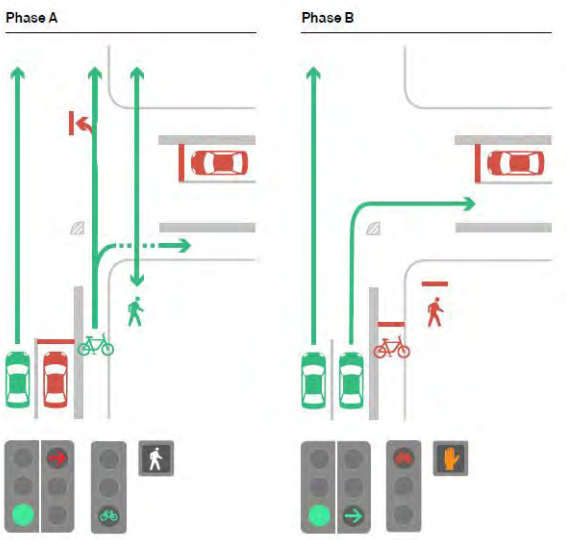
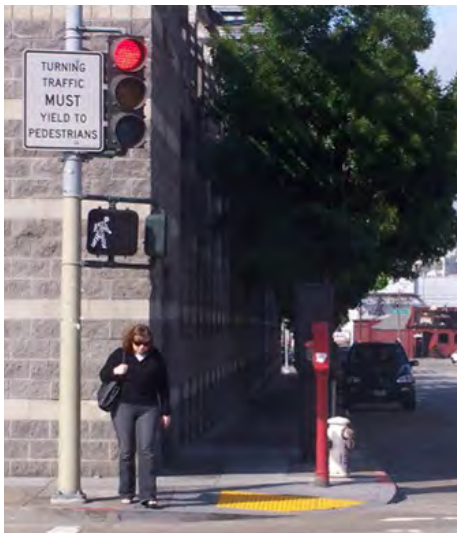


Figure 1 | Protected Bike Phase with Bike Signal

Source: NACTO

Leading Pedestrian Interval (LPI)

An LPI improves pedestrian visibility and reinforces pedestrians' right-of-way over turning vehicles in high-conflict areas by using a first phase that provides three to seven seconds for pedestrians to begin crossing the street in the same direction as through traffic before through and turning vehicles are given the green light. Turning vehicles must then yield to pedestrians already in the crosswalk. LPIs have been shown to reduce pedestrian-vehicle crashes by 60 percent at intersections.[1] This strategy can also be used to benefit bicyclists by installing a "Bikes Use Pedestrian Signal" plaque.



A leading pedestrian interval crossing.

Source: FHWA

Context-Specific Facilities

When selecting bicycle facilities on arterial roadways, it is important to consider traffic speed and volumes. Research shows that speed has a considerable impact on the likelihood of a pedestrian or cyclist surviving a crash with a vehicle (see Figure 2). With this in mind, it is important to provide protected facilities for non-motorized users when needed, and to use treatments to slow down vehicles in areas with conflict points, such as intersections and ramps.

FHWA's Bikeway Selection Guide uses the table found in Figure 3 to provide guidance on how motor vehicle speeds and volumes should be considered when choosing a bicycle facility type. Although these are preferred standards, considerations on facility type may be flexible based on context. In general, separated facilities, such as sidepaths, are the most appropriate for arterials due to their higher speeds and volumes. However, many arterials do not have the right-of-way necessary to accommodate an off-road facility. In these instances, a separated bike lane or two-way cycle track, along with striping and signage to indicate conflict points, should be used. More information on bicycle facility types is provided on pages 14 and 15.

Use of Green Paint

The optional use of green-colored pavement for bike lanes (IA-14) has interim approval from the MUTCD and is "used as a traffic control device to designate where bicyclists are expected to operate, and areas where bicyclists and other roadway traffic might have potentially conflicting weaving or crossing movements."

Figure 2 | Crash Death Statistics by Speed
Source: City of Philadelphia

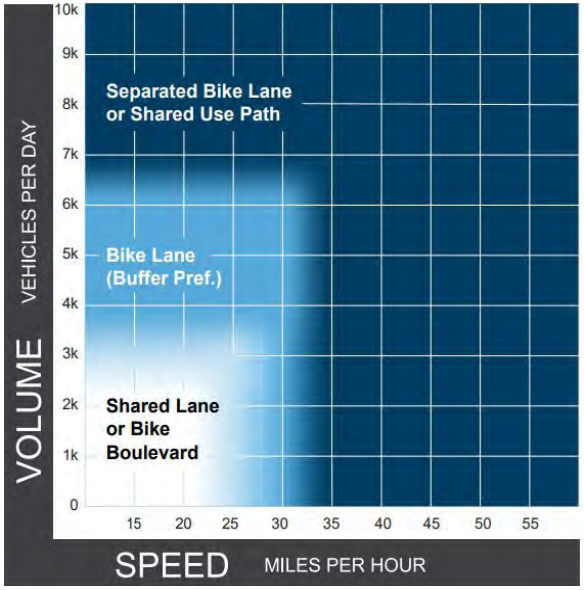


Figure 3 | Bicycle Facility Selection Table
Source: FHWA

According to FHWA, "The research has also shown that bicyclists and motorists both have a positive impression of the effect of the green colored pavement, with bicyclists saying that they feel safer when the green colored pavement is present, and motorists saying that the green colored pavement gives them an increased awareness that bicyclists might be present and where those bicyclists are likely to be positioned within the traveled way."

Although the use of green paint is considered best practice in high-conflict zones, it is not required by FHWA. Costs associated with upkeep and wear of green paint should be considered when developing a design. PennDOT does not maintain green paint, so its use in a PennDOT-controlled roadway would require an upkeep agreement with the municipality.

Interchange Treatments

The following design tools shown in Tables 1-7 are taken from the best practice guides named on page 3. All of these techniques have been used nationally in similar interchange environments, despite the fact that some treatments may not yet be approved in local guidelines. As with any treatment, final designs must consider proper Americans with Disabilities Act (ADA) compliance, emergency vehicle access, turning radii for large vehicles, drainage, sweeping, and snow removal during winter operations.

Pedestrian Crossing Treatments

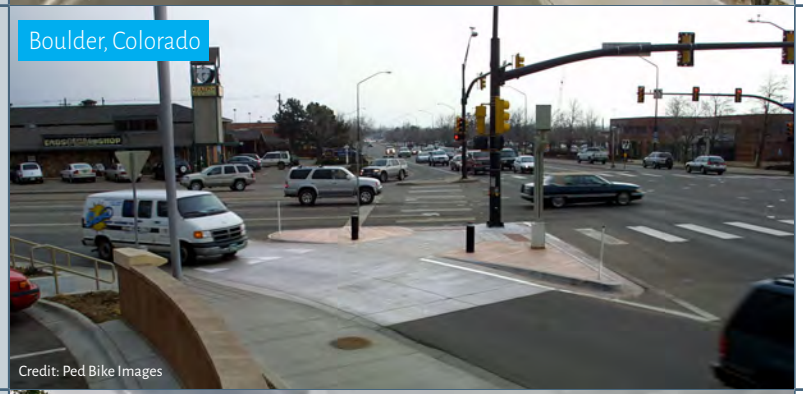
Treatment		What it is	Where it works	Benefit
High Visibility Crosswalks		Lighting, advanced or in street warning signage, pavement markings, and geometric design that indicate where pedestrians should cross a roadway.	At signalized and unsignalized intersections.	Increases motorist yielding and channelization of pedestrians.
Raised Crosswalk at Channelized Right Turn		Brings the roadway to the level of the sidewalk at a channelized turn lane to improve the visibility of crossing pedestrians and to slow down vehicles as they move through the turn.	Channelized right-turn lanes where pedestrian crossings exist or are proposed. Limit of 3,500 Annual average daily traffic (AADT) in Pennsylvania.	Provides traffic calming and improved crossing at unsignalized channelized turns.
Pedestrian Refuge Islands		A space in the center of a crosswalk that provides protection for pedestrians crossing the roadway.	In the center of a multilane roadway with crossings that has a minimum of six feet of right-of-way in the median.	56 percent reduction in pedestrian crashes.[2]

Table 1 | Pedestrian Crossing Treatments, Part One

Pedestrian Crossing Treatments

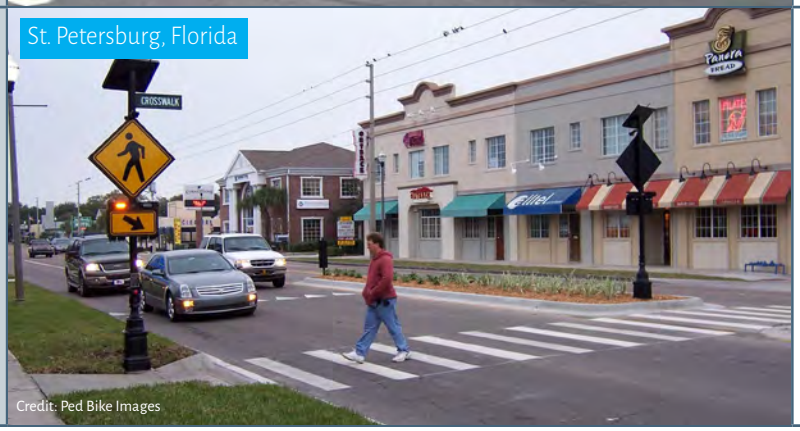
Treatment		What it is	Where it works	Benefit
Curb Extensions	 Issiqua Highlands, Washington Credit: Ped Bike Images	An extension of the curb into the roadway at an intersection.	At intersections with pedestrian crossings.	Reduces crossing distance, lowers the speed of turning vehicles, and improves visibility of pedestrians at intersections.
Centerline Hardening	 New York, New York Credit: NACTO	Modular curbs with or without delineators placed along the centerline next to left turn lanes.	At signalized intersections where pedestrian islands are not feasible, but protection from turning vehicles is needed.	Helps slow and delineate the appropriate path for turning vehicles at intersections.
Rectangular Rapid Flashing Beacon	 St. Petersburg, Florida Credit: Ped Bike Images	User-actuated lights that supplement warning signs. They can be activated by pedestrians manually by a push button or passively by a pedestrian detection system.	At unsignalized intersections or mid-block crossing.	Increases yielding from 18 percent to 81 percent over unsigned crossings.[3]

Table 2 | Pedestrian Crossings Treatments, Part Two

Bicycle Treatments

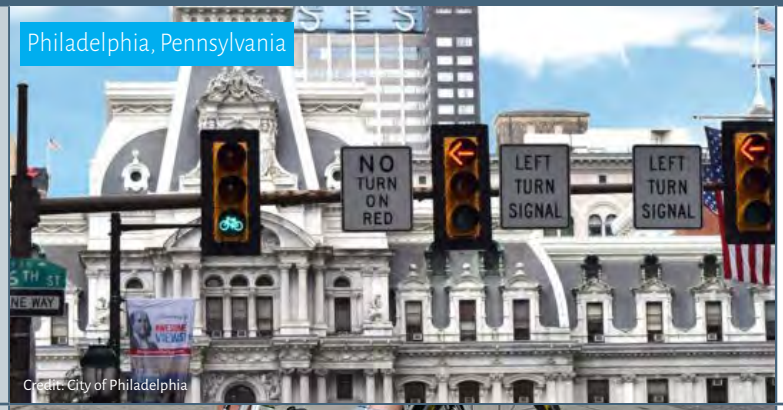
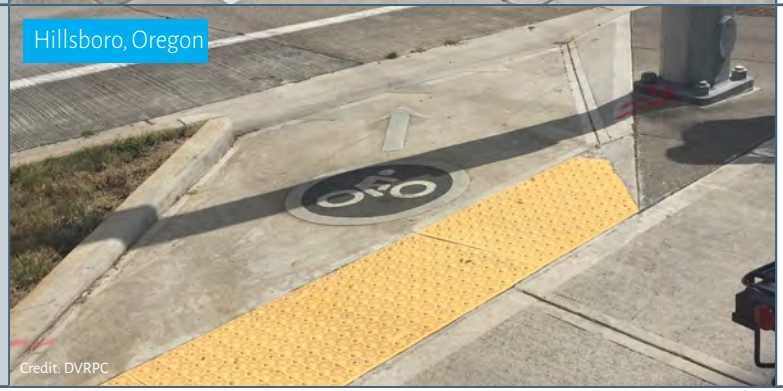
Treatment		What it is	Where it works	Benefit
Bicycle Signal		A signal head specifically for bicycle lane users at intersections that indicates when a bicycle dedicated signal phase begins and ends.	Intersections with vehicle-bicycle turning conflicts. Bicycle signals have interim approval in the MUTCD, meaning they may be used while official rule making is pending.	Provides priority for cyclists at intersections by separating bicycle movements from conflicting turning movements. This may improve real and perceived safety in high-conflict areas.
Bicycle Detection and Actuated Signal		A signal at which a cyclist can alert the signal controller that they need to cross an intersection by pushing a button or being automatically detected (inductive loop, video, or microwave) by placing themselves in a marked area.	At intersections with bicycle signal heads, bicycle-specific phasing, or where vehicle detection is required to trigger a green phase but motor vehicle volumes are low.	Reduces delay for bikes and provides adequate time to cross.
Bicycle Entry/Exit Ramp		A ramp from the bike lane onto or off of a sidepath, trail, or sidewalk.	Along arterials in advance of unsignalized ramps or complex/high-volume intersections.	Provides riders the option of exiting a bicycle facility in advance of a ramp crossing or high-volume intersection and allows them to dismount and cross with pedestrians.

Table 3 | Bicycle Treatments, Part One

Bicycle Treatments

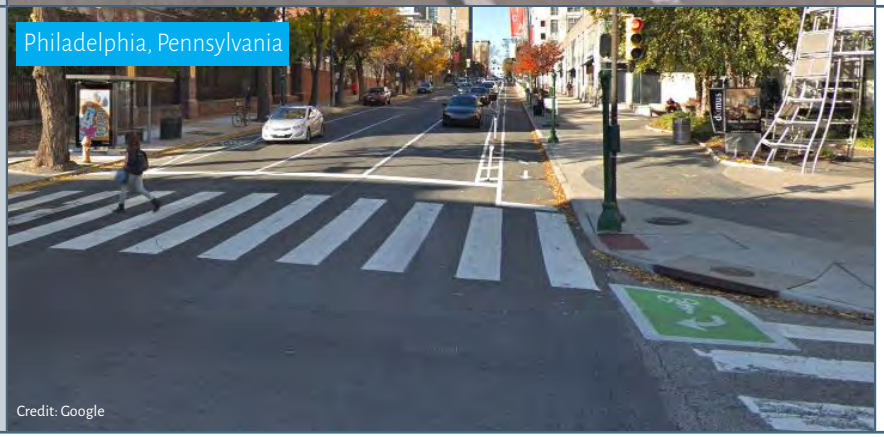
Treatment		What it is	Where it works	Benefit
Profiled Striping	 Hillsboro, Oregon Credit: Washington County, OR	Edge-line striping that features extruded markings that provide a rumble effect.	Roadways with unprotected bicycle facilities.	Creates a detectable warning for vehicles encroaching on the bike lane.
Bicycle-Friendly Edge-Line Rumble Strips	 Urbana, Illinois Credit: Google	A three-eighths-inch deep set of rumble strips set on top of the edge line or within the buffer of a bicycle lane that alerts drivers that are drifting off the roadway and encroaching on a bicycle lane. These strips should include gaps to allow bicycles to transition out of the lane.	On higher speed roadways with unprotected bicycle facilities.	Reduction of 13 percent to 51 percent in single-vehicle run-off-road fatal and injury crashes.[4]
Two-Stage Turns	 Philadelphia, Pennsylvania Credit: Google	Painted boxes that provide a way for cyclists to safely make left turns from a bicycle facility located on the right side of the roadway, or right turns for facilities located on the left side of a roadway. The boxes properly orient cyclists with stopped cross traffic, allowing them to wait for a green light.	At signalized multilane intersections with left turns where there is a right-side bicycle lane or cycle track. Requires No Turn On Red (R10-11). Left Turn May Use Turn Box (D11-20) and Left Turn Box (D11-20a) are optional.	-Helps cyclists to make turns at busy intersections more easily. -Defines space for cyclists. -Orients bikes perpendicularly to cross traffic.

Table 4 | Bicycle Treatments, Part Two

Bicycle Treatments

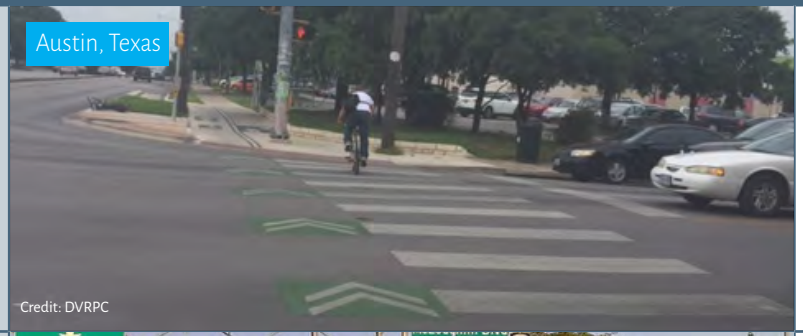
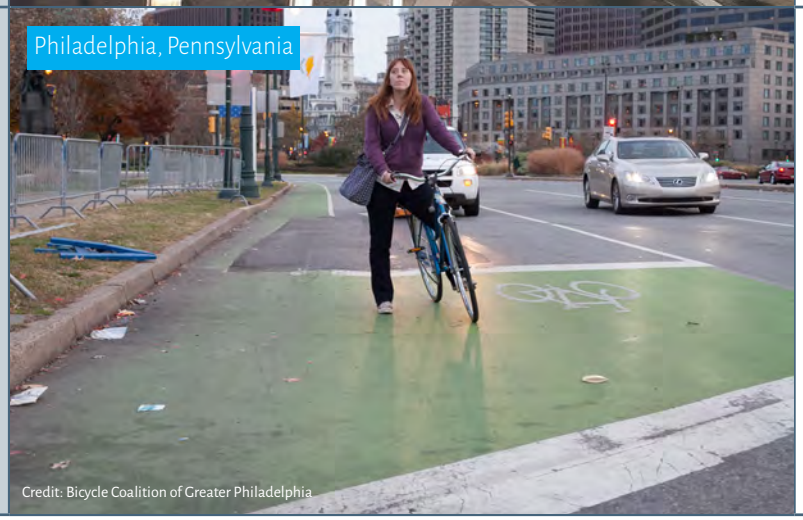
Treatment		What it is	Where it works	Benefit
Crossbike	 Credit: DVRPC	Arrows and dashes that help to guide bicyclists through intersections by providing a clear and direct path.	At intersections with bicycle lanes.	Markings make bicyclists' paths more predictable for drivers, reinforcing that they have priority over turning vehicles and bringing attention to their presence.
Conflict Markings	 Credit: Ped Bike Ima	Striped lines and colored paint that identify the correct alignment for cyclists through an intersection.	At unsignalized ramps and other areas where the paths of bicycles and cars are in conflict.	The use of paint in conflict zones signals to motorists that bicycles use this space and to proceed through it with caution.
Bike Boxes	 Credit: Bicycle Coalition of Greater Philadelphia	Designated areas located at the head of a traffic lane at a signalized intersection that provide bicyclists with a safe and visible way to get ahead of queuing traffic during a signal phase. Boxes are usually painted green or red and sometimes feature a short curbside lane that helps create space for cyclists to move to the front of the vehicle queue.	At intersections in combination with prohibited right on red.	Bike boxes provide increased visibility for bicyclists, reduce vehicle delay, mitigate turning conflicts, and reduce encroachment on pedestrian crosswalks by cyclists and motorists.

Table 5 | Bicycle Treatments, Part Three

Bicycle Treatments

Treatment		What it is	Where it works	Benefit
Conventional Bicycle Lane		A lane in the right-of-way exclusively for cyclists and non-motorized vehicles that is delineated by a solid line and bicycle symbol. A conventional bike lane width should be five to six feet.	On lower-volume/speed arterials where existing lanes can be narrowed or shoulders can be used to create a bicycle facility.	Increases bicycle comfort and confidence by creating a space separate from motor vehicles.
Buffered Bicycle Lane		A bicycle lane with a buffer created by painted markings. Buffered bike lanes are typically five-to-six-foot lanes with a three-foot buffer (1.5-foot minimum).	On arterials with low to moderate speeds and volumes where lanes can be narrowed or shoulders can be used to create a new facility.	Delineates a bicycle lane from a travel lane using paint and provides additional space between cyclists and drivers.
Protected Bicycle Lane		A bike lane that is delineated from the travel lane using paint and vertical deflection, such as a curb or flexible delineator, to provide additional space to improve comfort.	On arterials with moderate to high volumes and speeds, where lanes or shoulders can be taken or narrowed to create a facility.	Increases bicycle comfort by physically separating bicycle traffic from motor vehicle traffic.

Table 6 | Bicycle Facilities, Part One

Bicycle and Pedestrian Treatments

Treatment		What it is	Where it works	Benefit
Two-Way Cycle Track	 Pottstown, Pennsylvania Credit: Bicycle Coalition of Greater Philadelphia	Physically separated set of bike lanes that allows bicycle movement in both directions on the same side of a street. Minimum width 8 feet; desired width 12 feet.	Along arterials with high volumes and speeds that do not intersect frequently with driveways and intersections. This design can create issues for roadway user expectations at intersections and can limit intersection design options.	Provides two-way dedicated and protected space to cyclists.
Sidepath	 Northwest Landing, Washington Credit: Ped Bike Images	Sidepaths are bidirectional paved facilities suitable for both bicyclists and pedestrians that run alongside a roadway. Sidepaths are typically separated from the roadway with a grass median or a barrier. Minimum width eight feet; desired width 12 feet; lateral separation five feet.	On arterials with higher speeds and volumes where additional space exists beside the cartway that can be used to build a separated facility.	Provides a low-stress facility along roads with moderate to high traffic.
Sidewalks	 Chapel Hill. North Carolina Credit: Ped Bike Images	A raised walkway that provides a separation for pedestrians from vehicular traffic.	Alongside roadways.	Reduction of 65 percent to 89 percent in crashes involving pedestrians walking along roadways.[5]

Table 7 | Bicycle Facilities, Part Two

Low-Cost Interim Solutions

The following are low-cost interim materials that can be used along with paint to construct separated bicycle facilities along an arterial. Facilities should consider using both vertical and horizontal elements to provide protection.

Flex Posts

Flex posts (also known as flexible delineators) are the most commonly used device to create vertical separation between vehicles and bikes in separated bike lanes because of their visibility, ease of installation and removal, and low cost. Flex posts tend to have a shorter life span than other more durable solutions and can be difficult to sweep around depending on the size of the facility and the machinery being used.

Parking Stops

Parking stops help provide horizontal separation and are highly durable, low cost, and easy to install. In an interchange environment, intermittent use with a vertical element, such as a delineator, as shown in Figure 4, can be a good interim solution for a separated facility.

Jersey Barriers

Jersey barriers, either plastic or concrete, provide excellent vertical and horizontal protection for bike lanes and are highly durable. Jersey barriers are more costly than other interim solutions and can be more difficult in terms of managing stormwater and sweeping.

Figure 4 | Low-Cost Interim Solutions for Separated Bicycle Lanes

Source: People for Bikes, 2014

CHAPTER 3: DESIGN RECOMMENDATIONS FOR COMMON RAMP CONFIGURATIONS

Introduction

The facilities and treatments discussed in previous chapters can be applied to interchanges in the region to improve safety and comfort for pedestrians and cyclists. Although the ideal multimodal interchange would feature right-angle ramp intersections and signal control, many of the interchanges with arterial roadways in the region consist primarily of unsignalized, free-flow ramps. Where funding and other considerations prevent major ramp reconstruction and signalization, it is still possible to retrofit existing interchanges to improve multimodal access and safety.

The following section discusses principles for designing bicycle and pedestrian facilities at interchanges and illustrates the three major on- and off-ramp types found in the region and example designs to address key issues. Interchange elements to consider when redesigning include intersection control and the number of traffic lanes and ramp lanes. Treatments will sometimes differ between on-ramps and off-ramps due to different driver behaviors associated with each. A decision tree framework is provided to determine the most appropriate bicycle lane configuration under various conditions.

This report does not provide guidance for new alternative interchange types (such as Diverging Diamond Interchanges) due to their rarity in the region. However, the forthcoming ***Guide for Pedestrian and Bicycle Safety at Alternative Intersections and Interchanges*** (National Cooperative Highway Research Program 07-25), will touch on these topics.

Principles for Designing Bicycle and Pedestrian Facilities at Interchanges

This guidance used eight primary principles for designing bicycle and pedestrian facilities on arterials at interchanges (see Table 8). These principles are intended to improve safety by reducing speeds and making facilities easy to understand and use for all modes.

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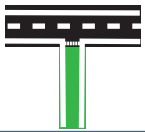
	**1. Square up the intersections** Where possible, make ramps meet the arterial at a 90 degree angle in order to force motorists to take turns at a slower speed.
	**2. Slow it down** Where appropriate, use treatments that reduce speed. Vehicle speeds have a documented impact on the severity of injuries in bicycle and pedestrian crashes.
	**3. Minimize exposure to conflicts** Shorten crossing distance and separate signal phases to reduce pedestrian and cyclist exposure.
	**4. Provide adequate sight distance** Design ramps to provide appropriate sight distance at bicycle and pedestrian crossings, and markings, signage, and signals throughout.
	**5. Clarify the right-of-way priority** Use markings, signage, and signals to indicate throughout the interchange who has the right-of-way.
	**6. Keep it direct** Keep pedestrian and bicycle paths as direct as possible and avoid precluding crossings. Consider distance, time, and effort needed to get through the interchange in the way it is designed.
	**7. Access for all** Aspire to design facilities that can be used by people of all ages, abilities, and skills at all times of day. This means creating well-lit facilities that follow the ADA, as well as Federal Highway Administration (FHWA) guidance on appropriate facilities based on speed and traffic volume.
	**8. Continuity** Make sure that your design connects into an existing bicycle or pedestrian network so that users are not stranded in an unsafe condition.

Table 8 | Principles for Designing Bicycle and Pedestrian Facilities at Interchanges

Source: DVRPC, 2019

Interchange Design Decision Tree

The following designs illustrate best practices for a number of common interchange configurations in the region. Pedestrian facilities require similar treatments across interchange types: a sidewalk or shared-use path and highly visible ramp crossings with minimal crossing distance.

Bicycle facility design, on the other hand, will differ depending on a number of factors, including intersection control and lane configuration. The decision tree in Figure 5 provides guidance for deciding which ramp design approach is most appropriate. All design decisions should be balanced by implementation considerations, such as funding, maintenance, and roadway constraints.

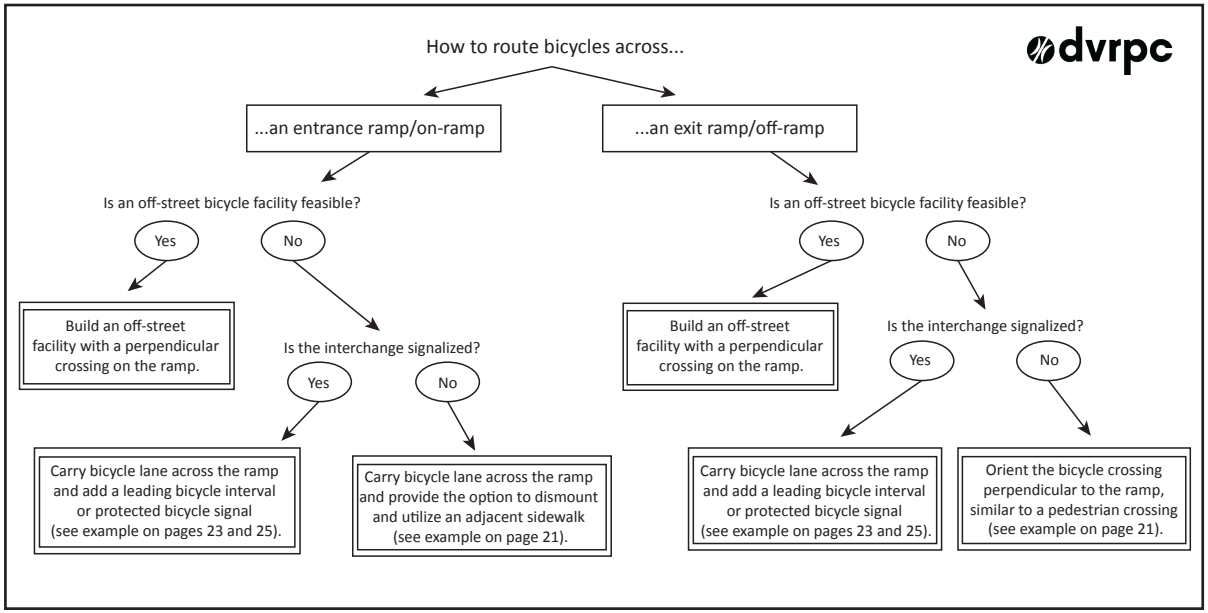


Figure 5 | Ramp Crossing Decision Tree

Source: DVRPC, 2019

UNSIGNALIZED SINGLE-LANE ON- AND OFF-RAMP ISSUES

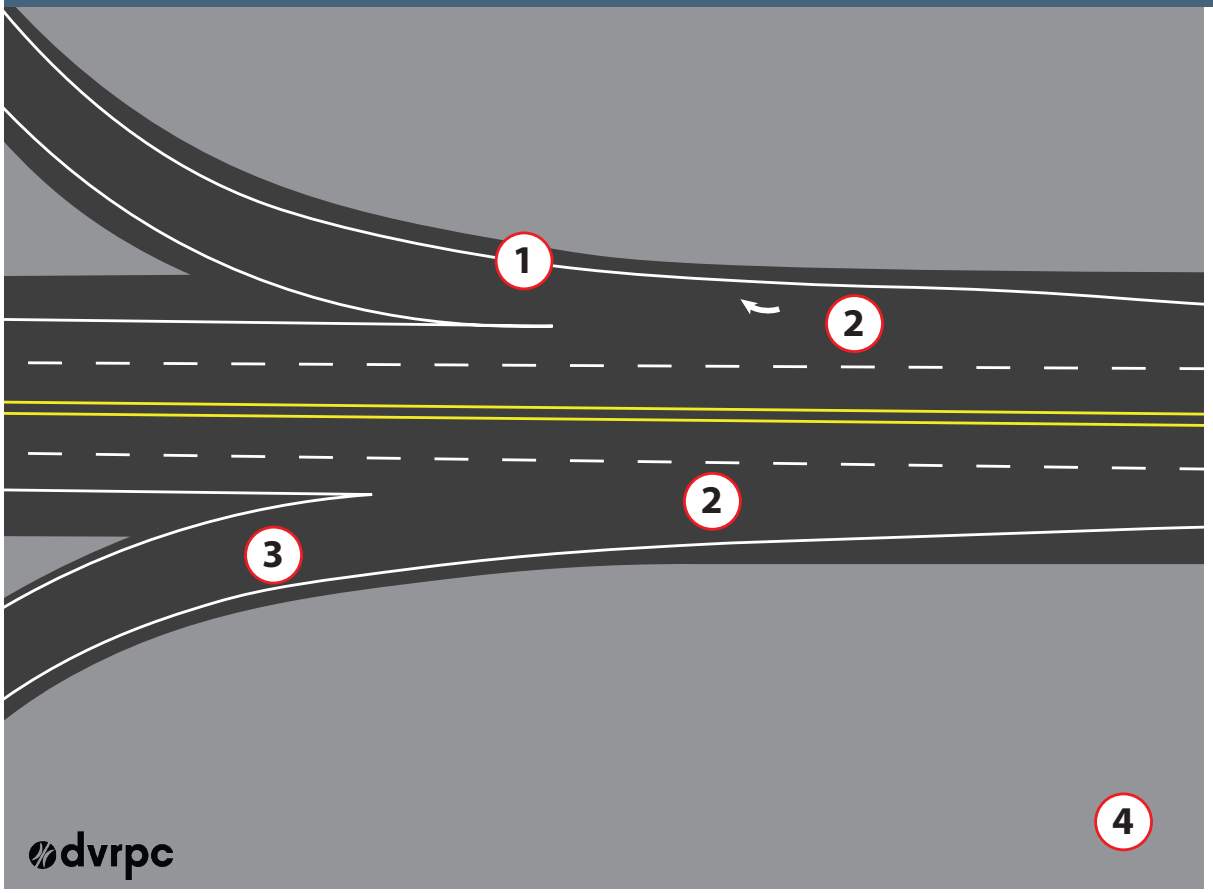


Figure 6 | Unsignalized Single-Lane On- and Off-Ramp Issues

Source: DVRPC, 2019

Issues at Unsignalized Single-Lane On- and Off-Ramps

1) Vehicles accelerate to highway speed.
2) A long conflict zone makes it unclear where vehicles will move over. This makes it difficult for bicyclists to judge the best path (see Figure 6).
3) Drivers using off-ramps are focused on merging with oncoming traffic and may not be looking for bicyclists or pedestrians. Obstacles in the line of sight may exacerbate this issue.
4) Overall, most unsignalized interchanges are designed to allow drivers to maintain high speeds. This makes yielding to cyclists or pedestrians difficult and potentially dangerous.

An on-ramp crossing in Philadelphia, Pennsylvania.
Source: Google, 2019

An on-ramp crossing in Cambridge, Massachusetts.
Source: Google, 2019

An off-ramp crossing in Needham, Massachusetts.
Source: Google, 2019

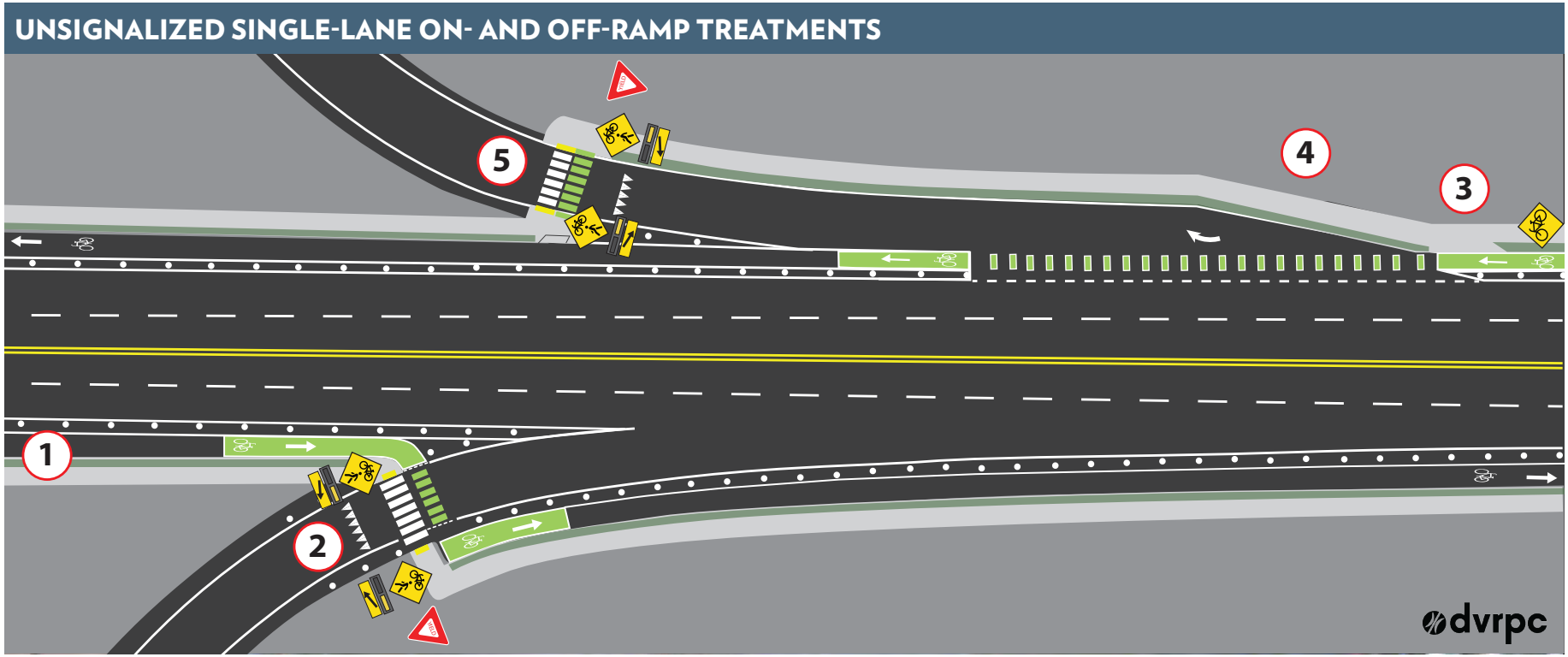


Figure 7 | Unsignalized Single-Lane On- and Off-Ramp Treatments

Source: DVRPC, 2019

Treatments at Unsignalized Single-Lane On- and Off-Ramps

1) Provide sidewalks, protected bicycle facilities, signage, and flexible delineators to guide bicyclists and pedestrians across the on-ramp perpendicularly (see Figure 7).
2) Use rapid flashing beacons, yield markings, an ADA-compliant crosswalk, and a bicycle intersection crossing to provide a safer crossing.
3) At the unsignalized off-ramp, provide bicycle signage in advance of the ramp, as well as an exit ramp from the bicycle lane that allows less confident riders to cross the ramp perpendicularly with pedestrians.
4) Mark vehicle entrance onto ramp with conflict markings to show that bicycles have priority.
5) At the unsignalized off-ramp, use paint and signage to guide bicyclists and pedestrians across the on-ramp perpendicularly. Use rapid flashing beacons, yield markings, and ADA-compliant crosswalk to provide a safer crossing.

Unsignalized off-ramp crossing with a rectangular rapid flashing beacon on the Hawthorne Bridge in Portland, Oregon.

Source: DVRPC, 2019

SIGNALIZED SINGLE-LANE ON- AND OFF-RAMP ISSUES

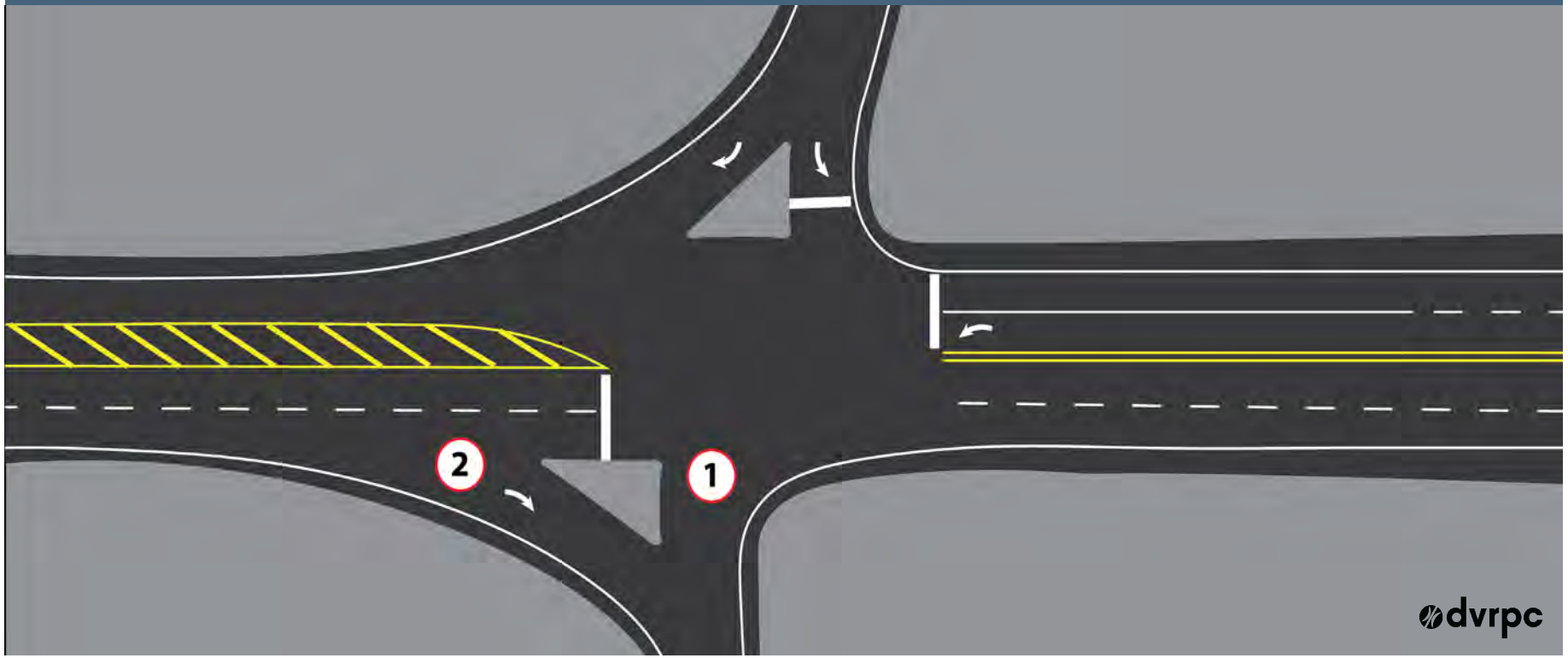
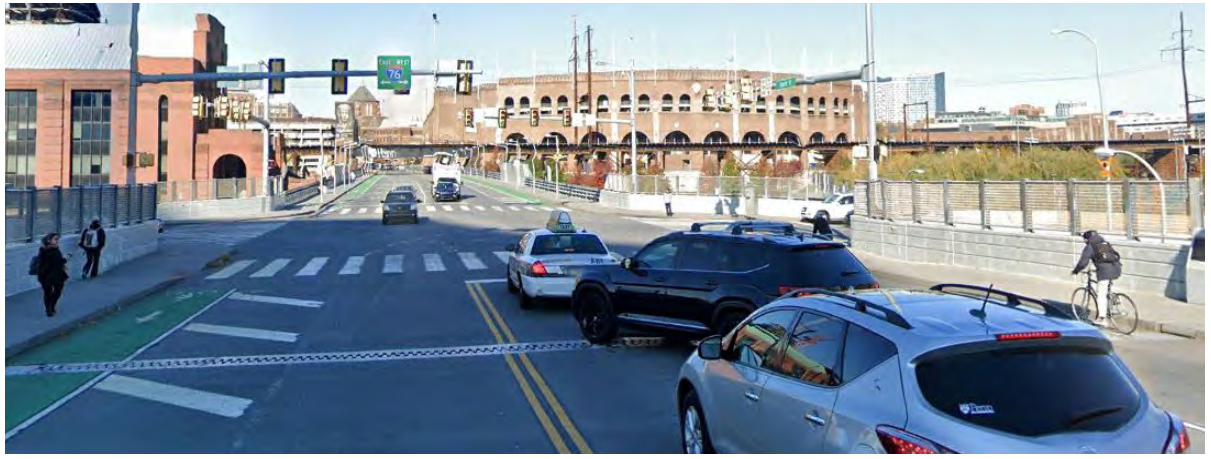


Figure 8 | Signalized Single-Lane On- and Off-Ramp

Source: DVRPC, 2019

Issues at Signalized Single-Lane On- and Off-Ramps

1) Bicyclists or pedestrians crossing the interchange typically share a green phase with vehicles turning onto the on-ramp. This creates a turning movement conflict.
2) Signalized interchanges with slip ramps introduce many of the same issues as unsignalized interchanges. Drivers using a slip ramp will be focused on accelerating and merging, and may not be aware of or yield to pedestrians or cyclists.



Green buffered bike lanes at the intersection of South Street and I-76 in Philadelphia, Pennsylvania.
Source: Google, 2019

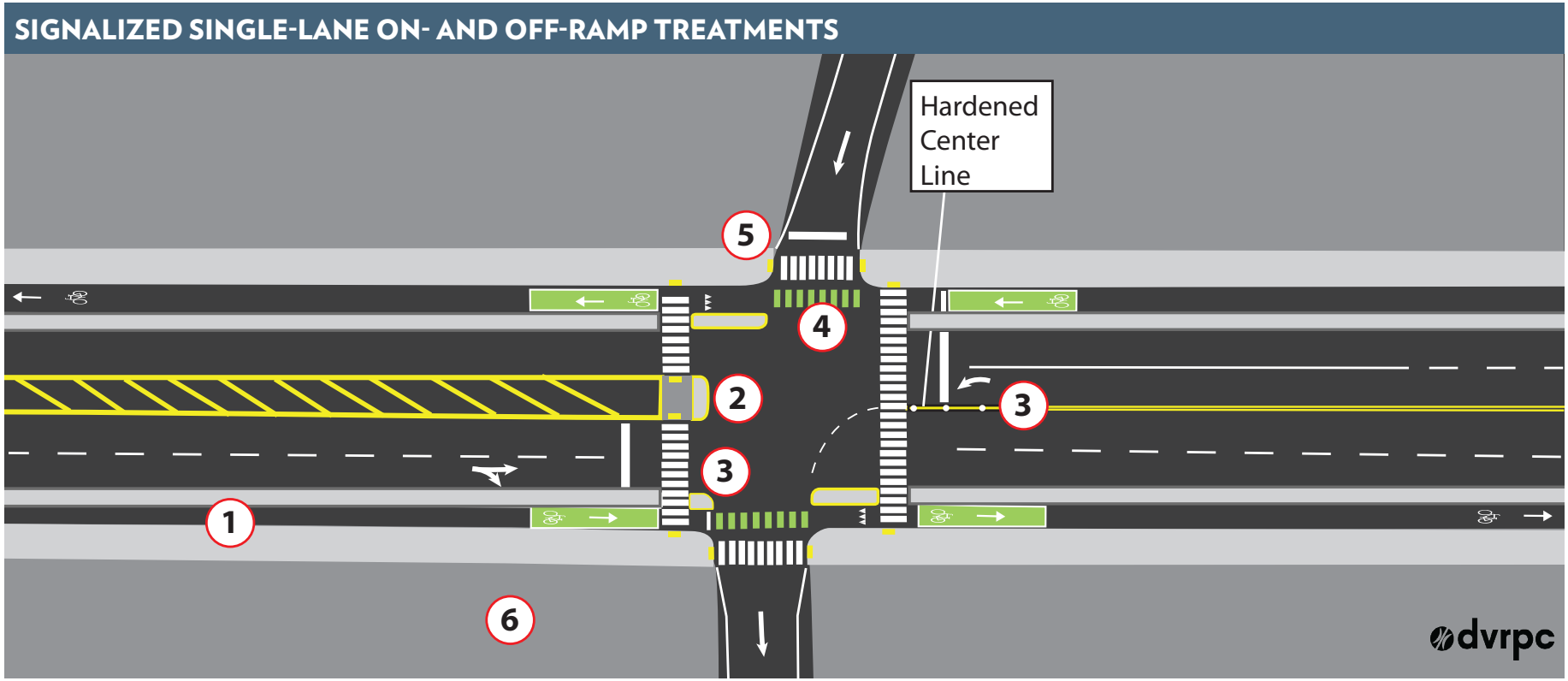


Figure 9 | Signalized Single-Lane On- and Off-Ramp Treatments

Source: DVRPC, 2019

Treatments at Signalized Single-Lane On- and Off-Ramps

1) Provide protected bicycle facilities to separate bicycles from high-volume/speed vehicular traffic (see Figure 9).
2)Provide an ADA-compliant crosswalk with a pedestrian median refuge and pedestrian leading signals to help people of all ages and abilities to safely cross the arterial.
3)A hardened centerline (shown on page 10) can help slow turning vehicles at conflict points with bicycles and pedestrians.
4) Green bicycle crossing markings show areas where bicycles have priority.
5) Extend the curbs at ramps to shorten crossing distance and slow down turning vehicles.
6) Consider closing the channelized turn lane in favor of a right-turn lane that forces vehicles to turn slowly or use a raised crosswalk in the channelized turn (as shown in Table 1 on page 9).

Separated bike lane at signalized interchange intersection in Pittsburgh, Pennsylvania.

Source: Google, 2017

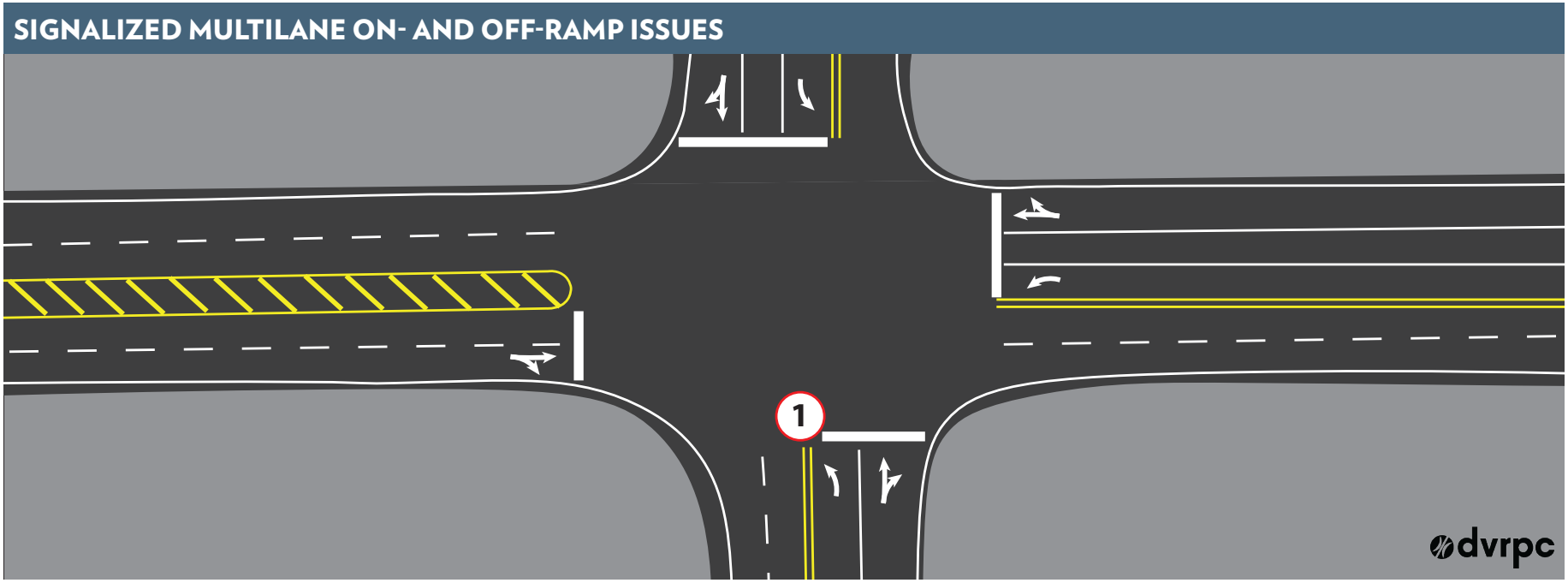


Figure 10 | Signalized Multilane On-and Off-Ramp Issues

Source: DVRPC, 2019

Issue at Signalized Multilane On- and Off-Ramps

1) Multilane signalized interchanges share the same turning movement conflicts but also feature longer crossing distances with increased exposure to turning vehicles (see Figure 10).

A sidepath crossing at a signalized off-ramp in Davis, California.

Source: Google, 2019

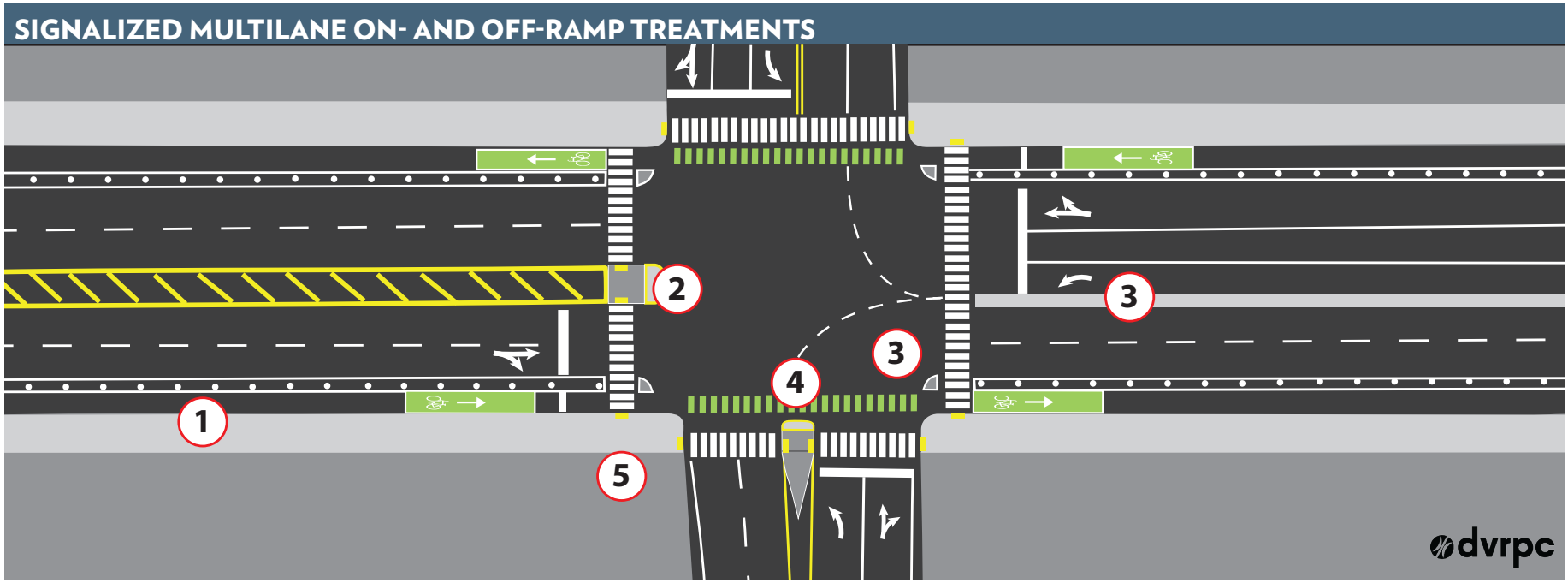
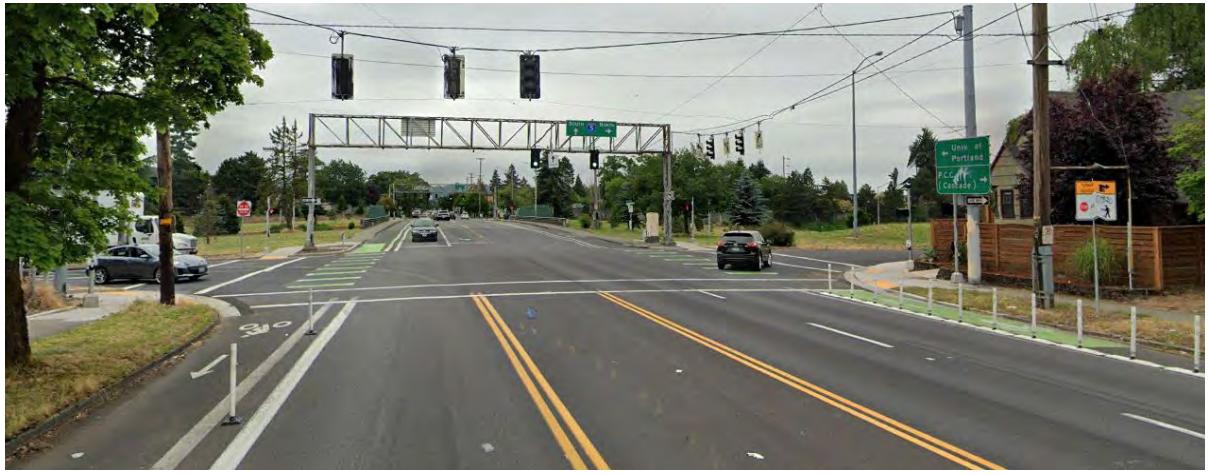


Figure 11 | Signalized Multilane On- and Off-Ramp Treatments

Source: DVRPC, 2019

Treatments at Signalized Multilane On- and Off-Ramps

1) Protected bicycle facilities separate bicycles from high-volume/speed vehicular traffic.
2) An ADA-compliant crosswalk with a pedestrian median refuge and pedestrian leading signals helps people of all ages and abilities to safely cross the arterial (see Figure 11).
3) A hardened centerline or median helps slow turning vehicles at conflict points with bicycles and pedestrians.
4) Green bicycle crossing markings show areas where bicycles have priority.
5) Close slip lanes in favor of signalized turns if they exist.



Separated bike lane on N. Rosa Parks Way at Interstate 7 in Portland, Oregon.

Source: Google, 2019

CHAPTER 4: LOCAL CONCEPTUAL DESIGN

Introduction

Few examples of best practice facilities at interchanges currently exist in southeastern Pennsylvania. However, there are a number of communities throughout the region interested in improving local mobility along arterials by incorporating bicycle and pedestrian design. As a way to demonstrate how current best practice could be applied within the region, DVRPC worked with county partners from Bucks, Delaware, Chester, and Montgomery counties, and the City of Philadelphia to identify one interchange in each county and develop conceptual designs that provide bicycle and pedestrian connections using current best practice.

All of the arterials shown are at least partly owned and maintained by PennDOT. These designs have attempted to take national guidance and make it applicable to PennDOT regulation. All MUTCD signage used in the designs can be found in Appendix A.

The conceptual designs in this chapter were developed under the following assumptions, informed by conversations with stakeholders:

1) No additional stop signs or signalization would be added.
2) Each roadway was at or near capacity.
3) Best practices should be balanced by implementation considerations, such as funding, maintenance, and roadway constraints.

CONCEPTUAL DESIGN: BUCKS COUNTY

Bucks County Conceptual Design: PA 309 and PA 113

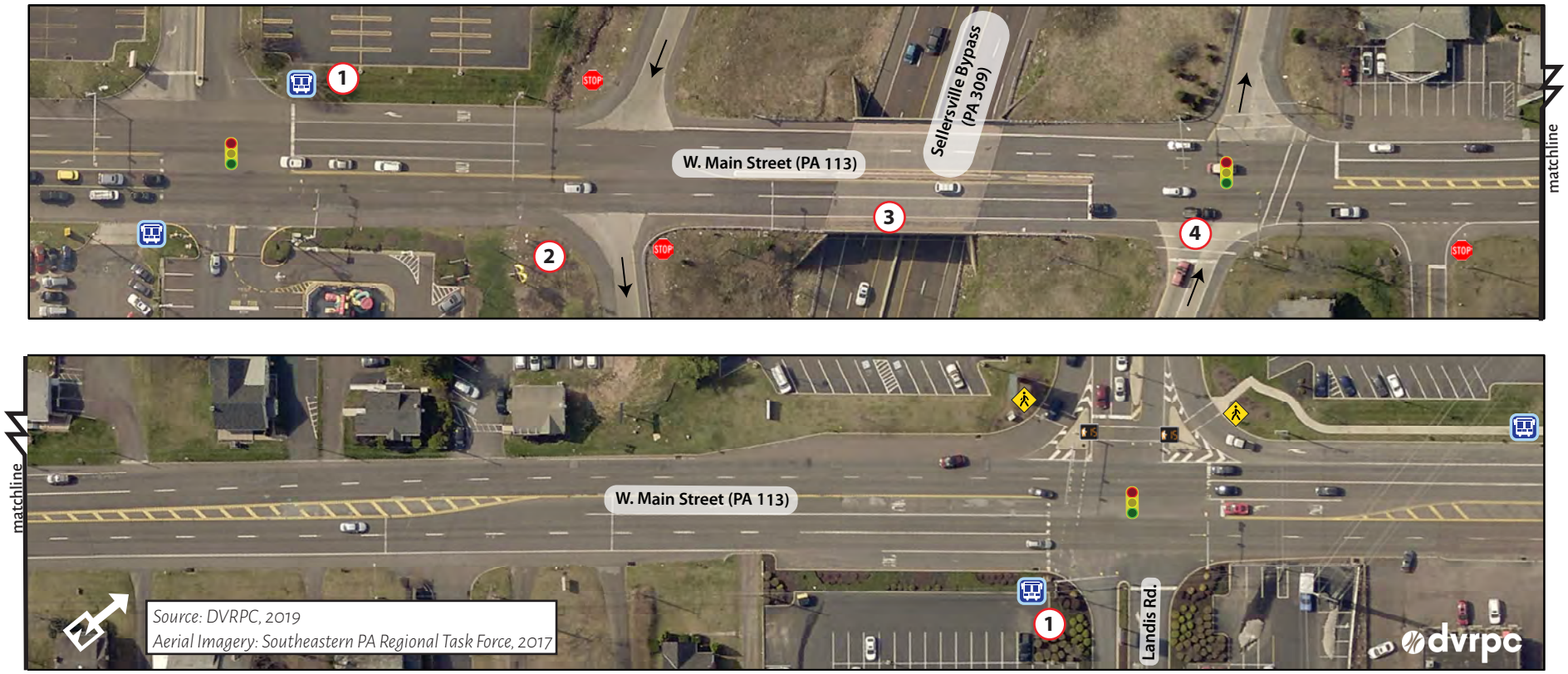


Figure 12 | Bucks County Case Study Issues

Location: Souderton, Pennsylvania
Posted Speed: 35 miles per hour
AADT: ~17,250

Background: The existing commercial areas on either side of the interchange would benefit from better pedestrian access. Bucks County has observed some bicycle and pedestrian activity on this segment of PA 113 and expects this to increase as residential development continues to the north and south.

Issues:
1) Existing bus stops do not have a designated waiting area and do not connect to a sidewalk. There is also no safe way to cross PA 113 to access a bus stop on the other side (see Figure 12).
2) The southbound ramps are unsignalized and have very wide turning radii. This may encourage fast turns and failure to yield to pedestrians.
3) There are no sidewalk facilities along PA 113. There is a shoulder across the PA 309 overpass where pedestrians might walk, but no marked crosswalks across the southbound ramps.
4) Where marked crosswalks are provided, they do not connect to a sidewalk.

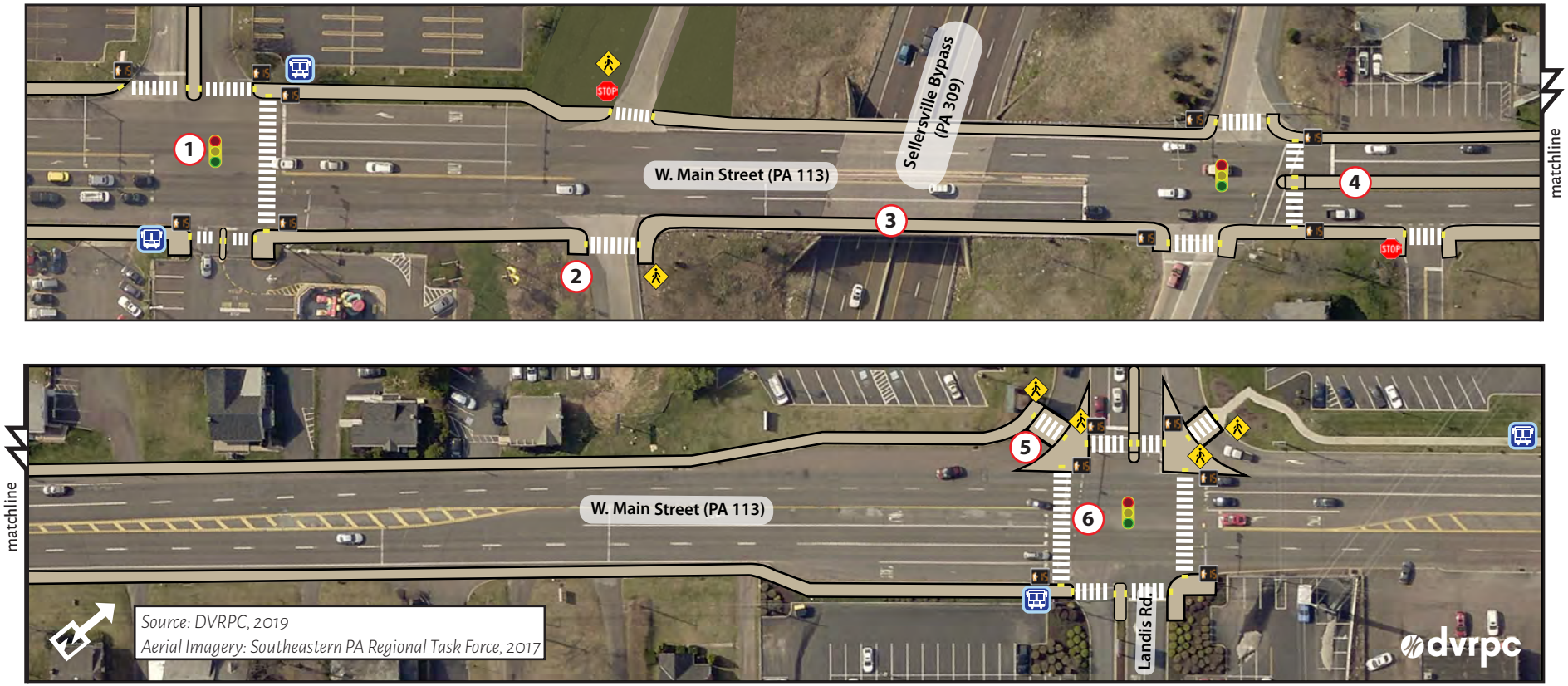


Figure 13 | Bucks County Case Study Treatments

Treatments:

1) Add crosswalks and sidewalks for bus access, including pedestrian medians across commercial driveways (see Figure 13).
2) Tighten the turning radii at ramps.
3) Provide a sidewalk across the interchange, including marked crosswalks and ADA ramps.
4) Harden the center median to provide a pedestrian refuge and decrease vehicle turning speeds. Adjust crosswalk geometry to minimize crossing distance.
5) Narrow commercial slip ramps and add pedestrian signage and raised crosswalks.
6) Add crosswalks and pedestrian signal heads.

CONCEPTUAL DESIGN: CHESTER COUNTY

Chester County Conceptual Design: Paoli Pike at US 202

Figure 14 | Chester County Case Study Issues

Location: West Goshen, Pennsylvania
Posted Speed: 35 miles per hour
AADT: ~14,250

Background: The Paoli Pike Trail is being planned along Paoli Pike between Line Road and Airport Road, just one mile east of the interchange with US 202. West Goshen Township is interested in continuing the trail or other bicycle and pedestrian facilities to connect to West Chester Borough.

Issues:
1) Wide turning radii encourage fast turns and discourage yielding to pedestrians (see Figure 14).
2) Marked crosswalks do not connect to a sidewalk.
3) There are no bicycle or pedestrian facilities along Paoli Pike.
4) There is no marked crossing at the entrance to Paoli Pike Park.

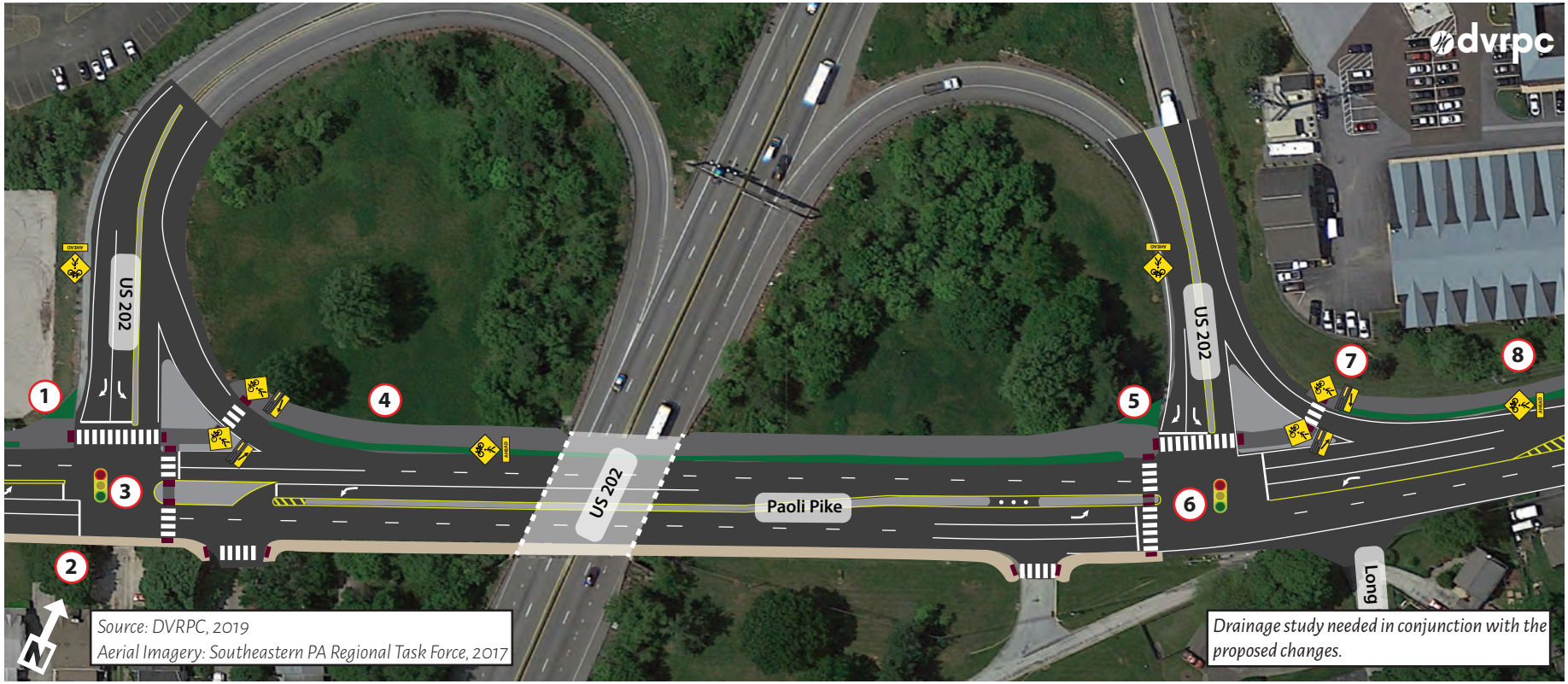


Figure 15 | Chester County Case Study Treatments

Treatments:

1) Tighten turning radii using curb extensions (see Figure 15).
2) Add a sidewalk on the south side of Paoli Pike.
3) Harden the gore area to create a pedestrian refuge island.
4) Add a buffered shared-use path on the north side of Paoli Pike.
5) Close the unsignalized off-ramp slip lane with a curb extension.
6) Add a marked crosswalk across Paoli Pike connecting to the entrance of Paoli Pike Park. Harden the center median to decrease turning speeds and provide a pedestrian refuge.
7) Add marked crosswalks and rectangular rapid flashing beacons at unsignalized ramps.
8) Add advanced waning signage to alert drivers to the bicycle and pedestrian crossings.

CONCEPTUAL DESIGN: DELAWARE COUNTY

Delaware County Conceptual Design: West Chester Pike (PA 3) between New Ardmore Avenue and Lawrence Road

Figure 16 | Delaware County Case Study Issues

Location: Broomall/Haverford Township, Pennsylvania
Posted Speed: 40 miles per hour
AADT: ~50,000
Background: This corridor connects residential neighborhoods and commercial properties. The roadway has wide shoulders, "share the road" signage, and striping across the unsignalized on- and off-ramps, which was done by PennDOT after a cyclist was fatally struck.

Issues:
1) Existing bicycle facilities (unmarked shoulders, "share the road" signage) are not in line with FHWA recommendations for bikeway selection based on speed and volumes (see Figure 16).
2) Unsignalized off-ramps have bicycle crossings marked straight across, rather than perpendicular, and do not include advanced warning signage to indicate that there is a bike crossing ahead.
3) Signalized intersections have crosswalks and pedestrian signals, but there is no sidewalk along the arterial for them to access.
4) Five-lane crossing with wide shoulders lengthens pedestrians' and bicyclists' exposure at intersection.
5) A proposed project along the westbound side of West Chester Pike between Lawrence Road and the 476 North on-ramps would make new bicycle facilities difficult to build, due to designs found in Appendix B.

Figure 17 | Delaware County Case Study Treatments

Treatments:

1) A barrier-protected sidepath along the south side of the right-of-way allows for a continuous separated bicycle and pedestrian connection with fewer unsignalized ramp crossings (see Figure 17).

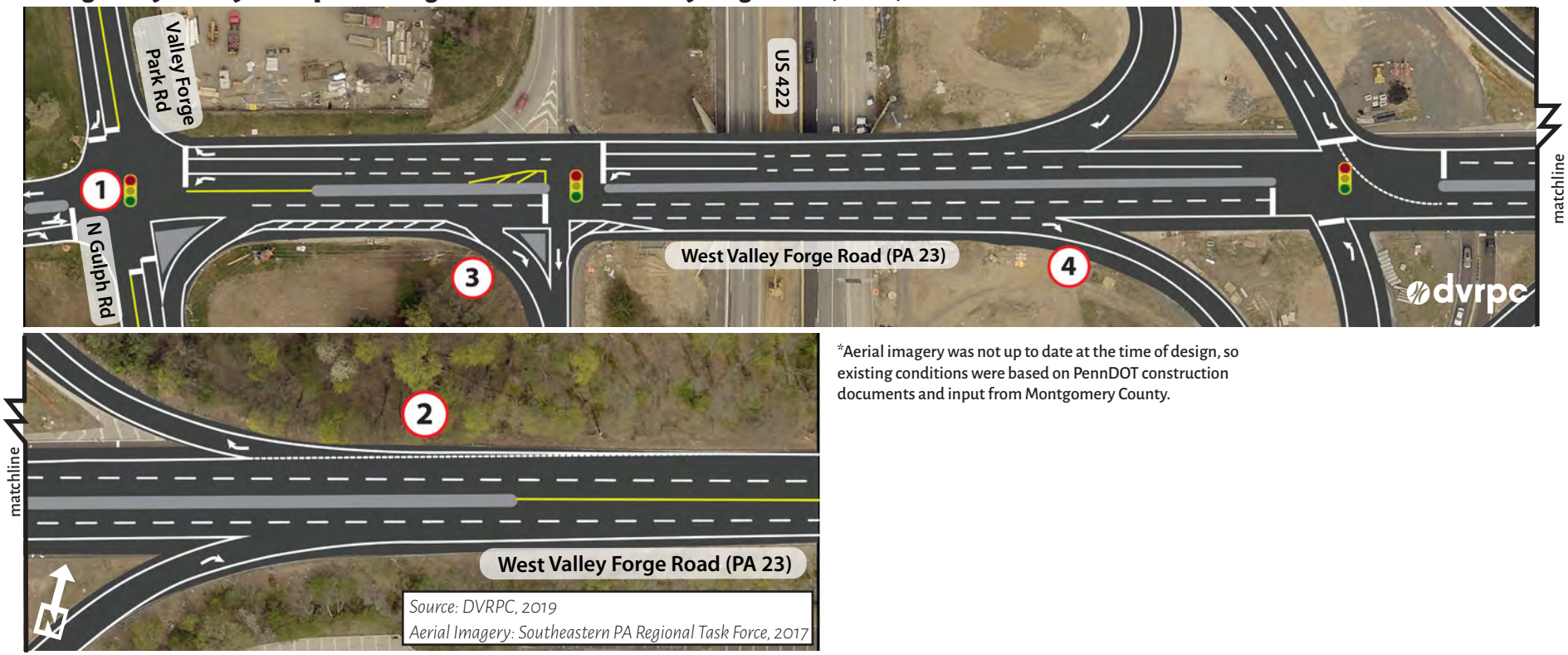
2) Crossing islands and curb extensions shorten crossing distances at square intersections.

3) Perpendicular crosswalks, yield markings, and rapid flashing beacons help improve safety at unsignalized on-ramps that meet the arterial at an angle.

4) Crosswalks, pedestrian signals, and signage provide improved bike and pedestrian crossing and visibility at signalized intersections. The existing median is expanded to create a more robust pedestrian refuge.

CONCEPTUAL DESIGN: MONTGOMERY COUNTY

Montgomery County Conceptual Design: US 422 at West Valley Forge Road (PA 23)



*Aerial imagery was not up to date at the time of design, so existing conditions were based on PennDOT construction documents and input from Montgomery County.

Figure 18 | Montgomery County Case Study Issues

Location: King of Prussia, Pennsylvania
Posted Speed: 35 miles per hour
AADT: ~22,500

Background: This segment of PA 23 is part of the planned Bike MontCo network. It connects to an entrance to Valley Forge National Park, which includes multiuse trails. Bicyclists and pedestrians have been observed crossing here without facilities. Vehicular speeding has also been observed by the county.

Issues:

1) PA 23 lacks a bicycle facility connecting to trails and attractions in Valley Forge National Park (see Figure 18).
2) Bicyclists may attempt to take the shoulder to make this connection, but it varies in width.
3) Some movements are signalized, but the interchange includes five unsignalized slip ramps with no clear path for cyclists.
4) These ramps feature wide turning radii, encouraging high speeds despite a 35 mile per hour speed limit along West Valley Forge Road. Speed limits of 25 miles per hour on the ramps lengthen bicyclists' exposure at intersections.

CONCEPTUAL DESIGN: MONTGOMERY COUNTY

Figure 19 | Montgomery County Case Study Treatments

This design prioritizes the movement of bicycles through the interchange due to its regular use by cyclists and its lack of nearby connecting sidewalk networks. The addition of pedestrian facilities with bicycle facilities is possible with a major reconstruction of the interchange. Additionally, this design uses flexible delineators to provide separation from high-speed, high-volume travel lanes, which is in line with national best practice.

The inclusion of delineators or other forms of separation in a final design is at the discretion of Montgomery County and PennDOT.

Treatments:

1) A protected in-street bicycle lane in each direction provides a connection to Valley Forge National Park (see Figure 19).
2) Advance warning signage and yield markings alert drivers to bicycle crossings on unsignalized ramps.
3) Cyclists cross unsignalized ramps at a perpendicular angle to minimize crossing distance and exposure to crash risk.
4) Excessively wide turning radii are decreased to encourage drivers to slow down and stay alert.
5) Flex posts provide vertical separation and prevent drivers from drifting into the bicycle lane or taking fast, wide turns.

CONCEPTUAL DESIGN: CITY OF PHILADELPHIA

City of Philadelphia Conceptual Design: Tacony Palmyra Bridge Interchange (West of I-95)

Figure 20 | City of Philadelphia Case Study Issues, West of Interstate 95

Location: Philadelphia, Pennsylvania
Posted Speed: 25 miles per hour
AADT: Levick Street ~14,000 (EB)
Background: The goal of this design (shown in two parts) is to better connect bicyclists and pedestrians from the Tacony neighborhood Northwest of I-95 (pages 36 and 37) to the pedestrian paths on the Tacony-Palmyra Bridge and to Lardner's Point Park/K&T Trail (pages 38 and 39).

Issues:
1) No crosswalk at channelized right turn onto Levick Street (see Figure 20).
2) Gap in sidewalk.
3) Wide turn at Robbins and Keystone Streets increases pedestrian exposure to traffic.
4) Wide right-of-way at channelized right turn encourages high speeds through turn.
5) Two-way stop on Keystone at northbound Levick is difficult to cross due to high vehicle volumes and speeds.
6) Change from two- to one-way traffic on Keystone between Robbins and Levick makes local east/west trips longer.

CONCEPTUAL DESIGN: CITY OF PHILADELPHIA

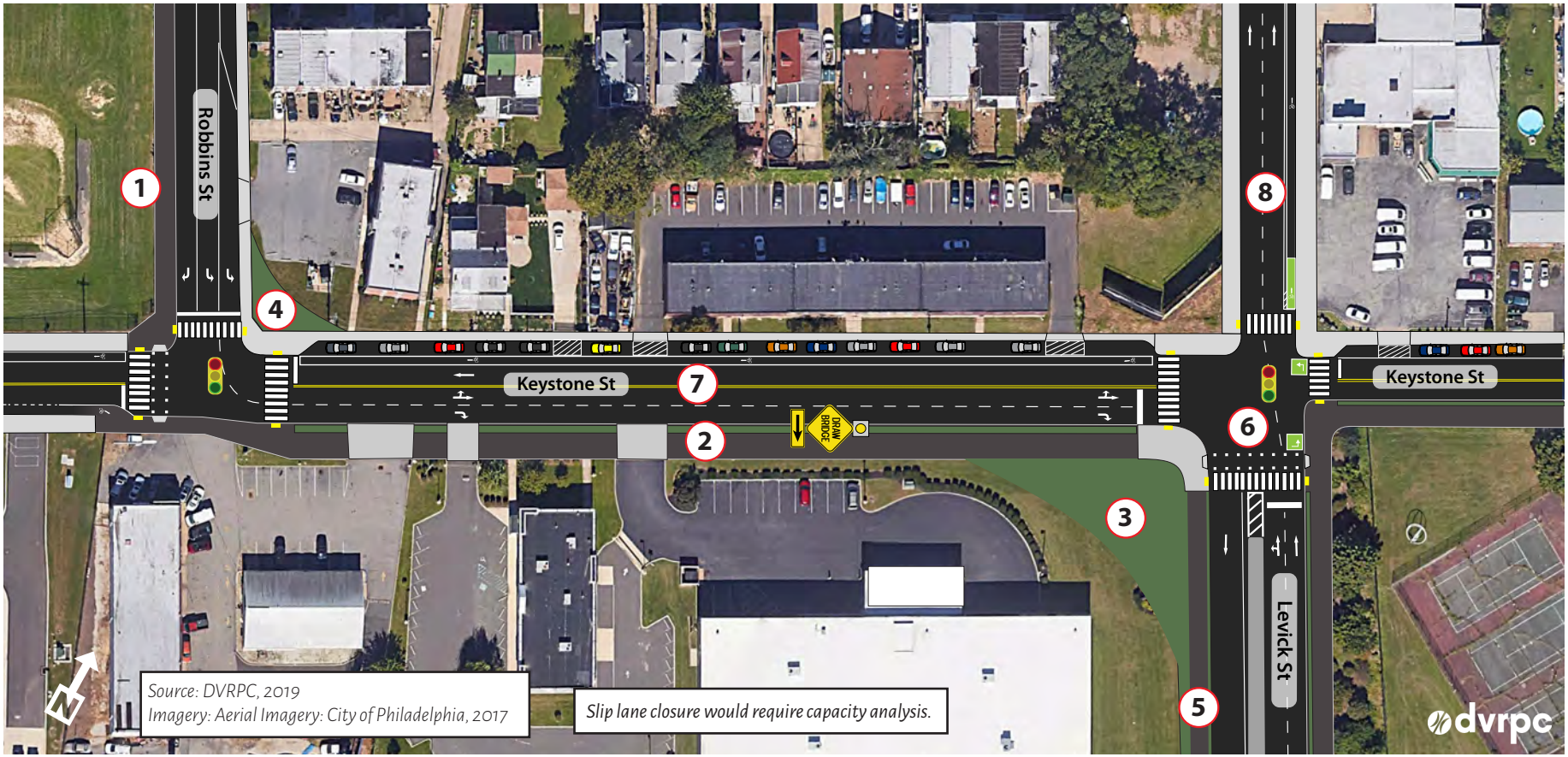


Figure 21 | City of Philadelphia Case Study Treatments, West of Interstate 95

Treatments:

1) Sidepath along the west side of Robbins Street connects cyclists to facilities north of the study area on Torresdale Avenue (see Figure 21).

2) Sidepath along the south side of Keystone takes the place of one of the existing turn lanes.

3) The closure of the slip lane onto Levick improves pedestrian crossings and slows down traffic, connecting users to destinations on either side of Levick Street, as well as proposed facilities on the other side of I-95.

4) Geometry of Robbins changed at intersection with Keystone so that the streets meet perpendicularly, helping to slow speeds and shorten crossings.

5) Existing sidewalk is widened to become a sidepath.

6) Crosswalks, crossbikes, pedestrian medians, two-stage left, and curb extensions help to improve pedestrian safety and connectivity.

7) Changing Keystone to become bidirectional allows for local southbound trips and narrows the right-of-way, encouraging slower speeds.*

8) Protected bicycle lane on Levick Street provides westbound bicycle connection.

CONCEPTUAL DESIGN: CITY OF PHILADELPHIA

City of Philadelphia Conceptual Design: Tacony Palmyra Bridge Interchange (East of I-95)

Figure 22 | City of Philadelphia Case Study Issues, East of Interstate 95

Posted Speed: 35–45 miles per hour
AADT: Levick Street ~11,00-15,000 (eastbound)
Issues:
1) Drawbridge opening causes traffic backups (see Figure 22).
2) Unsignalized slip lanes carry high volumes of fast-moving traffic on and off the bridge, making it difficult to safely access the pedestrian walkways on the bridge.
3) This portion of Levick Street sees practically no traffic volume.
4) Wide right-of-way, high speeds, and high volumes (especially southbound) make it difficult to cross Barnett Street to get to Lardner's Point Park, the Delaware River Trail, and the East Coast Greenway.
5) Missing sidewalk.
6) Pedestrian signal is accompanied by a "no pedestrian" sign and no crosswalk for a long and complicated crossing.
7) Unsignalized off-ramp is redundant and makes crossing difficult for pedestrians.

CONCEPTUAL DESIGN: CITY OF PHILADELPHIA

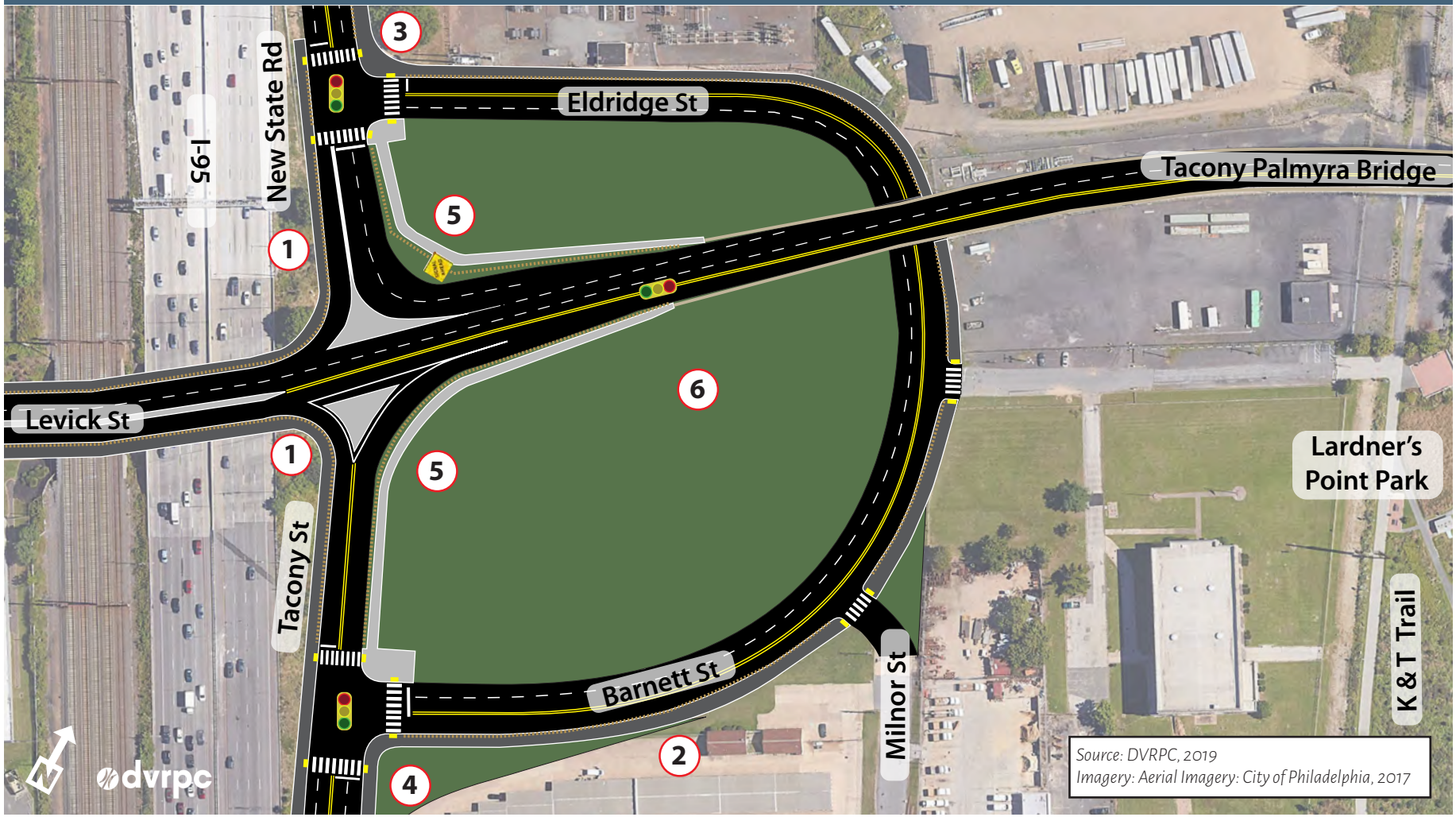


Figure 23 | City of Philadelphia Case Study Treatments, East of Interstate 95

Treatments:

1) Sidepath brings users to controlled intersections to cross high-volume roads (see Figure 23).

2) Sidepath replaces northbound outside travel lane.*

3) Square intersection to create perpendicular bicycle and pedestrian crossing.

4) Eliminate median and channelized right turn and square up the intersection to slow turns and reduce crossing distances for pedestrians and cyclists.

5) Eliminate slip lane and create new sidewalk to pedestrian path on bridge. **

6) Close Levick Street between Milnor and Tacony Streets.

** This would require a capacity analysis.*

***Cyclists must dismount and walk bike when crossing the bridge. See Appendix C for alternatives.*

ENDNOTES

1. Aaron C. Fayish and Frank Gross, "Safety Effectiveness of Leading Pedestrian Intervals Evaluated by a Before and After Study with Comparison Groups," Transportation Research Record 2198, 2010.
2. Desktop Reference for Crash Reduction Factors, FHWA-SA-08-011, September 2008, Table 11.
3. "Interim Approval for Optional Use of Bicycle Signal Face (IA-16)." Federal Highway Administration, December 24, 2013.
4. Sherbutt, J., R. Van Houten, and S. Turner. "An Analysis of the Effects of Stutter Flash LED Beacons to Increase Yielding to Pedestrians Using Multilane Crosswalks." Presented at the Transportation Research Board Annual Meeting, Washington, DC, 2008.
5. NCHRP Report 641, Guidance for the Design and Application of Shoulder and Centerline Rumble Strips.
6. Desktop Reference for Crash Reduction Factors, FHWA-SA-08-011, Table 11.

APPENDIX A

Relevant Bicycle and Pedestrian Signage from the MUTCD

R1-2

W3-2

R1-5a

W11-1

W11-2

W11-2
with RRFB

W11-15

W11-15
with RRFB

W16-7P

W16-9P

W11-15P

Source: MUTCD, 2012

APPENDIX B

PennDOT Proposed Changes to Westbound West Chester Pike between North Lawrence Road and Interstate 476 North On-ramp

Source: Pennoni Associates, 2019

City of Philadelphia Case Study Treatments, Roundabouts East of Interstate 95

Source:DVRPC, 2019

Aerial Imagery: City of Philadelphia, 2017

City of Philadelphia Case Study Treatments, Bridge Cantilever with Ramp

Source:DVRPC, 2019
Aerial Imagery: City of Philadelphia, 2017

Publication Title: Guidance for Pedestrian and Bicycle Facilities at Expressway Interchanges in Southeastern Pennsylvania

Publication Number: 19025

Date Published: December 2019

Geographic Area Covered: Bucks County, Chester County, Delaware County, Montgomery County, Philadelphia County, Southeastern Pennsylvania

Abstract: This study uses best practices from around the United States to develop guidance for designing safe pedestrian and bicycle facilities along arterials at expressway interchanges and provides example designs for Bucks, Chester, Delaware, and Montgomery counties, and the City of Philadelphia.

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