FEBRUARY 2024

DELAWARE VALLEY REGIONAL PLANNING COMMISSION (dvrpc)

Planning for New Jersey Transit Bus Service Alongside Bicycle Facilities

DESIGN, COMMUNICATION, AND OPERATIONAL STRATEGIES

The Delaware Valley Regional Planning Commission is the federally designated Metropolitan Planning Organization for the Greater Philadelphia region, established by an Interstate Compact between the Commonwealth of Pennsylvania and the State of New Jersey. Members include Bucks, Chester, Delaware, Montgomery, and Philadelphia counties, plus the City of Chester, in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer counties, plus the cities of Camden and Trenton, in New Jersey.

DVRPC serves strictly as an advisory agency. Any planning or design concepts as prepared by DVRPC are conceptual and may require engineering design and feasibility analysis. Actual authority for carrying out any planning proposals rest solely with the governing bodies of the states, local governments or authorities that have the primary responsibility to own, manage or maintain any transportation facility.

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

DVRPC's vision for the Greater Philadelphia Region is a prosperous, innovative, equitable, resilient, and sustainable region that increases mobility choices by investing in a safe and modern transportation system; that protects and preserves our natural resources while creating healthy communities; and that fosters greater opportunities for all.

DVRPC's mission is to achieve this vision by convening the widest array of partners to inform and facilitate data-driven decision-making. We are engaged across the region, and strive to be leaders and innovators, exploring new ideas and creating best practices.

DVRPC is funded through a variety of funding sources including federal grants from the U.S. Department of Transportation's Federal Highway Administration (FHWA) and Federal Transit Administration (FTA), the Pennsylvania and New Jersey departments of transportation, as well as by DVRPC's state and local member governments. The authors, however, are solely responsible for the findings and conclusions herein, which may not represent the official views or policies of the funding agencies.

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Executive Summary

The concept of Complete Streets encompasses the planning, designing, and operating of streets will all modes in mind, with the goal of making the transportation network safer and more efficient. As Complete Streets are implemented across New Jersey, New Jersey Transit (NJ TRANSIT) and other transit agencies are looking to align their operations to improve the safety of bus operators, passengers boarding and alighting at stops, bicyclists, and pedestrians. The project team from the Delaware Valley Regional Planning Commission (DVRPC) worked with NJ TRANSIT, local officials, and road owners to explore strategies to do so. This memo lays out the findings from this study and provides recommended strategies to reduce interactions between NJ TRANSIT buses and bicyclists. In this study, an interaction is defined as a situation in which one involved party performs an unexpected or risky maneuver to avoid a crash.

Recommended strategies to reduce bus–bicycle interactions fall into three categories: street design, stakeholder communication, and operational strategies. Main recommendations are listed in Table 1 on the following page.

Stakeholder communication and operational strategies can be applied consistently and universally by NJ TRANSIT. Street design strategies will vary based on local context, such as frequency of bus headways, level of urban density, traffic volumes, traffic speeds, cartway width, and amount of public right-of-way available. Street design changes will need to be planned, designed, and implemented on a case-by-case basis.

Therefore, the DVRPC project team organized a bus stop design workshop that brought key stakeholders including road owners, cycling advocates, and NJ TRANSIT together to brainstorm implementable bus stop designs that are expected to reduce bus–bicycle interactions at two NJ TRANSIT bus stops along Prospect Street in Mercer County, NJ. The resultant conceptual street designs (see Figures 25, 26, 29) only address the physical attributes that are expected to reduce bus–bicycle interactions, but they are the outcome of communication both internally between NJ TRANSIT departments and externally between stakeholders. Although the two bus stops are on the same street, the users and environments differ. The strategies and designs proposed could potentially be deployed elsewhere in the NJ TRANSIT service area, especially at locations known to have bus–bicycle interactions.

Table 1: Strategies Expected to Reduce Bus–Bicycle Interactions

Issue Type	Issue Description	Potential Strategy
Street Design	Modes forced to travel in close proximity	Prioritize mode separation in design guides and discussions with road owners
	Narrow stretch of cartway along a corridor	Adapt design to limited cartway (i.e., bike lane becomes shared lane marking)
	Lack of data about effective street designs	Use temporary materials to test performance of new street designs
Communication About Street Design	Street design changes occur without transit agency input	Initiate regular contact with road owners regarding changes on bus corridors
	Departments use varying criteria to evaluate street designs	Create a standard internal process to coordinate on street design changes
	Road safety initiatives omit transit agency perspective	Participate in Vision Zero task forces and other road safety initiatives
Operational	Difficult for operators to keep track of vulnerable road users	Use technology to alert road users to each others' presence
	Challenging for operators to react to bicyclist's movements	Continue education for operators on how to safely share the street with bicyclists
	Limited data collection from operators	Urge operators to report all interactions and give feedback on street design

Source: DVRPC (2023)

CHAPTER 1:

Introduction

Project Scope

The concept of Complete Streets encompasses the planning, designing, and operating of streets will all modes in mind, with the goal of making the transportation network safer and more efficient.[1] As Complete Streets are implemented across New Jersey, New Jersey Transit (NJ TRANSIT) and other transit agencies are looking to align their operations to improve the safety of bus operators, passengers boarding and alighting at stops, bicyclists, and pedestrians. The project team from the Delaware Valley Regional Planning Commission (DVRPC) worked with NJ TRANSIT, local officials, and road owners to explore strategies to do so. This memo lays out the findings from this study and provides recommended strategies to reduce interactions between NJ TRANSIT buses and bicyclists. In this study, an interaction is defined as a situation in which one involved party performs an unexpected or risky maneuver to avoid a crash.[2]

The project team completed the following tasks, all of which informed the final set of recommendations.

1. Compile existing bus–bicycle interactions within the NJ TRANSIT bus system. This includes bicycle crash data and input from NJ TRANSIT staff and relevant stakeholders.
2. Identify common interactions between buses and bicyclists. This includes gathering information about interactions and street designs from existing studies.
3. Research industry best practices for coordinating bus service alongside bicycle infrastructure. This includes conducting interviews with peer transit agencies in comparable jurisdictions.
4. Develop conceptual designs illustrating improvements expected to reduce bus–bicycle interactions. This includes working with NJ TRANSIT staff to identify case study locations within their service area and facilitating a bus stop design workshop that gathered relevant stakeholders.

The resulting recommended strategies to reduce bus–bicycle interactions fall into three categories: street design, stakeholder communication, and operational strategies. In this study, street design encompasses the entire public right-of-way and cartway (including elements that cannot be driven on, such as on-street parking lanes, bicycle lanes, shoulders, etc.).

Strategies evaluated in research studies and used by peer U.S. transit agencies are applicable and can be implemented in NJ TRANSIT's service area to reduce existing bus–bicycle interactions. Successful implementation will require partnership between key stakeholders including NJ TRANSIT, road owners, task forces (i.e., Vision Zero), advocacy organizations, and the bicycling community.

[1] "Complete Streets." U.S. Department of Transportation. Accessed July 31, 2023. www.transportation.gov/mission/health/complete-streets.

[2] Risser, Ralf. "Behavior in Traffic Conflict Situations." *Accident Analysis & Prevention* 17, no. 2 (1985): 179–97. doi.org/10.1016/0001-4575(85)90020-x.

Project Purpose and Background

The purpose of the project is to recommend street design, stakeholder communication, and operational strategies NJ TRANSIT and key stakeholders can use to reduce common bus-bike interactions in their service area. These strategies, when implemented together, can respond to existing street conditions and improve the safety of bus service alongside future bicycle infrastructure.

Improving bus–bicycle interactions is an equity issue. Fatality rates per 100 million miles traveled are systematically higher for Black and Latinx Americans for all modes and notably higher for vulnerable modes like bicycling and walking. For example, Black Americans die at almost 4.5 times the rate for white Americans while cycling.[3]

Additionally, faster-moving modes like e-bikes have increased the volume and demographic diversity of bicyclists, as they provide affordable and accessible ways for people to get around. Shared e-bike trips nearly doubled from 9.5 million in 2018 to 17 million in 2021.[4] In the DVRPC region, the introduction of e-bikes into Philadelphia's bike share fleet correlated with increased use in predominantly Black and low-income areas.[5] To better accommodate these faster-moving modes – and new riders with varying degrees of skill and expertise – Complete Streets strategies are crucial.

[3] Raifman, Matthew A., and Ernani F. Choma. "Disparities in Activity and Traffic Fatalities by Race/Ethnicity." *American Journal of Preventive Medicine* 63, no. 2 (August 2022): 160–67. doi.org/10.1016/j.amepre.2022.03.012.

[4] "Shared Micromobility in the U.S. 2020–2021." National Association of City Transportation Officials, December 7, 2022. nacto.org/shared-micromobility-2020-2021/.

[5] Caspi, Or. "Equity Implications of Electric Bikesharing in Philadelphia." *GeoJournal* 88, no. 2 (2022): 1559–1617. doi.org/10.1007/s10708-022-10698-1. The study analyzed three months of Indego usage across Philadelphia in 2019, using census data to identify neighborhoods that were predominantly Black and low-income. Bicycle users in these communities made up only about 22% of the city's total trips. However, these communities accounted for about 34% of the city's total e-bike trips.

Project Coordination

DVRPC held regular meetings with NJ TRANSIT staff. The core project team included:

- Hailey Graf: *Manager, Project Development, NJ TRANSIT Planning*
- Elmira Buongiorno: *Senior Manager of Bus Safety, NJ TRANSIT*
- Amy Bernknopf: *Manager, Office of Transit, Bicycle, and Pedestrian Planning, DVRPC*
- Cassidy Boulan: *Associate Manager, Office of Transit, Bicycle, and Pedestrian Planning, DVRPC*
- Marissa Volk: *Transportation Planner, DVRPC*
- Joanna Hecht: *Transportation Planner, DVRPC*

In addition to regular meetings, the project team conducted interviews with peer transit agencies in comparable jurisdictions. The purpose of the peer transit agency interviews was to identify street design, stakeholder communication, and operational strategies that comparable jurisdictions use to reduce interactions between buses and bicyclists, whether bike lanes are present in the service area or not. For more information about peer transit agency interviews, see Chapter 4.

Additionally, the DVRPC project team facilitated a two-hour, in-person bus stop design workshop that brought road owners, cycling advocates, and NJ TRANSIT together to brainstorm implementable bus stop designs that are expected to reduce bus–bicycle interactions at two stops on NJ TRANSIT bus route 601. When considering possible corridors or stops to feature in the workshop, the project team identified the following criteria for study locations:

1. There should be a path to near-term implementation for some of the recommendations.
2. The workshop and resultant design process should build upon existing relationships between NJ TRANSIT and road owners in the region.

3. The workshop should engage NJ TRANSIT and workshop participants in thinking through improvements that would work in different densities and different stop configurations. The stops should also be on streets that have or are planned to have dedicated bicycle lanes.

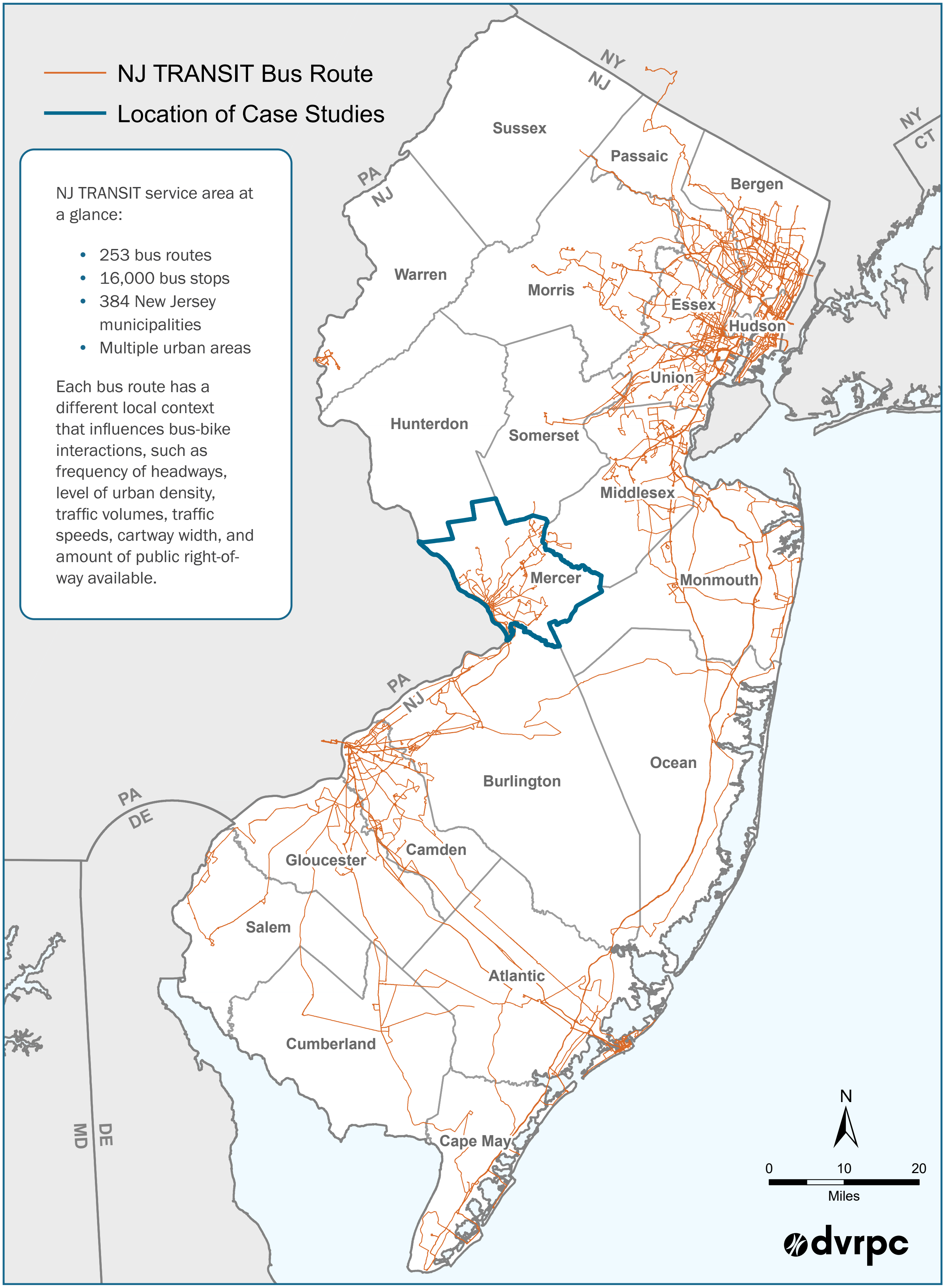
For more information about the workshop session, see Chapter 5.

Memo Organization

This memo is organized into seven chapters that cover the following topics:

- Chapter 1: Introduction (project background)
- Chapter 2: Existing Conditions in NJ TRANSIT Service Area (context that contributes to bus–bicycle interactions)
- Chapter 3: Literature Review (reviews research of common interactions between buses and bicyclists)
- Chapter 4: Strategies to Reduce Bus–Bicycle Interactions (findings from peer transit agency interviews)
- Chapter 5: Conceptual Design Process (process the project team used to select case study locations and create conceptual designs)
- Chapter 6: Conceptual Designs (designs expected to reduce bus–bicycle interactions)
- Chapter 7: Recommendations (near-term actions key stakeholders can take)

Figure 1: Map of NJ TRANSIT Service Area



Source: NJ TRANSIT (2023)

CHAPTER 2:

Existing Conditions in NJ TRANSIT Service Area

This chapter describes existing conditions in the NJ TRANSIT service area that contribute to different types of bus–bicycle interactions. As identified in Chapter 1, an interaction is defined as a situation in which one of the involved parties performs an unexpected or risky maneuver to avoid a collision or crash. Many of the interactions in the NJ TRANSIT service area align with findings from the literature review, which are detailed in Chapter 3.

NJ TRANSIT provides statewide transit service. Street designs that include dedicated bicycle lanes exist in parts of the service area. As Complete Streets strategies are implemented across the state, more bicycle facilities will be built along fixed bus routes. Key stakeholders including NJ TRANSIT, local officials, and other entities with jurisdiction over street design could pursue opportunities to improve bus service alongside existing and future bicycle infrastructure.

NJ TRANSIT's 253 bus routes serve over 16,000 bus stops across 384 New Jersey municipalities (see Figure 1 for a map of the service area). Each has a different local context that influences bus service, such as level of urban density, traffic volumes, vehicle speeds, cartway width, and amount of public right-of-way available. In addition to a range of physical contexts, communication regarding street design changes also varies widely. NJ TRANSIT may not always be consulted before designs are implemented on a bus corridor. This may pose a challenge in preparing bus operators to respond to changes.

In New Jersey, over 20% of households do not have regular access to a motor vehicle.[6] In urbanized areas, this number tends to be even higher. Many of these households may rely on riding a bicycle as a form of transportation. Bicyclists who are involved in a crash are exposed to a much higher risk of injury compared to motor vehicle users, because the mass and speeds of motor vehicles are much higher than those of bicycles. Complete Streets that include bus and bicycle infrastructure at intersections and along straightaways reduce bicyclist risk of injuries requiring hospitalization resulting from a crash.[7] NJ TRANSIT is a key stakeholder in advancing Complete Streets strategies in its service area.

Bus–Bicycle Interactions in NJ TRANSIT Service Area

NJ TRANSIT staff shared their local perspective about interactions between NJ TRANSIT buses and bicyclists. Many of these align with the common bus–bicycle interactions discussed in Chapter 3 of this memo and found in DVRPC's research. However, a few more considerations were noted.

- Field of vision obstructions can make it difficult for operators to keep track of bicyclists. There are areas around the bus that an operator cannot easily see due to the frame of the vehicle itself, the street curvature, vegetation, etc.
- Timely reaction to bicyclists' quick and sometimes unpredictable movements can be challenging due to vehicle limitations.
- Certain technologies have presented challenges in the past. E-mirrors may be distracting to some operators; the use of external annunciators brought noise complaints from residential areas.

[6] U.S. Census Bureau. American Community Survey, 2017–2021 American Community Survey 5-Year Estimates, Table S2504. data.census.gov.

[7] Reynolds, Conor C. O., M. Anne Harris, Kay Teschke, Peter A. Cripton, and Meghan Winters. "The Impact of Transportation Infrastructure on Bicycling Injuries and Crashes: A Review of the Literature." *Environmental Health* 8, no. 1 (2009). doi.org/10.1186/1476-069x-8-47.

- Operators are not always able to curb the bus for passenger boarding. Mid-block bus stops are particularly challenging for ADA ramp deployment due to lack of curb ramps.

Data Collection in NJ TRANSIT Service Area

Data documenting the nature, location, and consequences of bus–bicycle interactions was also collected from NJ TRANSIT staff. NJ TRANSIT provided the project team with recent bus–bicycle and bus-scooter crashes that occurred within DVRPC's member counties in New Jersey (Burlington, Camden, Gloucester, and Mercer counties). From the limited data available, bus–bicycle interactions seem to be more common in urbanized areas. This may be due to more frequent headways and/or a higher volume of bicyclists. Six of eight documented crashes occurred on streets with no dedicated bike lane.

CHAPTER 3:

Literature Review

This chapter reviews academic studies regarding common interactions between buses and bicyclists. As identified in Chapter 1, an interaction is defined as a situation in which one of the involved parties performs an unexpected or risky maneuver to avoid a collision or crash. In this chapter there will be six types of bus–bicycle interactions that are discussed. See Figure 2 for the list. All interaction types were found in research conducted for this project and will factor into the conceptual designs presented in Chapter 6. Many of these interactions aligned with existing bus–bicycle interactions shared with DVRPC by NJ TRANSIT staff, which are described in Chapter 2.

Street design influences how often buses and bikes are in close proximity to each other and may potentially interact. Through literature review, the project team identified six types of bus–bicycle interactions that are relevant for this study. Bus–bicycle interactions are possible in both streets with a dedicated bike lane and streets without one, but streets with dedicated bike lanes help increase the predictability of bicyclists' movements. Design is one tool to achieve the Complete Streets goal of safety for all road users, among other tools detailed in Chapter 4 of this memo. This chapter includes two call out boxes that detail different types of street designs: one includes street designs with bike lanes, and the other includes street designs without bike lanes.

Common Bus–Bicycle Interactions

Bus stops and intersections tend to be areas where interactions are most likely to happen (see Figure 2). At these locations multiple modes are forced to be in close proximity to each other — regardless of whether a bike lane is present. This proximity increases the likelihood of interaction.

Figure 2: Common Bus–Bicycle Interactions

Tends to happen at bus stops

1. Left Side Overtake
2. Curbing/Inability to Curb

Tends to happen at both bus stops and intersections

3. Right Side Overtake
4. Sidewalk Cyclists

Tends to happen at intersections

5. Right-Hook or Pull Out
6. Intersection Control Noncompliance

Source: DVRPC (2022)

1. Left Side Overtake

A bicyclist or bus operator performs a left side overtake by moving into the adjacent traffic lane and then merging back into the original lane. This interaction commonly occurs at bus stops and in stop-and-go traffic. See Figures 3 and 4 for examples. This maneuver requires each mode to be aware of the other's movements to ensure adequate merging distance. Bus operators may attempt a left side overtake because the bus speed is greater than the bicyclist's. Bicyclists may attempt a left side overtake

STREET DESIGNS WITHOUT A DEDICATED BIKE LANE

SHARED BICYCLE/BUS LANE

A shared bicycle/bus lane (SBBL) is a traffic lane exclusively used by buses, bicyclists, and, usually, right-turning vehicles.[8] SBBLs are not a preferred design in areas with frequent headways, high bus speeds, and/or high volume of bicyclists because it is very likely that modes will interact. SBBLs may be considered for short stretches where cartway width becomes too narrow to provide dedicated space for each mode or in areas where a SBBL will mean less probability of bicyclists interacting with vehicles. The latter was found to be the case in a Pittsburgh, Pennsylvania, study that found half of bicyclists in the study area's mixed traffic lane were likely to interact with a vehicle. In the SBBL, only a quarter of bicyclists were likely to interact with a bus.[9]

MIXED TRAFFIC LANE

A mixed traffic lane is a travel lane in which several categories of vehicles share the same lane space without any separation between motorized and micromobility modes.[10] Studies that examine bus–bicycle interactions within a mixed traffic lane were not found during research. However, a shared bicycle/bus lane (SBBL) can resemble a mixed traffic lane without proper enforcement that prevents personal vehicles from traveling in the SBBL. A 2012 report assessing SBBLs in the United States found that three of four SBBLs studied were not functioning as intended. Degradation of performance was attributed to high volumes of right-turn queuing in areas of heavy pedestrian traffic, and/or personal traffic using the SBBL as a through lane.[11] The project team determined that the road user experience in a SBBL is similar to that of a mixed traffic lane, and learnings from SBBL studies are applied to mixed traffic conditions for the purposes of this study.

[8] Center for Urban Transportation Research, Edward L. Hillsman, Sara Jay Hendricks, and JoAnne K. Fiebe. *A summary of design, policies and operational characteristics for shared bicycle/bus lanes* § (2012), vii.

[9] Martins Cavalcante de Macedo, Mateus. "Safety Evaluation of a Shared Bus-Bike Lane (SBBL) Using Video Recorded Conflict Data." D-Scholarship @ Pitt. University of Pittsburgh, 2019. http://d-scholarship.pitt.edu/37757/.

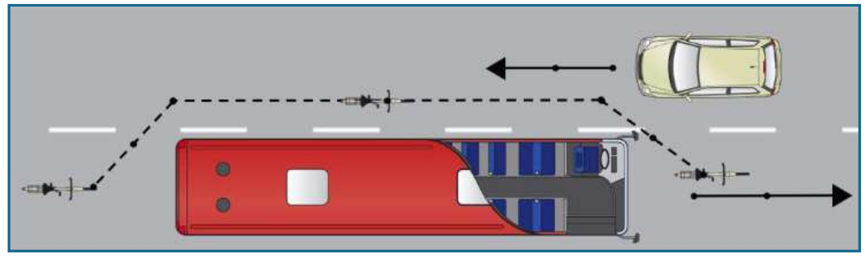
[10] Papathanasopoulou, Vasileia, and Constantinos Antoniou. "Flexible Car–Following Models for Mixed Traffic and Weak Lane–Discipline Conditions." *European Transport Research Review* 10, no. 2 (December 29, 2018). doi.org/10.1186/s12544-018-0338-0.

[11] Center for Urban Transportation Research, Edward L. Hillsman, Sara Jay Hendricks, and JoAnne K. Fiebe, *A summary of design, policies and operational characteristics for shared bicycle/bus lanes* § (2012), x.

because they feel unsafe in a bus blind spot or the bus is stopped for passengers boarding and alighting. When a bike lane is present, bicyclists may swerve leftward within the bike lane or leave the bike lane without performing a full overtake. This maneuver may be performed to avoid injury from an obstacle in the bike lane. Examples of obstacles are listed below:

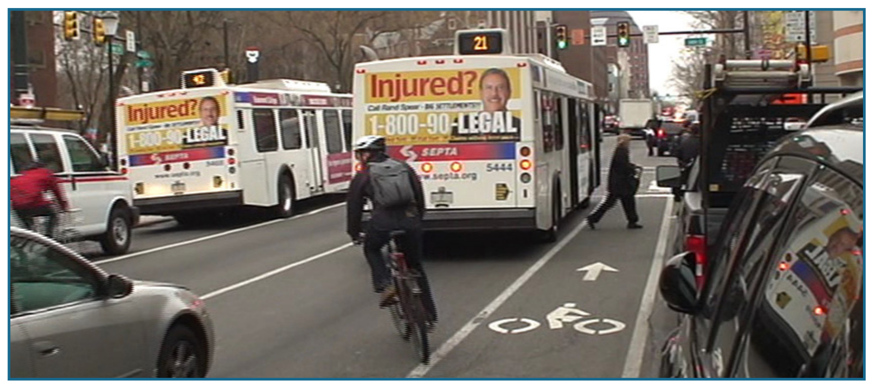
- When street parking is located adjacent to the bike lane, opening a motor vehicle door into the bike lane may block the path of a bicyclist.
- Maintenance issues, such as debris, snow, or potholes, may create unsafe situations in the bike lane.
- Other road users may obstruct the path of the bicyclist, such as pedestrians standing in the bike lane, motor vehicles parked in the bike lane, or slow-moving bicyclists.

Figure 3: Left Side Overtake, No Bike Lane Present



Source: Mateus Martins Cavalcante de Macedo (2019)

Figure 4: Left Side Overtake, Bike Lane Present

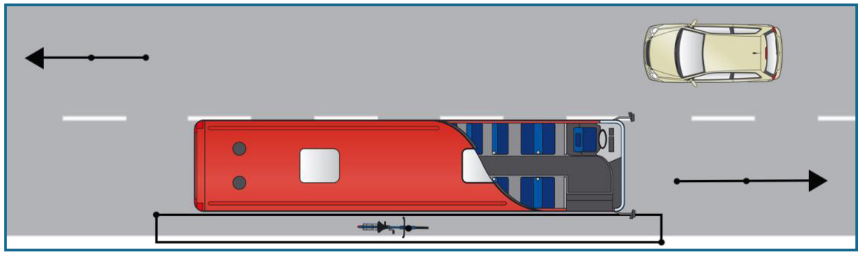


Source: DVRPC (2009)

2. Right Side Overtake

A bicyclist performs a right side overtake by squeezing into the limited space between a bus and the curb. This interaction commonly occurs at bus stops, in stop-and-go traffic, and at intersections. See Figures 5 and 6 for examples. Bicyclists may overtake on the right side if it appears safer than passing on the left side. This maneuver requires bus operators to track and anticipate the movement of bicyclists to avoid sideswipe collisions or bicyclist interference with passengers boarding and alighting.

Figure 5: Right Side Overtake, No Bike Lane Present



Source: Mateus Martins Cavalcante de Macedo (2019)

Figure 6: Right Side Overtake, Bike Lane Present

Source: DVRPC (2009)

STREET DESIGNS WITH A DEDICATED BIKE LANE

CONVENTIONAL BIKE LANE

Conventional bicycle lanes are located on the right side of the cartway, directly adjacent to the bus travel lane.[12] This forces both modes to travel in close proximity. A significant issue arises at bus stops, where the bus needs to be able to cross the bike lane to arrive at the curb. The bus's ability to curb is especially important for successful ADA ramp deployment.

SEPARATED BIKE LANE

Separated bicycle lanes are in-street, dedicated lanes that are separated from moving motor vehicle traffic by a buffer area, with or without vertical deflection. Vertical deflection ranges from painted buffers and flexible delineators to more substantial separation techniques including jersey barriers, concrete buttons, and raised cycle tracks (see Chapter 5 and 6 for examples). Options vary due to local context, such as available space and budget considerations.

PARKING SEPARATED BIKE LANE

Parking separated bicycle lanes (PSBLs) are in-street, dedicated lanes that are separated from moving motor vehicle traffic by a parking lane, buffer area, and vertical deflection. A buffer area with vertical deflection is necessary to prevent vehicle doors opening into the path of a bicyclist and to prevent parking encroachment into the bicycle lane. In a recent study, PSBLs were found to reduce instances of bicycling on the sidewalk, lower vehicle speeds, and reduce interactions between drivers and bicyclists.[13] See Chapter 6 for conceptual designs using parking separated bike lanes.

BIKE LANES ON ONE-WAY STREETS

Contra-flow bicycle lanes allow bicyclists to ride in the opposite direction of vehicular traffic, converting a one-way street into a two-way street: one direction for drivers and bicyclists, and the other for bicyclists only.[14] If any aforementioned bike lanes are on a one-way street, they may be configured as left-side bike lanes (located on left side of the cartway).

[12] National Association of City Transportation Officials. *Conventional Bike Lanes*, July 19, 2019. nacto.org/publication/urban-bikeway-design-guide/bike-lanes/conventional-bike-lanes/.

[13] Ahramjian, Laura, and Glenn Rowe. "Philadelphia Parking Separated Bike Lane Study." Office of Transportation, Infrastructure, and Sustainability, April 1, 2022. www.phila.gov/2022-04-01-philadelphia-parking-separated-bike-lane-study/.

[14] National Association of City Transportation Officials. *Contra-Flow Bike Lanes*, July 19, 2019. nacto.org/publication/urban-bikeway-design-guide/bike-lanes/contra-flow-bike-lanes/.

3. Bus Curbing or Inability to Curb

Buses need access to the curb for passengers to board and alight at bus stops. Yet, there are many situations in which curbing does not occur. Operators may choose not to curb to avoid difficulties re-entering traffic. They might be unable to curb when obstacles block the bus stop, such as illegally parked vehicles, pedestrians waiting in the cartway for the bus, or a bicyclist performing a right side overtake. Bus stops next to conventional bike lanes force operators to cross the bicyclists' path. Bicyclists may respond by attempting an overtake. Despite challenges, curbing is necessary to extend the bus's ADA ramp for passengers with mobility difficulties. See Figure 7 for examples of curbing difficulties due to the present bike lane.

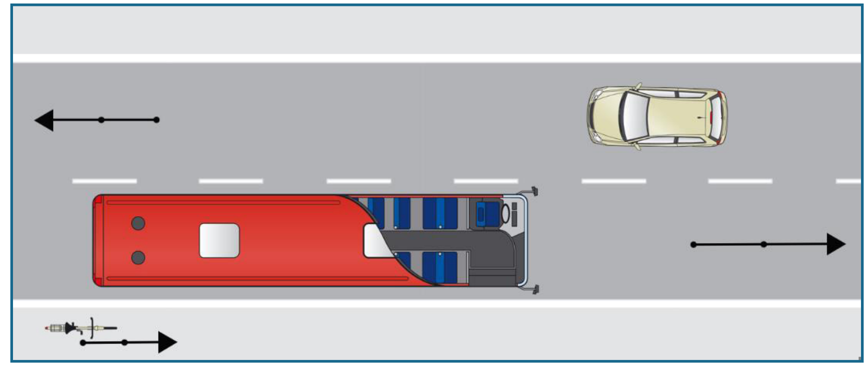
Figure 7: Inability to Curb, Bike Lane Present

Source: DVRPC (2022)

4. Sidewalk Bicyclists

Bicyclists tend to ride on the sidewalk when they do not feel safe traveling in the cartway or encounter obstacles blocking the bike or travel lane. This interaction commonly occurs at bus stops, in stop-and-go traffic, and at intersections. See Figure 8 for an example. At intersections with traffic queuing, bicyclists may try to filter forward by riding on the sidewalk. Bicyclists and buses are at risk of collision when a bicyclist transitions from the sidewalk into the cartway.

Figure 8: Sidewalk Bicyclist, No Bike Lane Present

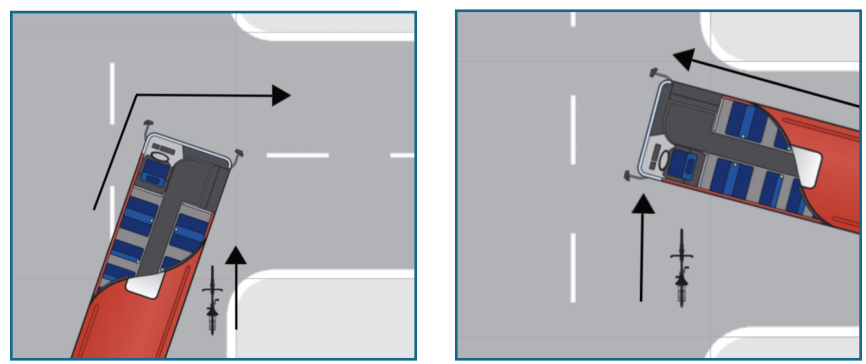


Source: Mateus Martins Cavalcante de Macedo (2019)

5. Right Hook and Right Pull-Out

A right hook occurs when a right-turning bus conflicts with a through bicyclist in the same lane or adjacent bike lane. A right pull-out occurs when a bus operator turns right from a cross street into the lane in which a bicyclist is traveling. This interaction commonly occurs at intersections. See Figure 9 for examples. Following the same principles, a left hook or left pull-out can occur on a one-way street with a left-side bike lane.

Figure 9: Right-Hook and Right Pull-Out



Source: DVRPC via Accident Sketch (2022)

6. Intersection Control Noncompliance

Traffic signals do not always detect the presence of a bicycle, or they are not designed to. Noncompliance tends to happen when signal phases are not triggered by a bicycle, or at intersections with long signal cycles. In these situations, bicyclists sometimes travel through the intersection before the signal phase indicates to. This interaction commonly occurs at intersections. Noncompliance can put bicyclists and vehicular traffic at risk of collision. See Figure 10 for an example.

Figure 10: Intersection Signal Noncompliance

Source: www.pedbikeimages.org / Toole Design Group

CHAPTER 4:

Strategies to Reduce Bus–Bicycle Interactions

As Complete Streets strategies are implemented across the state, more bicycle facilities will be built along fixed bus routes. This chapter describes design, communication, and operational strategies for coordinating NJ TRANSIT bus service alongside bicycle infrastructure, as shared during four interviews with peer transit agencies in comparable jurisdictions. For more information about existing conditions in the NJ TRANSIT service area, see Chapter 1.

Peer Transit Agency Interviews

The purpose of the peer transit agency interviews was to identify street design, stakeholder communication, and operational strategies that comparable jurisdictions use to reduce interactions between buses and bicyclists, whether bike lanes are present in the service area or not.

Peer transit agency interviews were held in four sessions:

1. January 26, 2023: Washington Metropolitan Area Transit Authority (WMATA) interview
2. February 3, 2023: Massachusetts Bay Transportation Authority (MBTA) interview
3. February 7, 2023: Metropolitan Transportation Authority (MTA) interview
4. March 20, 2023: Rhode Island Public Transit Authority (RIPTA) interview

Interviews were guided by a standard set of questions developed by the DVRPC project team in partnership with NJ TRANSIT. However, all attendees were encouraged to share comments and follow-up questions if they had them.

Interview questions focused on the following topics:

- Design solutions, including examples of street designs that have improved ADA accessibility and bus–bicycle interactions in urban, suburban, or rural areas
- Communication with road owners and other stakeholders when street design changes are under consideration
- In-vehicle technology including audio and visual cues to alert bus operators and road users of potential interactions
- Bus operations training regarding bicyclists and potential interactions
- Issues related to new mobility options such as e-bicycles and e-scooters
- Engagement in road safety partnerships such as Vision Zero

All four peer transit agencies acknowledged that pedestrian and bicyclist safety remains a top concern, particularly at bus stops. Road owners have employed various strategies, including signage, pavement markings, and vertical deflection to encourage bicyclists to slow down near bus stops. Several peer transit agencies have developed bus stop design guidelines in part to support consistent treatments throughout their service area so that customers and bicyclists know what to expect.

See Table 2 for a detailed list of design, communication, and operational strategies used by peer transit agencies to reduce bus–bicycle interactions and improve conditions in their respective service areas.

Table 2: Strategies Expected to Reduce Bus–Bicycle Interactions

Issue Type	Issue Description	Potential Strategy
Street Design	Modes forced to travel in close proximity	Prioritize mode separation in design guides and discussions with road owners
	Narrow stretch of cartway along a corridor	Adapt design to limited cartway (i.e., bike lane becomes shared lane marking)
	Lack of data about effective street designs	Use temporary materials to test performance of new street designs
Communication About Street Design	Street design changes occur without transit agency input	Initiate regular contact with road owners regarding changes on bus corridors
	Departments use varying criteria to evaluate street designs	Create a standard internal process to coordinate on street design changes
	Road safety initiatives omit transit agency perspective	Participate in Vision Zero task forces and other road safety initiatives
Operational	Difficult for operators to keep track of vulnerable road users	Use technology to alert road users to each others' presence
	Challenging for operators to react to bicyclist's movements	Continue education for operators on how to safely share the street with bicyclists
	Limited data collection from operators	Urge operators to report all interactions and give feedback on street design

Source: DVRPC (2023)

Design Strategies Used by Peer Transit Agencies

1. Prioritize separation of modes in bus stop design guidelines and conversations with road owners.

Transit agencies interviewed for this project were uniformly in support of separate facilities for buses and bicycles whenever possible as the safest and most comfortable option for bicyclists, bus operators, and passengers.

The Washington, D.C. District Department of Transportation (DDOT) installed shared bus–bicycle lanes as part of early attempts to prioritize buses and create lower-stress areas for bicyclists. Negative feedback from both bicyclists and bus operators has caused DDOT to move away from this strategy and focus on separating modes. WMATA and DDOT have worked together to design and implement bus boarding islands on streets with bike lanes that channel bicyclists between the boarding area and the curb (see Figure 11 for an example from nearby Montgomery County, MD). In town center contexts, similar installations have included permanent boarding islands (i.e., constructed from concrete) and rear and side fences to discourage passengers from crossing into the bike lane unexpectedly. In suburban contexts that do not have right-of-way constraints, some road owners have installed side paths to allow bicyclists to travel behind bus shelters, away from vehicular traffic.

Figure 11: Bus Boarding Island in Silver Spring, MD

Source: Google Street View of Wayne Avenue & Georgia Avenue (2021)

SUMMARY OF EACH TRANSIT AGENCY INTERVIEW

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY (WMATA)

WMATA has experience with both temporary and permanent infrastructure upgrades aimed to reduce interactions between people riding bicycles, bus operators, and bus passengers. The typical pattern of these interventions channels bicyclists behind the bus boarding area, away from vehicular traffic, and uses signage and/or vertical deflection to caution bicyclists that they are entering mixing areas and should yield to pedestrians. WMATA and the Washington, D.C. District Department of Transportation (DDOT) remain concerned about passenger and bicyclist safety in areas where pedestrian walkways cross bicycle lanes. They continue to improve signage to alert road users to each others' presence.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY (MBTA)

MBTA highlighted the strong visions for bicycle infrastructure that many of the municipalities they serve are pursuing. In response, MBTA is advocating for separate bus and bicycle infrastructure. When bus and bicycle facilities exist side by side, MBTA works with road owners on minor design changes like moving bike lanes to left side of the cartway on one-way streets or using signals to separate the timing of the modes. Operator training has benefited from specific bicycle-oriented content developed by a local bicycle advocacy organization.

METROPOLITAN TRANSPORTATION AUTHORITY (MTA)

MTA has seen tremendous growth in bicycle infrastructure and bicycling in its service area in recent years. The Authority is an active participant in Vision Zero efforts and conducts targeted internal campaigns focusing on safety and professionalism for its operators. MTA emphasized focusing on what is within their control when it comes to adapting to new street and bus stop designs. MTA prefers street designs with separation between buses and bicycles. MTA has identified that the majority of bus-bike crashes take place in Manhattan, with fewer in less dense environments.

RHODE ISLAND PUBLIC TRANSIT AUTHORITY (RIPTA)

Of the peer agencies interviewed for this project, RIPTA was most similar to NJ TRANSIT in providing statewide service in a variety of settings, from rural to urban. RIPTA reported relatively few bicyclists in their service area. However, the City of Providence has begun to install bicycle infrastructure on streets with bus routes, which has required increased coordination with RIPTA. RIPTA also developed a bus stop design guide in collaboration with RIDOT that provides guidance for municipalities statewide. RIPTA applied for and received funding from the federal Safe Streets for All grant program to work with 32 municipalities to create safe streets plans.

MTA spoke highly of left-side bike lanes on New York City's one-way streets and their ability to separate bicyclists and buses. They noted that dedicated bike lanes had the added safety benefit of slowing down vehicular traffic, regardless of whether they were located on the left or right side of the cartway. See Figure 12 for an example of a left-side bike lane.

Figure 12: Left-Side Bike Lane in New York City

Source: Google Street View of West 70th Street & Columbus Avenue (2022)

RIPTA considers topography when designing bicycle and scooter infrastructure. For example, scooter riders have been observed using a dedicated bus tunnel to circumvent a hilly section of Providence, RI. As RIPTA redesigns the tunnel they are looking for alternate bicycle and scooter routes that avoid steep grades.

2. Street design should adapt to stretches of limited right-of-way throughout a corridor.

The City of Cambridge wants to support both bicycle activity and MBTA bus activity on Massachusetts Avenue, a major thoroughfare. With areas of limited right-of-way, mode separation is not possible on the entire corridor. The final design includes bus priority lanes and separated bike facilities on most of the corridor, with a few spaces where mixing is necessary. In these mixing zones, bicyclists are expected to yield to passengers boarding and alighting. Although the design is not ideal for supporting bus priority, the municipality was able to adjust signal timing to help it function better.

Areas with fewer right-of-way constraints allow for increased separation. For example, in WMATA's region, multi-use sidepaths direct bicyclists behind bus stops, away from boarding and alighting passengers and the motor vehicle travel lanes.

3. Use temporary materials to pilot and test performance of new designs.

Temporary bus boarding platforms have been used in all four jurisdictions to test new road configurations and gain an understanding of how they impact the behavior of road users. These modular platforms allow the bus to curb in-lane and provide more space for people boarding, alighting, and waiting for the bus. The platforms often continue the bike lane behind the bus boarding area using ramps (see Figure 13).

WMATA reported that temporary platforms presented challenges for maintenance. When they are installed in lanes used by cars, there have been instances of cars driving up onto the temporary platforms. WMATA has found that clear vertical indicators (like jersey barriers and bollards) are required to alert motorists. Since the jurisdiction finds value in the boarding island design, temporary infrastructure will be upgraded to more permanent design solutions, such as concrete bus boarding islands (see Figure 11).

Figure 13: Temporary Bus Boarding Platform in Washington, DC

Source: Nearmap (2021)

RIPTA shared an example of a wooden temporary bus boarding platform and spray-chalked bike lane installation on Hope Street. While the materials were less durable than the plastic or metal temporary platforms used elsewhere, they were well-accepted.

Communication Strategies Used by Peer Transit Agencies

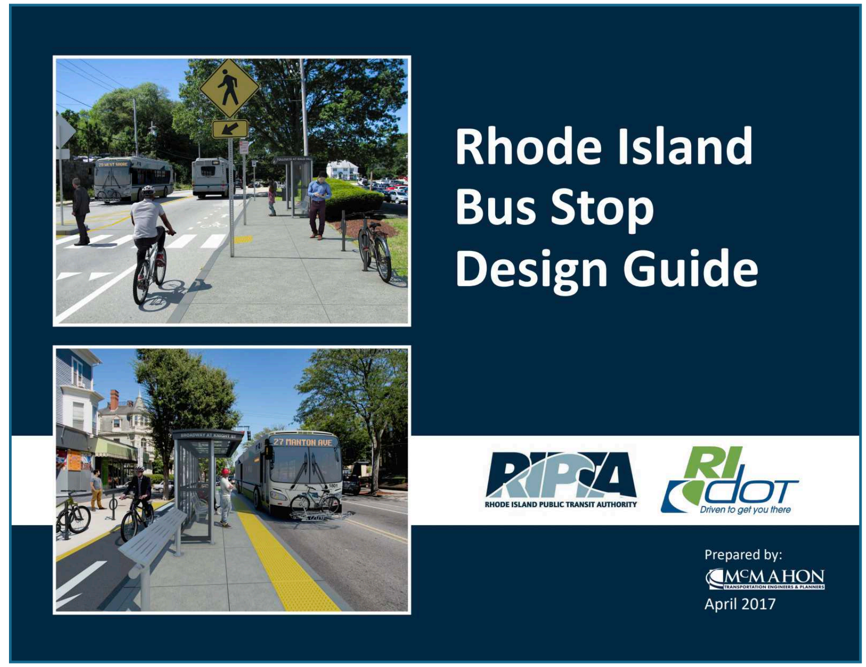
1. Initiate regular contact with road owners.

Regular meetings with road owners provide a forum for discussing new interventions or providing feedback on changes to infrastructure. WMATA, MBTA, RIPTA, and MTA all have regular meetings with road owners, several focused explicitly on street design and safety. MBTA's meetings are focused more broadly on bus priority. Several transit agencies interviewed for this project worked collaboratively with road owners in their service areas to develop bus stop design guidelines. Both the process of jointly developing the guidelines and their use as a standard has improved communication regarding street design changes.

MTA maintains regular contact with New York City Department of Transportation (NYC DOT), the largest road owner in their service area, regarding street redesigns. At times MTA has to adapt their service based on NYC DOT. An example of this is instructing operators to straddle two lanes if one is too narrow to navigate safely.

RIPTA worked closely with the Rhode Island Department of Transportation (RIDOT) to develop bus stop guidelines for the state (see Figure 14).[15] RIPTA intended to train municipalities on the bus stop design guide, but with staffing changes among those who had participated in developing the guide, it was unclear whether planned training had occurred. RIPTA reported successful improvements in communication with the DOT in Providence, their service area's largest road owner. They established monthly calls with the Providence Department of Public Works, which has helped to bridge communication gaps.

Figure 14: Rhode Island Bus Stop Design Guide



Source: RIPTA (2017)

2. Create a uniform process to coordinate internally on bus stop and street design changes.

MBTA has an internal process of circulating proposed street design changes that they receive from road owners to different teams within the agency, including an accessibility team. A uniform process ensures that each department within the agency is able draw on their respective subject matter expertise to provide comments.

[15] "Rhode Island Bus Stop Design Guide (2017)." RIPTA, July 16, 2020. www.ripta.com/projects/rhode-island-bus-stop-design-guide-2017/.

Figure 15: MTA Vision Zero Bus Operator Materials

Source: MTA

3. Join and actively participate in Vision Zero task forces and other road safety initiatives.

Five municipalities in the MBTA service area have adopted Vision Zero, and they prioritize that above everything else in designing the right-of-way. Some of the municipalities' prioritization of the safest possible pedestrian and bicycle infrastructure means that bus priority infrastructure is deprioritized. It puts an emphasis on protecting the most vulnerable people on the street.

MBTA supports these efforts, recognizing that their passengers start their journeys as pedestrians and bicyclists, and attempts to work collaboratively with municipalities to find solutions that benefit buses as well.

MTA is an active participant in Vision Zero task force meetings. Their focus is on ensuring that changes recommended improve safety for vulnerable road users while maintaining acceptable conditions or introducing improvements for bus operators. See Figure 15 for an example of Vision Zero training materials for MTA bus operators

Operational Strategies Used by Peer Transit Agencies

1. Use in-vehicle and on-street technology to alert road users to each others' presence.

Peer transit agencies are experimenting with technology to better serve passengers with disabilities and to reduce obstructed views for bus operators.

DDOT is considering non-visual cues that can inform blind or vision-impaired individuals that the bus is boarding on an island rather than at the sidewalk, including automatic annunciators to announce when the bus is approaching. DDOT is also considering installing audible indicators that are activated by approaching bicyclists.

MBTA is piloting an audio warning on its buses that announces to customers when boarding requires crossing a bicycle lane or mixing area.

MTA has tested several different technologies to improve the safety of interactions between buses and bicycles or pedestrians. Most MTA buses are equipped with front- and rear-facing cameras, and MTA reviews footage regularly to identify potential hazards. They also use pedestrian turn warning signals ("bus is turning" external audio) in combination with signal lights flashing. MTA is running a 90-day, 5-bus pilot to re-institute a pedestrian collision system that is sensor- and camera-based. It will alert the operator if the system identifies a hazard that could turn into an emergency (uses a color system of green, yellow, and red to indicate increasing probability of whether a person will be struck). MTA used this system some years ago and got a lot of false readings, but is hopeful that the technology has since improved.

MTA is also in the process of launching a pilot to test e-mirrors. This system would replace physical exterior bus mirrors with cameras that feed video footage into two screen displays in view of the bus operator. If successful, the shift to e-mirrors will require extensive outreach and training.

Finally, MTA electric buses have courtesy lights that illuminate the entire right side of the bus during right turns (and vice versa for left turns). Operator feedback has been largely positive and it hasn't been reported as a distraction while driving.

RIPTA buses have turning movement warning announcements. They have also piloted on-board video monitors to enhance drivers' lines of sight.

2. Train operators regarding how to safely share the street with bicyclists.

Peer agencies varied in their approach to training operators on matters of safety related specifically to bicycles.

For smaller projects, WMATA has distributed information to operators at quarterly division safety meetings. More comprehensive and permanent corridor updates will be addressed through targeted outreach to operators who will be driving the route when it is first implemented and leave-behind materials for operators who will be new to the route in the future.

MBTA provides training to its operators on operating buses safely around bicyclists. The training was developed by a local bicycle advocacy organization.

Bus-related training is incorporated into MTA's extensive training program, including using footage of collisions as a tool to spark operator discussion about what could have been handled differently. MTA's training materials promote operator professionalism and encourage operators to focus on elements within their control. MTA also provides mentorship opportunities for new operators to learn from experienced operators.

RIPTA reported when new infrastructure is installed, the training team creates videos that play on a loop in the employee lounge.

3. Build in regular opportunities for operators to report all types of bus–bicycle interactions and give feedback on street design changes.

Agencies vary in their methods for collecting operator feedback on street changes.

MBTA's Transit Priority Team has been tabling at garages to solicit operator feedback on corridor transformation projects. Operators, superintendents, and trainers have expressed gratitude for the opportunity to provide input.

MTA trains its bus operators to report everything. For example, if someone leans on the bus to rest while cycling, operators will report it as an interaction. This leads to over-reporting, but the agency prefers to be over-inclusive when it comes to safety data. In addition, each bus depot has a suggestion box where operators can raise concerns, including those related to street design changes. MTA staff investigates such concerns and submits recommendations for changes to New York City's 311 system.

RIPTA incorporated an operator survey into its evaluation of temporary boarding platforms on Hope Street. Results of this survey are forthcoming.[16]

[16] "Hope Street Temporary Trail." Providence Streets Coalition, May 26, 2023. pvdstreets.org/hope/.

CHAPTER 5:

Conceptual Design Process

This chapter describes the process the project team used to select case study locations and create conceptual designs illustrating improvements expected to reduce bus–bicycle interactions at two case study bus stops in Mercer County, NJ.

Case Study Selection

The purpose of the case studies was to apply street design, stakeholder communication, and operational strategies recommended by the project team to corridors and bus stops in NJ TRANSIT's service area. The team identified three criteria when considering possible case study locations:

1. There should be a path to near-term implementation for some of the recommendations.
2. The conceptual design process should build upon existing relationships between NJ TRANSIT and road owners in the region.
3. Different urban densities and different bus stop configurations should be considered. The stops should also be on streets that have or are planned to have dedicated bicycle lanes.

Based on knowledge of the region, the DVRPC team suggested two locations on Prospect Street — one in the City of Trenton and one in Ewing Township. The portion in Trenton is on a segment owned and maintained by the City of Trenton, while the Ewing Township section is owned and maintained by Mercer County. See Figure 16 for the approximate locations of the case study bus stops within the NJ TRANSIT service area.

On the section of Prospect Street owned by Mercer County, there are currently buffered bike lanes. On the section of Prospect Street owned by the City of Trenton, there is currently no bicycle infrastructure. The forthcoming Trenton bike plan recommends delineator-separated bike lanes on Prospect Street, with one side protected with on-street parking.

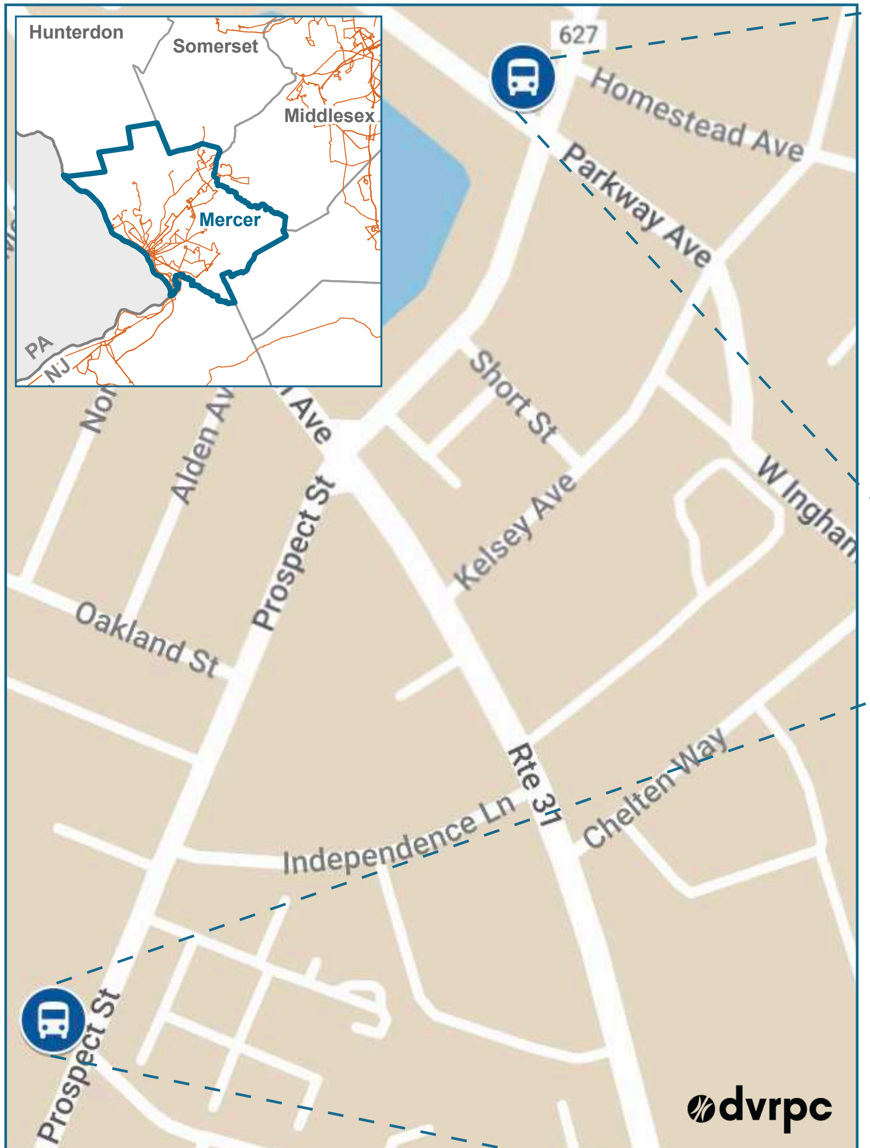
The City of Trenton has plans to repave a portion of Prospect Street under its control in the next year. Repaving presents a low-cost opportunity to stripe separated bike lanes, install delineators, and evaluate safety impacts of the changes. As repaving occurs across Trenton, there is also an opportunity to establish a working group to identify and pilot lighter-weight bus–bicycle improvements recommended in this study along other Trenton corridors.

Figures 17 and 18 on the following page show Google Street View imagery of the two locations and summarize key characteristics of the street segments.

In-Person Collaborative Workshop

A common theme the DVRPC project team heard is there is a need for improved communication between stakeholders when a bike facility is proposed and built. Feedback from peer transit agency interviews (see Chapter 4) indicated that consistent communication both internally and externally across and between stakeholders was beneficial to the outcome of new bicycle facility designs for multimodal streets. To help facilitate communication between stakeholders for the case study locations, the DVRPC project team organized a bus stop design workshop.

Figure 16: Approximate Locations of Case Study Bus Stops



Source: NJ TRANSIT via Google My Maps (2023)

Figure 17: Ewing Township Case Study Bus Stop

- County-owned road, AADT ~10,400
- Near-side bus stop
- Buffered bike lanes
- Nearby residential areas

Source: DVRPC (2023) via Google Street View (2022)

Figure 18: City of Trenton Case Study Bus Stop

- City-owned road, AADT ~11,700
- Mid-block bus stop
- No existing bicycle infrastructure
- Nearby senior and recreation center, affordable housing

Source: DVRPC (2023) via Google Street View (2022)

Workshop Goals

The bus stop design workshop brought key stakeholders including road owners, cycling advocates, and NJ TRANSIT together to brainstorm implementable bus stop designs that are expected to reduce bus–bicycle interactions at two bus stops on NJ TRANSIT bus route 601. Gathering this group was intended to create connections and hopefully ensure continued communication regarding future project implementation.

The workshop was held at Trenton City Hall on June 5, 2023, and included representatives from DVRPC, NJ TRANSIT, New Jersey Department of Transportation, City of Trenton, Mercer County, Alan M. Voorhees Transportation Center, Bicycle Coalition of Greater Philadelphia, and Trenton Cycling Revolution.

Workshop Description

The workshop began with presentations about common bus–bicycle interactions, bike lane dimensions, and project context. Workshop participants then broke out into small groups to develop bus stop designs using a toolkit of signage, pavement markings, and infrastructure elements (see Figure 19: Toolkit of Bike Lanes and Physical Separation and Figure 20: Toolkit of Signage and Pavement Messages). The toolkit was developed by DVRPC staff to give examples of elements that can reduce bus–bicycle interactions. Each breakout group consisted of at least one DVRPC facilitator, road owner, cycling advocate, and NJ TRANSIT staff — each involved in designing, implementing, and navigating street design changes.

Although the two bus stops are on the same street, the users and environments are different. The workshop concluded with workshop participants discussing next steps to implement, fund, and maintain the two bus stops on Prospect Street. The strategies and enhancements discussed could potentially be deployed elsewhere in the NJ TRANSIT service area, especially at locations known to have bus–bicycle interactions.

Workshop Outcome

Workshop participants appreciated the opportunity to work through this exercise with NJ TRANSIT. Following the workshop, the project team drafted conceptual designs illustrating improvements expected to reduce bus–bicycle interactions. These are shown in the next chapter (see Figures 25, 26, 29). Designs were reviewed by workshop participants, updated to incorporate comments, and finalized for this memo.

In addition, the following suggestions emerged from the workshop session:

1. Minimum infrastructure requirements should be developed for bus stops to account for the growth in new mobility options.
2. Further infrastructure can be added to the minimum requirements in response to crash data or local context such as increased vehicle and bicycle volumes, vehicular speeds, space available, and availability of funds.
3. Vertical barriers (i.e., delineators) to keep vehicles in the travel lane will be important to preserve longevity of striping treatments, but will present maintenance considerations for the road owner.
4. To document these considerations, many agencies have developed bus stop design guides. See SEPTA Bus Stop Design Guidelines[17] for an example developed by DVRPC.
5. Innovative designs may need to be funded locally, as federal funds have requirements such as purchasing from American companies and meeting MUTCD standards.

[17] Delaware Valley Regional Planning Commission. *SEPTA Bus Stop Design Guidelines*, 2019. www.dvrpc.org/reports/18029.pdf.

Figure 19: Toolkit of Bike Lanes and Physical Separation

ARMADILLOS
Recommended width (barrier + bike lane)
6.5 feet - 8 feet

Protection Level
1 **2** 3 4

Installation Cost
$ **$$** $$$ $$$$

Armadillo Lifespan
Short Term → Mid Term

CAST IN PLACE CURB
Recommended width (barrier + bike lane)
6 feet - 8 feet

Protection Level
1 2 **3** 4

Installation Cost
$ $$ **$$$** $$$$

Curb Lifespan
Mid Term → Long Term

CONCRETE BUTTONS
Recommended width (barrier + bike lane)
6.5 feet - 8 feet

Protection Level
1 **2** 3 4

Installation Cost
$ **$$** $$$ $$$$

Concrete Button Lifespan
Short Term → Mid Term

CONCRETE JERSEY BARRIERS
Recommended width (barrier + bike lane)
7 feet - 8 feet

Protection Level
1 2 3 **4**

Installation Cost
$ $$ $$$ **$$$$**

Jersey Barrier Lifespan
Mid Term → Long Term

FLEXIBLE DELINEATORS
Recommended width (barrier + bike lane)
8 feet

Protection Level
1 **2** 3 4

Installation Cost
$ **$$** $$$ $$$$

Delineator Lifespan
Pilot → Short Term

FLEXIBLE DELINEATORS*
Recommended width (barrier + bike lane)
11.5 feet - 13 feet

Protection Level
1 **2** 3 4

Installation Cost
$ **$$** $$$ $$$$

Delineator Lifespan
Pilot → Short Term

**Shown as two-way cycle track*

PARKING PROTECTED*
Recommended width (barrier + bike lane)
14 feet - 16 feet

Protection Level
1 2 3 **4**

Installation Cost
$ **$$** $$$ $$$$

Delineator Lifespan
Short Term → Mid Term

**Shown with flexible delineators*

PARKING STOPS
Recommended width (barrier + bike lane)
5.5 feet - 8 feet

Protection Level
1 2 **3** 4

Installation Cost
$ $$ **$$$** $$$$

Parking Stop Lifespan
Short Term → Mid Term

PLANTERS
Recommended width (barrier + bike lane)
8 feet plus the planter width

Protection Level
1 2 3 **4**

Installation Cost
$ $$ $$$ **$$$$**

Planter Lifespan
Pilot → Mid Term

RAISED BIKEWAY
Recommended width (barrier + bike lane)
5.5 feet

Protection Level
1 2 **3** 4

Installation Cost
$ $$ $$$ **$$$$**

Bikeway Lifespan
Mid Term → Long Term

RIGID BOLLARDS
Recommended width (barrier + bike lane)
7 feet - 8 feet

Protection Level
1 2 3 **4**

Installation Cost
$ $$ $$$ **$$$$**

Rigid Bollard Lifespan
Short Term → Mid Term

STRIPED BUFFER
Recommended width (barrier + bike lane)
8 feet

Protection Level
1 2 3 4

Installation Cost
$ $$ $$$ $$$$

Striping Lifespan
Pilot → Long Term

KEY

Protection Level
1 = No vertical barrier to reduce vehicle impact
2 = Vertical barrier improves driver behavior, with minimal change to vehicle impact
3 = Vertical barrier will slow vehicle before impact
4 = Vertical barrier will significantly slow or stop vehicle before impact

Installation Cost (estimate)
$ = $8K-$15K per lane-mile
$$ = $15K-$30K per lane-mile
$$$ = $30K-$80K per lane-mile
$$$$ = $80K-$20M per lane-mile
Additional source: Tactical Urbanism Guide

Lifespan (estimate)*
Pilot = Some maintenance after few months
Short Term = Some maintenance after 1 year
Mid Term = Some maintenance after 5 years
Long Term= Some maintenance after >5 years
**All materials dependent on volume and weather. Striping and markings may last 3-72 months.*

Source: DVRPC (2023); photo sources on the following page. Note: Workshop participants used this toolkit to generate bus stop design ideas.

Figure 20: Toolkit of Signage and Pavement Messages

BIKE BOX
Placement
Signalized intersections
Purpose
Increase cyclist visibility when queuing
Per-Unit Cost (Raw materials only)
$250 - $600
Lifespan
Pilot ⟶ Mid Term

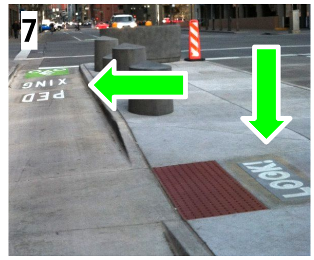
BIKES YIELD TO PEDS SIGN
Placement
Bus stops and crosswalks
Purpose
Use in combination with other features to slow/stop bicyclists
Per-Unit Cost (Raw materials only)
$25 - $200
Lifespan
Pilot ⟶ Long Term

CHANGE IN MATERIALS
Placement
Bus stops and crosswalks
Purpose
Alert bicyclists and signal to pedestrians where to safely stand and cross
Per-Unit Cost (Raw materials only)
$10 - $100 per square foot
Lifespan
Mid Term ⟶ Long Term

COLORED PAINT
Placement
Bike lane or bus lane
Purpose
Increase visibility of lane throughout a corridor or as a spot treatment
Per-Unit Cost (Raw materials only)
$1 - $10 per square foot
Lifespan
Pilot ⟶ Long Term

CONTINENTAL CROSSWALK
With signage and yield line / shark teeth
Placement
Near-side, far-side, mid-block
Purpose
Provide high visibility pedestrian crossing
Per-Unit Cost (Raw materials only)
$0.50 - $5 per linear foot
Lifespan
Pilot ⟶ Long Term

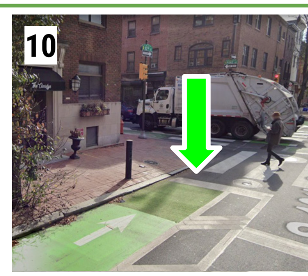
MODE SEPARATION SIGNAGE
Placement
Conflict areas
Purpose
Use in combination with other features to encourage mode separation
Per-Unit Cost (Raw materials only)
$25 - $500
Lifespan
Pilot ⟶ Long Term



PAVEMENT MARKINGS
Placement
Conflict areas
Purpose
Draw attention to conflict areas and direct behavior using clear visual cues
Per-Unit Cost (Raw materials only)
$150 - $500
Lifespan
Pilot ⟶ Mid Term

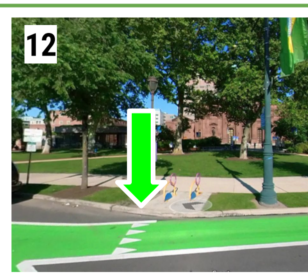
RADAR SPEED SIGN
Placement
Corridors on which speeding is an issue
Purpose
Encourage vehicles to slow down
Per-Unit Cost (Raw materials only)
$2,500 - $10,000
Lifespan
Mid Term ⟶ Long Term

RAISED CROSSWALK
Shown with flashing beacon
Placement
Near-side, far-side, mid-block
Purpose
Increase pedestrian visibility and allows them to cross at sidewalk-level
Per-Unit Cost (not including beacon)
$35,000 - $75,000
Lifespan
Mid Term ⟶ Long Term



STOP BAR
Placement
Bike lane or vehicle lane
Purpose
Inform bicyclists where to stop to maintain a safe distance from pedestrians
Per-Unit Cost (Raw materials only)
$0.50 - $5 per linear foot
Lifespan
Pilot ⟶ Long Term

TACTILE INTERVENTIONS
Truncated domes (blister / lozenge pattern)
Placement
At each end of pedestrian crossings
Purpose
Alert visually impaired pedestrians
Per-Unit Cost (Raw materials only)
$50 - $100 per square foot
Lifespan
Mid Term ⟶ Long Term



YIELD LINE / SHARK TEETH
Placement
Conflict areas
Purpose
Alert bicyclists to potential conflict zones
Per-Unit Cost (Raw materials only)
$0.50 - $5 per linear foot
Lifespan
Pilot ⟶ Long Term

KEY

Lifespan (estimate)*
Pilot = Some maintenance after few months
Short Term = Some maintenance after 1 year
Mid Term = Some maintenance after 5 years
Long Term= Some maintenance after >5 years
**All materials dependent on volume and weather.*
Striping and markings may last 3-72 months.

Source: DVRPC (2023); photo sources on the following page. Note: Workshop participants used this toolkit to generate bus stop design ideas.

Figure 19 photo sources (see page 25):

1. Bike Delaware (2014)
2. BikePortland.org (2019)
3. AustinTexas.gov (date unknown)
4. San Francisco Municipal Transportation Agency (2017)
5. DVRPC (2023)
6. Bicycle Coalition of Greater Philadelphia (2019)
7. Seattle Department of Transportation (2022)
8. Center City District Philadelphia (2023)
9. NACTO Urban Bikeway Design Guide (date unknown)
10. Google Maps, Denton, TX (2023)
11. Google Maps, Ewing Township, NJ (2022)
12. Seattle Department of Transportation (2022)

Figure 20 photo sources (see previous page):

1. City of Spokane Valley Comprehensive Plan (2011)
2. Capital Metropolitan Transportation Authority (2021)
3. DVRPC (2022)
4. Google Maps, Philadelphia, PA (2022)
5. Google Maps, Philadelphia, PA (2023)
6. DVRPC (2022)
7. Denver Department of Public Works via NACTO (date unknown)
8. “Radar speed sign -- close-up -- over limit” by Richard Drdul, Creative Commons 2.0 License (2006)
9. DVRPC (2022)
10. Google Maps, Philadelphia, PA (2022)
11. Seattle.gov (2017)
12. Google Maps, Philadelphia, PA (2022)

CHAPTER 6:

Conceptual Designs

This chapter describes the conceptual design goals, parameters, and conceptual bus stop designs expected to reduce bus–bicycle interactions at two case study bus stops in Mercer County, NJ. Trenton bus stop improvements primarily include a side boarding island and delineator-separated bike lanes to reduce interactions between transit vehicles and bicycles. Ewing Township bus stop improvements primarily include colored pavement and additional signage to alert all road users to mixing areas. All designs were reviewed by NJ TRANSIT, road owners, and cycling advocates.

Conceptual Design Goals

Street design is one tool among the many tools needed to plan for bus service alongside bicycle facilities. Design works best in conjunction with effective enforcement, communication, education, and training. See Chapter 4 for more detailed recommendations related to these topics. The goals and parameters of the conceptual designs include the following:

- Improve mobility of all road users, including — but not limited to — cyclists, bus passengers and operators, pedestrians, and drivers.
- Reduce common bus–bicycle interactions (identified in Chapter 3), respond to NJ TRANSIT local observations (see Chapter 2), and employ best practices used in peer transit agency interviews (see Chapter 4).
- Maintain ADA compliance and create equal access for persons with limited mobility or vision (see page 35 for NJ TRANSIT official guidance on this topic).
- Work within existing cartway dimensions and focus on low-cost treatments with a path to near-term implementation.
- Accommodate cyclists of various abilities and confidence levels (see following pages for information about determining bicycle facility type).
- Separate modes whenever possible.
- Retain as much on-street parking as possible.

The conceptual designs (see Figures 25, 26, 29) each include both the minimum infrastructure standards to manage multimodal traffic and additional infrastructure for stops with higher passenger and bicycle volumes. These elements are noted in each conceptual design key as “required” (per MUTCD, FHWA, state law, etc.) or “recommended” (additional best practices that are tailored to each bus stop’s specific context, are sensitive to cost, and are responsive to common bus-bicycle interactions). Innovative designs may need to be funded locally, as federal funds have requirements such as purchasing from American companies and meeting MUTCD standards.

Additionally, the project team assumed bus operators will curb at all bus stops unless vertical deflection (i.e., flexible delineators) prevents them from doing so. In this case, the bus stop design should improve boarding and alighting conditions within the cartway by using a side boarding island (see Figures 25 and 26). Side boarding islands are separated from the sidewalk by a bike lane, reducing bus–bicycle interactions at stops.[18]

Though these designs were developed for the two specific case study locations (see Chapter 5), design strategies could potentially be deployed by relevant stakeholders throughout their service area.

[18] “Side Boarding Island Stop.” National Association of City Transportation Officials, January 19, 2017. nacto.org/publication/transit-street-design-guide/stations-stops/stop-configurations/side-boarding-island-stop/.

Figure 21: Bicycle Facility Type Based on Speed and Volume

ADT	85TH PERCENTILE SPEED[1]						
	≤ 20	25	30	35	40	45	≥50
≤ 2,500	A B C D E F	A [2] B C D E F	C D E F	C D E F	C D E F	D E F	F
2,500–5,000	B C D E F	B C D E F	C D E F	C D E F	D E F	D E F	F
5,000–10,000	B [3] C D E F	B [3] C D E F	C D E F	D E F	D E F	E F	F
10,000–15,000	D E F	D E F	D E F	D E F	E F	E F	F
≥15,000	D E F	D E F	D E F	E F	E F	F	F

A: Shared Street/Bicycle Boulevard **B:** Shared-lane Markings **C:** Bicycle Lane **D:** Buffered Bicycle Lane
E: Separated Bicycle Lane **F:** Shared-use Path

[1] If data not available, use posted speed
[2] Bicycle boulevards are preferred at speeds ≤25 mph
[3] Shared-lane markings are not a preferred treatment with truck percentages greater than 10%

Source: State of New Jersey Complete Streets Design Guide (2017)

Determining Bicycle Facility Type

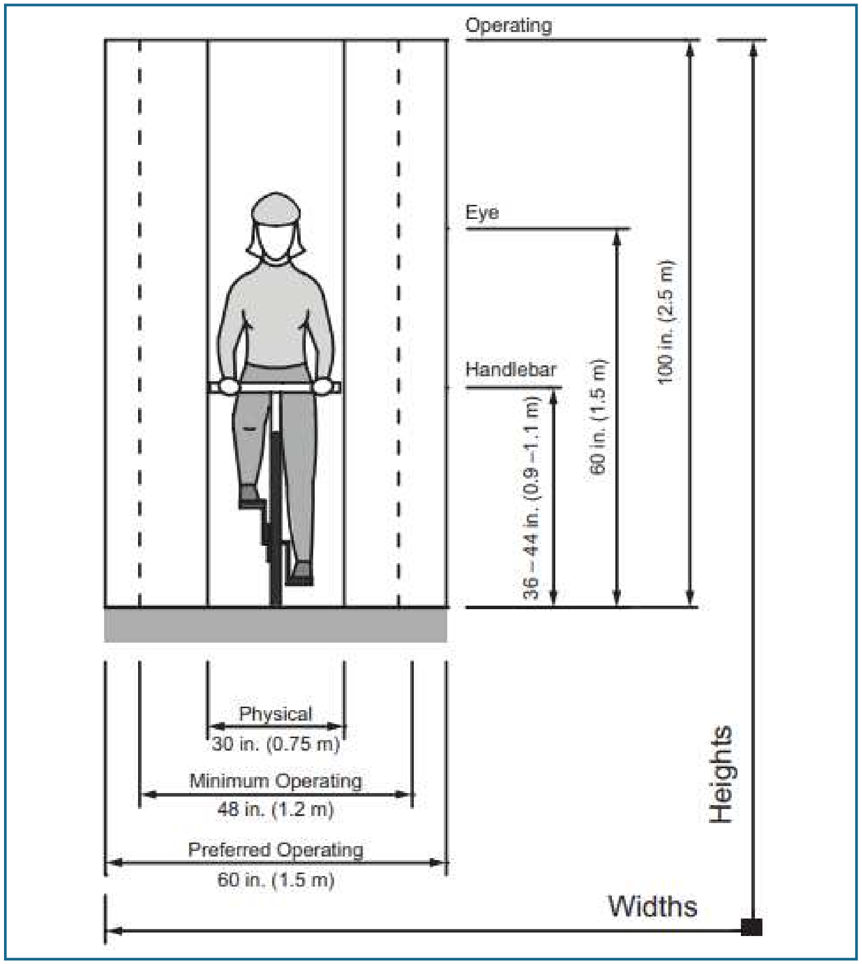
According to the Bicycle Facility Table in the 2017 *State of New Jersey Complete Streets Design Guide*, average daily traffic (ADT) and 85th percentile motor vehicle speeds are used to determine which bicycle facility type is appropriate and comfortable for most adults (if not available, use posted speed). See Figure 21 for the table. Generally the goal is to make a street a Bicycle Level of Traffic Stress (LTS) of 2 or better.[19] The LTS analysis is a tool used to quantify a bicyclist's comfort level given the current conditions of the street. The LTS method identifies four levels of stress: LTS 1 is the level most users can tolerate (including children and seniors); LTS 2 is the level tolerated by most adults; LTS 3 is the level tolerated by "enthusiastic" riders who might still prefer dedicated space; LTS 4 is the level tolerated by the most experienced riders. Characteristics such as vehicle class and cartway width should also be factored into determining the bicycle facility type. Separated bicycle facilities are most preferred by bicyclists of all ages and ability levels.

To determine recommended facility type for the two case study bus stops, the project team used the Bicycle Facility Table above. The two case study locations have a posted speed of 25 miles per hour (speed data was not available) and annual average daily traffic (AADT) in the 10,000-15,000 range. AADT is calculated by applying adjustments such as monthly and day of the week factors to ADT.[20] In this context, the recommended bicycle facilities include a buffered bicycle lane, separated bicycle lane, or a shared-use path. The forthcoming Trenton bicycle plan recommends delineator-separated bike lanes on Prospect Street, with one side protected with on-street parking. See Figure 22 for minimum bicyclist dimensions for dedicated bicycle lanes.

[19] WSP | Parsons Brinckerhoff. "2017 State of New Jersey Complete Streets Design Guide." NJDOT, 2017. www.state.nj.us/transportation/eng/completestreets/pdf/NJCS_DesignGuide.pdf, 106.

[20] Federal Highway Administration, "Traffic Data Computation Method Pocket Guide," U.S. Department of Transportation, August 2018, www.fhwa.dot.gov/policyinformation/pubs/pl18027_traffic_data_pocket_guide.pdf, 11.

Figure 22: Minimum Bicyclist Dimensions



Source: AASHTO Guide for the Development of Bicycle Facilities (2012)

ADA Access on NJ TRANSIT Buses

Both case study bus stops are located along local NJ TRANSIT bus route 601. Local NJ TRANSIT bus operators deploy the wheelchair lift from the front door of the vehicle. Bus boarding and alighting areas should provide a minimum clear length of 60 inches plus the length of the deployed lift, measured perpendicular to the curb or vehicle lane edge, and a minimum clear width of 60 inches, measured parallel to the vehicle lane edge.

Furthermore, guidelines used by NJ TRANSIT for reviewing bus stops state: “Full accessibility is more difficult to achieve when different organizations are responsible for different portions of the path (which is usually the case). Either way, the ‘equal access’ provision of the ADA requires that the route for persons with limited mobility or vision be as accessible as the route used by those without disabilities. A person with disabilities should not have to travel further, or use a roundabout route, to get to a designated area.”[21] These ADA requirements were used to guide conceptual designs discussed on the following pages.

Case Study Context

About 30 percent of Trenton households do not have regular access to a motor vehicle.[22] Many residents may rely on public transit, cycling, or walking as their main form of transportation. The Trenton Complete and Green Streets Ordinance, passed in 2022, responds to this by mandating that streets must safely accommodate all users – especially vulnerable users like cyclists and pedestrians. Implementing these conceptual designs will create an improved environment for these users.

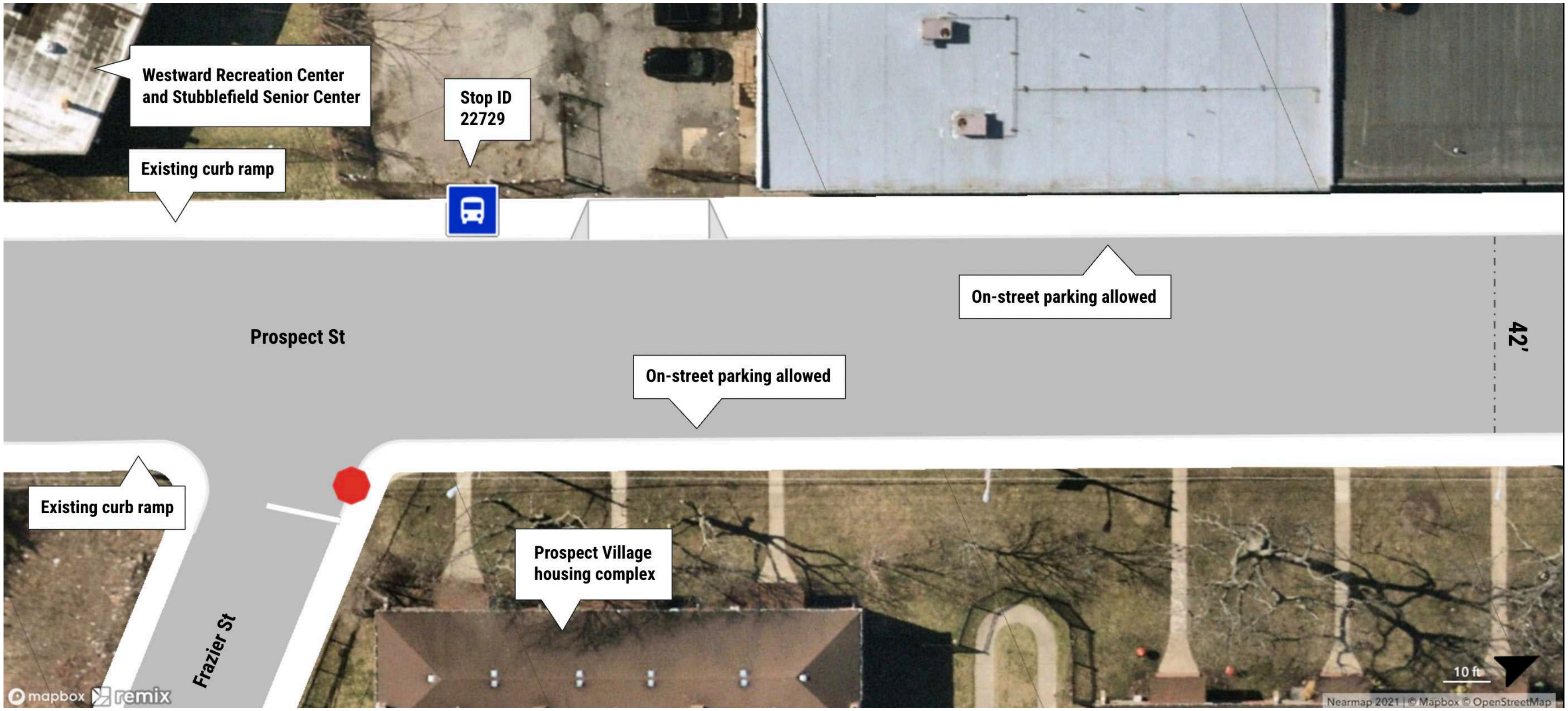
Both bus stops are situated along Prospect Street, which runs through Trenton and into other jurisdictions in Mercer County. Prospect Street is on Trenton’s Vision Zero High Injury Network, which includes roads on which high numbers of traffic deaths and serious injuries occur. Additionally, Prospect Street is multimodal:

- NJ TRANSIT bus route 601 has approximately 40-60 minute headways or about 21 buses per day.
- The project team observed Prospect Street is used by at least a few bicyclists per hour.

[21] Transit Cooperative Research Program and Transportation Research Board. *Guidelines for the location and design of bus stops* (1996), 60.

[22] U.S. Census Bureau. American Community Survey, 2017–2021 American Community Survey 5-Year Estimates, Table S2504. data.census.gov.

Figure 23: Aerial View of Trenton Bus Stop



Source: DVRPC via Remix (2023). Note: Stop ID 22729 on NJ TRANSIT bus route 601.

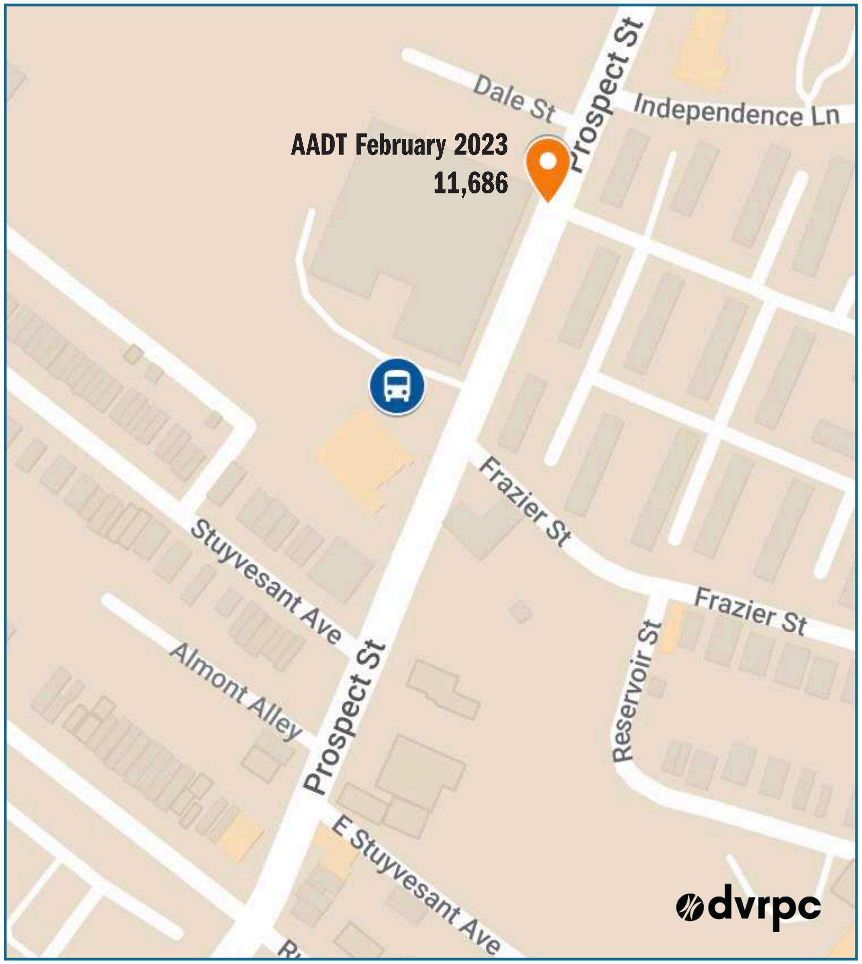
City of Trenton Case Study: Prospect Street at Frazier Street

This mid-block bus stop is located on Prospect Street, a local road with a 42-foot wide cartway with street parking on both sides, and no existing centerline or bicycle infrastructure. Nearby land uses include Westward Recreation Center, Jennye Stubblefield Senior Center, and Prospect Village housing complex (see Figure 23). The annual average daily traffic (AADT) in February 2023 was 11,686 at the Prospect Village entrance, between Frazier Street and Dale Street (see Figure 24).

There are existing curb ramps between Westward Recreation Center and the bus stop, and on the far side of the Frazier Street intersection. However, it is unclear if curb ramps are compliant with current standards. The City of Trenton should consider evaluating curb ramp ADA compliance at this intersection and upgrading them if needed.

Two conceptual designs were developed for this bus stop. The first (see Figure 25 and Table 3) shows minimum requirements expected to reduce bus–bicycle interactions. The second design (see Figure 26 and Table 4) illustrates additional infrastructure that could be implemented at bus stops with high ridership (especially of passengers with limited mobility) and high bicycle volumes. In both designs, vertical deflection is necessary to prevent vehicle encroachment into the bicycle lane. See Figure 19 for a list of barriers that could be used in place of the flexible delineators shown in the designs.

Figure 24: Traffic Count at Prospect Village



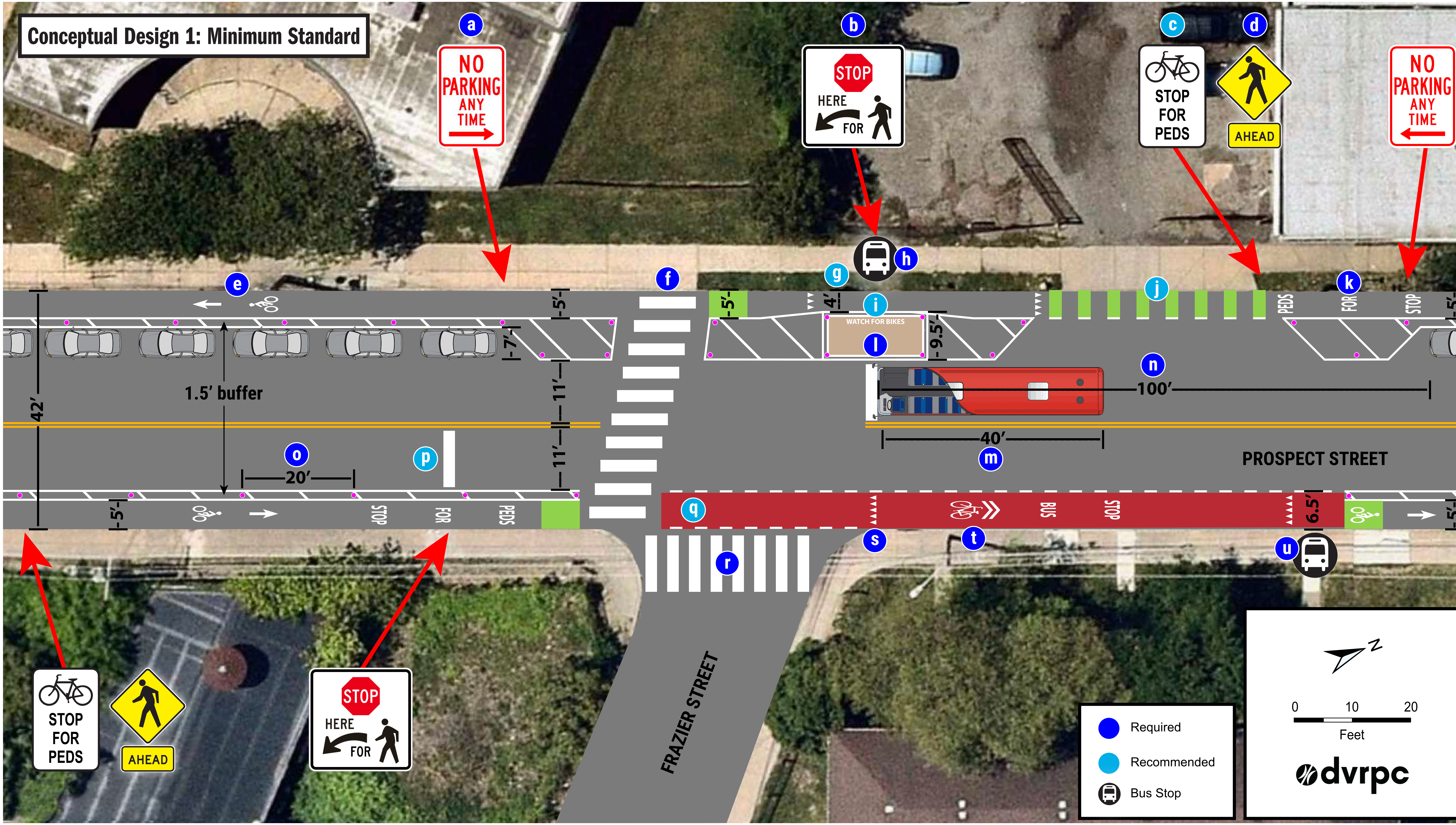
Source: DVRPC via Google My Maps (2023). Prospect Village is about 325 feet north of bus stop.

Figure 25 illustrates the minimum standard suitable for bus stops with low ridership, infrequent service, and relatively low bicycle volumes. The concept is designed to utilize existing curb ramps between Westward Recreation Center and the bus stop, and on the far side of Frazier Street intersection. Additionally, the painted landing pad is ADA compliant. See Table 3 for the conceptual design key that describes why design decisions were made and breaks down the elements that are required (per MUTCD, FHWA, etc.) or recommended (additional best practices that are tailored to each bus stop's specific context, are sensitive to cost, and are responsive to common bus-bicycle interactions).

This bus stop may serve a significant population of persons with limited mobility due to the nearby Jennye Stubblefield Senior Center. Therefore, additional infrastructure should be considered — though it may increase maintenance, cost, and implementation complexity for the City of Trenton. Figure 26 illustrates this additional infrastructure in the form of an elongated pedestrian island that connects passengers directly with the crosswalk. See Table 4 for the conceptual design key that describes why design decisions were made and breaks down the elements that are required (per MUTCD, FHWA, etc.) or recommended (additional best practices that are tailored to each bus stop's specific context, are sensitive to cost, and are responsive to common bus-bicycle interactions).

The elongated pedestrian island helps discourage vehicles from parking in what (in both designs) is not legal parking. It is also preferred for ADA accessibility because it provides a clear path for passengers boarding and alighting. As an alternative to an elongated pedestrian island, re-siting this bus stop (and/or others in the NJ TRANSIT service area) may save on cost, while still improving access to the bus from the sidewalk.

Figure 25: Conceptual Design 1 for Trenton Bus Stop (ADA Landing Pad)



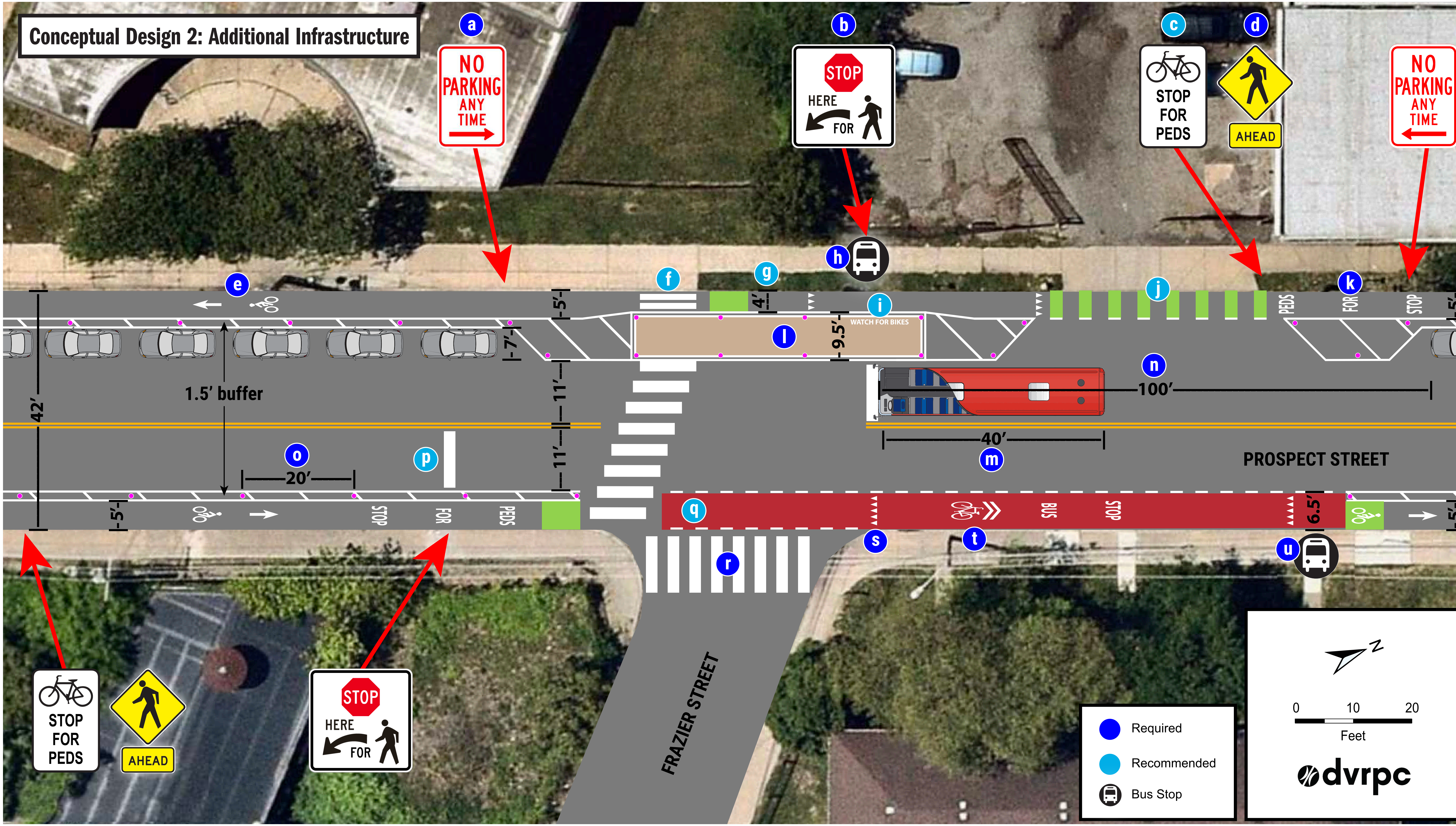
Source: DVRPC (2023), Nearmap (2023)

Table 3: Conceptual Design Key 1 for Trenton Bus Stop (ADA Landing Pad)

Graphic Key	Design Element	Priority Level	Reference	Explanation	Placement and Application
a.	MUTCD sign R7-1	Required	State law	State law prevents motorists from parking within 25 feet of a crosswalk, and 100 feet in advance of a bus stop.	25 feet from the edge of the nearest crosswalk line and 100 feet in advance of the bus stop.
b.	MUTCD sign R1-5b	Required	State law	State law requires motorists to stop for pedestrians in the crosswalk.	20 to 50 feet in advance of the nearest crosswalk line (shown as approximately 25-30 feet in advance).
c.	MUTCD sign R9-6 (modified)	Recommended	Custom to project	Per MUTCD guidelines, "BIKES YIELD TO PEDS" signs shall be installed on shared-use paths at points where bicyclists have an adequate view of conflicting traffic as they approach the sign, and where bicyclists are required to yield the right-of-way to that conflicting traffic. However, State law requires motorists to stop, rather than yield, to pedestrians. The sign variant "BIKES STOP FOR PEDS" is therefore custom to the *Coordinating Safe New Jersey Transit Bus Service Alongside Bicycle Facilities* memo.	Shown as 100 feet in advance of the crosswalk.
d.	MUTCD signs W11-2 (diamond-shaped) and W-16-9p ("AHEAD")	Required	MUTCD	Used in advance of a pedestrian crossing. Supplement W11-2 with plaques with the legend "AHEAD" or "XX FEET" to inform road users that they are approaching a point where crossing activity might occur.	Shown as 100 feet in advance of the nearest crosswalk line.
e.	Parking separated bike lane	Required	*NJ Complete Streets Design Guide* (2017) and FHWA *Separated Bike Lane Planning and Design Guide* (2015)	Parking separated bike lanes (PSBLs) are in-street bikeways that are separated from moving motor vehicle traffic by a parking lane and a buffer area. PSBL elements include: [1] MUTCD-compliant pavement marking "Helmeted Bicyclist Symbol." [2] Conventional bicycle lane paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane. A buffered bicycle lane is allowed as per MUTCD guidelines for buffered preferential lanes (section 3D-01). [3] Flexible delineators centered within the width of the buffer and spaced 20' apart, except where the bike lane crosses an intersection, driveway, pull out, or crosswalk. [4] In-street parking lane. See p. 106 of *NJ Complete Streets Design Guide (2017)* for an explanation of why a dedicated bicycle lane is needed on Prospect Street.	FHWA *Separated Bike Lane Planning and Design Guide* (2015) requires a 5 foot minimum width bicycle lane when against a curb. A buffered area is required to be 3 feet when right-of-way allows. Gore striping within the buffered area is required. Flexible delineators are recommended to be placed every 10-30 feet within the center of the buffered area. In-street parking lane is recommended to be 8 feet when right-of-way allows.
f.	Crosswalk (shown as continental crosswalk)	Required	MUTCD	In conjunction with signs and other measures, crosswalk markings alert road users of a designated pedestrian crossing point across roads at locations that are not controlled by traffic control signals or stop or yield signs.	Shown at pre-existing curb cuts at the Frazier Street intersection. Crosswalk lines are shown as 10 feet long and 2 feet wide.
g.	Reduced-width bike lane	Recommended	AASHTO *Guide for the Development of Bicycle Facilities* (2012)	Narrowing the bike lane for short stretches encourages cyclists to slow down. Per AASHTO's *Guide for the Development of Bicycle Facilities* (2012), 4 feet is the minimum operating width sufficient to accommodate forward movement by most bicyclists.	Situations in which pedestrians need to cross bicycle lane(s) to reach a pedestrian island or side boarding island. Bicycle lane shown as 4 feet wide.
h.	NJ TRANSIT bus stop sign	Required	NJ TRANSIT	Existing stop (Stop ID: 22729).	Siting determined by NJ TRANSIT.
i.	Word pavement marking ("WATCH FOR BIKES")	Recommended	Custom to project	The NACTO *Transit Street Design Guide* (2016) shows a side boarding island stop with word markings at the edge of the island to alert pedestrians to the presence of the bicycle lane and reduce bicycle-pedestrian interactions as they cross from the bicycle lane to the curb.	Shown at the edge of the painted landing pad closest to the bicycle lane.
j.	Colored pavement within bicycle lane	Recommended	MUTCD and NACTO	Interim Approval 14 issued by MUTCD allows the optional use of green colored pavement in marked bicycle lanes and in extensions of bicycle lanes through intersections and other traffic conflict areas. NACTO recommends colored pavement within a bicycle lane to improve the visibility of the facility and alert road users to potential conflict areas (i.e., intersections, high volume driveways, mixing zones).	Colored pavement can be utilized either as a corridor treatment along the entire length of a bicycle lane, or as a spot treatment for potential conflict areas.
k.	Elongated-Letter Word Pavement Markings ("STOP FOR PEDS" and "BUS STOP")	Required	MUTCD	Word, symbol, and arrow markings on the pavement are used for the purpose of guiding, warning, or regulating traffic. These pavement markings supplement signs and provide additional emphasis for important regulatory, warning, or guidance messages, because the markings do not require diversion of the road user's attention from the road surface.	The "STOP FOR PEDS" marking is placed in the bicycle lane in advance of pedestrian crossings and passenger loading zones. The "BUS STOP" marking is placed in shared bus–bicycle areas within bus zones.
l.	ADA landing pad	Required	Custom to project	Paint coloring should closely match the color of the sidewalk to indicate that the space is meant for pedestrians. Dimensions must accommodate a wheelchair turning radius as well as two passing wheelchairs (at minimum 8 feet wide by 5 feet long per *ADA Std.* 810.2.2). Use gore striping on either side of the painted area to indicate that it is not a driving lane. Use vertical deflection at the edges of the painted area to prevent motorists from driving through it (shown as flexible delineators).	Bus stops alongside protected bicycle lanes.
m.	NJ TRANSIT bus	Required	NJ TRANSIT	Route 601 is a local line and deploys the wheelchair lift from the front.	Curbside lane.
n.	Bus zone	Required	State law	State law prohibits motorists from parking 100 feet in advance of a bus stop.	100 feet in advance of bus stop.
o.	Vertical separation (shown as flexible delineators)	Required	*NJ Complete Streets Design Guide* (2017)	Vertically-separated bicycle lanes prevent vehicle encroachment, improve safety, and deter double-parking.	Every 10-30 feet, centered within the buffer area of the bicycle lane (shown as every 20 feet).
p.	Stop bar	Recommended	MUTCD	A stop bar may be used in advance of a midblock crosswalk to show vehicles where to stop for a pedestrian only if there is a State law that requires vehicles to stop for (rather than yield to) pedestrians in crosswalks. A stop bar may be used to indicate the point behind which motorists are required to stop in compliance with a Stop Here For Pedestrians (R1-5b) sign.	The stop bar should be placed at the desired stopping point, but should not be placed more than 30 feet or less than 4 feet from the nearest edge of the intersecting traveled way (shown as approximately 25-30 feet in advance of the crosswalk).
q.	Colored pavement within bus zone	Recommended	MUTCD	Interim Approval 22 issued by MUTCD allows the optional use of red-colored pavement to enhance the conspicuity of station stops, travel lanes, or other locations in the road that are reserved for (1) the exclusive use by public transit vehicles or (2) multimodal facilities where public transit is the primary mode.	At bus stops, within bus zones and bus travel lanes (shown within bus zone).
r.	Crosswalk (shown as continental crosswalk)	Required	MUTCD	In conjunction with signs and other measures, crosswalk markings alert road users of a designated pedestrian crossing point across roads at locations that are not controlled by traffic control signals or stop or yield signs.	Shown at pre-existing curb cuts at the Frazier Street intersection.
s.	Yield lines	Required	MUTCD	Yield lines shall consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made.	20-50 feet in advance of the nearest crosswalk line. Can also be placed in advance of other crossings (i.e. bus stops).
t.	Shared lane marking	Required	MUTCD	The shared lane marking alerts cyclists to ride defensively and anticipate the need to stop for a curbing bus. Per MUTCD guidelines, a shared lane marking serves the following purposes: assists bicyclists with lateral positioning in lanes that are too narrow for a motor vehicle and a bicycle to travel side by side within the same traffic lane, alerts road users of the bicyclists' lateral positioning, encourages safe passing, and reduces wrong-way bicycling.	Shown as 60 feet in advance of bus stop.
u.	NJ TRANSIT bus stop sign	Required	NJ TRANSIT	Existing stop (Stop ID: 22831).	Siting determined by NJ TRANSIT.

Source: DVRPC (2023)

Figure 26: Conceptual Design 2 for Trenton Bus Stop (Combined Pedestrian Island and ADA Landing Pad)



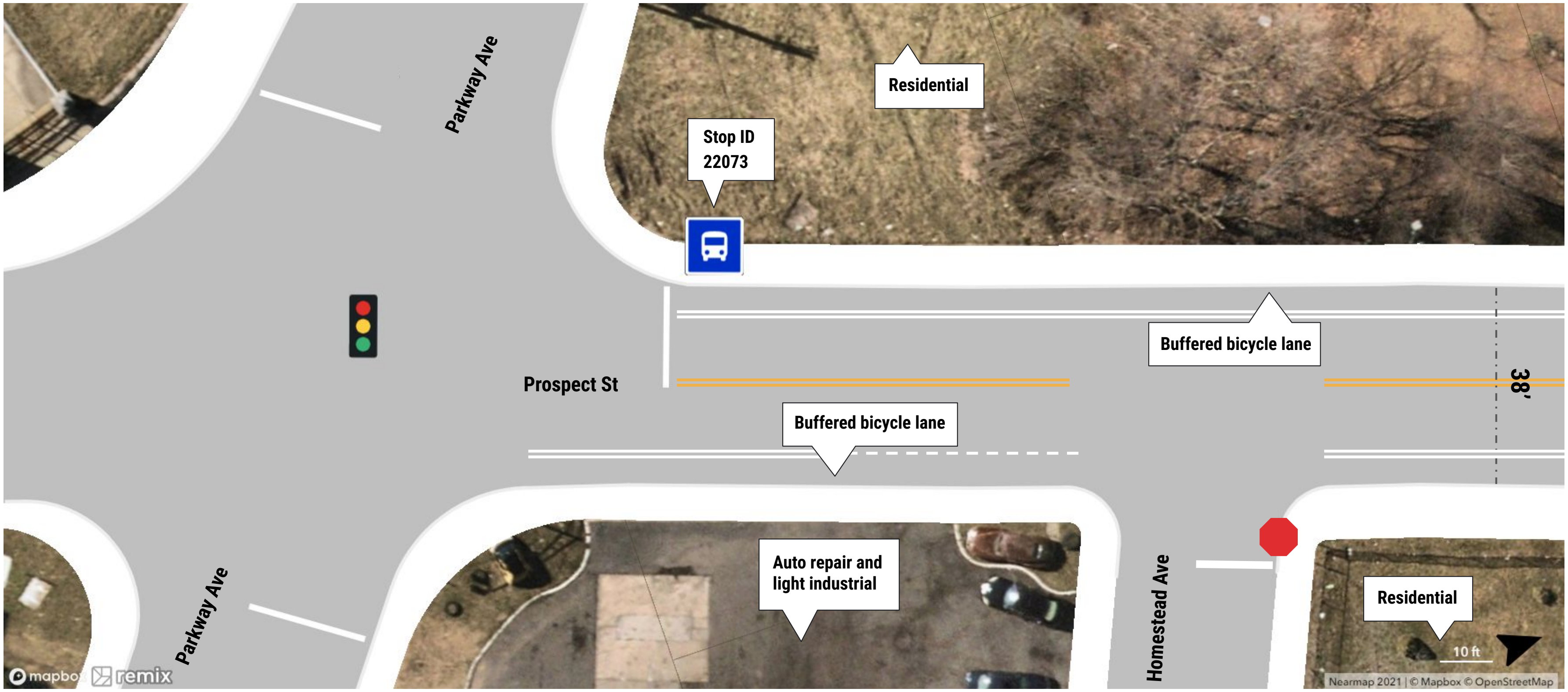
Source: DVRPC (2023), Nearmap (2023)

Table 4: Conceptual Design Key 2 for Trenton Bus Stop (Combined Pedestrian Island and ADA Landing Pad)

Graphic Key	Design Element	Priority Level	Reference	Explanation	Placement and Application
a.	MUTCD sign R7-1	Required	State law	State law prevents motorists from parking within 25 feet of a crosswalk, and 100 feet in advance of a bus stop.	25 feet from the edge of the nearest crosswalk line and 100 feet in advance of the bus stop.
b.	MUTCD sign R1-5b	Required	State law	State law requires motorists to stop for pedestrians in the crosswalk.	20 to 50 feet in advance of the nearest crosswalk line (shown as approximately 25-30 feet in advance).
c.	MUTCD sign R9-6 (modified)	Recommended	Custom to project	Per MUTCD guidelines, "BIKES YIELD TO PEDS" signs shall be installed on shared-use paths at points where bicyclists have an adequate view of conflicting traffic as they approach the sign, and where bicyclists are required to yield the right-of-way to that conflicting traffic. However, State law requires motorists to stop, rather than yield, to pedestrians. The sign variant "BIKES STOP FOR PEDS" is therefore custom to the *Coordinating Safe New Jersey Transit Bus Service Alongside Bicycle Facilities* memo.	Shown as 100 feet in advance of the crosswalk.
d.	MUTCD signs W11-2 (diamond-shaped) and W-16-9p ("AHEAD")	Required	MUTCD	Used in advance of a pedestrian crossing. Supplement W11-2 with plaques with the legend "AHEAD" or "XX FEET" to inform road users that they are approaching a point where crossing activity might occur.	Shown as 100 feet in advance of the nearest crosswalk line.
e.	Parking separated bike lane	Required	*NJ Complete Streets Design Guide* (2017) and FHWA *Separated Bike Lane Planning and Design Guide* (2015)	Parking separated bike lanes (PSBLs) are in-street bikeways that are separated from moving motor vehicle traffic by a parking lane and a buffer area. PSBL elements include: [1] MUTCD-compliant pavement marking "Helmeted Bicyclist Symbol." [2] Conventional bicycle lane paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane. A buffered bicycle lane is allowed as per MUTCD guidelines for buffered preferential lanes (section 3D-01). [3] Flexible delineators centered within the width of the buffer and spaced 20' apart, except where the bike lane crosses an intersection, driveway, pull out, or crosswalk. [4] In-street parking lane. See p. 106 of *NJ Complete Streets Design Guide (2017)* for an explanation of why a dedicated bicycle lane is needed on Prospect Street.	FHWA *Separated Bike Lane Planning and Design Guide* (2015) requires a 5 foot minimum width bicycle lane when against a curb. A buffered area is required to be 3 feet when right-of-way allows. Gore striping within the buffered area is required. Flexible delineators are recommended to be placed every 10-30 feet within the center of the buffered area. In-street parking lane is recommended to be 8 feet when right-of-way allows.
f.	Scaled-down crosswalk bars	Recommended	MUTCD and NACTO	The NACTO *Don't Give Up at the Intersection Guide* (2019) shows proportionally-scaled down crosswalk bars to fit within the width of the bicycle lane. Per MUTCD guidelines, pavement words, symbols, and arrows may be smaller than suggested on narrow, low-speed shared-use paths.	Situations in which pedestrians need to cross bicycle lane(s) to reach a pedestrian island or side boarding island.
g.	Reduced-width bike lane	Recommended	AASHTO *Guide for the Development of Bicycle Facilities* (2012)	Narrowing the bike lane for short stretches encourages cyclists to slow down. Per AASHTO's *Guide for the Development of Bicycle Facilities* (2012), 4 feet is the minimum operating width sufficient to accommodate forward movement by most bicyclists.	Situations in which pedestrians need to cross bicycle lane(s) to reach a pedestrian island or side boarding island. Bicycle lane shown as 4 feet wide.
h.	NJ TRANSIT bus stop sign	Required	NJ TRANSIT	Existing stop (Stop ID: 22729).	Siting determined by NJ TRANSIT.
i.	Word pavement marking ("WATCH FOR BIKES")	Recommended	Custom to project	The NACTO *Transit Street Design Guide* (2016) shows a side boarding island stop with word markings at the edge of the island to alert pedestrians to the presence of the bicycle lane and reduce bicycle-pedestrian interactions as they cross from the bicycle lane to the curb.	Shown at the edge of the painted landing pad closest to the bicycle lane.
j.	Colored pavement within bicycle lane	Recommended	MUTCD and NACTO	Interim Approval 14 issued by MUTCD allows the optional use of green colored pavement in marked bicycle lanes and in extensions of bicycle lanes through intersections and other traffic conflict areas. NACTO recommends colored pavement within a bicycle lane to improve the visibility of the facility and alert road users to potential conflict areas (i.e. intersections, high volume driveways, mixing zones).	Colored pavement can be utilized either as a corridor treatment along the entire length of a bicycle lane, or as a spot treatment for potential conflict areas.
k.	Elongated-Letter Word Pavement Markings ("STOP FOR PEDS" and "BUS STOP")	Required	MUTCD	Word, symbol, and arrow markings on the pavement are used for the purpose of guiding, warning, or regulating traffic. These pavement markings supplement signs and provide additional emphasis for important regulatory, warning, or guidance messages, because the markings do not require diversion of the road user's attention from the road surface.	The "STOP FOR PEDS" marking is placed in the bicycle lane in advance of pedestrian crossings and passenger loading zones. The "BUS STOP" marking is placed in shared bus–bicycle areas within bus zones.
l.	Painted pedestrian island and ADA landing pad	Required	Custom to project	Paint coloring should closely match the color of the sidewalk to indicate that the space is meant for pedestrians. Dimensions must accommodate a wheelchair turning radius as well as two passing wheelchairs (at minimum 8 feet wide by 5 feet long per *ADA Std.* 810.2.2). Use gore striping on either side of the painted area to indicate that it is not a driving lane. Use vertical deflection at the edges of the painted area to prevent motorists from driving through it (shown as flexible delineators).	Bus stops alongside protected bicycle lanes.
m.	NJ TRANSIT bus	Required	NJ TRANSIT	Route 601 is a local line and deploys the wheelchair lift from the front.	Curbside lane.
n.	Bus zone	Required	State law	State law prohibits motorists from parking 100 feet in advance of a bus stop.	100 feet in advance of bus stop.
o.	Vertical separation (shown as flexible delineators)	Required	*NJ Complete Streets Design Guide* (2017)	Vertically-separated bicycle lanes prevent vehicle encroachment, improve safety, and deter double-parking.	Every 10-30 feet, centered within the buffer area of the bicycle lane (shown as every 20 feet).
p.	Stop bar	Recommended	MUTCD	A stop bar may be used in advance of a midblock crosswalk to show vehicles where to stop for a pedestrian only if there is a State law that requires vehicles to stop for (rather than yield to) pedestrians in crosswalks. A stop bar may be used to indicate the point behind which motorists are required to stop in compliance with a Stop Here For Pedestrians (R1-5b) sign.	The stop bar should be placed at the desired stopping point, but should not be placed more than 30 feet or less than 4 feet from the nearest edge of the intersecting traveled way (shown as approximately 25-30 feet in advance of the crosswalk).
q.	Colored pavement within bus zone	Recommended	MUTCD	Interim Approval 22 issued by MUTCD allows the optional use of red-colored pavement to enhance the conspicuity of station stops, travel lanes, or other locations in the road that are reserved for (1) the exclusive use by public transit vehicles or (2) multimodal facilities where public transit is the primary mode.	At bus stops, within bus zones and bus travel lanes (shown within bus zone).
r.	Crosswalk (shown as continental crosswalk)	Required	MUTCD	In conjunction with signs and other measures, crosswalk markings alert road users of a designated pedestrian crossing point across roads at locations that are not controlled by traffic control signals or stop or yield signs.	Shown at pre-existing curb cuts at the Frazier Street intersection. Crosswalk lines are shown as 10 feet long and 2 feet wide.
s.	Yield lines	Required	MUTCD	Yield lines shall consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made.	20-50 feet in advance of the nearest crosswalk line. Can also be placed in advance of other crossings (i.e. bus stops).
t.	Shared lane marking	Required	MUTCD	The shared lane marking alerts cyclists to ride defensively and anticipate the need to stop for a curbing bus. Per MUTCD guidelines, a shared lane marking serves the following purposes: assists bicyclists with lateral positioning in lanes that are too narrow for a motor vehicle and a bicycle to travel side by side within the same traffic lane, alerts road users of the bicyclists' lateral positioning, encourages safe passing, and reduces wrong-way bicycling.	Shown as 60 feet in advance of bus stop.
u.	NJ TRANSIT bus stop sign	Required	NJ TRANSIT	Existing stop (Stop ID: 22831).	Siting determined by NJ TRANSIT.

Source: DVRPC (2023)

Figure 27: Aerial View of Ewing Township Bus Stop



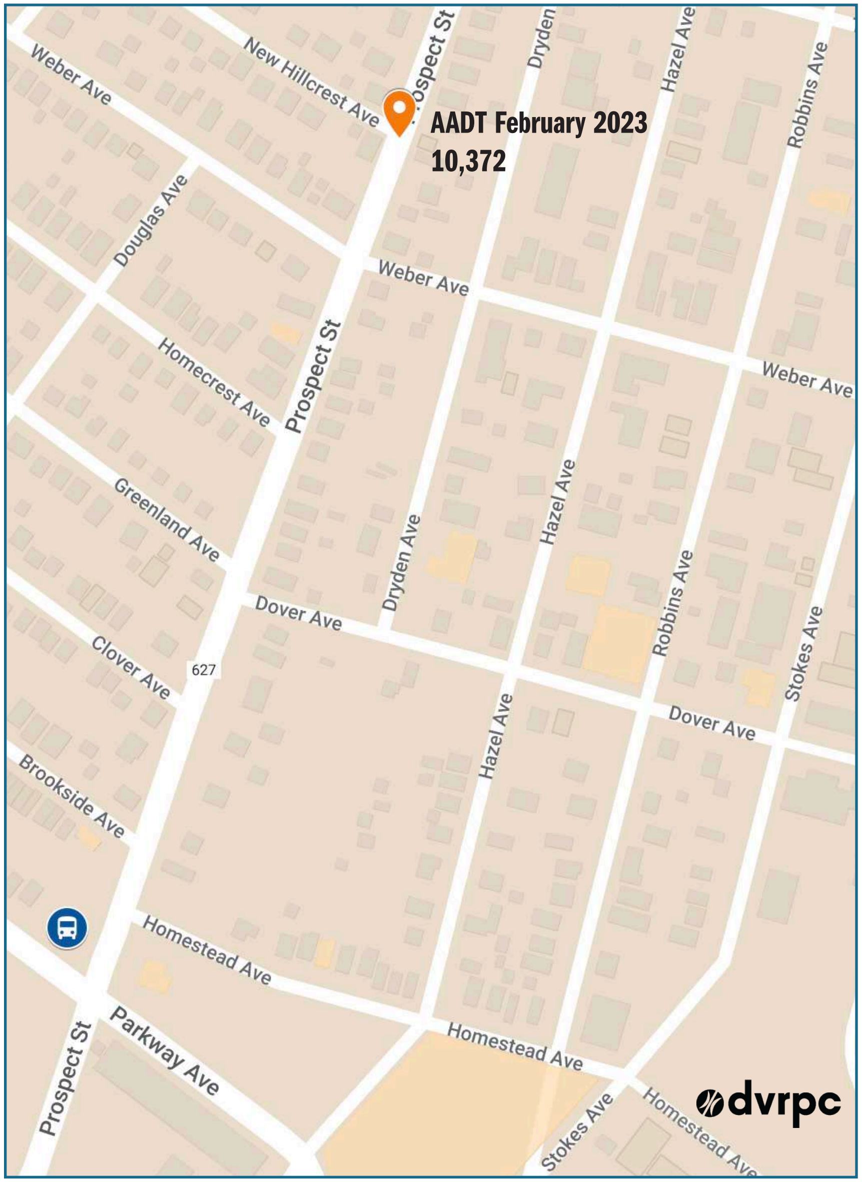
Source: DVRPC via Remix (2023). Note: Stop ID 22073 on NJ TRANSIT bus route 601.

Mercer County Case Study: Prospect Street at Parkway Avenue

This near-side bus stop is located at a signalized four-way intersection in Ewing Township in Mercer County, along NJ TRANSIT bus route 601. At this location, Prospect Street is a county road with a 38-foot cartway that includes buffered bicycle lanes adjacent to each curb. Nearby land uses include detached residential, auto repair, and light industrial (see Figure 27). The annual average daily traffic (AADT) was 10,372 at Prospect Street and New Hillcrest Avenue as of February 2023 (see Figure 28).

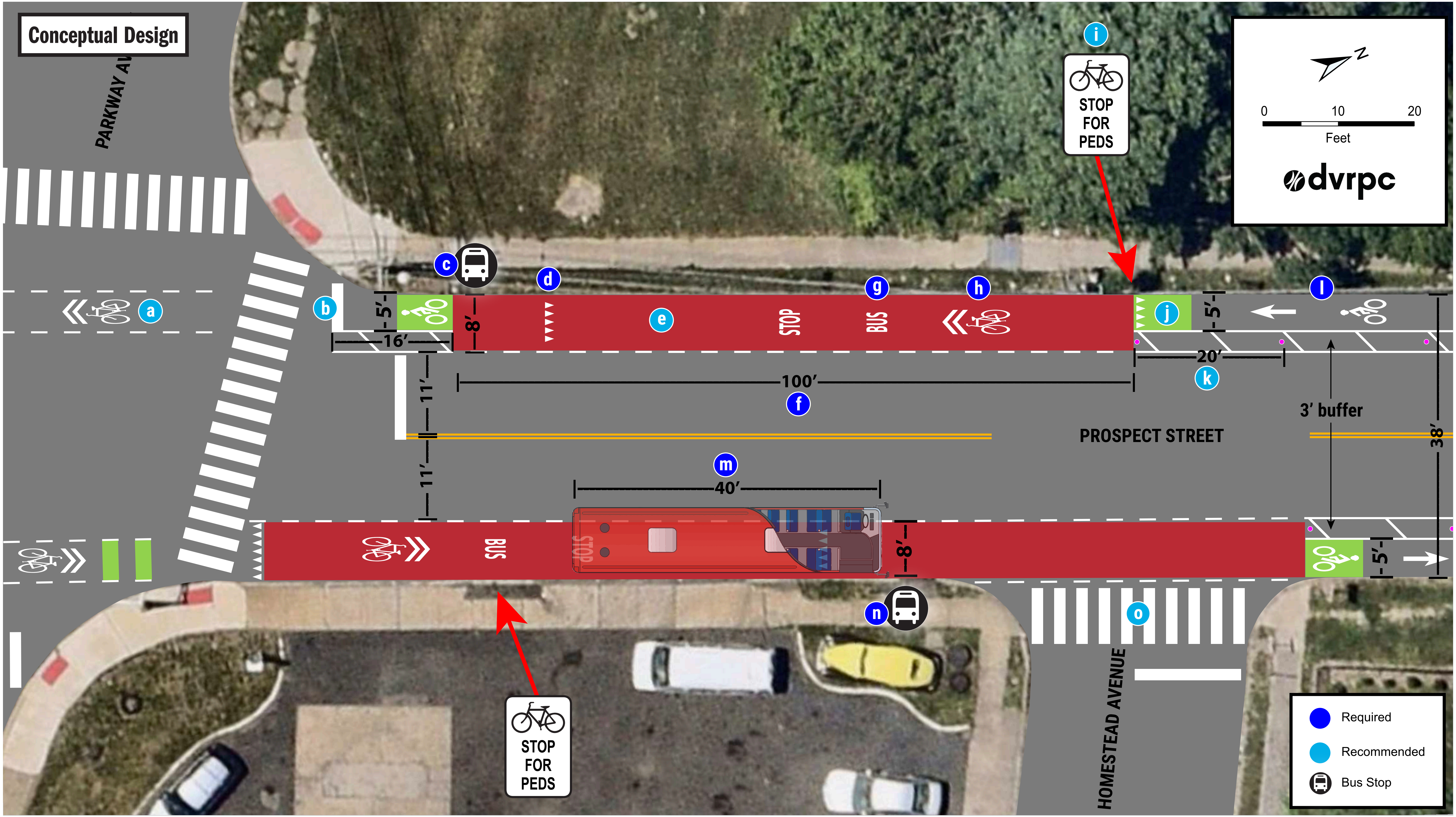
In contrast to the Trenton bus stop, where on-street parking spaces could be reallocated in a variety of ways (see Figures 25 and 26), only one conceptual design was developed for the Ewing Township bus stop due to limited cartway width and pre-existing bicycle lanes. See Figure 29 for the conceptual design. See Table 5 for the conceptual design key that describes why design decisions were made and breaks down the elements that are required (per MUTCD, FHWA, etc.) or recommended (additional best practices that are tailored to each bus stop's specific context, are sensitive to cost, and are responsive to common bus-bicycle interactions).

Figure 28: Traffic Count at New Hillcrest Avenue



Source: DVRPC via Google My Maps (2023). New Hillcrest Avenue is about 0.3 miles north of the bus stop.

Figure 29: Conceptual Design for Ewing Township Bus Stop



Source: DVRPC (2023), Nearmap (2023)

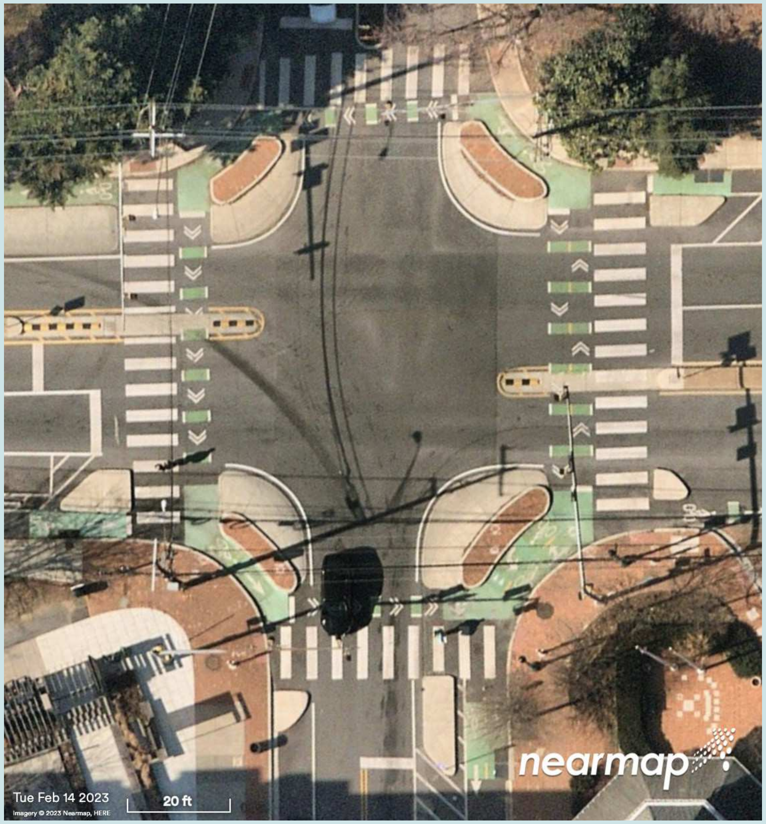
Table 5: Conceptual Design Key for Ewing Township Bus Stop

Graphic Key	Design Element	Priority Level	Reference	Explanation	Placement and Application
a.	Intersection crossing markings	Recommended	NACTO	Intersection crossing markings indicate the intended path of bicyclists. They guide bicyclists on a direct path through intersections, including driveways and ramps. They provide a clear boundary between the paths of through bicyclists and motor vehicles in the adjacent lane.	Across signalized intersections, particularly through wide or complex intersections where bicycle path may be unclear.
b.	Bicycle forward stop bar	Recommended	NACTO and MUTCD	Per NACTO major street crossing guidance, encouraging bicyclists to stop at the nose of the curb extension helps bicyclists take full advantage of the design by decreasing the crossing distance. It also improves bicyclists' view of cross traffic and provides better visibility of bicyclists waiting for a crossing opportunity. Per MUTCD, stop and yield lines may be staggered longitudinally on a lane-by-lane basis.	The stop bar should be placed closer to the intersection than the motor vehicle stop bar in a location that does not block the crosswalk (shown as approximately 8 feet in advance of the motor vehicle stop line).
c.	NJ TRANSIT bus stop sign	Required	NJ TRANSIT	Existing stop (Stop ID: 22073).	Siting determined by NJ TRANSIT.
d.	Yield lines	Required	MUTCD	Yield lines shall consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made.	20-50 feet in advance of the nearest crosswalk line. Can also be placed in advance of other types of crossings (i.e. bus stops).
e.	Colored pavement within bus zone	Recommended	MUTCD	Interim Approval 22 issued by MUTCD allows the optional use of red-colored pavement to enhance the conspicuity of station stops, travel lanes, or other locations in the road that are reserved for (1) the exclusive use by public transit vehicles or (2) multimodal facilities where public transit is the primary mode.	At bus stops, within bus zones and bus travel lanes (shown within 100-foot bus zone).
f.	Bus zone	Required	State law	100 feet allows the bus to fully curb parallel to traffic to avoid an area of reduced visibility that occurs when buses are angled-in at the curb.	100 feet in advance of bus stop.
g.	Elongated-Letter Word Pavement Markings ("BUS STOP")	Required	MUTCD	Word, symbol, and arrow markings on the pavement are used for the purpose of guiding, warning, or regulating traffic. These pavement markings supplement signs and provide additional emphasis for important regulatory, warning, or guidance messages, because the markings do not require diversion of the road user's attention from the road surface.	Shown in shared bus–bicycle areas within bus zones.
h.	Shared lane marking	Required	MUTCD	The shared lane marking alerts cyclists to ride defensively and anticipate the need to stop for a curbing bus. Per MUTCD guidelines, a shared lane marking serves the following purposes: assists bicyclists with lateral positioning in lanes that are too narrow for a motor vehicle and a bicycle to travel side by side within the same traffic lane, alerts road users of the bicyclists' lateral positioning, encourages safe passing, and reduces wrong-way bicycling.	Shown as 60 feet in advance of bus stop.
i.	MUTCD sign R9-6 (modified)	Recommended	Custom to project	Per MUTCD guidelines, "BIKES YIELD TO PEDS" signs shall be installed on shared-use paths at points where bicyclists have an adequate view of conflicting traffic as they approach the sign, and where bicyclists are required to yield the right-of-way to that conflicting traffic. However, State law requires motorists to stop, rather than yield, to pedestrians. The sign variant "BIKES STOP FOR PEDS" is therefore custom to the *Coordinating Safe New Jersey Transit Bus Service Alongside Bicycle Facilities* memo.	Shown 50-100 feet in advance of the bus stop.
j.	Colored pavement within bicycle lane	Recommended	MUTCD and NACTO	Interim Approval 14 issued by MUTCD allows the optional use of green colored pavement in marked bicycle lanes and in extensions of bicycle lanes through intersections and other traffic conflict areas. NACTO recommends colored pavement within a bicycle lane to improve the visibility of the facility and alert road users to potential conflict areas (i.e., intersections, high volume driveways, mixing zones).	Colored pavement can be utilized either as a corridor treatment along the entire length of a bicycle lane, or as a spot treatment for potential conflict areas.
k.	Vertical separation (shown as flexible delineators)	Recommended	*NJ Complete Streets Design Guide* (2017)	Vertically-separated bicycle lanes prevent vehicle encroachment, improve safety, and deter double-parking.	Every 10-30 feet, centered within the buffered area of the bicycle lane (shown as every 20 feet).
l.	Separated bike lane	Required	*NJ Complete Streets Design Guide* (2017) and FHWA *Separated Bike Lane Planning and Design Guide* (2015)	Separated bicycle lanes are bikeways that use a variety of methods for physical separation from passing traffic. A separated bicycle lane provides vertical separation to prevent vehicle encroachment and improve safety. Elements include: [1] MUTCD-compliant pavement marking "Helmeted Bicyclist Symbol." [2] Conventional bicycle lane paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle travel lane. A buffered bicycle lane is allowed as per MUTCD guidelines for buffered preferential lanes (section 3D-01). [3] Flexible delineators centered within the width of the buffer and spaced 20 feet apart, except where the bike lane crosses an intersection, driveway, pull out, or crosswalk. See p. 106 of *NJ Complete Streets Design Guide* (2017) for an explanation of why a dedicated bicycle lane is needed on Prospect Street.	FHWA *Separated Bike Lane Planning and Design Guide* (2015) requires a 5 foot minimum width bicycle lane when against a curb. A buffered area is required to be 3 feet when right-of-way allows. Gore striping within the buffered area is required.
m.	NJ TRANSIT bus	Required	NJ TRANSIT	Route 601 is a local line and deploys the wheelchair lift from the front.	Curbside lane.
n.	NJ TRANSIT bus stop sign	Required	NJ TRANSIT	Existing stop (Stop ID: 22061).	Siting determined by NJ TRANSIT.
o.	Continental crosswalk	Recommended	FHWA	High-visibility crosswalks use patterns (i.e., continental) that are visible to both the driver and pedestrian from farther away compared to traditional transverse line crosswalks, which are currently used at the Homestead Avenue intersection.	Shown at all pedestrian crossings. Crosswalk lines are shown as 10 feet long and 2 feet wide.

Source: DVRPC (2023)

LONG-TERM CONSIDERATIONS FOR NEAR-SIDE BUS STOPS

This memo examined two bus stops along NJ TRANSIT bus route 601, neither of which are at a location on the route where the bus needs to make a right turn. On routes where a NJ TRANSIT bus does need to cross a dedicated bike lane to make a right turn, relevant stakeholders could explore a protected intersection design, which gives cyclists a dedicated path through an intersection and reduces vehicle-bike conflicts. A protected intersection helps protect cyclists from right-hook and right pull-out interactions (see Chapter 2 for more information about types of bus-bike interactions) through physical separation and by creating a tight corner radius to slow vehicle turns. It also creates distance between cyclists and the parallel motor vehicle traffic. See Figure 30 for an example.



Source: Nearmap aerial view of 2nd Avenue and Spring Street, Silver Spring, MD (2023)

CHAPTER 7:

Recommendations

This section contains recommendations to continue to advance the implementation of Complete Streets in the NJ TRANSIT service area.

Establish a Task Force and Working Groups

To get started on this work, key stakeholders could establish a statewide Complete Streets task force and working groups to ensure communication between and amongst themselves. A first step would be a kickoff meeting that DVRPC could help to coordinate and host. Following the first meeting, area-specific or topic-specific working groups could be developed. Groups that could be included in this task force are listed below.

- *NJ TRANSIT staff.* This could include the planning department, the surface transit operations department, the safety department, and bus operator representatives.
- *Advocacy groups.* In selected NJ TRANSIT service areas, this could include, but would not be limited to Tri-State Transportation Campaign, Bicycle Coalition of Greater Philadelphia, and New Jersey Bike and Walk Coalition. In Trenton specifically this could include Trenton Cycling Revolution, Trenton Vision Zero, and East Trenton Collaborative's Traffic Safety Community Organizing Committee. DVRPC learned from a peer agency interview that in the Boston area a statewide bike advocacy group was helpful in developing training materials for operators and distributing literature.
- *Road owners.* In the NJ TRANSIT service area this would include New Jersey Department of Transportation (NJDOT), counties, and municipalities that are interested and leading in bicycle infrastructure planning and implementation.
- *NJDOT, New Jersey Federal Highway Administration (NJ FHWA), New Jersey Federal Transit Administration (NJ FTA).* State and federal agencies will be integral to balancing priorities of all road users and providing useful feedback about standards and regulations.
- *Subject Matter Experts (SMEs).* Representation from NJ Bicycle and Pedestrian Advisory Council (BPAC) and SMEs from colleges and universities could be helpful. Experts in the field can assist in researching, planning, and implementing ideas that stem from this group.

Working groups could be formed to effectively move action items forward that come out of this task force. Subcommittees could be formed on the following topics.

- Vision Zero's impact on future street designs and priorities
- Bus operator perspectives and training
- Faster-moving micromobility modes like e-bikes and e-scooters
- Pedestrian connections to transit

Pilot and Evaluate Designs

Piloting conceptual designs can serve as a proof of concept and help decision-makers base proposed street designs on observed behavior. Temporary materials like painted landing pads and flexible delineators can be used to mark and protect boarding areas. The case study bus stop on Prospect Street in Trenton, NJ, may be an effective location to pilot in the near-term, as it is slated to be repaved in the next fiscal year.

Update Internal Guidelines and Create External Guidelines

Once designs have been piloted and evaluated, strategies and enhancements discussed in this memo could potentially be deployed elsewhere in the NJ TRANSIT service area, and especially at locations with a history of bike-bus interactions. NJ TRANSIT currently uses NJTPA's *Bus Stop Safety Toolbox* (2011) to coordinate internally among staff.[23] These internal guidelines could be updated with strategies and enhancements discussed in this memo. Additionally, guidelines that communicate NJ TRANSIT bus stop standards to external decision-makers could be created. These external guidelines can be proactively shared with the many road owners in the NJ TRANSIT service area, to enhance communication and serve as a reference prior to designing a street.

[23] North Jersey Transportation Planning Authority. Bus Stop Safety Toolbox, 2011. www.njtpa.org/NJTPA/media/Documents/Planning/Regional-Programs/Studies/Pedestrian%20Safety%20at%20and%20Near%20Bus%20Stops%20Study/Bus-Stop-Safety-Tool-Box_final13.pdf.

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Abstract

The concept of Complete Streets encompasses the planning, designing, and operating of streets will all modes in mind, with the goal of making the transportation network safer and more efficient. As Complete Streets are implemented across New Jersey, New Jersey Transit (NJ TRANSIT) and other transit agencies are looking to align their operations to improve the safety of bus operators, passengers boarding and alighting at stops, bicyclists, and pedestrians. The project team from the Delaware Valley Regional Planning Commission (DVRPC) worked with NJ TRANSIT, local officials, and road owners to explore strategies to do so. This memo lays out the findings from this study and provides recommended street design, stakeholder communication, and operational strategies to reduce interactions between NJ TRANSIT buses and bicyclists.

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