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MEMORANDUM

July 1, 2021 Project #: 21093.005

To: Richard Montanez, P.E.
Deputy Commissioner of Transportation
Department of Streets

CC: Kelley Yemen, AICP

From: Laura Ahramjian, AICP, and Glenn Rowe, P.E.

RE: Philadelphia PSBL Study – Final Report

INTRODUCTION

The purpose of the Philadelphia Parking Separated Bicycle Lanes Study is to understand the safety benefits, operational effectiveness, and impacts on usage of parking separated bike lanes (PSBLs). The study documents best practices for facility selection, design, maintenance, and operation of PSBLs, assesses existing PSBLs in Philadelphia, reviews the current pending PSBL legislation in Pennsylvania, and makes recommendations for how PSBLs can be safely accommodated on Philadelphia's streets and roads throughout the Commonwealth.

To evaluate PSBLs and make recommendations on their installation, maintenance, and operation, several tasks have been completed and summarized in this final report. A literature search was conducted and included a collection of best practices from municipal, state, and national sources. The sources for the literature review included the National Association of City Transportation Officials (NACTO), the Federal Highway Administration (FHWA), the National Transportation Safety Board (NTSB), the National Cooperative Highway Research Program (NCHRP), and the Manual on Uniform Traffic Control Devices (MUTCD). A survey was distributed to several states and five (5) peer states were selected for review of their guidelines regarding PSBLs. Two of Philadelphia's piloted PSBLs were studied, including field observations and an analysis of before and after data. Meetings were conducted with City and State officials and with other key stakeholders. Crash Modification Factor (CMF) analysis was performed, and proposed legislation was reviewed for compatibility with national standards. The results of these efforts are summarized herein. Additional information regarding the literature and peer state review is available in Appendix A: Literature and Peer State Review Summary Report, including source references and summaries. Appendix B: Study of Philadelphia's Parking Separated Bike Lanes includes more detail on the Philadelphia PSBL pilot project, CMF analysis, and legislation review.

PSBL Background

PSBLs are in-street bikeways that are separated from passing motor vehicle traffic by a parking lane and buffer. PSBLs dedicate a separate and defined space for cyclists using striping, markings, signage, vertical elements, and intersection treatments. They are typically attractive to all ages and abilities, which may increase cyclist volumes along a corridor due in part to the comfort and perceived safety of the facility. They also maintain some parking capacity, which may be valuable to businesses and communities.

Cities around the world and across the US are installing PSBLs on their street networks as a means of providing dedicated bicycle infrastructure that is accessible to more people. Much of this implementation is to reduce mid-block bicycle crash rates, which result in more fatalities and serious injuries as compared to intersection bicycle crashes. Several cities and states have incorporated PSBL standards, invested in specialized maintenance equipment, and have documented the measurable benefits of PSBLs in their neighborhoods.

PSBLs in Pennsylvania

It has been previously interpreted that PSBLs are not allowable under current Pennsylvania (PA) legislation, which requires parking to be located within 12 inches of the curb; furthermore, the current Roadway Design Manual does not provide an allowance for parking next to bike lanes. House Bill 792 (known as Susan's and Emily's Law) of the 2019-2020 Session was recently passed unanimously in the House and is under review by the Senate. This bill would provide for the necessary flexibility to install and operate PSBLs in Pennsylvania.

The City of Philadelphia (the City) launched a PSBL pilot project in June 2018. Prior to the pilot, much of the City's bicycle network included painted bicycle lanes adjacent to vehicular traffic. Absent separated infrastructure, motor vehicles were stopping, parking, and passing in the bike lanes, requiring cyclists to weave in and out of traffic. With the goal of implementing bicycle infrastructure that would be more accessible to cyclists of a variety of ages and abilities, the City partnered with the Pennsylvania Department of Transportation (PennDOT) to pilot a network of PSBLs. This solution was offered as a means of improving the bicycle network while also meeting parking demand and offering designated loading space. As part of the pilot program, the City began designing and installing PSBLs on 10 streets that were already planned for separated bike lanes. Major design and implementation consideration was given to national design guidance, corner clearance and sight lines, emergency services coordination, drainage, vertical elements, snow removal, and maintenance.

Two of those 10 pilot streets are discussed herein. Those 2 projects have been constructed such that there is sufficient before and after data to evaluate them as part of this study. The findings of this study as well as future studies of the other pilot streets will be used to inform conversations with PennDOT around allowing PSBLs outside of the June 2018 pilot project and how PennDOT publications can be updated to reflect best practices for PSBLs.

SAFETY OF PSBLS

Much of this study focused on how PSBLs may impact the safety of a corridor for all users. With PSBLs being newly implemented in many US cities, some crash data is limited or not yet available. Continuing study of crash data will be helpful to defining standards for installation, maintenance, and operation. There is an active NCHRP research effort (15-74) being undertaken by the Texas A&M Transportation Institute called "Safety Evaluation of On-Street Bicycle Facility Design Features" that will likely be relevant and complementary of the information compiled herein. NCHRP Report 15-73 is also active regarding "Design Options to Reduce Turning Motor Vehicle – Bicycle Conflicts at Controlled Intersections." This research may be particularly useful for understanding and enhancing safety at intersections.

The New York City Department of Transportation is one agency that has multiple years of safety data evaluated for their PSBL network, some of which was installed as far back as 2007. Their results show that even as cyclist volumes have increased, the new facilities have reduced overall injury crashes (-17%), pedestrian injury crashes (-22%), bicyclist injury crashes (minor decrease), and total injuries (-20%). New York City identified significant decreased average risk of serious injury to cyclists (-75% from 2001 to 2003). None of the studied streets (with at least 3 years of data) saw an increase in injury crashes, even with increases in bicycle volumes.

The FHWA Separated Bike Lane Planning and Design Guide (FHWA) determined that per capita crash rates for cyclists appeared to decrease in most facilities after separated bike lanes were installed. FHWA found that separated bike lanes offer a high level of human error accommodation and that separated bike lanes may accommodate more ages and abilities due to the separation between motor vehicles and bicyclists.

Many of the reviewed case studies found that PSBLs increase perceived safety and comfort for cyclists and national guidance suggests that as a result these facilities may better serve more ages and abilities. Typically, the installation of PSBLs has reduced crash rates for motor vehicle drivers, bicyclists, and pedestrians, especially at mid-block locations where crash injuries tend to be most severe. PSBLs typically reduce cycling on the sidewalk, result in lower vehicle speeds, reduce interaction between vehicles and cyclists mid-block, and eliminate the risk of side swiping. Some case studies did result in an increase in crashes at intersections and/or driveways; as such, dedicated intersection and conflict zone infrastructure is key to safety along corridors with PSBLs. Other factors such as maintenance, debris removal, parking enforcement, grades, and sight lines all impact the safety of PSBLs. Best practices and design solutions are referenced herein to respond to safety concerns. Additional detail, including specific values, regarding these conclusions is provided herein as well as in Appendix A.

Mid-Block Safety

The NTSB Bicyclist Safety on US Roadways Report (NTSB) found through a nationwide roadway crash data review that a bicyclist is twice as likely to sustain a fatal or serious injury if a crash occurs at a mid-block location. The two (2) types of crashes that contribute most to mid-block cyclist fatalities are a motorist overtaking a bicyclist and other circumstances surrounding parallel movements. Separating bicycle and motor vehicle traffic could potentially prevent such mid-block crashes and reduce severe injuries and fatalities. NTSB recommends that separated bike lane facilities be included as a treatment on FHWA's list of Proven Safety Countermeasures.

The NACTO Urban Bikeway Design Guide (NACTO) indicated that protected cycle tracks improve perceived comfort and safety and eliminate collisions caused by vehicles over-taking cyclists. Dooring may be avoided with a wide buffer and is less frequent with a PSBL than a typical bike lane. If dooring occurs, the cyclist will not be struck into moving motor vehicle traffic.

As related to ***mid-block safety***, based on the reviewed case studies, PSBLs:

- Either do not impact or else decrease mid-block crashes for all users
- Decrease bicyclist crash severity
- Decrease mid-block interactions between motor vehicles and bicyclists
- Increase perceived mid-block safety and cyclist comfort
- Result in fewer cyclists on the sidewalk
- Increase bicycle volumes
- Either do not impact or else decrease mid-block motor vehicle speeds
- Do not impact motor vehicle volumes

The NYC Columbus Avenue Case Study reported a 34% decrease in all crashes (vehicular, bicycle, pedestrian). The Telegraph Ave Case Study in Oakland saw a 40% reduction in all collisions (vehicular, bicycle, pedestrian). The San Francisco Case Study noted a 99% decrease in interactions between motorists and cyclists at mid-block locations. Refer to Appendix A for additional information regarding these case studies and their findings.

Intersection Safety

As related to ***intersection safety***, based on the reviewed case studies, PSBLs:

- May increase intersection crashes for bicyclists
- Do not impact bicyclist crash severity

Intersection treatment and design may affect the safety of the facility in terms of:

- Interactions between cyclists and motor vehicles
- Interactions between cyclists and pedestrians
- Perceived safety and cyclist comfort
- Visibility and awareness

Intersection design is critical to a successful PSBL facility. The FHWA Separated Bike Lane Planning and Design Guide determined that while separated bike lanes reduce conflicts mid-block, they may introduce conflicts at intersections and driveways. Typically, intersection crashes take place at lower speeds and result in less severe injuries as compared to those at mid-block. Intersection treatments are necessary to facilitate safe operation of the facility and mitigate crash potential. Signage, lighting, striping, and markings can be used to inform and create visibility at intersections. NCHRP Research Report 500 references several additional ways to modify the geometry of an intersection to improve bicycle safety, including realignment of the intersection to reduce crossing distances and eliminate skews. Raised refuge islands or medians may reduce exposure for cyclists in intersections, allowing them to cross one direction of traffic at a time.

NCHRP Research Report 926 found that for high traffic volumes (i.e., 12,000 ADT) and speed limits (i.e., 40 mph), more physical separation is required between motor vehicles and cyclists at intersections. In these scenarios, a bicycle signal or comparable intervention may be required. At lower speeds and volumes, infrastructure that requires yielding may be more appropriate. NCHRP Research Report 500 recommends providing adequate clearance intervals, bicycle sensors, and / or a leading bicycle interval.

A study of PSBLs at intersections in New York City determined that implementing standard treatments reduces crashes at intersections by 30% when installed as part of a PSBL project. Mixing zones reduce the crash rate by 27%. The San Francisco Case Study noted that the new bike signal as part of their PSBL project reduced intersection close calls by 29%. This project resulted in a decrease in intersection conflicts, particularly related to right-hook conflicts. Case studies in Washington, DC and Madison, WI recommended bike signals, green paint, pedestrian refuges, and bike boxes in response to the results of their pilot projects.

Several sources emphasized improving visibility at intersections, suggesting increased sight distance at intersection approaches, clearing sight triangles of any obstructions, and improved lighting. Parking should be prohibited near intersections to improve visibility. NACTO indicates a desired 30' from each side of the crossing with no parking. Sidewalk furnishing and/or other features should accommodate a sight triangle of 20' to the cycle track from a minor street crossing and 10' from driveway crossings. NCHRP Report 15-73 is an ongoing project that is anticipated to shed additional light and offer definitive guidance on reducing conflicts between cyclists and motor vehicles at intersections.

Crash Modification Factors of PSBLs

CMF Background

The evaluation of Philadelphia's Parking Separated Bike Lanes was used to inform initial research on how a Crash Modification Factor (CMF) could be developed to quantify the potential safety benefits of PSBLs. A CMF is a multiplicative factor that indicates the proportion of crashes that would be expected after implementing a countermeasure, such as a pedestrian crossing island or a road diet. CMFs with a value less than 1.0 indicate

an expected decrease in crashes; CMFs greater than 1.0 indicate an expected increase in crashes. Typical sources for CMFs include the Crash Modification Factors Clearinghouse and FHWA's Proven Safety Countermeasures. FHWA promotes the use and widespread implementation of safety treatments and strategies that have proven effective at reducing crash rates. There are 20 FHWA Proven Safety Countermeasures, none of which include PSBLs or Separated Bike Lanes (SBLs).

The CMF Clearinghouse does include several countermeasure listings for "Install Separated bicycle lane"; all of these are based on the 2016 Separated Bike Lane Crash Analysis paper highlighting the safety data analysis completed as part of the Federal Highway Administration's (FHWA) Separated Bike Lane Planning and Design Guide. These CMFs are given a 1-star quality rating (out of 5), suggesting low quality or confidence in the results of the study producing the CMF. Two of these CMFs directly reference outcomes in separated bike lanes that use parking as the method of separation; however, since the reference report used to develop the CMFs did not report the number of crashes in the after period, the Project Team determined that these CMFs should not be used.

CMF Development

Development of a high quality PSBL-specific CMF will be critical to more widespread implementation and adoption by state and federal agencies. Due to the relatively recent implementation of PSBLs in the US, comprehensive research reports that can be used for CMF development are still not available However, two ongoing research projects are currently evaluating the safety implications of separated bicycle facilities and will be very helpful to this effort once completed:

- **FHWA Development of Crash Modification Factors for Different Separated Bike Lane Configurations:** The Study will "determine the influence of separated bike lanes/bikeways (SBLs) on the total number and severity level of crashes with particular attention to crashes that involve bicycles". Phase I of the study evaluated the feasibility and requirements for developing crash modification factors (CMFs) for intersection-related crashes separately from crashes occurring at mid-block locations. Phase II, currently underway, will focus on how to perform the analysis, collecting data through video recordings of crashes or recording the way bicyclists behave on the road with motor vehicles. Phase II will also focus on developing CMFs for mid-block SBL locations.

- **NCHRP 15-74 Safety Evaluation of On-Street Bicycle Facility Design Features:** The objective of this research is to provide practitioners at state DOTs and other transportation agencies with data-driven guidelines for selecting context-appropriate design features for safety improvements to existing separated and non-separated on-street bicycle facilities and for the planning of new facilities. The guidelines will be based on an up-to-date, quantitative analysis of crash patterns as well as an evaluation of the roadway characteristics, land use patterns, and human factors that increase conflicts and the risk and severity of mid-block crashes that involve bicyclists.

Best practice data considerations for development of a PSBL CMF are as follows:

1. Identify a variety of PSBL sites and comparable roads without PSBLs. 30 sites are needed, but a corridor can be broken up into segments (i.e., 30 different PSBLs corridors are not required)
2. Collect before and after data on PSBL and non-PSBL sites (traffic volumes, bicycle volumes, crash data)
3. Document the following for each site:
    - Facility location + extents
    - Length of facility
    - Before/after roadway typical section
    - Number of signalized intersections
    - Before/after traffic and bicycle volumes
    - Before/after crash data
    - Date of installation

A high-quality PSBL-specific CMF that is approved by FHWA and state and local transportation agencies would be beneficial to encourage the implementation of PSBLs in Pennsylvania. Ongoing research efforts by FHWA and NCHRP will provide useful analysis that will either directly result in Separated Bike Lane/PSBL CMFs or data that can be used to develop PSBL-specific CMFs.

PSBL DESIGN BEST PRACTICES

The literature review involved identifying design guidelines and best practices as determined by national research. The review covers methods for maintenance, service, and operation offered by municipal organizations and includes case studies of PSBLs in cities around the country. Refer to Appendix A for a full list of sources referenced for the literature review. Appendix A includes source summaries and clarifies which information was derived from each.

In addition to determining best practices, the PSBL study explored common operational challenges that may impact the safety, success, and suitability of a PSBL facility. To fully evaluate the implications of PSBLs, both the challenges and the mitigating best practices are outlined herein. They are compiled from all Study tasks, including the literature review and Philadelphia Pilot Project review.

General Design

General design considerations include the typical cross section of PSBLs. Like any bicycle facility, the design of PSBLs must take the needs of all road users into consideration, including cyclists, drivers, transit operators and riders, pedestrians, and city and emergency services. A main challenge in the general design of PSBLs is ensuring there is enough road space for the PSBLs and other road users. Best practices set guidelines on minimum widths to ensure enough space and protection for bicyclists in the PSBLs.

PSBLs are generally appropriate on streets with moderate to high vehicle volumes and moderate to high vehicle speeds. The MassDOT Separated Bike Lane Planning & Design Guide recommends separated bike lanes, including PSBLs, on streets with more than 6,000 vehicles per day and speeds greater than or equal to 25 MPH. However, land use context is important to consider. PSBLs might not be appropriate on roads with high frequency of driveways and/or no existing parking or low parking demand.

Best Practices

- 5-foot minimum one-way bike lane width (4-foot minimum when accommodating an ADA access aisle).
- 7-foot minimum one-way bike lane width where there are high volumes, steep inclines, and anticipated passing.
- 2- to 3-foot minimum buffer width.
- 7- to 8-foot minimum parking lane width.
- Preferred 11-feet for combined parking lane and buffer.

Intersections

Intersections are a key challenge because of conflicting movements between drivers, bicyclists, and pedestrians. At an intersection, the bike lane does not have the buffer and parked cars for protection, which can present a safety concern. Bicyclists can be less visible to motorists where cars are parked too close to the intersection, thus blocking the view of bicyclists as vehicles are turning at the intersection. Intersection treatments such as bike signals, bike boxes, and daylighting can help bicyclists move safely through an intersection and increase the visibility of bicyclists.

It should be noted that existing PA State Law prohibits parking a vehicle "within 15 feet of a fire hydrant, within 20 feet of a crosswalk at an intersection, [and] within 30 feet upon the approach to any flashing signal, stop sign, yield sign, or traffic-control signal located at the site of a roadway" (Title 75, 3353). Daylighting and vertical separation help enforce these existing requirements at intersections. Additionally, new driveway permits may require parking be eliminated from sight distance triangles, further enforcing the best practices mentioned herein.

Challenges

- Visibility of cyclists and pedestrians is impeded by parked cars.
- Confusion about how bicyclists make turning movements.
- Potential conflicts between thru bicyclists and turning vehicles.
- Potential conflicts with crossing or waiting pedestrians.
- Lack of designated space for cyclists turning off the PSBL facility for turns that require crossing the street. (e.g., a bicyclist making a left turn when the PSBL is on right side of the road).

Best Practices

- Bike signals are the most effective intersection treatments (especially at high speed, high volume locations).
    - Per NCHRP Research Report 926, bicycle signals or some other form of physical separation may be required where ADT is over 12,000 and speed limits are 40 mph or higher.
    - Bicyclists need longer minimum green times than motor vehicles due to slower acceleration speeds.
    - There is no national standard for calculating the appropriate clearance interval for bike signals. Bicyclist travel speed and intersection width are the two most important variables in determining the clearance interval.
    - Bicycle sensors and/or a leading bicycle interval may be needed to accommodate traffic flow.

    - A "Bicycle Signal" sign should be placed with the bike signal head to increase awareness.
    - To avoid conflicts with turning vehicles, a "No Right/Left On Red Sign" should be used.
- Turning zones are less effective intersection treatments followed by mixing zones, which may be appropriate at low volume, low speed locations.
- Bike boxes should be implemented where applicable.
- Daylighting (at least 20 feet, preferably 30 feet to 60 feet) should be implemented at intersections and access points (e.g., driveways and alleys) to ensure sufficient sight distance.
- Green paint should be implemented at conflict zones.
- Vertical treatments should be implemented to enforce daylighting and clear zone areas and provide separation between bicyclists and vehicles.
- Other obstructions, street furniture, etc. should be eliminated and prevented in sight triangles.
- Consider reducing crossing distance, eliminating skews, and providing refuges for bicyclists.

Mid-Block

Design of PSBLs mid-block is important to ensure safety of bicyclists and pedestrians, preserve access to destinations, and maintain parking access. In a PSBL, the bike lane is between the curb and on-street parking, which can result in "doorings" of bicyclists if an adequate buffer is not provided. Because parked cars are no longer next to the curb, pedestrians need to walk in the bike lane to access the sidewalk. This can create potential conflicts between bicyclists and pedestrians and issues with ADA access. Proper design of the buffer zone and parking regulations can address these challenges.

Challenges

- Potential for dooring with parking next to bike lane.
- Potential for double parking or vehicles loading / parking in the bike lane where vertical treatments are not in place.
- Frequent driveways may create conflicts between bicycles and motor vehicles.
- Initial confusion from drivers on how to park.
- Placement of parking meters in the buffer can cause conflicts with the bike lane.
- Conflicts with pedestrians crossing bike lane from parking lane/sidewalk.
- Pedestrians loitering in the buffer.

Best Practices

- Buffers should be wide enough to prevent dooring (at least 3 feet).
- Ample loading zones should be provided to prevent double parking and parking in non-designated areas.
- Vertical treatments should be implemented for parking enforcement.
- PSBLs may not be a preferred facility along a corridor with frequent driveways or alleys.
- Where there are driveways or alleys, refer to intersection best practices, including daylighting, sight triangles, conflict markings, signage, etc.
- Ample permanent signage and markings should be provided warning pedestrians to look for cyclists before crossing the bike lane.
- Signage, striping, and markings are also key to identifying the facility and how to park and maneuver around it.
- Case study lessons learned suggest not putting parking meters in the buffer (where pedestrians need to be in the buffer or bike lane to pay for parking).

- Sidewalk furnishings can be used to prevent pedestrians from accessing the bike lane in undesirable locations.

Vertical Separation

Vertical separation in the buffer is important to add additional protection for bicyclists and prevent drivers from parking in the bike lane. There is no one perfect option, and municipalities continue to test out different options. Each type of separation has benefits and limitations relating to cost, maintenance, and drainage impacts. Some types of separation may work best for short-term implementation due to low cost and flexible design. Other types of separation may require long-term capital investments. The different types of separation evaluated for this effort include:

- Flexible Delineator Posts
- Low-Profile Bicycle Lane Separator
- Bollards
- Concrete Barriers
- Raised Median/Curb – including 12-in extruded curb.
- Planters – including smaller moveable planters and more permanent landscaping in curbed planting areas or rain gardens.
- Temporary Curbing (e.g., parking stops, armadillos)

Challenges

- Vertical elements may require frequent maintenance and/or replacement.
- Vertical elements can be costly to purchase, operate, or maintain.
- There may be a desire to move or remove vertical elements.
- Vertical elements may be required for crash protection.
- Vertical elements may impact the aesthetics of the community.
- Vertical elements may create tripping hazards for motorists exiting parked vehicles, especially if they do not include a conspicuous vertical element.
- Vertical element selection may impact comfort and perceived safety of the facility for bicyclists.
- Vertical element positioning and spacing may impact drainage, parking and loading enforcement, and ADA parking accessibility.

General Considerations by Type of Vertical Separation

Each type of vertical separation has different advantages and disadvantages related to cost, durability and maintenance, aesthetic quality, ADA and drainage. Depending on roadway context, some types of vertical separation may be more appropriate than other types. **Table *1*** provides a summary of each type of vertical separation evaluated for this report.

Table 1. Summary of Vertical Separation Options

Vertical Separation Type	Description	Typical Spacing	Pros	Cons	Potential Applications
Flexible Delineator Posts		MIDBLOCK: 10 to 40 feet (20 feet typical in urban areas) INTERSECTION: 5 to 10 feet	• Low cost • High visibility • Easy to install/adjust • Does not impact roadway drainage • Minimal tripping hazard	• Require frequent replacement/ maintenance • Low aesthetic quality	• Short-term installation
Low Profile Bicycle Lane Separator		10 to 40 feet (20 feet typical in urban areas)	• Low cost • High visibility • Easy to install/adjust • Mountable base • Does not impact roadway drainage • Minimal tripping hazard	• Require frequent replacement/ maintenance • Low aesthetic quality	• Short-term installation
Bollards		10 to 40 feet (20 feet typical in urban areas)	• Stronger, more rigid barrier	• High cost – depending on spacing and material • As fixed objects, may create a crash hazard for both drivers and bicyclists	• Lower speed roads
Raised Median/ Curb		N/A – Continuous separation	• Cast in place or precast • Provides continuous raised buffer • Requires little long-term maintenance • Opportunity to incorporate landscaping	• High cost • May block emergency vehicle access (mountable curb can be used to assist with emergency vehicle access) • May impede ADA access • May create a tripping hazard for people parking their cars and crossing to the sidewalk • Requires accommodation for drainage	• Streets with small number of driveways • Adequate buffer space for ADA access aisle

Vertical Separation Type	Description	Typical Spacing	Pros	Cons	Potential Applications
Planters		Maintain consistent spacing	• Aesthetically pleasing • Quick to install • Can be used for stormwater management if large enough	• High cost – depending on spacing • High maintenance needs for landscaping • High speed/high truck volume roads can be inhospitable to plantings	• Central business district with identified maintenance partners • Low speed/low truck volume roads
Temporary Curbing	 Temporary Curb  Parking stops  Armadillo  Zicla Zipper System  Concrete "Pills"	• N/A • 6 ft • 5 feet, rotated 30˚ desired • 8 feet max • 1 to 4 feet • 7 to 10 feet	• Relatively low cost • Easy to install/adjust • High durability • Gaps between curb segments allow drainage	• May create a tripping hazard for people parking their cars and crossing to the sidewalk • May allow cars to block the bike lane • Do not provide same level of bicyclist comfort due to low height (this can be mitigated by providing flexible delineator posts in conjunction with the curb segments)	• Locations with narrow buffer • Pilot locations to test out effectiveness

Short-Term Best Practice: Flexible Delineator Posts

Flexible delineator posts are a common type of vertical separation. Due to their low cost and ease of installation, flexible delineator posts are a good choice for short-term projects. The location of delineators can easily change, allowing cities to experiment to find an ideal placement. The typical spacing of delineator posts varies. FHWA guidance provides a range from 10-foot to 40-foot spacing; tighter spacing may be required at intersections and daylighting areas. Parking demand and curbside access influence delineator spacing.

Signage and Pavement Markings

Implementing unfamiliar infrastructure may create operational challenges at first. When people expect parking to be against the curb and it is not there, there may be confusion or hesitancy on how to travel along the street. This may be the case for all users: cyclists, motor vehicle drivers, transit riders, pedestrians, delivery drivers etc. There is potential for people to be moving in the wrong direction and/or making inappropriate decisions.

Adequate signage and markings help people identify and use PSBLs. It is important to clarify through signage and pavement markings which space is dedicated for which users, and how that space shall be used. Signage and pavement markings warn and direct users. For instance, signage may warn a pedestrian who has just parked their vehicle to be on the lookout and be prepared to yield to a cyclist in the bike lane before crossing to the sidewalk. Or pavement markings may warn a cyclist when they are approaching a conflict zone. Signage and markings also help facilitate transitioning to and from the facility.

Challenges

- Defining and identifying the bicycle facility.
- Education regarding unfamiliar infrastructure.
- Parking and loading enforcement.
- Conflicts with other signs and markings such as for ADA or transit infrastructure.
- Visibility and awareness of all users.

Best Practices

- Bicycle lane word, symbol, and arrow pavement markings shall be installed per MUTCD requirements.
- Buffer pavement markings shall be installed per MUTCD requirements.
- The following signs are recommended to identify and define the PSBL facility:
    - "Bike Lane".
    - "No Cars".
    - "No Turn on Red" is recommended in PSBL facilities.
    - "Turning Vehicles Yield to Bikes".
    - "Bicyclists Yield to Pedestrians".
    - "Bicyclists May Use Full Lane".
    - "No Parking, Bike Lane".
    - "Bicycle Signal Actuation".
    - "Right Turn Lane Must Turn Right".
    - "Begin Right Turn Lane, Yield to Bikes".
    - "Bicycle / Pedestrian Warning".
- "Do Not Enter" (R5-1) signage should be used to specify and warn of facility direction and the "Except Bicycles" (R3-7bP) plaque incorporated where there are contra flow PSBLs

- Recommended pavement markings include turn arrows, yield line pavement markings ("shark's teeth"), "Slow", and "Bike Only" lane markings to supplement MUTCD required markings.
- White transverse markings are recommended in the buffer.
- Green paint should be implemented at conflict zones.
- Green paint, yield lines, and "Yield to Bikes" signage should be provided at driveways.
- Provide ADA signage in applicable zones.
- Provide clear parking and loading signage to reduce confusion.
- Provide signage requiring cyclists to yield at transit stops.

Curbside Needs

The curbside along a PSBL facility should be designed to separate users. Vehicles should be prevented from parking or loading in the bike lane. Pedestrians should be discouraged from accessing the bike lane unless they are crossing from a parked vehicle. Barriers can be strategically implemented on both sides of the bike lane to maintain that dedicated space.

There is also a loss of parking capacity typically resulting from a PSBL project as curbside space is used for intersection and driveway daylighting, loading zones, extended transit stops, ADA parking etc. The Philadelphia Pilot Project did significant outreach with stakeholders to talk through parking needs and potential impacts, which helped get those stakeholders on board about the roadway changes. Considering parking impacts may affect the context and type of street that makes for a good PSBL. The corridor should be mostly parked for protection, but perhaps within proximity to other parking opportunities where that capacity is especially important.

Challenges

- Potential for double parking or vehicles loading / parking in the bike lane
- Loss of curbside parking to daylighting

Best Practices

- Ample loading zones should be provided to prevent double parking and parking in non-designated areas.
- Vertical treatments should be implemented for parking and loading enforcement.
- Provide a mix of designated parking – for bicycles, cars, motorcycles, special equipment, loading, etc.

Accessibility

Proposed street infrastructure must be accessible to all users. PSBLs may present challenges for the ADA community, particularly for people using wheelchairs, walkers, or other users who may have challenges getting across the bike lane to the curb. The design and installation of PSBLs should consider how various users may approach and understand the facility whether through tactile or sound indicators. The facility needs to be free of tripping hazards and obstacles and incorporate a wide enough access aisle to allow movement between an ADA parking space and the adjacent curb ramp. For some users, signage and markings are not an adequate form of information and thus, the facility must direct and warn those users in some other form.

Several of the reviewed case studies referenced engagement with the ADA community during the design and installation process. Education and outreach specifically with the ADA community is also key to success. Several considerations are offered below.

Challenges

- Limited right-of-way and/or curb-to-curb space
- Lack of accessible aisles between ADA parking spaces and curb ramps
- Paratransit accessibility
- Education regarding unfamiliar infrastructure

Best Practices

- A 5-foot landing area (combined width of bike lane and buffer) is needed for car user accessibility.
- An 8-foot landing area (combined width of bike lane and buffer) is needed for van user accessibility.
- Mid-block curb ramps provide additional egress points for wheelchair users.
- ADA parking situated near intersections may provide more flexibility.
- Roadway cross-slopes should be less than 2% for accessibility.
- Paratransit, taxi, and rideshare loading zones should be designated where needed.
- Design elements can be selected to provide tactile indication of measures.
- Vertical elements can be positioned to support ADA users.
- "Yield to Pedestrians" signage may be needed to identify accessible areas.
- Education and outreach with the community may introduce street elements that are otherwise unfamiliar to users.

Public Transportation

Transit riders are important road users, and special consideration is needed to ensure the PSBL does not encroach on transit access. With a PSBL, buses may not be able to pull alongside the curb to pick up and drop off riders, which may result in riders walking in the bike lane. Adequate space needs to be provided to ensure there is an accessible route to the sidewalk. Pavement markings and signage can help warn bicyclists to yield to pedestrians. Early and frequent communication with transit operators can help ensure the PSBL design incorporates transit needs.

Challenges

- Bus stops may conflict with PSBLs.
- Transit riders may be required to cross the bike lane.
- Busses make wide turns, which may limit PSBL design.
- PSBLs must not impact bus routes or schedules.

Best Practices

- PSBL design and installation should consider bus turning radii, stop configurations, and other impacts.
- Signage, markings, and accessibility are key considerations.
- On one-way streets and depending on other street characteristics, the PSBL could be placed on the opposite side of transit stops to avoid conflicts.
- Bike lanes may be wrapped behind the stop.
- Bike lanes at transit stops can include a ramp with yielding signage and markings to alert bicyclists to crossing pedestrians.
- Extended mixing zones may be appropriate with adequate signage (where there is infrequent service).
- Shelters should be transparent and set back from PSBL infrastructure.
- Green conflict markings should be incorporated where applicable.
- Daylighting on either side of the stop should be provided for visibility.

Micro Mobility

E-scooters and other motorized forms of micro mobility should be considered in the design and implementation of PSBLs. Many state and municipal agencies have been challenged with how to classify and regulate these types of vehicles. There is consensus that they are not safe on sidewalks amongst pedestrian traffic nor in the street with motor vehicle traffic. Still, they offer a sustainable and affordable transportation option, and there is a demand for these vehicles, especially in an urban context.

There is limited data, research, and guidance specific to motorized vehicles in PSBLs. Other municipalities, such as Portland, OR, see separated bicycle infrastructure as being appropriate for e-scooters and other forms of micro mobility. NACTO has done some research regarding micro mobility and cites studies in Alexandria, VA, and Hoboken, NJ, where respectively, 53% and 88% of e-scooter riders feel safer riding in bike lanes. NACTO says that a robust and interconnected bike lane network makes streets safer for cyclists, pedestrians, and those on scooters.

E-scooters are currently illegal in Pennsylvania and do not fit under any classification of the PA Motor Vehicle Code. While some private citizens may be seen operating e-scooters in Pennsylvania, shared e-scooter services

such as Bird or Lime are prohibited in the state. The City of Pittsburgh was recently approved for a 2-year pilot program to test out a scooter share program; this will be the only allowed location in Pennsylvania.

Equity

There is an integral link between bicycle infrastructure and the community. Separated bike lanes can offer greater mobility to lower income populations and can offer connectivity to transit and employment opportunities. The FHWA Separated Bike Lane Planning and Design Guide states: "As part of a connected bicycle network, separated bike lanes can: Provide a more comfortable experience for less-skilled riders; Improve access to destinations such as schools, jobs, health care facilities, and essential services; Enhance access to public transportation, for example by helping to solve the first/ last mile challenge; Improve access to employment opportunities, especially for those without access to a private automobile; and Provide a linkage between regional trail systems." With PSBLs, these benefits can be achieved while also maintaining some of the parking availability that is frequently valued by communities.

MAINTENANCE + OPERATION CONSIDERATIONS OF PSBLS

Successful implementation of PSBLs requires coordination with relevant stakeholders and agencies. Based on case study review and discussion with City staff on Philadelphia's pilot PSBLs, the following categories represent common types of consideration that are needed and inter-agency coordination that is required.

General Maintenance

The type of vertical separation affects the level of maintenance required. Flexible delineator posts are inexpensive and desirable for short-term implementation. However, delineator posts are vulnerable to vehicular movements and require frequent replacement. This includes the delineator post itself as well as the reflective tape that provides necessary nighttime visibility of the delineator. The low initial cost of delineators needs to be weighed against long term maintenance costs. Installing PSBLs as part of resurfacing projects may be a helpful solution. Maintenance plays an important role in overall usage; a PSBL that looks well maintained will generally attract more riders than a poorly maintained PSBL.

Challenges

- Delineator posts may require frequent replacement.
- Delineator posts at corners are especially vulnerable (where they may conflict with turning trucks and busses).
- Delineator posts at corners are especially important to directing traffic and maintaining a comfortable facility.
- Preserving the reflective tape of delineator posts is especially important and challenging.
- Lack of maintenance may impact usage of the facility.

Best Practices

- Delineator post affordability may need to be weighed against durability and estimated frequency of maintenance.
- A delineator post maintenance crew may be required to dedicate appropriate oversight.
- While delineator posts may be a good short-term solution, a more durable alternative may be required to reduce maintenance efforts in the long term.
- Installing and maintaining PSBLs as combined with resurfacing may be an economical solution.
- PSBLs may be most appropriate for streets that are more frequently resurfaced, to ensure the pavement markings are updated more regularly.

Snow Removal and Street Cleaning

Due to the narrow bike lane and parked cars away from the curb, municipalities may need specialized equipment to clear and clean the bike lane. Failure to remove snow and debris may make the bike lane inaccessible. Providing wider facilities may remove the need for specialized equipment.

Challenges

- Specialized equipment may be required to clear and maintain more narrow facilities.
- There may be limited space for disposal of trash, debris, snow, leaves, etc.
- Snow or debris build up may create unsafe conditions or may make the bike lane inaccessible

Best Practices

- Minimize creation of snowbanks in the buffer. Consider a wider buffer if there is inadequate space elsewhere for snow storage.
- Parking restrictions during snow events can facilitate snow removal.
- Vertical elements can be removable in winter.
- Wide PSBLs may not require specialized equipment.
- Investment in equipment can be maximized by getting a multifunctional vehicle with year-round utility (something useful on other facilities like greenways, alleys, parking lots, basketball courts, etc.).
- Maintenance around trash day may be required to keep the lanes clear.
- Additional maintenance during leaf season may be required.
- Equipment can be piloted before purchase to test possible short comings and opportunities.
- Equipment may need to fit under street trees and ideally can store debris internally.

Emergency Services

Any street improvement should consider how fire trucks, ambulances, and other emergency vehicles are accessing surrounding land uses. Infrastructure should not obstruct nor impede the rate at which emergency services can be provided. The design of PSBLs should incorporate input from emergency service providers. Design elements such as vertical separation, loading zone designation, turning radii etc. should account for the needs of emergency service agencies.

Challenge

- Emergency service access must be considered in the design of PSBL infrastructure.

Best Practice

- Coordinate and engage with various emergency service agencies.
- Consider vertical elements that can be traversed, mounted, moved, or adjusted during an emergency.
- Consider how other design elements may be coordinated such as turning radii, loading zones, lane widths, etc.

Loading Zones and Waste Management

PSBLs should be designed to prevent motor vehicles from accessing the bike lane. As a result, some parking space may need to be dedicated to other operations. With less direct access to the curb, solutions may be required for where and how waste should be collected.

Challenges

- Potential for double parking or vehicles loading / parking in the bike lane.
- Loading vehicles may impact visibility and sight distance of bicyclists in PSBLs.
- Delivery vehicles blocking bike lanes, turning lanes, etc.
- Paratransit, taxi, or other specialized loading areas may be required for equitable facility design.
- Limited space for trash storage and pick up.
- Buildup of debris in the bike lane around trash day.

Best Practices

- Loading zones should be designated along a PSBL corridor to prevent double parking.
- Vertical treatments may help enforce legal loading practices.
- Outreach and education may assist with new waste management and loading practices.
- The buffer area could be used for garbage pickup.
- Maintenance around trash day may be required to keep the lanes clear.

Drainage

Drainage infrastructure must function with proposed street improvements. Sometimes this infrastructure requires valuable real estate between curbs. Additional design consideration may be needed regarding slopes, barriers, vertical elements, and maintenance practices. Some drainage grates can obstruct or create conflicts for bicycles.

The preference derived from the literature review is to dedicate separate space for cyclists and drainage infrastructure. Where there is insufficient curb-to-curb space, other mitigations such as traversable grates or green infrastructure solutions should be explored and employed.

Challenges

- Bicycle traffic should not be impeded nor obstructed by drainage infrastructure.
- Limited right-of-way and/or curb-to-curb space

Best Practices

- It is desirable to locate drainage infrastructure outside the usable bike lane width or to utilize bicycle safe drainage features (e.g., grates).
- The width of the bike lane should be increased where the gutter seam extends more than 1 foot from the curb.
- Green infrastructure such as bioswales and landscaping should be considered with PSBL projects.
- Vertical element selection must account for drainage.

PEER STATE APPROACHES TO PSBLS

Peer State Selection Methodology

Five peer states were selected to review department of transportation policies and guidelines related to PSBLs. To select the appropriate peer states, an online survey was sent to AASHTO Committee on Traffic Engineering (CTE) members to determine if their state allows PSBLs and if so, whether their state provides any guidance on planning and designing PSBLs. In addition to the survey, Kittelson also reviewed peer states PennDOT previously evaluated in the PA Active Transportation Plan, including Massachusetts, Virginia, Washington, and Oregon. The five states selected as peer states for this effort are Massachusetts, Virginia, Minnesota, Florida, and Washington. Below is a brief summary of each state's policies and guidelines for PSBLs.

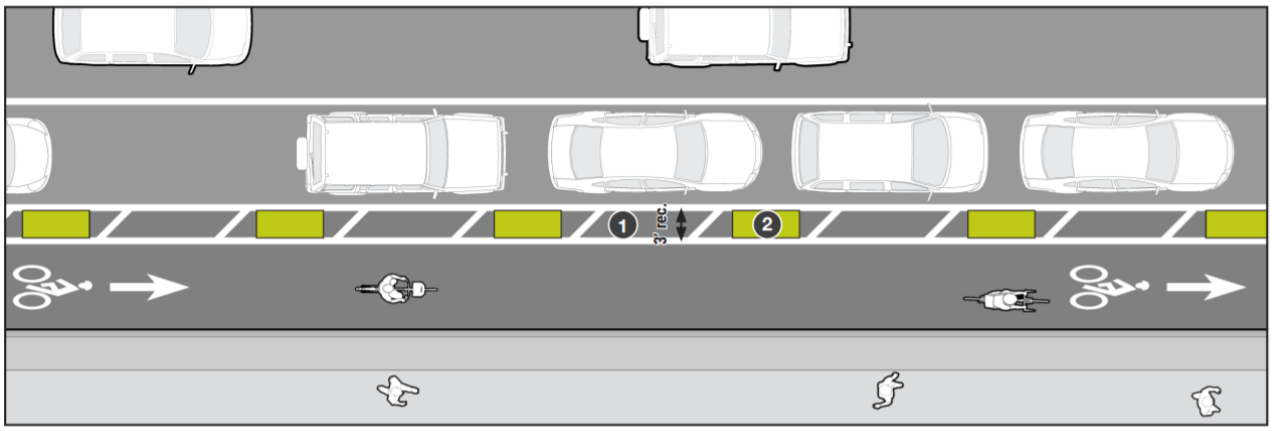
Massachusetts

The Massachusetts Department of Transportation (MassDOT) allows PSBLs in Massachusetts and on state roads. However, with few exceptions, parking is prohibited on state highways in Massachusetts. In 2015, MassDOT published the MassDOT Separated Bike Lane Planning & Design Guide. This document serves as a resource for considering, evaluating, and design separated bike lanes. The document covers planning, general design considerations, intersection design, curbside activity design, signals, and maintenance.

Separated bike lanes are recommended on streets with vehicle operating speeds greater than 25 miles per hour and vehicle volumes greater than 6,000 vehicles per day. Other important considerations when determining if a separated bike lane is recommended are number of lanes, curbside conflicts, number of large vehicles, vulnerable populations, low-stress network connectivity gaps, and unusual peak hour volumes.

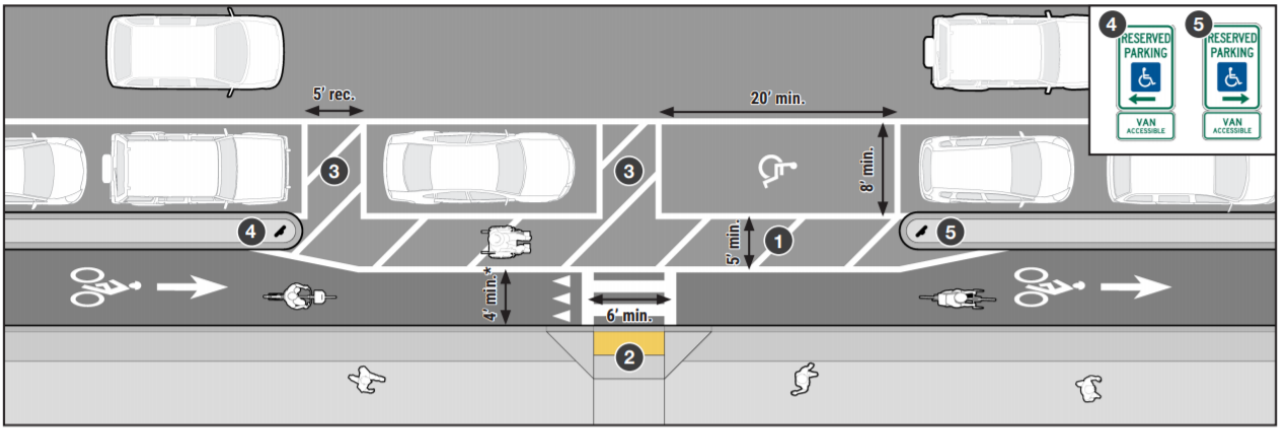
While the MassDOT guide is general for all separated bike lanes, there is guidance on PSBLs. A 3-foot (2-foot minimum) buffer is recommended when on-street parking is adjacent to the bike lane to avoid conflicts with motor vehicle doors. Vertical objects in the buffer zone, such as flexible delineator posts, should be provided to prohibit vehicles parking in the bike lane. Vertical objects can also help in commercial areas where on-street parking turnover is high, or locations where parking demand is low. The guide notes the importance of prohibiting parking close to the intersection to ensure enough sight distance for safe intersection movements.

EXHIBIT 5A: CONVENTIONAL ON-STREET MOTOR VEHICLE PARKING (MID-BLOCK)



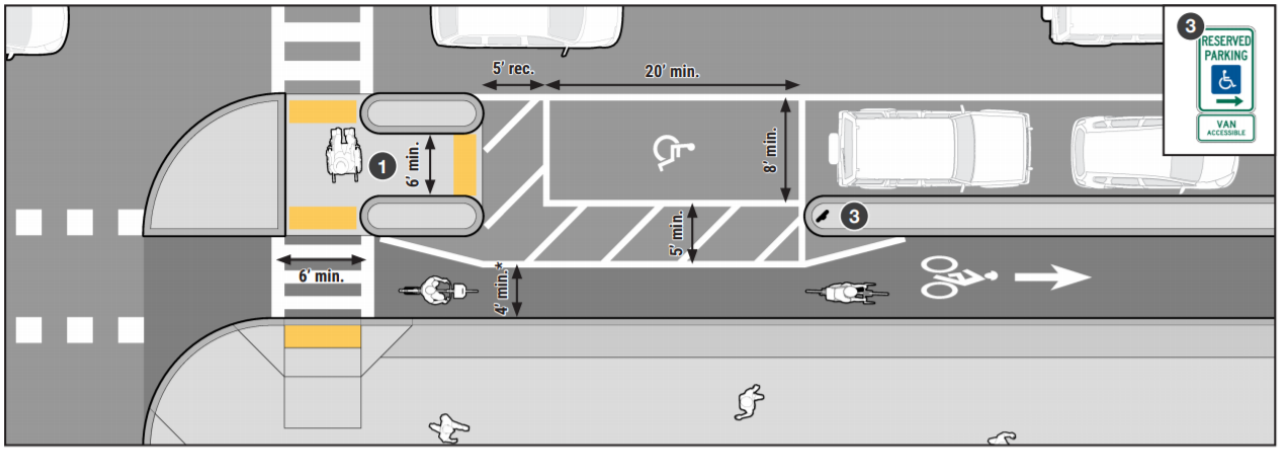
The guide includes sections on how PSBLs can be designed to accommodate ADA accessible parking spaces. To accommodate accessible parking, the bike lane may be narrowed to 4 feet with a design exception. A 5-foot minimum street level access aisle is required to access the sidewalk from the ADA parking space(s). Rear access aisles are recommended for driver-side access to the sidewalk. At all locations where pedestrians are expected to cross the bike lane, it is important to communicate to bicyclists they may need to yield to pedestrians.

EXHIBIT 5B: ACCESSIBLE ON-STREET MOTOR VEHICLE PARKING (MID-BLOCK)



* A bike lane width narrower than 5 ft. requires a design exception.

EXHIBIT 5C: ACCESSIBLE ON-STREET MOTOR VEHICLE PARKING (INTERSECTION)



* A bike lane width narrower than 5 ft. requires a design exception.

Virginia

The Virginia Department of Transportation (VDOT) allows PSBLs and is open to considering PSBLs on state roads. However, currently there are no PSBLs on VDOT maintained roads. VDOT does not have any specific guidelines or studies on PSBLs. The VDOT Road Design Manual recommends users to refer to the FHWA Separated Bike Lane Planning and Design Guideline. VDOT also recommends users reference the NACTO Urban Bikeway Design Guide for additional information.

Information on VDOT's bicycle and pedestrian facility guidelines can be found in Appendix A(1) – VDOT Complete Streets: Bicycle and Pedestrian Facility Guidelines, Bus Stop Design and Parking Guidelines, of the VDOT Road Design Manual. Within the appendix, there is a short section on separated bike lanes. According to VDOT, designers can choose from a variety of options to provide the vertical separation between the bike lane and the travel lane. These options include, but are not limited to, on-street parking, raised curbs or medians, bollards, or landscaping. VDOT refers users to FHWA and NACTO for further design guidance.

Minnesota

The Minnesota Department of Transportation (MnDOT) allows PSBLs in the state and on state roadways. The 2020 Minnesota Bicycle Facility Design Manual provides information to planners and designers to plan and design context-appropriate bicycle facilities within MnDOT right-of-way.

As stated in the manual, MnDOT has adopted FHWA's Separated Bike Lane Planning and Design Guide as its guidance for separated bike lanes. However, MnDOT provides additional guidance for PSBLs as it relates to ADA accessibility. These additional guidelines are listed below:

- A separated bicycle facility between the parking lane and the curb can be considered a barrier to accessibility. Due accessibility concerns, PSBLs are discouraged on trunk highways. If used, they should comply with the best practices to accommodate all users.
- Include designated ADA parking spaces that meet 2010 ADA standards. The location of the accessible parking spaces should consider directness of access to services and key destinations on the street.
- Include designate ADA vehicle ramp lift spaces.
- Include an 8-foot access aisle from the accessible parking spaces to the sidewalk, including any curb ramps.
- If the bike lane serves as the accessible route to access the sidewalk, the bike lane should have a cross slope of 2% or less.
- Additional considerations needed in areas with paratransit and dial-a-ride operations that need pick-up and drop-off locations near building entrances.

Florida

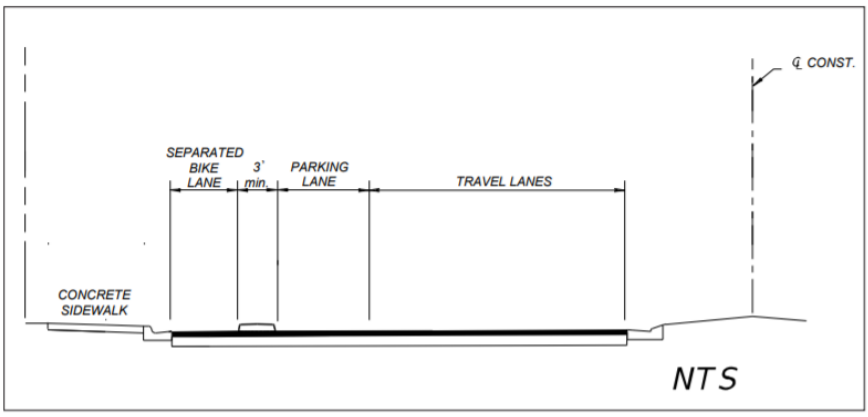
The Florida Department of Transportation (FDOT) allows PSBLs in the state and on state roadways. Guidance on bicycle facility design is part of the FDOT Design Manual, Chapter 223.

FDOT refers users to FHWA's Separated Bike Lane Planning and Design Guide for more detailed design guidance on PSBLs. However, FDOT does provide some additional guidance. FDOT recommends using on-street parking as a form of separation on roads with speeds of 35 miles per hour or less. A 3-foot minimum width raised island separation is required when the bike lane is adjacent to on-street parking.

Key Findings from FDOT's approach to PSBLs:

- FDOT follows FHWA guidance and recommendations
- Raised curb island for vertical separation is mandatory
- Limited use of PSBLs at first and FDOT plans to phase them in slowly
- Facilities are designed for all users, including children
- Avoid mixing zones at intersections wherever possible
- FDOT sets speed limits on streets with on-street parking according to context classification. FDOT is open to lowering speed limits to allow PSBLs on streets that do not currently have parking

Figure 223.2.2 On-Street Parking Minimal Separation



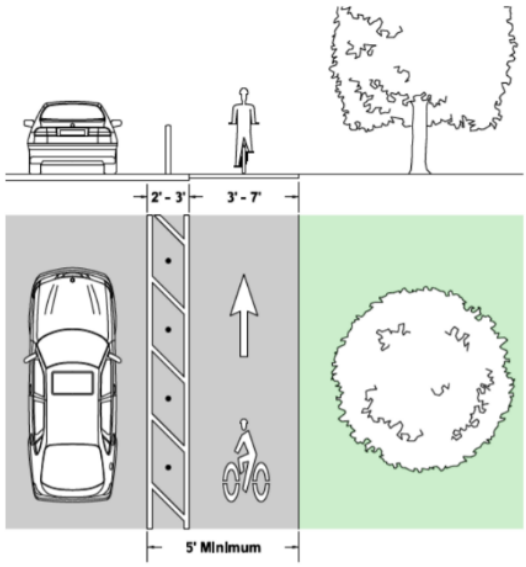
Washington

The Washington State Department of Transportation (WSDOT) allows PSBLs in the state and on state roadways. Guidance on separated bicycle facilities is included in the WSDOT Design Manual, Chapter 1520: Roadway Bicycle Facilities.

Section 1520.02(2) provides specific guidance related to separated bike lanes. Guidance relevant to PSBLs is summarized below:

- If parked vehicles are serving as the vertical separation, then the parking zone cannot encroach onto the buffer area.
- Painted buffer strips with flexible tubular marks help differentiate between the parking lane and the bike lane.
- A 3-foot-wide buffer should be used whenever possible.
- With a buffer, the bike lane itself may be 3 feet in width. However, 5 feet is recommended for the bike lane to enable passing between bicyclists and to account for the effective width needs for bicyclists to avoid drainage features.

Exhibit 1520-2 Separated Buffered Bike Lane



PHILADELPHIA'S PSBL CASE STUDY

Overview

Two recently piloted PSBLs on Market Street and JFK Boulevard in downtown Philadelphia were selected for a local case study of PSBLs in Pennsylvania. The case study includes field observation of the facilities, perspective from City Maintenance and Operations Staff, stakeholder feedback, and before and after data evaluation. It reports on the implications that the pilot has had on vehicle speeds, bicycle volumes, maintenance, and crash data.

The Market Street and JFK Boulevard PSBLs were implemented in 2018, before the current COVID-19 pandemic. As a result, field observation and analysis may be impacted by the circumstances of the pandemic.

Market Street PSBL

Market Street is a one-way eastbound corridor at the heart of Philadelphia's Center City. The Market Street PSBL runs along the north (left) side of the corridor from 20th Street to 15th Street. The typical cross section includes a 6-foot wide bike lane, 5-foot wide buffer, 8-foot wide parking lane, three (3) 11-foot wide vehicular travel lanes, and a 10-foot wide parking lane / right-turn lane on the south side of the street. The buffer contains flexible delineator posts spaced 20 feet to 40 feet apart at mid-block and at 8 feet apart near intersections. Daylighting is marked with striping and flexible bollards at the intersections. At some locations, bollards create "bump outs" around the crosswalks. There are bicycle signals and vehicular left turn lanes at 16th Street and 18th Street to facilitate left turning traffic movements. Figure 1 and Figure 2 represent existing conditions on Market Street. Refer to Appendix B for additional photos of the Market Street PSBL.

Figure 1. Typical Section on Market Street

Figure 2. Bike Signal at Market Street and 18th Street

JFK Boulevard PSBL

JFK Boulevard runs westbound from 15th Street to 20th Street, where it begins carrying 2-way traffic over the Schuylkill River to 30th Street Station. The PSBL runs along the south (left) side of the street. The typical cross section includes a 3-foot-wide drainage grate, 6-foot wide bike lane, 9-foot wide buffer, 9-foot wide parking lane, three (3) 11-foot wide vehicular lanes, and a north side 7-foot wide parking lane. Between 15th and 16th Streets, the bike lane and buffer are narrower, each at 5 feet wide. At 17th and 19th Streets, there are turning or transition zones in which the motor vehicle and bicycle lanes are swapped to allow through bicycle movements while cars make left turns.

Between 19th and 20th Streets, the JFK facility becomes a buffered bike lane adjacent to the parking rather than a PSBL. This is likely due to limited curb to curb spaces where there are double left turn lanes at the intersection of JFK Boulevard and 20th Street. The buffered bike lane section contains a 7-foot parking lane, 6-foot painted buffer, 6-foot bike lane, and a subsequent 5-foot painted buffer next to the travel lanes.

For the PSBL sections of the corridor, the buffer typically contains delineator posts spaced 20 feet apart in mid-block locations and 5 feet apart at intersections and in conflict zones. Daylighting is marked with striping and delineator posts at the intersections. The JFK facility also has green paint near the intersections and at conflict points, including intersection crossings, driveway crossings, and at transition zones where the bike lane shifts to accommodate the vehicular left turn lane. Figure 3 and Figure 4 represent existing conditions on JFK Boulevard. Refer to Appendix B for additional photos of the JFK Boulevard PSBL.

Figure 3. Typical Section on JFK Boulevard

Figure 4. Transition Zone at JFK Boulevard and 17th Street

Field Observations

A field evaluation of the PSBLs on Market Street and JFK Boulevard in Philadelphia was done to observe the operations of the PSBL facilities. On the day of the field evaluation, traffic volumes (including bikes, cars, and pedestrians) were observed to be less than typical given the impacts of COVID-19.

One concern noted on both Market and JFK was that there appeared to be no accommodations for right turning bicycles, except for crosswalks. The facilities seemed more useful as through corridors, as is typical of many types of bicycle infrastructure such as buffered or general bike lanes. There was also limited signage throughout both facilities. There were signs for the start and end of the facilities, but there was no permanent PSBL-specific signage as seen in some other case studies.

Market Street

Overall, the Market Street PSBL appeared to be operating effectively. There were 10 to 15 bicyclists on Market Street, half in the PSBL and the other half sharing the vehicle lanes. Striping, marking, and delineator posts were in "fair" condition. Vehicles were typically parked and loaded legally. Motorcycles were observed in designated areas near the intersections. There were no obstructions noticed in the daylighting areas and no debris, garbage, nor other obstructions identified in the bike lanes. There were no observed conflicts with buses, which have stops on the south (right) side of the street. One concern that was identified along Market Street was obstructed sight distance at the driveway between 17th and 18th Streets.

Three (3) people were observed on e-scooters in the Market Street bike facility, two of which were travelling in the wrong direction; e-scooters are prohibited by law in Pennsylvania. Throughout the corridor, pedestrians were seen queueing in the crosswalk next to the buffer area (not blocking the bike lane nor in conflict with the motor vehicle lanes). Both bike signals appeared to be operating effectively. However, the signal location may

be confusing for bicyclists and motor vehicle drivers since it is not directly aligned with the bicycle lane. While most drivers and cyclists made the appropriate maneuvers, one driver was seen illegally turning left on red.

JFK Boulevard

Overall, the JFK Boulevard PSBL appeared to be operating effectively. There were 2 bicyclists observed on JFK Boulevard on the day of the field visit. While most parking and loading zones were appropriately in use, there were 2 vehicles spotted idling in the buffered bike lane. This was in the section of JFK that contains a painted buffered bike lane rather than a PSBL. There are no delineator posts in this location.

Striping, marking, delineator posts, and green paint were in "good" condition throughout the JFK corridor. The driveway located west of 17th Street on JFK Boulevard was observed to have adequate sight distance and green conflict markings. However, there was a newsstand located at the southeast corner of JFK and 18th Street that may be limiting sight distance at that intersection. Another concern identified on JFK was that the buffer was so wide between 16th and 17th Streets that pedestrians were seen standing and chatting in the buffer. Also, at the subway stations, pedestrians were observed cutting through the bike lane from the crosswalk to the sidewalk.

On JFK, where there appeared to be fewer cyclists, the intersection treatment at 17th and 19th Streets is a transition zone that swaps the left turning motor vehicle lane with the through bicycle lane. At one intersection, a truck was loading in the turning lane such that cars were forced to queue in the bike lane. At the other intersection, some drivers did not pull all the way over to the left turn lane and instead queued for the light in the bike lane. The Team witnessed two queues of left turning vehicles with no dedicated space for cyclists. Additional signage and delineator posts between the through travel lanes and the bike lane in these locations may better define the space for bicycles.

Key Findings

The Philadelphia PSBL Pilot Project successfully implemented PSBL facilities on Market Street and JFK Boulevard that operate appropriately and serve a variety of bicycle users. The facilities have been implemented mostly in line with best practices and national guidance. Vehicles are typically parking, loading, and turning in designated locations, especially where there are delineator posts. Cyclists are using the facilities, which are typically clear of debris and obstructions. The daylighting areas are creating adequate sight lines, which is necessary at driveways as well. The facilities are most useful as through facilities for cyclists; right turns can be more problematic. Increased signage may improve operations and awareness of the facilities.

Per meetings with City Operations and Maintenance Staff, there are challenges and additional considerations required to properly maintain PSBLs. Frequent replacement of flexible delineator posts in the buffer zones and daylighting areas is required after being run over and scuffed, particularly when the reflective tape is damaged. Snow, leaf, and debris removal require specialized equipment and significant testing to ensure

Before and After Data Analysis
Key Takeaways:

- **Crashes** – Small decrease in total crashes and decrease in number of fatalities. However, more crash data are needed due to uncertainties from COVID-19.
- **Vehicle Speeds** – Average decrease of **6%** in average speed across all time periods.
- **Bike Counts** – **96%** average increase in the number of bikes on the PSBL side of JFK Boulevard and Market Street.
- **Transit Vehicle Speeds** – Modest decrease in average transit vehicle speeds.

they are functional. Installing PSBLs as part of resurfacing may make the project more economical and result in longer lasting thermoplastic pavement markings. Due to limited maintenance funding and capacity, it is important to consider which streets would make strong candidates for PSBLs and their corresponding maintenance, and which ones may be less ideal.

Public stakeholder feedback indicates that the facilities are being used and are effective. Cyclists feel safer on Market Street and JFK Boulevard following PSBL installation. The bike signals are more comfortable intersection treatments for cyclists as compared to the transition zones. Maintenance of delineator posts is important to branding the facility as being official and useful.

Based on analysis before and after installation of PSBLs, the following key findings are summarized below:

- **Crashes** – Small decrease in total crashes and decrease in number of fatalities. However, more crash data are needed due to uncertainties from COVID-19.
- **Vehicle Speeds** – Decrease in average speed in all time periods. An increase in travel time during the AM peak hour and a decrease in travel time during the PM peak hour.
- **Bike Counts** – Increase in the number of bikes on the PSBL side of JFK Boulevard and Market Street, and a decrease in the number of bikes on the non-PSBL side.
- **Pedestrian Counts** – No meaningful change in pedestrian counts on JFK Boulevard. Large decrease in pedestrian counts on Market Street right after installation, but pedestrian counts increased again.
- **Transit Vehicle Speeds** – Modest decrease in average transit vehicle speeds.

More detailed analysis of before and after data on the Market Street and JFK Boulevard PSBLs can be found in Appendix B.

PA LEGISLATION ON PSBLS

Representative David M. Maloney (R) proposed House Bill 140, otherwise known as **Susan's and Emily's Law,** that would permit the installation of pedalcycles lanes (a.k.a. parking separated bike lanes) and protected pedestrian plazas on public roadways.

House Bill 140 unanimously passed the House on March 17, 2021. The significant components of HB 140 are as follows:

- Allows for pedalcycles lanes and protected pedestrian plaza on left or right side of the road.
- Requires vehicles to be parked 12" from the outside line of the buffered area of the pedalcycles lane or protected pedestrian plaza.
- Locals may enact parking regulations to provide for a special, alternative, or temporary configuration and signing.
- Allows for locals to control handicap parking.
- Outlines fines for standard and handicap parking violations.

The proposed legislation currently rests with the Senate. While the House fully supports HB 140, there are concerns within the Senate. The major issues are:

- The perceived impacts to properties such as potential loss of parking.
- Safety and convenience concerns of having to cross the bicycle lane after existing a parked vehicle.
- The additional expenses of installing and maintaining PSBL under a transportation budget that cannot meet existing demands.

- Operational concerns about not requiring bicyclists to use PSBLs when available and prohibit riding in the lanes of traffic.

HB 140 will likely have a challenge passing the Senate unless there is more specificity written into the bill that will address some of the Senators' concerns listed above.

STUDY RECOMMENDATIONS

Based on research of national guidelines, peer states, and Philadelphia's pilot PSBLs, the Study recommends the following:

Pilot Project Expansion

It is recommended that the Philadelphia PSBL Pilot be expanded to other communities. A challenge or solution relevant to Philadelphia's urban context may be not applicable or not appropriate elsewhere in the state. As such, in the absence of legislation change, it may be worthwhile to pilot projects in other municipalities. PennDOT could also consider allowing pilot PSBLs on state roads in an effort to collect additional data. This will allow for the further documentation of challenges and experimentation of best practices. The following recommendations are made concerning an expanded pilot:

1. Incorporate, test, and evaluate best practices document in the Study.
2. Collect consistent and thorough before and after data
3. Share data with other agencies to aid in the development of a PSBL CMF
4. Monitor maintenance challenges and solutions in different community contexts
5. Require local municipalities to create a budgetary and maintenance plan for PSBLs
6. Evaluate temporary and permanent vertical separation methods
7. Monitor micro mobility ridership in PSBLs and corresponding challenges and solutions
8. Model pilot similar to FHWA's Request to Experiment Process

City of Philadelphia Recommendations

The City of Philadelphia has successfully implemented pilot PSBLs on Market Street and JFK Boulevard.. The City also has 3 recently constructed pilot PSBLs, another in construction, and others in 60% or final design phases. As the City continues to roll out these facilities, the following recommendations are made to further improve, operate, and monitor these pilot PSBLs:

1. Continue to collect data and monitor operations on the pilot PSBLs. Update before and after data evaluations as new data are collected.
2. Share collected data with outside agencies and organizations to help with the development of CMFs for PSBLs.
3. Monitor and review on-going and future studies and reports regarding CMFs for PSBLs.
4. Continue to monitor challenges and solutions regarding maintenance.
5. Measure impacts and opportunities if a more permanent vertical element is installed.
6. Test and evaluate other vertical elements such as "concrete pills" or other types of vertical separation mentioned herein.
7. Consider incorporating more permanent signage on pilot PSBLs.
8. Consider green paint in conflict zones on Market Street.
9. Expand daylighting at the driveway on Market Street.
10. Consider installing flexible delineator posts in transition zones on the JFK facility (bike signal may be a future improvement if capital funding is available).
11. Remove obstructions from sight triangles on JFK Boulevard and consider furnishings such as planters, street trees, benches, trash cans, etc. along the sidewalk to discourage pedestrians from cutting through the bike lane at intersections.

PennDOT Design Manual Recommendations

Based on the information compiled and evaluated herein, it is recommended that PSBLs be included as a type of "Physically Separated Bicycle Lane" in the PennDOT Design Manual Part 2 (DM-2): Contextual Roadway Design (April 2021). The Design Manual discusses how physically separated bike lanes (one of four types of on-road bicycle facilities) are considered "the most desirable and safest of all on-road bicycle facilities." In alignment with the information already provided in Section 14.3.4, PSBLs separate bicycle travel from the other modes, which improves safety for all users. PSBLs reduce conflicts between motor vehicles and cyclists at mid-block, where cyclist crashes typically result in more severe and fatal injuries. Besides increased protection and accessibility for bicyclists, PSBLs also maintain the parking capacity that is typically valued by communities in PA.

Much of the existing guidance in the manual regarding physically separated bicycle lanes is applicable to PSBLs. Typically, the existing guidance in the manual meets or exceeds the best practices mentioned herein. The Design Manual already provides guidance on daylighting, markings, and signage that are applicable to PSBLs. It also details considerations for accessibility, sight distance, access management, and intersection treatments.

Recommendations for modifying the existing guidance and incorporating more PSBL-specific information include the following:

1. If there is a desire to provide contextual guidance regarding roadways on which PSBLs would be most appropriate, the following criteria could be incorporated. These criteria are not meant to be exclusive nor prevent PSBLs from being implemented on other street types, but rather to offer guidance based on case studies and best practices:
    a. Based on FHWA guidance, PSBLs may be appropriate on streets with operating speeds above 30 MPH or vehicle volumes greater than 6,000 vehicles per day.
    b. In addition to speed and volumes, other factors to consider if a PSBL is appropriate include number of lanes, curbside conflicts, number of driveways, share of large vehicles, vulnerable populations, low-stress network connectivity gaps, and unusual peak hour volumes.
    c. PSBLs are typically appropriate on urban roads with existing/future parking demand.
    d. Installation may be most recommended on frequently resurfaced streets and/or those with frequent maintenance
2. Include PSBLs as an option in Exhibit 14.2.1 Range of Bicycle Facilities Applicable to Various Roadway Environments in DM-2. PSBLs should be included with the protected bicycle lane and buffered bicycle lane in the arterial/highway bikeway continuum (with curb and gutter) and the collector bikeway continuum.
3. Include PSBLs as an option in Exhibit 14.2.2 Urban and Suburban Facility Selection Matrix in DM-2. PSBLs should be included with Separated Bike Lanes.
4. Include "Parked Vehicles" as a form of separation for Physically Separated Bike Lanes in Section 14.3.4.
5. The minimum bike lane width (not including buffer) for a one-way PSBL should be at least 5 feet wide, with 7 feet preferred to allow passing.
6. The minimum buffer width should be at least 2 feet, with 3 feet or more preferred, as already specified in Section 14.3.4.b.
7. A vertical separation element should be included in the buffer to add more protection and prevent drivers from parking in the bike lane. Flexible delineator posts are a recommended short-term option due to their low cost and adaptability. Other forms of separation, including raised curbs and planters may also be used for vertical separation. Guidance should inform designers of the costs and benefits of each type of separation.

8. ADA and other curbside access is an important consideration in the design process. Designers should follow guidance in Chapter 5 of the MassDOT Separated Bike Lane Planning and Design Guide to accommodate ADA and other curbside needs.
9. Intersection treatments should prioritize minimizing cyclists exposure to conflicts from turning vehicles, provide adequate sight distance, and communicate right-of-way priority.
10. Include guidance regarding maintenance of PSBLs – guidance for keeping lanes free of snow and debris, purchasing specialized equipment, and coordinating with appropriate stakeholders
11. Provide guidance on micro mobility and the extent to which motorized vehicles should be allowed in separated bicycle infrastructure.

CONCLUSION

Parking separated bike lanes serve as a means of dedicating street space and network connectivity to bicyclists of all ages and abilities. With adequate intersection treatments, they improve the safety of a corridor for all users. As municipalities identify maintenance and operational challenges, solutions continue to be developed such that these facilities can adequately serve the communities that need them. PSBLs are a necessary on-street bicycle alternative and thus, they should be available in the City of Philadelphia and within the state of Pennsylvania.

Appendix A:
Literature and Peer State Review
Summary Report

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P 267.551.3447

MEMORANDUM

June 18, 2021 Project #: 21093.005

To: Richard Montanez, P.E.
Deputy Commissioner of Transportation
Department of Streets

CC: Kelley Yemen, AICP

From: Laura Ahramjian, AICP

RE: Appendix A: Literature and Peer State Review Summary Report

INTRODUCTION

The purpose of the Philadelphia Parking Separated Bicycle Lanes Study is to understand and document the safety benefits, operational effectiveness, and impacts on usage of parking separated bike lanes (PSBLs). The following literature and peer state review collects guidance and best practices for PSBL facilities at the municipal, state, and national level. This review includes survey results from five (5) peer states regarding their guidelines, laws, and lessons learned. The policies and design requirements for each of those states have been reviewed in in detail and are summarized herein. The literature review involves national design guidelines and best practices as determined by national research. The review covers methods for maintenance, service, and operation offered by municipal organizations and includes case studies of PSBLs in cities around the country. This summary may assist in establishing new guidelines and standard practices for the design and implementation of PSBLs in Philadelphia and across the state of Pennsylvania.

PEER STATE REVIEW

Peer State Selection Methodology

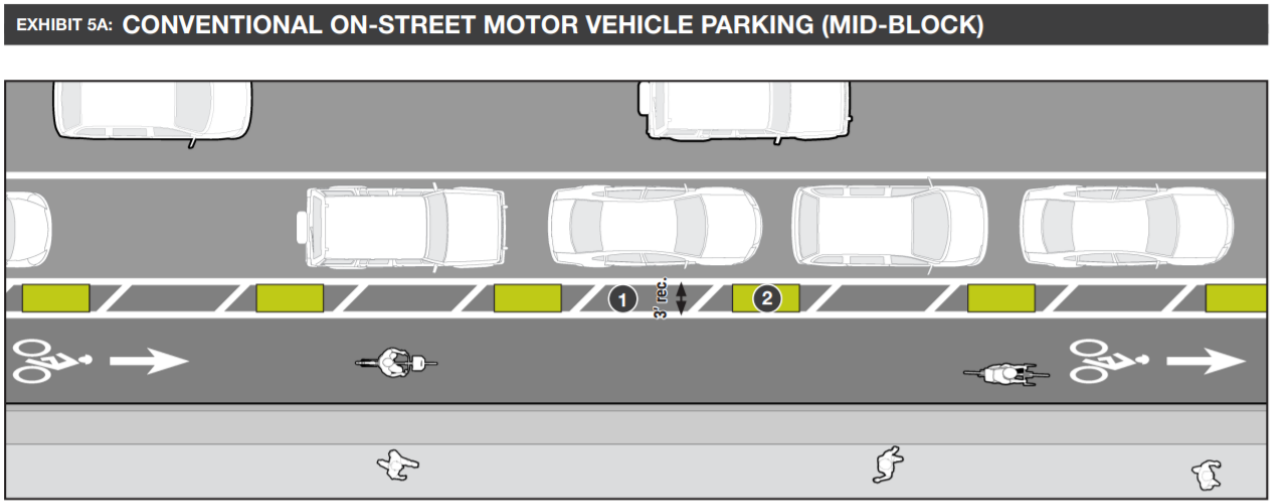
Five peer states were selected to review department of transportation policies and guidelines related to PSBLs. To select the appropriate peer states, an online survey was sent to AASHTO Committee on Traffic Engineering (CTE) members to determine if their state allows PSBLs and if so, whether their state provides any guidance on planning and designing PSBLs. A total of 13 survey responses were received. Of those 13, only one state does not allow PSBLs, Arkansas. Most of the states that allow PSBLs also allow them on their state roads. However, only a few states had state specific guidelines related to PSBLs. In addition to the survey, Kittelson also reviewed peer states PennDOT previously evaluated in the PA Active Transportation Plan, including Massachusetts, Virginia, Washington, and Oregon. The survey results and the Active Transportation Plan peer states were discussed with City staff, and emphasis was placed on states with recently published bicycle design guidance. Five states were selected as peer states for this effort, Massachusetts, Virginia, Minnesota, Florida, and Washington. Below is a brief summary of each state's policies and guidelines for PSBLs.

Massachusetts

The Massachusetts Department of Transportation (MassDOT) allows PSBLs in Massachusetts and on state roads. However, with few exceptions, parking is prohibited on state highways in Massachusetts. In 2015, MassDOT publish the MassDOT Separated Bike Lane Planning & Design Guide. This document serves as a resource for considering, evaluating, and design separated bike lanes. The document covers planning, general design considerations, intersection design, curbside activity design, signals, and maintenance.

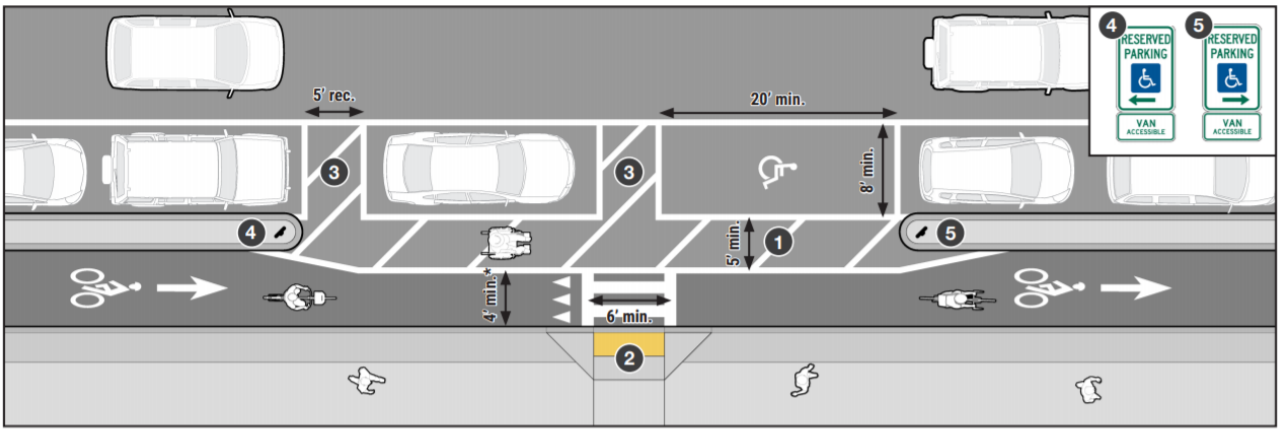
Separated bike lanes are recommended on streets with vehicle operating speeds greater than 25 miles per hour and vehicle volumes greater than 6,000 vehicles per day. Other important considerations when determining if a separated bike lane is recommended are number of lanes, curbside conflicts, number of large vehicles, vulnerable populations, low-stress network connectivity gaps, and unusual peak hour volumes.

While the MassDOT guide is general for all separated bike lanes, there is guidance on PSBLs. The guide notes that on-street motor vehicle parking increases the comfort of people bicycling in the separated bike lane by providing physical separation between the bike lane and vehicle travel lane. A 3-foot. (2-foot. minimum) buffer is recommended when on-street parking is adjacent to the bike lane to avoid conflicts with motor vehicle doors. Vertical objects in the buffer zone, such as flexible delineator posts, should be provided to prohibit vehicles parking in the bike lane. Vertical objects can also help in commercial areas where on-street parking turnover is high, or locations where parking demand is low. The guide notes the importance of prohibiting parking close to the intersection to ensure enough sight distance for safe intersection movements..



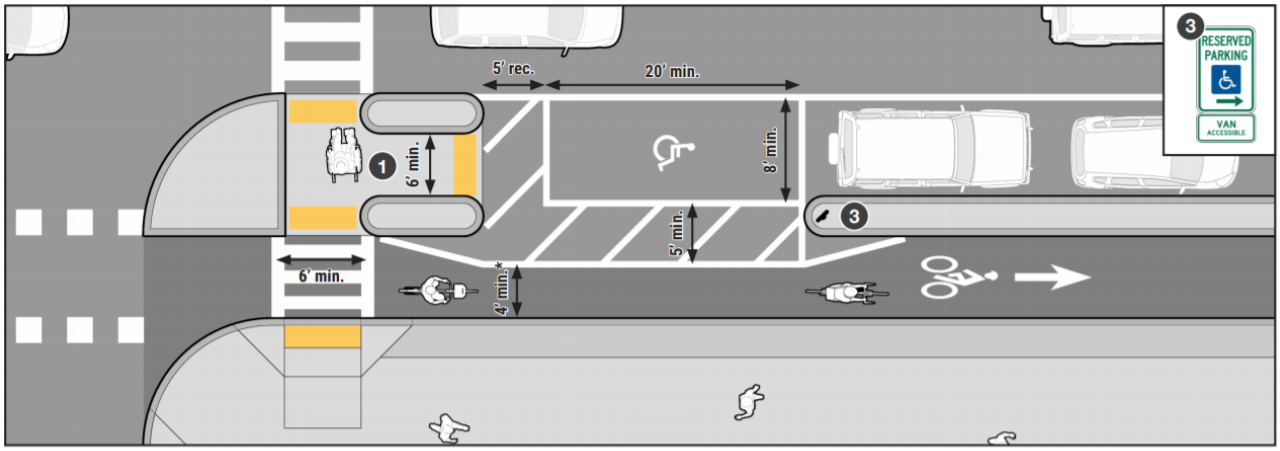
The guide includes sections on how PSBLs can be designed to accommodate ADA accessible parking spaces. To accommodate accessible parking, the bike lane may be narrowed to 4-feet. with a design exception. A 5-feet. minimum street level access aisle is required to access the sidewalk from the ADA parking space(s). Rear access aisles are recommended for driver-side access to the sidewalk. At all locations where pedestrians are expected to cross the bike lane, it is important to communicate to bicyclists they may need to yield to pedestrians.

EXHIBIT 5B: ACCESSIBLE ON-STREET MOTOR VEHICLE PARKING (MID-BLOCK)



* A bike lane width narrower than 5 ft. requires a design exception.

EXHIBIT 5C: ACCESSIBLE ON-STREET MOTOR VEHICLE PARKING (INTERSECTION)



* A bike lane width narrower than 5 ft. requires a design exception.

At intersections, there are four guiding design principles that apply to separated bike lanes, including PSBLs:

- Minimize exposure to conflicts
- Reduce speeds at conflict points
- Communicate right-of-way priority
- Provide adequate sight distance.

Bike signals are recommended at all traffic control signals with a separated bike lane in order to provide a uniform experience for bicyclists. A mixture of different types of bicycle traffic controls may result in lower compliance with the bike signals.

Virginia

The Virginia Department of Transportation (VDOT) allows PSBLs and is open to considering PSBLs on state roads. However, currently there are no PSBLs on VDOT maintained roads. VDOT does not have any specific guidelines

or studies on PSBLs. The VDOT Road Design Manual recommends users to refer to the Federal Highway Administration's (FHWA) Separated Bike Lane Planning and Design Guideline. VDOT also recommends users reference the National Association of City Transportation Officials' (NACTO) Urban Bikeway Design Guide for additional information. A summary of the FHWA and NACTO guidebooks is provided in the literature review section of this report.

Information on VDOT's bicycle and pedestrian facility guidelines can be found in Appendix A(1) – VDOT Complete Streets: Bicycle and Pedestrian Facility Guidelines, Bus Stop Design and Parking Guidelines, of the VDOT Road Design Manual. Within the appendix, there is a short section on separated bike lanes. According to VDOT, designers can choose from a variety of options to provide the vertical separation between the bike lane and the travel lane. These options include, but are not limited to, on-street parking, raised curbs or medians, bollards, or landscaping. VDOT refers users to FHWA and NACTO for further design guidance.

Minnesota

The Minnesota Department of Transportation (MnDOT) allows PSBLs in the state and on state roadways. In 2020, MnDOT published their bicycle design manual. The 2020 Minnesota Bicycle Facility Design Manual provides information to planners and designers to plan and design context-appropriate bicycle facilities within MnDOT right-of-way.

As stated in the manual, MnDOT has adopted FHWA's Separated Bike Lane Planning and Design Guide as its guidance for separated bike lanes. However, MnDOT provides additional guidance for PSBLs as it relates to ADA accessibility. These additional guidelines are listed below:

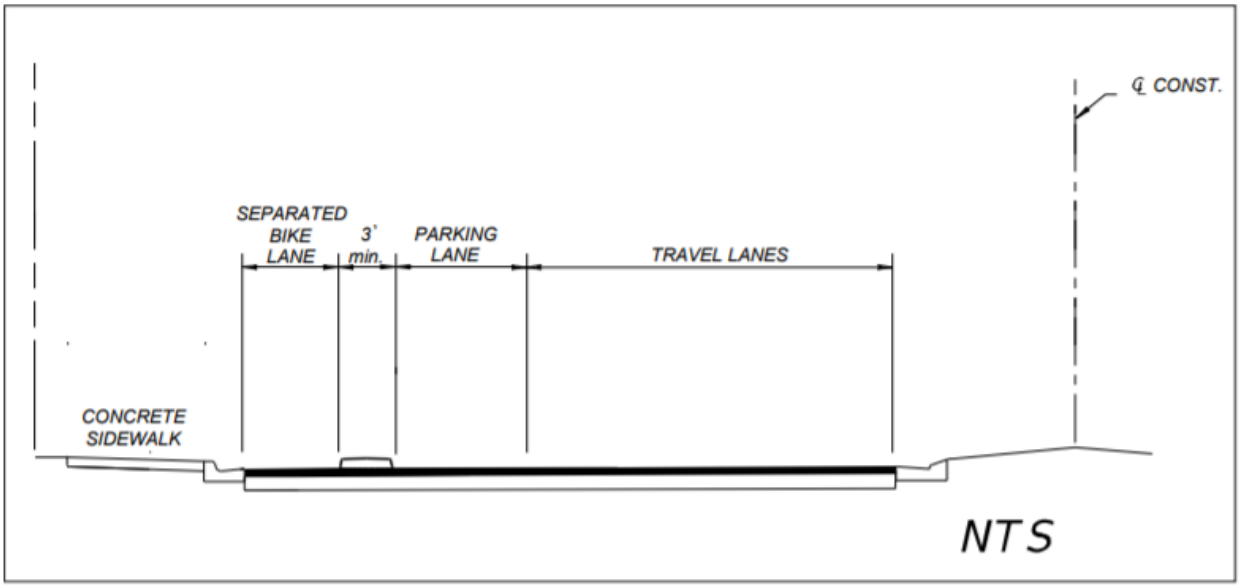
- A separated bicycle facility between the parking lane and the curb can be considered a barrier to accessibility. Due accessibility concerns, PSBLs are discouraged on trunk highways. If used, they should comply with the guidelines listed below.
- Include designated ADA parking spaces that meet 2010 ADA standards. The location of the accessible parking spaces should consider directness of access to services and key destinations on the street.
- Include designate ADA vehicle ramp lift spaces.
- Include an 8-foot. access aisle from the accessible parking spaces to the sidewalk, including any curb ramps.
- If the bike lane serves as the accessible route to access the sidewalk, the bike lane should have a cross slope of 2% or less.
- Additional considerations needed in areas with para-transit and dial-a-ride operations that need pick-up and drop-off locations near building entrances.

Florida

The Florida Department of Transportation (FDOT) allows PSBLs in the state and on state roadways. Guidance on bicycle facility design is part of the FDOT Design Manual, Chapter 223.

FDOT refers users to FHWA's Separated Bike Lane Planning and Design Guide for more detailed design guidance on PSBLs. However, FDOT does provide some additional guidance. FDOT recommends using on-street parking as a form of separation on roads with speeds of 35 miles per hour or less. A 3-foot. minimum width raised island separation is required when the bike lane is adjacent to on-street parking.

Figure 223.2.2 On-Street Parking Minimal Separation



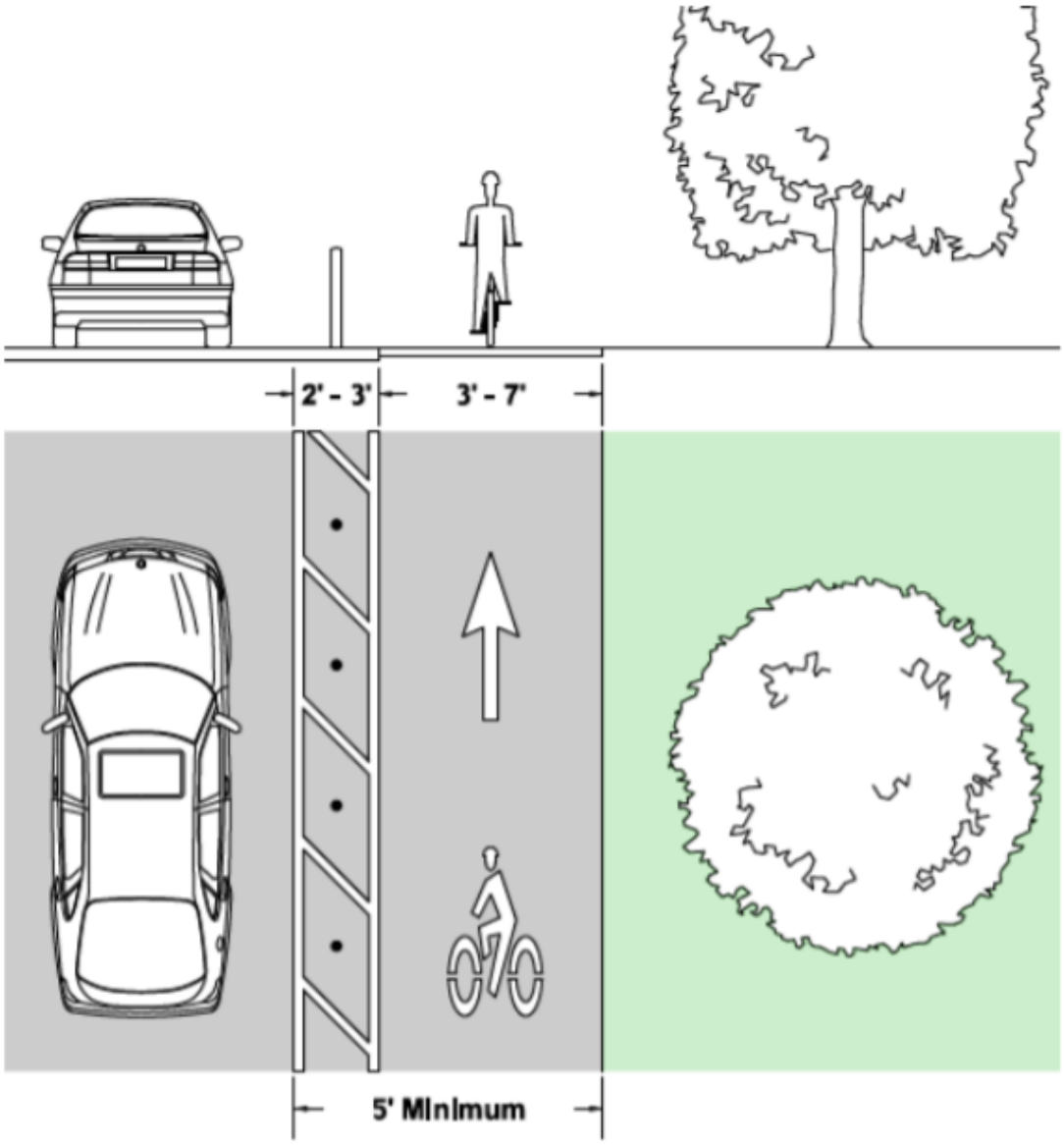
Washington

The Washington State Department of Transportation (WSDOT) allows PSBLs in the state and on state roadways. Guidance on separated bicycle facilities is included in the WSDOT Design Manual, Chapter 1520: Roadway Bicycle Facilities.

Section 1520.02(2) provides specific guidance related to separated bike lanes. Guidance relevant to PSBLs is summarized below:

- If parked vehicles are serving as the vertical separation, then the parking zone cannot encroach onto the buffer area.
- Painted buffer strips with flexible tubular marks help differentiate between the parking lane and the bike lane.
- A 3-foot wide buffer should be used whenever possible.
- With a buffer, the bike lane itself my be 3-feet. in width. However, 5-feet is recommended for the bike lane to enable passing between bicyclists and to account for the effective width needs for bicyclists to avoid drainage features.

Exhibit 1520-2 Separated Buffered Bike Lane



LITERATURE AND BEST PRACTICE REVIEW

Best Practice Selection Methodology

A variety of sources have been selected to review and evaluate safety, operations, and design guidance regarding PSBLs. Sources include national design guides and research as well as lessons learned from local municipalities. Some sources are focused specifically on PSBL facilities while others discuss general bicycle facilities (separated or not). Much of this information may still be applicable given that one form of physical separation is parked vehicles. Some of the sources herein were provided to Kittelson by the City of Philadelphia. Other sources were selected based on industry knowledge and a preliminary review of recent research.

The sources have been summarized based on major considerations that are important to the City of Philadelphia and the Pennsylvania Department of Transportation (PennDOT), including national design guidelines, intersection design, corner clearance and sight lines, vertical treatments, transit service, emergency vehicle accessibility, snow removal, street cleaning, maintenance, drainage, and safety. A few case studies have been selected and reviewed as examples of PSBLs that have been piloted and evaluated with results that are helpful to establishing criteria in Pennsylvania.

Summary of Sources

Source: NACTO One-Way Protected Cycle Tracks
Author: National Association of City Transportation Officials (NACTO)

Summary: This source is part of the NACTO Urban Bikeway Design Guide. It is not specific to PSBLs and discusses several methods of physical separation between motor vehicles and bicyclists, including parking. The source includes benefits, applications, design guidance, ADA consideration, and maintenance of facilities. It references 17 additional sources regarding separated bicycle facilities, many from other countries.

Source: NACTO Transit Street Design Guide Shared Cycle Track Stop
Author: National Association of City Transportation Officials (NACTO)

Summary: The Shared Cycle Track Stop section is part of the larger NACTO Transit Street Design Guide. It offers guidance on the overlap between separated bike lanes and transit infrastructure, including in constrained corridors. This source discusses application, context, benefits, and considerations. It outlines critical and recommended design guidelines.

Source: NACTO Case Studies: Downsized Street Maintenance Vehicles
Author: National Association of City Transportation Officials (NACTO)

Summary: This resource summarizes case studies of downsized street maintenance equipment in Boston, Salt Lake City, Cambridge, MA, and Chicago. This report is an addendum to the 2018 resource: "Optimizing Large Vehicles for Urban Environments." The source outlines how cities have developed solutions for selecting, retrofitting, and implementing maintenance equipment to address snow, leaves, and other debris in separated bike facilities. It offers product examples and lesson learned, including the importance of collaboration with maintenance staff.

Source: FHWA Separated Bike Lane Planning and Design Guide
Author: Federal Highway Administration (FHWA)

Summary: This resource from 2015 discusses multiple types of separated bike lanes, including PSBLs. It covers definitions and planning and design recommendations, including concepts like implementation, safety, users, context, funding, and maintenance. This resource offers a menu of recommendations for designing separated bike lanes.

Source: FHWA On-Street Motor Vehicle Parking and the Bikeway Selection Process
Author: Federal Highway Administration (FHWA)

Summary: This 2021 report discuss on-street parking and the bikeway selection process. It is a supplementary resource to the FHWA Bikeway Selection Guide. The report outlines on-street parking and bikeway facility types. It provides dimensional considerations, trade-off analysis, preferred alternatives, and strategies for facility selection. The report is not specific to PSBLs in its entirety but includes discussion of PSBLs.

Source: FHWA Small Town and Rural Design Guide on Physically Separated Bike Lanes
Author: Federal Highway Administration (FHWA)

Summary: This resource offers benefits, considerations, and design guidance for separated bike facilities in a more rural context. It comments on geometric design preferences, signage, markings, and intersection design. It also includes case studies and selected examples. This resource is focused more generally on different types of separation, including parking, and it cites several sources.

Source: NTSB Bicyclist Safety on US Roadways: Crash Risks and Countermeasures
Author: National Transportation Safety Board (NTSB)

Summary: This 2019 report analyzes bicyclist safety issues and corresponding improvements. The report focuses on improving roadway infrastructure, enhancing visibility, and mitigating head injuries, which are the deadliest of bicycle injuries in the US. The report discusses the benefits of separated bike lanes, and states that on-street parking can be used as a form of separation. It outlines findings, recommendations, and references.

Source: NCHRP Research Report 926: Guidance to Improve Pedestrian and Bicyclist Safety at Intersections
Author: National Cooperative Highway Research Program (NCHRP)

Summary: This 2020 NCHRP report outlines a process for designing intersections that are safe and operational for pedestrians and cyclists. It offers guidelines for selecting counter measures at intersections. This resource is not specific to PSBLs nor to separated bike lanes.

Source: NCHRP Report 500: A Guide for Reducing Collisions Involving Bicycles

Author: National Cooperative Highway Research Program (NCHRP)

Summary: This 2008 NCHRP Report outlines affordable, implementable countermeasures for reducing bicycle crashes. It provides application guidance for reducing injuries and fatalities on the highway system. Strategies are offered to reduce crashes at intersections, along roadways, and at mid-block crossings. The report also discusses reducing motor vehicle speeds, increasing safety awareness, and bicycle safety equipment. This resource is not specific to PSBLs nor to any type of bicycle facility, but it provides a depth of information on strategies for improving infrastructure to reduce bicycle crashes.

Source: Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S.

Author: Portland State University Transportation Research and Education Center

Summary: This 2014 report evaluates separated bicycle facilities across 5 states, with the intention to evaluate locations with different climates, populations, and other contextual factors. Three (3) of the studied sites, Dearborn Street and N Milwaukee Ave in Chicago, Illinois and NE Multnomah Street in Portland, Oregon, contain PSBLs. The report offers findings such as changes in ridership, intersection effectiveness, use of traffic signals, buffer design, and safety.

Source: San Francisco MTA Safe Streets Evaluation 2019 Report

Author: San Francisco Municipal Transportation Agency (SFMTA)

Summary: This 2019 year-end report evaluates San Francisco's Vision Zero Safe Streets Program. The resource is not specific to PSBLs, but it does cover PSBL pilot project results. The SFMTA installed separated bike lanes on Valencia Street, Polk Street, 2nd Street, Masonic Avenue, 7th Street, and other corridors. They used quick build methodology to get infrastructure on the ground quickly and determined that the new separated bike lanes result in steady increases in the number of bicycle commutes.

Source: District Department of Transportation Bicycle Facility Evaluation

Author: District Department of Transportation (DDOT)

Summary: This 2012 report evaluates three bicycle improvements in the District, including the 15th Street NW two-way cycle track, which is parking separated. It studies facility use, operations, convenience, comfort, and safety.

Source: 15th Street Separated Bike Lane Pilot Project: Interim Results and Next Steps

Author: District Department of Transportation (DDOT)

Summary: This case study was also referenced in the District Department of Transportation Bicycle Facility Evaluation referenced above. The goals of the 15th Street PSBL Pilot were to calm traffic speeds, provide more options for cyclists, increase cycling trips along the corridor, and serve as an example for future design and implementation. This pilot took place in 2010.

The PSBL facility serves 2-way bicycle traffic with an 8-foot wide lane and a 3-foot wide buffer. The buffer includes flexible delineator posts. After installation, there was a 205% - 272% increase in bicycle volumes and steady motor vehicle counts along the corridor. The study noted fewer cyclists on the sidewalk. While bicycle LOS increased, segment LOS for motor vehicles stayed about the same and there were minor changes in motor vehicle speed. Public surveys showed that 80% of residents see the cycle track as an asset to the neighborhood. The study made recommendations for future facilities, including incorporating bike signals, using green paint at conflict areas, adding bike boxes, and construction pedestrian refuges to reduce conflicts between bicyclists and pedestrians.

Source: NYC Columbus Ave Parking Protected Bicycle Path Preliminary Assessment

Author: New York City Department of Transportation (NYC DOT)

Summary: Piloted in 2011, this case study involves a PSBL on Columbus Avenue, pedestrian safety islands, reduced crossing distances, mixing zones, left-turn lanes, and loading zones. The project increased loading zone areas by 475% and reduced double parking rates as a result. Crashes decreased by 34%, with lower vehicle speeds and fewer cyclists on the sidewalk. There were steady motor vehicle counts and a 56% increase in bicycle volumes.

Source: Telegraph Avenue Progress Report – Oakland, CA

Author: Oakland Department of Transportation

Summary: This 2017 case study involves 8 new high-visibility crosswalks and 9 blocks of new PSBLs on Telegraph Avenue. The project, which is along a high injury corridor in Oakland, involved repurposing one (1) vehicle lane in each direction to provide PSBLs. The results included reduced crash rates, improved perceived safety, more people walking and biking along the corridor, and reduced vehicle speeds. The City also measured a 9% increase in retail sales along the corridor following installation of the PSBLs. They used beige paint in the daylighting areas, which resulted in instances where illegal parking was taking place and blocking sight distance. The report recommends more visual and physical enforcement of parking (i.e., vertical separators and more signage), replacing the beige paint, and improving communication with the community.

Source: North Bassett Street Parking Protected Bike Lane Pilot - Madison, WI

Author: City of Madison Department of Traffic Engineering

Summary: This 2020 pilot evaluation primarily focuses on community feedback on the North Bassett Street Parking Protected Bike Lane Pilot. Throughout the pilot, the City partook in an educational campaign in the form of letters, emails, webpages, press releases, and media coverage. After implementation of the PSBL, there was no increase in crash severity for people walking, biking, nor driving. The City documented a 30% increase in bicycle volumes (although this may be due in part to the Pandemic). They received mostly positive feedback from public surveys and from the cyclist community. People biking indicated that they felt safer on the corridor, especially with children in tow. Concerned feedback was received regarding visibility of bicyclists, garbage can placement, and blocked driveways. The evaluation recommends involving ADA related stakeholders in the conceptual and final design process, installing signage and markings around driveways for parking enforcement, and including bike lane symbols and green paint to better identify the facility as a bike lane.

Source: Cycling at a Crossroads – The Design Future of New York City Intersections

Author: New York City Department of Transportation (NYC DOT)

Summary: This 2018 study examines new and traditional design treatments at intersections with PSBLs. It evaluates safety and provides recommendations on design and use. The study found that mixing zones and fully split phase intersections have substantial bicycle crash rate reductions as part of protected bike lane projects. Key findings suggest that mixing zones are best at small intersections. However, bicyclists report not

feeling as comfortable in the mixing zone as compared to a fully split phase intersection. While the fully split phase intersection provides more bicyclist comfort, long delays for the bicyclists can encourage risky behavior such as red-light running.

Summary Findings

Safety

Many of the reviewed sources discuss how PSBLs may impact the safety of a corridor for all users. Typically, the installation of PSBLs have reduced crash rates for motor vehicle drivers, bicyclists, and pedestrians, especially at mid-block locations. PSBLs lower vehicle speeds, reduce interaction between vehicles and cyclists mid-block, and eliminate the risk of side swiping. Dedicated intersection infrastructure is key to safety in intersections along corridors with PSBLs. Many of the reviewed case studies founds that PSBLs increase perceived safety and comfort for cyclists and national guidance suggests that these facilities may better serve more ages and abilities.

The NACTO One-Way Protected Cycle Tracks resource says that one-way protected cycle tracks "dedicate and protect space for bicyclists in order to improve perceived comfort and safety" and that they "eliminate risk and fear of collisions with over-taking vehicles." This resource also highlights how a PSBL reduces dooring as compared to a more typical bike lane and eliminates the risks of a cyclist falling into moving vehicle traffic during a dooring incident. NACTO indicates that PSBLs may be appropriate where high speed, high volume vehicle lanes would create stress for cyclists on a more typical bike lane.

The FHWA Separated Bike Lane Planning and Design Guide includes a study of separated bicycle facilities, which found a decrease in overall crashes, but an increase in bicycle crashes following implementation. However, the study found that when accounting for increased cyclist volumes, per capita bicycle crash rates decreased for most of the studied facilities. The study found that following separated bike lane installation, most crashes occurred at intersections rather than mid-block. This resource along with other sources mentions that ongoing study of these facilities is needed to continue to evaluate crash data. This source says: "In conjunction with a Complete Streets planning approach, separated bike lanes can be a tool for improving safety outcomes for all street users, including cyclists."

The FHWA On-Street Motor Vehicle Parking and The Bikeway Selection Process Report notes that parking separated bike lanes may accommodate more ages and abilities due to the separation between motor vehicles and bicyclists. The parking separation allows for intersection treatments that increase the visibility of bicyclists. The Report notes, "with sufficient width in buffer, dooring can be eliminated." It warns that pedestrians looking to access a parked vehicle are required to cross the bike lane, which may introduce a conflict. Drivers may also have difficulty noticing bicyclists when turning at intersections, which may increase the potential for right-hook crashes. This can be mitigated through intersection treatments.

The NTSB Bicyclist Safety on US Roadways: Crash Risks and Countermeasures Report indicates that where there are no separated bike facilities, there are typically more bicycle crashes at intersections and higher crash severity at mid-block locations where the vehicle speeds are higher. The Report comments that these mid-block crashes are more likely to result in fatal or serious injuries for the bicyclist. The Report concludes: "Separated bike lanes could prevent bicycle crashes involving motor vehicles at midblock locations and, thereby, also reduce the number of fatalities and serious injuries associated with such crashes." Reducing motor vehicle speeds and increasing visibility of the bicyclist are both key to reducing crash rates and severity. This NTSB Report suggests that separated bike lane facilities should be included as a treatment on FHWA's list of Proven Safety Countermeasures.

The Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S. includes findings on both perceived and observed safety on three studied PSBLs. With the new PSBLs in place, 60%-80% of cyclists felt that safety had increased significantly. There were no collisions nor near collisions observed on these streets during the evaluation.

The San Francisco MTA Safe Streets Evaluation 2019 Report found that San Francisco's new separated bike lanes "reduce(d) or eliminate(d) mid-block dooring conflicts." By installing separated bike signals, the MTA noticed "dramatic decreases in intersection conflicts, specifically right-hook conflicts." There was a 99% decrease in interactions between motorists and bicyclists at mid-block locations and no dooring instances after installation of the PSBL on Valencia Street. The bike signal at Valencia and Duboce (upgraded from a mixing zone) reduced close calls by 29%.

The NYC Columbus Ave Parking Protected Bicycle Path Preliminary Assessment documented a 34% decrease in crashes following PSBL installation. Along with other reviewed case studies, this assessment noted that the new bicycle facility decreases the number of cyclists biking on the sidewalk, improving safety and comfort for pedestrians.

The Telegraph Avenue Progress Report – Oakland, CA documented a 40% reduction in overall crashes along the corridor with the new PSBL. The evaluation noted no reported crosswalk crashes (for the first time in 5 years). Southbound motor vehicle speeding decreased by 45% and northbound speeding decreased by 27%. Median speeds are equivalent to the speed limit after implementation of the PSBLs. The report also mentions that 79% of bicyclists and 63% of pedestrians feel safer on the street after the redesign.

As documented in the North Bassett Street Parking Protected Bike Lane Pilot - Madison, WI, the City of Madison received this feedback following installation of the PSBL: "it was pleasant and felt quite safe. We felt comfortable enough to have a 10- and 12-year-old use them." The report also documents this cyclist's feedback: "Please more of these! As a year-round cyclist, it is so much safer for me and my daughter to ride to daycare with these in place." The City did receive some concerned feedback related to restricted sight distance and concern that cyclists and motor vehicle drivers cannot see each other.

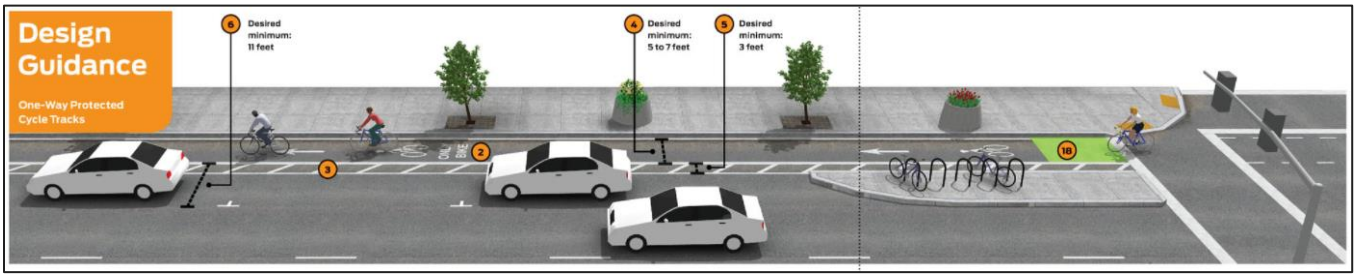
National Design Guidelines

There are no national requirements related to the width of a PSBL. NACTO and FHWA offer recommended minimum widths for the bike lane, buffer, and parking lane. These sources also make suggestions for signage and markings.

The NACTO One-Way Protected Cycle Tracks resource includes required, recommended, and optional design guidance for separated bike lanes, including PSBLs. Per this NACTO reference, bike lane markings are required under MUTCD standards at the beginning and periodically along PSBLs. Solid white lane markings shall be used to delineate between the parking lane and the bike lane.

NACTO recommends a minimum bike lane width of 5-feet. A 7-foot width should be provided where there are high bicycle volumes and / or uphill sections to allow for passing. The bike lane width should be proportionally larger in locations where the gutter seam extends more than 1-foot from the curb. A 3-foot buffer is desired to avoid dooring and to provide room for loading. The desired parking lane width is 8-feet, such that the parking lane plus buffer is equal to 11-feet.

NACTO offers optional guidelines such as the use of "Bike Lane" or "No Cars" signage. Specialized markings can be offered such as "BIKE ONLY" and colored pavement can be used to better identify the facility.



The FHWA Separated Bike Lane Planning and Design Guide speaks to directional and width characteristics. It specifies a minimum 5-foot bike lane and a 7-foot bike lane where frequent passing is expected. A minimum 3-foot buffer should be provided. FHWA lists similar design guidelines to those of NACTO such as not including the gutter pan in the useable bike lane width and providing periodic bike lane markings. The FHWA guide states that "signs and pavement markings supplement good design and reinforce appropriate behavior for all roadway users." It offers signage and marking options on Pages 127 through 130.

The FHWA On-Street Motor Vehicle Parking and the Bikeway Selection Process resource suggests that a PSBL may be a preferred facility because it provides separation between moving motor vehicle traffic and bicyclists. This source suggests dimensional guidelines based on peak hour directional bicyclist volume. For separated bike lanes, it recommends a 6-foot to 8-foot width bike lane where bicycle volumes are less than 150 per day, an 8-foot to 9.5-foot bike lane where bicycle volumes are between 150 and 750 per day, and a greater than 9.5-foot wide bike lane where bicyclist volumes exceed 750 per day. It offers an absolute minimum bike lane width of 4-feet under constrained conditions. A 2-way separated bike lane should be at least 9.5-feet to 11.5-feet wide for less than 150 bicyclists per day, 11.5-feet to 15.5-feet wide for 150 to 350 bicyclists per day, and more than 15.5-feet wide for more than 350 bicyclists per day. The minimum width for a 2-way separated bike facility should be 8-feet where there are constraints.

The Small Town and Rural Design Guide on Physically Separated Bike Lanes indicates that separated bike lanes are appropriate on streets with high volumes and moderate to high vehicle speeds. They can serve as primary connections on major roads and be used in locations with moderate to high volume of bicyclists and pedestrians. Like other sources, the Rural Design Guide recommends a 5-foot to 7-foot wide bike lane and a 3-foot buffer.

Accessibility

Several of the reviewed sources provide design guidance on maintaining ADA accessible parking in conjunction with PSPBIs. Sources also emphasize the importance of engaging with ADA stakeholders during the design and installation of PSBLs. NACTO and FHWA offer guidelines on integrating PSBLs with ADA parking. The sources also discuss education and outreach with the community given that PSBLs may introduce street elements that are otherwise unfamiliar to users.

The NACTO One-Way Protected Cycle Tracks resource states that mid-block curb ramps may be provided near marked accessible parking spaces or at a consistent interval along the cycle track to provide additional egress points for wheelchair users. These ramps may also serve as accommodation for curbside freight delivery. Roadway cross-slopes should be considered for accessibility. A greater than 2% cross slope may create difficulty for bicyclists and some disabled users. If a corridor is significantly used for taxi or paratransit service, corresponding loading zones shall be provided.

This source indicates: "Where the combined width of the cycle track and buffer is less than 8 feet, parking placed next to the cycle track will not be accessible for disabled persons using vans or taxis (though they may

be accessible to car users, for whom a 5-foot level landing area is needed). Consider local needs for van-accessible spaces and how best to meet those needs."

NACTO mentions that PSBL infrastructure may be unfamiliar to individuals with sight-impairments. An outreach effort may be required to educate and assist these travelers. Design elements can be selected to provide tactile indication of measures. Vertical delineators can be positioned to support disabled users.

The guidance NACTO provides is consistent with ADA guidance presented in the MassDOT Separated Bike Lane Planning and Design Guide and the MnDOT Bicycle Facility Design Manual.

The FHWA Separated Bike Lane Planning and Design Guide indicates that situating ADA parking near intersections provides more flexibility for designing bike lanes around it. A buffer area without vertical obstructions should be provided. A "Yield here to pedestrians" sign can be provided to further identify the area.

The North Bassett Street Parking Protected Bike Lane Pilot - Madison, WI evaluation noted that on future projects, the City will enhance communication and collaboration with ADA-related stakeholders. The study found that this input is key to a successful concept and final design.

Intersections

Intersection design is critical to a successful PSBL facility. As previously discussed, while PSBLs reduce conflicts mid-block, they may introduce conflicts at intersections. As a result, intersection treatments are necessary to facilitate safe operation of the facility. The reviewed sources offer guidance on where treatments may be most applicable and how to prioritize treatments under budgets and right-of-way constraints. Creating dedicated space for cyclists is core to various treatments. Signage, lighting, striping, and markings can be used to inform and create visibility at intersections.

The NCHRP Research Report 926: Guidance to Improve Pedestrian and Bicyclist Safety at Intersections specifies these guiding principles for selecting countermeasures at intersections: 1) assume people will bicycle and walk, 2) minimize and manage conflict points, 3) minimize travel time and delay – especially for pedestrians and bicyclists, 4) minimize exposure to conflicts, 5) control speeds and minimize speed differentials at conflict points, 6) prioritize comfort, 7) provide and convey a predictable, reasonable path, 8) manage sight lines and visibility, 9) ensure accessibility. This source specifies tiered mitigations based on the number of travels lanes, vehicle ADT, and speed limit. For high traffic volumes (i.e., 12,000 ADT) and speed limits (i.e., 40 mph), more physical separation is required between motor vehicles and cyclists. In these scenarios, intervention is generally required to stop and separate the traffic. At lower speeds and volumes, infrastructure that requires yielding may be more appropriate.

The NCHRP Report 500: A Guide for Reducing Collisions Involving Bicycles indicates that signal timing and detection shall be verified to accommodate bicycle traffic. This may involve providing adequate clearance intervals, bicycle sensors, and / or a leading bicycle interval. This resource also mentions the importance of providing adequate signage to improve bicycle safety at intersections. This source recommends bicycle boxes and colored bike lanes at intersections and hazardous locations to improve bicyclist safety.

This NCHRP report also discusses intersection geometry as a strategy for improving bicyclist safety. It recommends reducing crossing distance, eliminating skews, and providing refuges for bicyclists.

The Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S. evaluated intersection effectiveness after the implementation of separated bike lanes. The study looked at mixing zones, turning zones, and bike signals. Mixing zones allow the motor vehicles and bicyclists to come together in one lane, with

vehicles making the turn movement while bicyclists can either turn or go through the intersection. Turning zones swap turning cars with through bicycles so that the users stay in separate lanes. Bike signals keep the vehicles and bicyclists in their designated lanes and give them different opportunities to make their desired movements. For mixing zones, the study found that most motorists used the lane correctly, but that most bicyclists chose to use the buffer to get around vehicles. For turning zones, the study found that most users accessed their movement from the correct lane. For bike signals, the report indicates that most users complied. The study suggests that green pavement markings are effective but shall not be overused. It found that most bicyclists felt safe in each of the types of treatments, but that the largest percentage of cyclists felt safe at the bike signal location.

The San Francisco MTA Safe Streets Evaluation 2019 Year-End report provides an evaluation of the City's safe streets program. The evaluation found that the signal timing and enforcement are key factors to a successful bike signal. Contrary to the above Green Lanes Report, this study found low bicycle and vehicle compliance at four new separated bike signals. However, other bike signals throughout the city were found to have high (81%) compliance of people biking. Excluding the new signals, there was an 89% decrease in conflicts between through bicyclists and right-turning vehicles and a 90% decrease in observed close calls following the Safe Streets improvements.

The Cycling at a Crossroads – The Design Future of New York City Intersections report examines designs for managing conflicts at intersections where there are PSBLs. The study finds that implementing standard treatments reduces crashes at intersections by 30% when installed as part of a PSBL project. Mixing zones reduced the crash rate by 27%. The source says that mixing zones may be efficient, but less comfortable facilities and may be most appropriate at smaller intersections. The fully split phase bike signal offers comfort, but long delays end up causing risky cyclist behavior. NYC DOT recommends bike signals at larger intersections. The study piloted a delayed turn (similar to a leading pedestrian interval) and found low conflict rates. The protected intersection pilot resulted in 93% of cyclists feeling comfortable through the intersection, but the configuration often left cyclists yielding to speedy motor vehicle turns. The study recommends shorter mixing zones, left-turn traffic calming methods, improved signal coordination, and more high visibility markings.

The 15th Street Separated Bike Lane Pilot Project: Interim Results and Next Steps recommended adding Bike signals, green paint at conflict areas, pedestrian refuges, and bike boxes. The North Bassett Street Parking Protected Bike Lane Pilot - Madison, WI made similar recommendation following their PSBL pilot project.

Corner Clearance and Sight Lines

Several of the reviewed sources discuss facilitating adequate sight distance at intersections and driveways to increase visibility of cyclists in PSBLs and improve the safety of the facility. The sources offer guidance on daylighting dimensions and suggest maintaining clear sight lines that are clear of any obstructions.

The NACTO One-Way Protected Cycle Tracks resource indicates that when crossing driveways and minor intersections, parking should be prohibited near the crossing to improve visibility. NACTO indicates a desired 30' from each side of the crossing with no parking. Sidewalk furnishing and/or other features should accommodate a sight triangle of 20' to the cycle track from the minor street crossing and 10' from driveway crossings.

The FHWA Small Town and Rural Design Guide on Physically Separated Bike Lanes indicates "under all conditions parking, if present, should be prohibited within 20-feet of the intersection to improve visibility."

The NCHRP Report 500: A Guide for Reducing Collisions Involving Bicycles emphasizes improving visibility at intersections to reduce bicycle crashes (both at public street intersections as well as at private access points). This resource suggests increasing sight distance at intersection approaches, clearing sight triangles of obstructions, and improving lighting at intersections. Installing bicycle racks on the street corners may prevent

cars from parking or idling in the sight triangle. This resource also highlights the importance of making traffic control devices visible to both the motorists and the cyclists. This may require repositioning signal heads so that cyclists can better see and respond to them.

In Oakland, California, beige zones were painted within the buffer to discourage drivers from parking in the buffer. These beige zones also served an important safety role by providing sufficient sight lines for bicyclists and pedestrians at intersections. According to the Telegraph Avenue Progress Report, the beige zones were not enough to keep drivers from parking in the buffer or in the bike lane, which can cause restrictions to sight distance. The report recommends physical separators to keep the buffer zone clear.

Vertical Elements

On PSBL facilities, the parked vehicles serve as a vertical element that separates the users along the corridor. The reviewed sources suggest that an additional type of vertical element can be implemented in the buffer area to further identify the lanes, enforce parking designation, and contribute to the perception of safety such that more cyclists feel comfortable using the facility.

The FHWA Separated Bike Lane Planning and Design Guide says that "vertical elements in the buffer area are critical to separated bike lane design." This source evaluates the following vertical separation alternatives: delineator posts, bollards, concrete barriers, raised medians, raised lanes, planters, and parking stops. Regarding PSBLs, it says: "barrier types that obstruct the opening of car doors or create tripping hazards should be avoided." Alternative selection may be based on cost, aesthetics, durability, and maintenance requirements. A combination of vertical treatments may be preferred. Flexible delineator posts are a popular type of separation and can be combined with on-street parking. FHWA recommends typical 10-feet to 40-feet typical spacing of flexible delineators.

The Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S. surveyed cyclists on different barrier types and determined that cyclists feel more comfortable riding along a buffer with an object in it as compared one with just paint. Planters resulted in the highest stated comfort ratings. Flexible delineator posts also got high ratings even though they do not provide much physical protection.

A few of the reviewed case studies did not include vertical elements in the buffer and have recommend it on future projects. For instance, the Telegraph Avenue Progress Report – Oakland, CA notes that without physical barriers, they anticipate ongoing illegal parking in daylighting areas.

The North Bassett Street Parking Protected Bike Lane Pilot - Madison, WI evaluation noted that the City needed to replace 5 out of 20 flexible bollards in 1 year of service. They intend to replace their bollards with a design that is more visible and more durable.

Public Transportation

Many corridors considered for installation of PSBLs also carry public transportation infrastructure, which introduces another set of users accessing the facility. National guidance offers different solutions for integrating bus lanes and stops with PSBLs. The sources also discuss signage, markings, and accessibility as related to the overlapping of the facilities.

The NACTO One-Way Protected Cycle Tracks resource suggests wrapping the bike lane behind transit stops to reduce conflicts. At intersection bus stops, NACTO suggests that an extended mixing zone may be appropriate with adequate signage telling cyclists to yield to buses and passengers. If applicable on one-way streets, PSBLs should be positioned on the opposite side of the bus stops to avoid these potential conflicts.

In the NACTO Transit Street Design Guide Shared Cycle Track Stop resource, the shared cycle track stop involves a ramp within the bike lane. The bicyclists must yield to transit users when the bus is making a stop. This facility may be beneficial where there is limited right-of-way. Signage, markings, and detectable warning strips are critical to the safe operation of this kind of bus stop. Consideration should be given to how this kind of ramp may complicate maintenance operations. Bus shelters should be set back on the sidewalk so that pedestrians do not need to walk in the bike lane to access the shelter. Shelters should be transparent so that all users can see each other. NACTO indicates to "terminate the boarding platform at least 10 feet from the crosswalk to allow bicyclists to queue in front of transit vehicles."

Figure 16

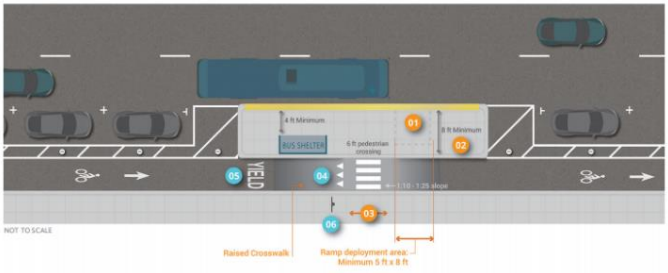


Figure 17

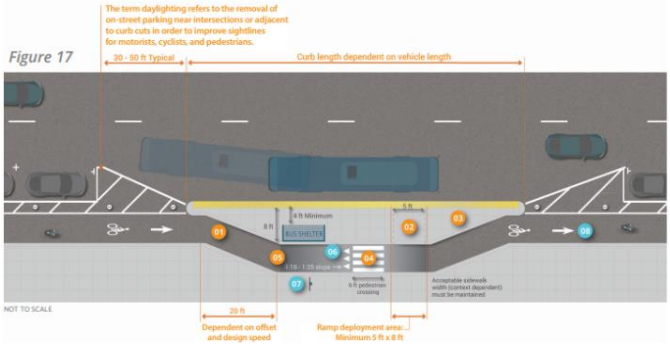
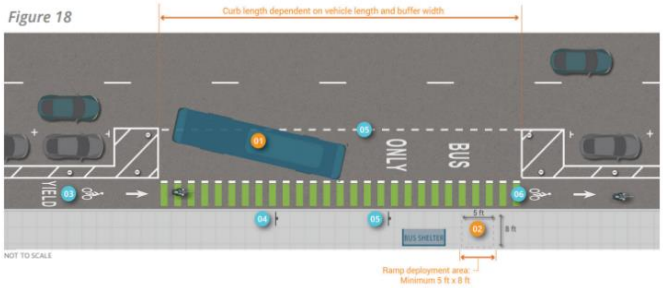


Figure 18



The FHWA Separated Bike Lane Planning and Design Guide contains the adjacent conceptual designs for integrating bus stops with parking separated bike lanes on Pages 93 through 95. The first (Figure 16) is an island platform without a separated bike lane bend. The second (Figure 17) is an island platform with a separated bike lane bend. The third (Figure 18) is a transit stop mixing with the separated bike lane.

Emergency Services

It is imperative that emergency service access is not impeded nor prevented by PSBL infrastructure. The FHWA Separated Bike Lane Planning and Design Guide indicates the need for coordination with public agencies regarding emergency vehicle access. Selection of vertical elements shall consider emergency vehicle access and thus, may need to be mountable or non-rigid.

Maintenance, Snow Removal, and Street Cleaning

Street maintenance is a key consideration in the design and installation of PSBLs. In some cases, specialized maintenance equipment and procedures may be required to clean and clear PSBLs, which are constrained in width by parked vehicles and the curb. This is a problem that has been solved by many municipalities and agencies. Smaller scale equipment is available and can be used on other facilities and with year-round utility to maximize investment.

The NACTO One-Way Protected Cycle Tracks resource mentions that separated bike lanes may need more frequent maintenance and clearing of debris as compared to the rest of the street, particularly during the fall. It also includes the following considerations regarding maintenance:

- "Snow removal procedures should minimize the creation of snowbanks in the buffer zone, because snow melt flowing across the cycle track can freeze at night, requiring frequent salting in order to avoid hazardous conditions."
- "Snow removal may be simplified by putting the cycle track at sidewalk level or by constructing a raised median between the parking lane and the cycle track."
- "Consider restricting parking at a regularly scheduled time of the week or day to facilitate snow removal and street cleaning."
- "Bollards or flexible delineators may be removed in winter to provide improved access by snow removal equipment."

The NACTO Resource, "NACTO Case Studies: Downsized Street Maintenance Vehicles," outlines 4 case studies regarding sweeping and plowing separated bike facilities. The Boston Public Works Department (PWD) has a fleet of multifunctional "compact sweeping and plowing vehicles." To leverage their investment, the vehicles are used in parking lots and on narrow streets and alleys. Salt Lake City has had success with their "Tennant ATLV 636a "stadium-style" sweeper." This piece of equipment clears 3 miles of bike lanes in 2 hours and is estimated to handle 60 miles of bike lanes before a second vehicle is needed. To deal with snow fall, Salt Lake City's existing equipment can clear bike lanes that are 7-feet or wider. For more narrow facilities, the City has two "Kubota RTVX1100 units with V-plows." These vehicles can clear 3 miles of bike lanes in 2 hours. The City of Cambridge, MA has also invested in smaller scale sweepers that can clean sidewalks, park facilities, and parking lots in addition to separated bike lanes. Their compact snowplows blow snow from bike lanes and sidewalks into an adjacent dump truck. Chicago has two "Multihogs" with different attachments to maintain their facilities in all seasons.

This resource discusses the significance of coordination between Planning Staff and Maintenance Staff. New equipment should have Maintenance Staff buy in and be safe, comfortable, and easy to use. Some departments have had success doing pilots to try equipment before purchasing it. Equipment that is multifunctional for year-round use and can serve different kinds of facilities offers the greatest return on investment.

The FHWA Separated Bike Lane Planning and Design Guide indicates that "consideration should include an inventory of existing maintenance equipment, whether it will fit in the proposed separated bike lane, and alternative options if the equipment will not be compatible." Separated bike lane facility planning and design requires adequate coordination between Planning and Maintenance agencies. FHWA mentions that more equipment products are expected in the future as separated bike lanes become more popular.

In the N Bassett Street Parking Protected Bike Lane Pilot Evaluation, one cyclist in Madison, WI noted: "One benefit that I hadn't realized until recently is that the separation of lanes also prevents the build-up of snow/ice that tends to happen in bike lanes that are adjacent to moving traffic lanes from plows. This often forces bikers to take car lanes even on roads where bike lanes exist, which creates uncomfortable situations with drivers who don't understand why bikers need to do this."

This Pilot Evaluation also makes the following comment regarding street maintenance: "The parking protected bike lane also requires some adjustments to leaf pick up and large item pick up. These activities necessitate blocking the bike lane at times although this is also the case with bike lanes that are not protected. The parking along this section does not allow parking on Thursday mornings as part of the Clean Streets Clean Lake program, which helps make it easier to do maintenance and garbage, recycling, and large item pick up."

Loading Zones and Waste Management

Street space is also used for loading and waste management. Depending on surrounding land uses, space is needed for ride sharing, making deliveries, distributing mail, and collecting waste. These operations need to be safe for all street users and should not inhibit moving vehicles nor cyclists. The reviewed sources identify a need for designating loading space to avoid double parking and corresponding conflicts. Physical barriers may be required to avoid illegal maneuvers and outreach and education may assist in new waste management and loading practices.

The 2019 SF MTA Safe Streets Evaluation discusses how commercial and passenger loading zones were prioritized in some locations over parking to create space for loading without blocking the bike lane. The Evaluation notes that physical barriers help prevent loading in the bike lane.

The NYC Columbus Ave Parking Protected Bicycle Path Preliminary Assessment project added 7 loading zones in conjunction with the new PSBL. This decreased double parking and lowered the number of commercial vehicles parked in travel lanes.

In the N Bassett Street Parking Protected Bike Lane Pilot Evaluation, the City of Madison, WI, asked residents to put their garbage cans in the buffer area for pick up. The Pilot Evaluation reports that the multi-unit character of the residences required a few different methods of information and education to be sure that all people living on the street were aware of the requirement. And new education and reminders are needed each year. The Evaluation indicates general adoption of the process, but there are some concerns and negative feedback related to this topic from the community. The City experiences improperly places garbage cans elsewhere in the city as well.

Drainage

Drainage infrastructure is necessary to safely maintain streets. In many cases, PSBLs are being proposed within the cartway and may have impacts on drainage operations. The reviewed sources detail how to best integrate drainage infrastructure along a PSBL corridor.

The NACTO One-Way Protected Cycle Tracks resource refers to how different vertical elements may impact drainage. NACTO indicates that using parking as a barrier can reduce costs by not requiring specific drainage infrastructure. This resource says that "gutter seams, drainage inlets, and utility covers should be configured so as not to impede bicycle travel and to facilitate run-off." Preferably, the width of the bike lane should be increased where the gutter seam extenders more than 1-foot from the curb.

The FHWA Separated Bike Lane Planning and Design Guide mentions that drainage should be considered and accommodated in making design decisions. "When building separated bike lanes to accommodate drainage, planners should consider environmentally friendly options such as bioswales within landscaped medians that can absorb precipitation and serve as the facility's form of physical separation from vehicular traffic." This resource also mentions that the usable bike lane width should not include drainage grates and gutter seams.

Equity

There is an integral link between bicycle infrastructure and the community. The FHWA Separated Bike Lane Planning and Design Guide discusses how separated bike lanes can offer greater mobility to lower income populations and can offer connectivity to transit and employment opportunities. The Guide says: "As part of a connected bicycle network, separated bike lanes can: Provide a more comfortable experience for less-skilled riders; Improve access to destinations such as schools, jobs, health care facilities, and essential services; Enhance access to public transportation, for example by helping to solve the first/ last mile challenge; Improve access to employment opportunities, especially for those without access to a private automobile; and Provide a linkage between regional trail systems." With PSBLs, these benefits can be achieved while also maintaining the parking availability that is frequently valued by communities.

KEY FINDINGS

Based on the peer state and literature review, the key findings are summarized below as they relate to safety and design best practices of PSBLs.

Safety

FHWA determined that per capita crash rates for cyclists appeared to decrease in most facilities after separated bike lanes were installed. FHWA found that separated bike lanes offer a high level of human error accommodation and that separated bike lanes may accommodate more ages and abilities due to the separation between motor vehicles and bicyclists.

NTSB found through a nationwide roadway crash data review that a bicyclist is twice as likely to sustain a fatal or serious injury if a crash occurs at a mid-block location. The two (2) types of crashes that contribute most to mid-block cyclist fatalities are a motorist overtaking a bicyclist and other circumstances surrounding parallel movements. Separating bicycle and motor vehicle traffic could potentially prevent such mid-block crashes. NTSB recommends that separated bike lane facilities be included as a treatment on FHWA's list of Proven Safety Countermeasures.

NACTO indicated that protected cycle tracks improve perceived comfort and safety and eliminate collisions caused by vehicles over-taking cyclists. Dooring may be avoided with a wide buffer and is less frequent with a PSBL than a typical bike lane. If dooring occurs, the cyclist will not be struck into moving motor vehicle traffic.

Based on the reviewed case studies, PSBLs:

- Either do not impact or else decrease crashes
- Decrease interactions between motor vehicles and bicyclists
- Increase perceived safety and cyclist comfort
- Result in fewer cyclists on the sidewalk
- Increase bicycle volumes
- Either do not impact or else decrease motor vehicle speeds
- Do not impact motor vehicle volumes

The NYC Columbus Avenue Case Study reported a 34% decrease in all crashes (vehicular, bicycle, pedestrian). The Telegraph Ave Case Study in Oakland saw a 40% reduction in all collisions (vehicular, bicycle, pedestrian).

The San Francisco Case Study noted a 99% decrease in interactions between motorists and cyclists at mid-block locations. This case study noted that the new bike signal reduced intersection close calls by 29%.

Design Best Practices

General Design:

- 5-foot minimum bike lane width (4-feet when accommodating an ADA access aisle)
- 7-foot bike lane width where there are high volumes, steep inclines, and anticipated passing
- 2-3-foot buffer width and 8-foot parking lane width
- Buffers should be wide enough to prevent dooring (at least 3-feet wide)
- Usable bike lane width should not include drainage infrastructure or should use bicycle friendly drainage grates
- Vertical treatments should be implemented to enforce daylighting and clear zone areas
- Other obstructions, street furniture, etc. should be eliminated and prevented in sight triangles
- Coordination with the following stakeholder, advocates, and agencies is key:
    - ADA advocacy groups
    - Maintenance staff including street sweeping, plowing, leaf removal
    - Waste Management
    - Transit authority
    - Stakeholders in need of loading areas
    - Emergency Services

Intersections:

- Bike signals are the most effective intersection treatments (especially at high speed, high volume locations)
- Turning zones are less effective intersection treatments followed by mixing zones, which may be appropriate at low volume, low speed locations
- Bike boxes should be implemented where applicable
- Daylighting should be implemented at intersections and access points to ensure sufficient sight distance
- Green paint should be implemented at conflict zones
- Vertical treatments should be implemented to enforce daylighting and clear zone areas
- Other obstructions, street furniture, etc. should be eliminated and prevented in sight triangles

Mid-Block:

- Buffers should be wide enough to prevent dooring
- Vertical treatments should be implemented for parking enforcement
- It is desirable to located drainage infrastructure outside the usable bike lane width or to utilize bicycle safe drainage features (e.g., grates)
- Ample loading zones should be provided to prevent double parking

Curbside Needs

- Ample loading zones should be provided to prevent double parking and parking in non-designated areas
- Vertical treatments should be implemented for parking and loading enforcement

Maintenance

- Vertical treatments can be removable in the winter
- Specialized maintenance equipment may be required to clear and maintain facilities

- Maximize investment by getting a multifunctional vehicle with year-round utility (something useful on other facilities like greenways, alleys, & parking lots)
- Pilot equipment with Maintenance Agency before purchasing

Appendix B: Study of Philadelphia's Parking Separated Bike Lanes

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MEMORANDUM

June 18, 2021 Project #: 21093.005

To: Richard Montanez, P.E.
Deputy Commissioner of Transportation
Department of Streets

CC: Kelley Yemen, AICP

From: Laura Ahramjian, AICP

RE: Appendix B: Study of Philadelphia's Parking Separated Bike Lanes

INTRODUCTION

The purpose of the Philadelphia Parking Separated Bicycle Lanes Study is to understand and document the safety benefits, operational effectiveness, and impacts on usage of parking separated bike lanes (PSBLs). The following memo is a comprehensive study of the recently piloted PSBLs on Market Street and JFK Boulevard in Philadelphia. The study involves field observation of the facilities, perspective from City Maintenance and Operations Staff, stakeholder feedback, and before and after data evaluation. It reports on the implications that the pilot has had on vehicle speeds, bicycle volumes, maintenance, and crash data.

PHILADELPHIA'S PARKING SEPARATED BIKE LANES

Overview

The City of Philadelphia (the City) launched a PSBL pilot project in June, 2018. Prior to the pilot, much of the City's bicycle network included painted bicycle lanes adjacent to vehicular traffic. Absent dedicated and separated infrastructure, motor vehicles were stopping, parking, and passing in the bike lanes, requiring cyclists to weave in and out of traffic. This rendered the facilities uncomfortable for most cyclists. With the goal of implementing bicycle infrastructure that would be more accessible to cyclists of a variety of ages and abilities, the City partnered with the Pennsylvania Department of Transportation (PennDOT) to pilot a network of PSBLs. This solution was offered as a means of improving the bicycle network while also meeting parking demand and offering designated loading space.

The City began designing and installing PSBLs on 10 streets that were already planned for separated bike lanes. Major design and implementation consideration was given to national design guidance, corner clearance and sight lines, emergency services coordination, drainage, vertical element spacing, specification, and installation, and snow removal and maintenance.

The Market Street and JFK Boulevard PSBLs were implemented in 2018, before the current Covid-19 Pandemic. As a result, field observation and analysis may be impacted by the circumstances of the Pandemic.

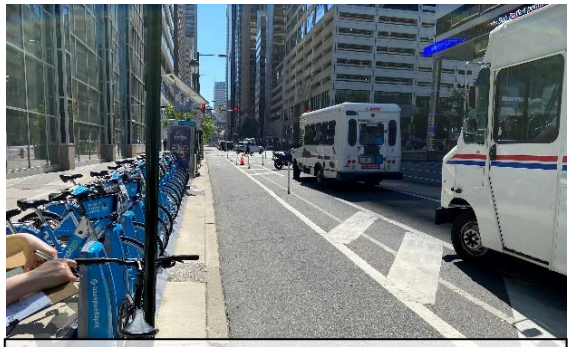
Market Street PSBL

Market Street is a one-way eastbound corridor at the heart of Philadelphia's Center City. It carries three (3) vehicular lanes of eastbound traffic with on-street parking on both sides. Market Street is a bus route with stops on the south side of the street and provides access to the Market-Frankford and Broad Street rapid transit lines. It is flanked by mostly office, retail, and hotel uses. The Market Street PSBL runs along the north side of the corridor from 20th Street on the west to 15th Street on the east, terminating in front of Philadelphia City Hall and Dilworth Park. There are Indego bikeshare stations along Market Street and ample bicycle parking. Vehicular parking is divided into various zones, including some designated loading zones. There is one driveway along the corridor, located between 17th and 18th Streets.

The Market Street PSBL design includes a 6-foot wide bike lane, 5-foot wide buffer, 8-foot wide parking lane, three (3) 11-foot wide vehicular travel lanes, and a 10-foot wide parking lane / right-turn-lane on the south side of the street. The buffer contains flexible delineator posts spaced 20-feet to 40-feet apart at mid-block and at 8-feet apart near intersections. Daylighting is marked with striping and flexible bollards at the intersections. At some locations, bollards create "bump outs" arounds the crosswalks. There are bicycle signals at 16th Street and 18th Street to facilitate left turning traffic movements; vehicular left turn lanes are also provided at these intersections.

The Market Street PSBL starts at 20th Street where Market Street changes from two-way to one-way. Eastbound bicycle traffic on Market Street approaching 20th Street transitions into the facility while crossing 20th Street. At the facility's terminus at 15th Street, the PSBL transitions to a bike lane that crosses 15th Street and runs on the east side of the street along Dilworth Park for 250-feet. At the fork with Penn Square South, there is a bike box, bike crossing, and pedestrian signal that allows bikes to cross Penn Square South and continue southbound on 15th Street.

Start of the Market Street PSBL near 20th Street



Market Street PSBL mid-block along parking and loading zones

Daylighting area with delineator posts at intersection

Market Street bike signal at 16th Street

JFK Boulevard PSBL

JFK Boulevard runs one-way westbound from 15th Street to 20th Street, where it begins carrying 2-way traffic over the Schuylkill to 30th Street Station. JFK is also a bus route with stops on the north side of the street and provides connectivity to the Market-Frankford and Broad Street rapid transit lines. The PSBL runs along the south side of the street from 15th Street to 20th Street. There is one driveway along the corridor, located between 17th and 18th Streets.

Typically, the JFK PSBL includes a 3-foot wide drainage grate, 6-foot wide bike lane, 9-foot wide buffer, 9-foot wide parking lane, three (3) 11-foot wide vehicular lanes, and a north side 7-foot wide parking lane. Between 15th and 16th Streets, the bike lane and buffer are narrower, each at 5-feet wide. At 17th and 19th Streets, there are turning or transition zones in which the motor vehicle and bicycle lanes are swapped to allow through bicycle movements while cars make left turns.

Between 19th and 20th Streets, the facility becomes a buffered bike lane adjacent to the parking rather than a PSBL. The buffered bike lane section contains a 7-foot parking lane, 6-foot painted buffer, 6-foot bike lane, and a subsequent 5-foot painted buffer next to the travel lanes.

For the PSBL sections of the corridor, the buffer typically contains delineator posts spaced 20-feet apart in midblock locations and 5-feet apart at intersections and in conflict zones. Daylighting is marked with striping and flexible bollards at the intersections. The JFK facility also has green paint near the intersections and at conflict points, including intersection crossings, driveway crossings, and at transition zones where the bike lane shifts to accommodate the vehicular left turn lane.

The JFK Boulevard facility starts on the west side of the Penn Square/15th Street intersection. Westbound bicycle traffic on JFK Boulevard approaching 15th Street transitions into a painted buffered bike lane on the south side of the street at the fork with Penn Square. At the facility's terminus at 20th Street, there is a full width painted bike box that allows cyclists to get out in front of motor vehicles to make their desired movement, including continuing westbound on JFK Boulevard, turning right onto 20th Street, and turning left onto 20th Street.

Start of JFK Blvd PSBL

JFK Blvd PSBL mid-block location, with drainage grates and fully occupied parking

Buffered bike lane on one portion of the JFK facility

Signage at the end of the JFK Blvd PSBL

Field Observations

On the morning of Tuesday, May 18th, 2021, Kittelson and Associates (the Team) performed a field evaluation of the PSBLs on Market Street and JFK Boulevard in Philadelphia. The purpose of this field evaluation was to observe the operations of the Market Street and JFK Boulevard PSBL facilities as well as the implications for all users, including bicyclists, motor vehicle drivers, pedestrians, transit users, etc. The Team intended to better understand the function and maintenance of the facilities and how they interact with the transportation network. Field measurements were taken to determine if the as-built condition differed from the design plans. On the day of the field evaluation, traffic volumes (including bikes, cars, and pedestrians) were observed to be less than typical given the impacts of Covid-19.

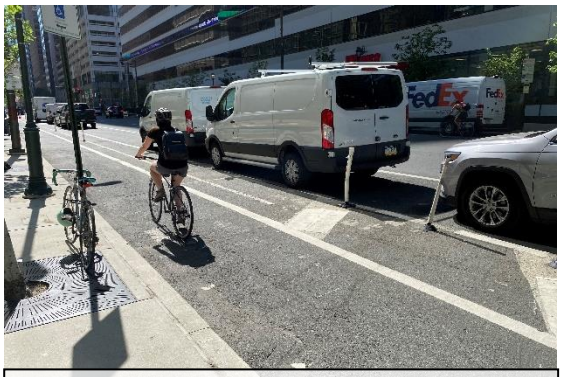
Market Street

Overall, the Market Street PSBL appeared to be operating effectively. The Team observed approximately 10 to 15 bicyclists on Market Street. About half of the cyclists were in the PSBL and the other half were sharing the vehicle lanes. Striping, marking, and delineator posts were in "fair" condition throughout the corridor. There did not appear to be any missing or significantly damaged delineator posts. Vehicles were typically parked and loaded legally. Typically, delineator posts were installed in the center of the buffer, providing a small gap between the parked cars and the delineator posts. Motorcycles were observed in designated areas near the intersections. There were no obstructions noticed in the daylighting areas and no debris, garbage, nor other obstructions identified in the bike lanes. There were no observed conflicts with buses, which have stops on the south side of the street.

One concern that was identified along Market Street, was obstructed sight distance at the driveway between 17th and 18th Streets. While the plans called for 44-feet of daylighting, there appeared to be about 31-feet of daylighting installed in the field. A large van was parked 2.5-feet from the driveway, making it difficult for a turning vehicle to see a cyclist in the PSBL. Conversations with City staff confirmed that this area was incorrectly installed.

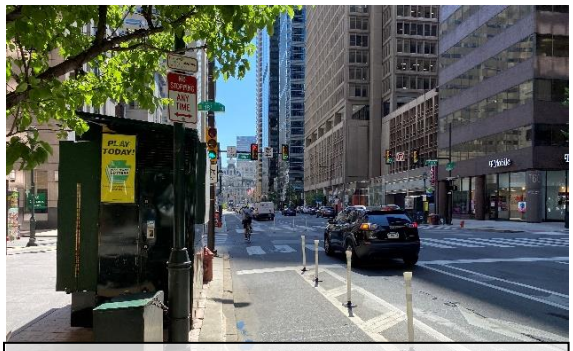
Three (3) people were observed on scooters in the Market Street bike facility, two of which were travelling in the wrong direction. Throughout the corridor, pedestrians were seen queueing in the crosswalk next to the buffer area (not blocking the bike lane nor in conflict with the motor vehicle

Parking and loading zone signage along the Market Street PSBL



Cyclist using the Market Street PSBL

Restricted sight distance at driveway on 1700 block of Market Street



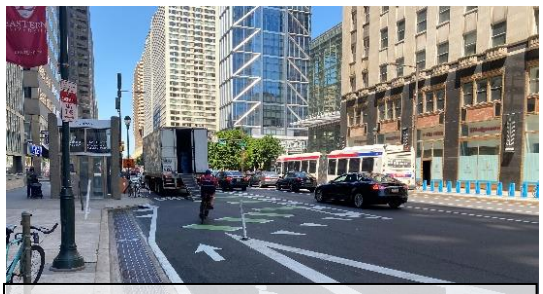
Vehicle stopped while cyclist continues through the 18th Street bike signal on Market

lanes). This behavior was reinforced by the marked "bump outs" with delineator posts on the west side of the high visibility crosswalk and it was also noticed at the bike signals. Both bike signals appeared to be operating effectively. The Team noted that the signal location may be confusing for bicyclists and motor vehicle drivers, since it is not directly aligned with the bicycle lane. While most drivers and cyclists made the appropriate maneuvers, one driver was seen turning left on red.

Daylighting and conflict markings at driveway on JFK

JFK Boulevard

Overall, the JFK Boulevard PSBL appeared to be operating effectively There were 2 bicyclists overserved on JFK Boulevard on the day of the field visit. One of the bikes on JFK Boulevard was using the facility and the other was on the sidewalk. Like Market Street, most of the parking was filled along the JFK PSBL and most loading zones were in use. There was one exception: between 19th and 20th Streets, 2 vehicles were spotted idling in the buffered bike lane. This was in the section of JFK that contains a painted buffered bike lane rather than a PSBL. There are no delineator posts in this location.

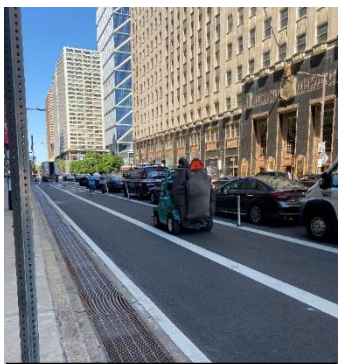


Delivery vehicle blocks turning lane such that turning vehicles must use bike lane on JFK Blvd

Striping, marking, and delineator posts were in "good" condition throughout the JFK corridor. The green markings, including green skips along conflict areas, were also in "good" condition. On JFK, the delineator posts are located more directly next to the parked vehicles, whereas on Market Street, there is a small gap. This delineator post placement on JFK appeared to better require parked vehicles to stay out of the buffer. The driveway located west of 17th Street on JFK Boulevard was observed to have adequate sight distance and green conflict markings. However, there was a newsstand located at the southeast corner of JFK and 18th Street that may be limiting sight distance at that intersection.

Cars queue in bike lane at transition zone on JFK Blvd

One concern identified on JFK was that the buffer was perhaps so wide between 16th and 17th Streets, that pedestrians were seen standing and chatting in the buffer. Also, at the subway stations, pedestrians were observed cutting through the bike lane from the crosswalk to the sidewalk.



Pedestrians loiter in wide buffer on JFK

Pedestrian walks through bike lane on JFK

On JFK, where there appeared to be fewer cyclists, the intersection treatment at 17th and 19th Streets is a transition zone that swaps the left turning motor vehicle lane with the through bicycle lane. At one intersection, a truck was loading in the turning lane such that cars were forced to queue in the bike lane. At the other

intersection, some drivers did not pull all the way over to the left turn lane and instead queued for the light in the bike lane. The Team witnessed two queues of left turning vehicles with no dedicated space for cyclists. Additional signage and delineator posts between the through travel lanes and the bike lane in these locations may better define the space for bicycles.

One concern noted on both Market and JFK was that there appeared to be fewer accommodations for right turning bicycles. The facilities seemed more useful as through corridors. There was also limited signage throughout both facilities. There were signs for the start and end of the facilities, but there were no PSBL-specific signage as seen on some other case studies.

City Operations and Maintenance

To better understand the maintenance of PSBLs, meetings were conducted with staff from the City of Philadelphia, including Steve Lorenz, Chief Highway Engineer, and Rich Montanez, Deputy Commissioner of Transportation. City Staff noted that the Pandemic has likely impacted the maintenance process.

Operations

The main topics of discussion regarding operation of the Market Street and JFK Boulevard PSBLs included parking, signage, delineator posts, waste management, and intersection treatments. The following information came from this meeting with City Staff:

- The Center City District (CCD) did significant outreach to property owners in advance of implementation. As a result, the City received fewer complaints from property owners and businesses along the corridors regarding parking changes.
- Pedestrians who have just parked are not always looking for cyclists when crossing to the sidewalk.
- Temporary informational signage was installed in the buffer area, but it was not intended to be permanent.
- Significant coordination was required with SEPTA for delineator post placement to accommodate bus turning radii.
- Preference of 5-foot spacing of delineator posts near intersections and 16-foot or 32-foot spacing mid-block.
- As observed in the field, delivery vehicles are often blocking the bike lane on JFK Boulevard.
- Waste management vehicles back up into the bike lane for trash pickup on JFK Boulevard.
- The bike signals are working well, after an initial adjustment period for drivers to get used to them.
- Bike lanes must be aligned with new bicycle signals to operate effectively.
- Signals must be able to handle the bike signal modification without overly complex setups that would be confusing for repairs.
- Bike signals are the preferred design option for facilitating vehicular left turns with PSBLs, but there are budget constraints that preclude the ability to secure capital funds for bike signals for all PSBLs.

Maintenance

After the initial installation in 2018, the Market Street and JFK Boulevard PSBLS were refreshed in 2020. Market Street paint and delineator posts were replaced by City Forces, and JFK Boulevard paint and delineator posts were replaced by PennDOT in conjunction with a resurfacing project on JFK Boulevard. This difference in installation is likely due to the more advanced wear and tear on the Market Street thermoplastic paint; the paint adheres better to new asphalt, which was the installation method on JFK Boulevard. There was also significant construction on Market Street since installation, which causes wear and tear to the striping and

markings. The green thermoplastic paint used by PennDOT on JFK Boulevard is a mixture of paint and aggregate that cures quickly after application but is more difficult to install precisely than the City's preferred product from Sherwin Williams. The green paint typically lasts 3-4 years before needing replacement.

In meeting with City Staff, the following maintenance challenges regarding the flexible delineator posts were discussed:

- Maintenance of delineator posts has been more challenging than anticipated.
- Delineator posts require frequent replacement, with the City doing so every few months.
- The City has had to replace 50% of the delineator posts at $50 per post.
- Delineator posts are especially vulnerable at corners where trucks make sweeping turns.
- The reflective tape is frequently peeling off, which is integral to safe visibility at night; once most of the reflective tape comes off, the delineator post must be replaced.
- Cheaper delineator posts options are available, like the ones installed on JFK in 2020, but they are less resistant to damage from being hit by vehicles.
- The City is putting a crew together for maintenance where one inspector drives the corridor, notes delineator posts that are down and alerts maintenance for replacement.

Regarding debris and snow removal, City Staff offered the following lessons learned:

- The City uses specialized equipment to plow the PSBLs within 24 hours of a snow event.
- Vehicle travel lanes are completed first and during that time, the City uses the parking area to stage plow equipment.
- The City learned that larger equipment, such as a backhoe, is necessary to remove larges pieces of ice and snow.
- Property owners and businesses were shoveling snow into the bike lane where there was nowhere else for it to go.
- A dump truck is needed to accompany the equipment to collect the snow as it is cleared (a few of the reviewed case studies identified the same problem and solution).
- Debris builds up after trash day that requires an additional piece of equipment to clear the PSBL. The CCD does some debris removal but is not ultimately responsible for the bike lanes.
- The City researched and purchased a 6-foot wide mechanical broom, which needs to be able to get under street trees and store trash while sweeping. The mechanical broom was purchased out of the general vehicle budget this past winter and has not be used yet. It will likely get sent out monthly but will need to include a dumpster with it to collect the debris.

City Staff is concerned about maintenance funding for PSBLs, particularly with the elimination of the Special Gas Tax (SGT), which currently pays for delineator posts. The City does not have a dedicated maintenance fund for PSBLs, and the City maintenance fund is constrained. This will especially be an issue on streets that do not require regular resurfacing like Market and JFK and are unlikely to undergo restriping regularly. Maintenance capacity and planned resurfacing projects should be considered when identifying streets for PSBL installation.

Stakeholder and Public Perception

To better understand the success of the PSBL pilot project, local stakeholder input was provided through a discussion with Sarah Stuart, Director of the Bicycle Coalition of Greater Philadelphia (BCGP). BCGP has not received negative feedback from the cycling community on the PSBLs, and their main impression is that the PSBLs on Market Street and JFK Boulevard are well-used and are working well. The facilities feel safer for cyclists while also preserving parking, which results in a "win-win,". BCGP feels that the facilities strike the right balance

of serving both experienced cyclists and novices. The bike signals on Market Street generally seem to be working well and are preferred to the transition zones on JFK, which sometimes have loading and queueing vehicles blocking the bike lane.

The following operations and maintenance concerns were noted by BCGP:

- Poor condition of the delineator posts, since bent, deformed, and scuffed posts may impact the aesthetics of the corridor. The more that these facilities look maintained, official, and "up for the job," the more they will be used. Maintenance of the delineator posts is of particular importance at the left turn locations for directing traffic accordingly.
- Snow removal has been spotty, a trend was identified in several of the case studies that were reviewed as part of Task 2.
- Leaf accumulation in the PSBLs can be dangerous to cyclists.
- Left turning vehicles sometimes do not see the bike signals on Market Street.
- The left turn transition zones at 17th and 19th Streets on JFK are less comfortable than the consistent PSBL on Market Street; 17th Street is the trickiest intersection to maneuver as a cyclist.

Overall, the bicycle community, as represented by the Bicycle Coalition, feels comfortable and protected on the new Market and JFK facilities.

Compliance with Best Practice Design Guidelines

In many ways, the Market Street and JFK Boulevard PSBLs comply with the best practices identified during the literature and peer state review process. The minimum suggested bike lane width of 5-feet and buffer width of 3-feet are provided or exceeded on the Market and JFK PSBLs. On JFK Boulevard, the bike lane runs adjacent to drainage grates as recommended by national guidance.

The use of delineator posts, daylighting, and green paint aligns with best practices. The solid white lane markings in the daylighting and buffer areas adhere to MUTCD requirements. The corridors both include ample loading zones and clear signage for parking restrictions. The bike signals on Market Street are preferred over the transition zones on JFK Boulevard, but given the lower cyclist volumes on JFK, it is the better corridor for this treatment. Both corridors may benefit from increased signage. Obstructions in intersection and driveway sight triangles should be removed.

In line with other cities, the City of Philadelphia has purchased maintenance equipment that better serves PSBLs and is continuing to implement solutions to maintenance problems that arise. The City has made efforts to engage local property owners, applicable agencies, and stakeholders.

Before and After Data Evaluation

Before and after data for the Market and JFK corridors was evaluated to determine the performance and outcomes of the PSBLs. The City collected the before and after data for vehicle speeds, bike counts, pedestrian counts, and transit vehicle speed; before and after crash data was provided by PennDOT.

Crashes

Table 1 shows the total number of crashes on both Market Street and JFK Boulevard before and after the PSBLs were installed. Since the before and after time periods span different number of years, the average number of crashes per year was used to compare changes in crash rates. After installation of the PSBLS, there was a decrease of nearly 20% of all crashes, and a 20% decrease in crashes resulting in any injuries. When looking at specific crash types, pedestrian and bicycle crashes showed a slight decrease. **Table 2** and **Table 3** show the before and after crashes on JFK Boulevard and Market Street, respectively. Both corridors saw similar declines in the total number of crashes. On Market Street, there was a small increase in the number of pedestrian crashes per year.

Due to the COVID-19 pandemic, vehicle volumes generally decreased in response to stay-at-home orders. The change in travel patterns likely had an effect on crashes in 2020. Future crash data are needed to fully assess the impacts PSBLs have on crash rates.

Table 1. Total Crashes Before and After

	Before (2012 to 2016)[1]			After (2019 to 2020)[2]			
	Number of Crashes	**Percent[3]**	**Average Number of Crashes per Year**	**Number of Crashes**	**Percent[3]**	**Average Number of Crashes per Year**	**Percent Change**
Total Crashes	140	100%	28	45	100%	23	-19.6%
Pedestrian Crashes	68	49%	14	25	56%	13	-8.1%
Bicycle Crashes	13	9%	3	4	9%	2	-23.1%
Crashes with Any Injuries	122	87%	24	39	87%	20	-20.1%
Total Injuries	154	100%	31	60	100%	30	-2.6%
Pedestrian Injuries	67	44%	13	25	42%	13	-6.7%
Bicycle Injuries	13	8%	3	4	7%	2	-23.1%
Vehicle Injuries	74	48%	15	31	52%	16	+4.7%

1. Source: City of Philadelphia
2. Source: Pennsylvania Crash Information Tool
3. Percentages may not add up to 100% due to rounding

Table 2. Total Crashes on JFK Boulevard Before and After

	Before (2012 to 2016)[1]			After (2019 to 2020)[2]			
	Number of Crashes	**Percent[3]**	**Average Number of Crashes per Year**	**Number of Crashes**	**Percent[3]**	**Average Number of Crashes per Year**	**Percent Change**
Total Crashes	71	100%	14	22	100%	11	-22.5%
Pedestrian Crashes	34	48%	7	9	41%	5	-33.8%
Bicycle Crashes	6	8%	1	2	9%	1	-16.7%
Crashes with Any Injuries	62	87%	12	20	91%	10	-19.4%
Total Injuries	84	100%	17	29	100%	15	-13.7%
Pedestrian Injuries	34	40%	7	9	31%	5	-33.8%
Bicycle Injuries	6	7%	1	2	7%	1	-16.7%
Vehicle Injuries	44	52%	9	18	62%	9	+2.3%

1. Source: City of Philadelphia
2. Source: Pennsylvania Crash Information Tool
3. Percentages may not add up to 100% due to rounding

Table 3. Total Crashes on Market Street Before and After

	Before (2012 to 2016)[1]			After (2019 to 2020)[2]			
	Number of Crashes	**Percent[3]**	**Average Number of Crashes per Year**	**Number of Crashes**	**Percent[3]**	**Average Number of Crashes per Year**	**Percent Change**
Total Crashes	69	100%	14	23	100%	12	-16.7%
Pedestrian Crashes	34	49%	7	16	70%	8	+17.6%
Bicycle Crashes	7	10%	1	2	9%	1	-28.6%
Crashes with Any Injuries	60	87%	12	19	83%	10	-20.8%
Total Injuries	70	100%	14	31	100%	16	+10.7%
Pedestrian Injuries	33	47%	7	16	52%	8	+21.2%
Bicycle Injuries	7	10%	1	2	6%	1	-28.6%
Vehicle Injuries	30	43%	6	3	42%	7	+8.3%

1. Source: City of Philadelphia
2. Source: Pennsylvania Crash Information Tool
3. Percentages may not add up to 100% due to rounding

Vehicle Speeds

Figure *1* and **Figure 2** show average vehicle speed during different times of day on JFK Boulevard and Market Street, respectively. The speed data were collected in several radar speed surveys conducted before installation (May 2018) and after installation (between September 2018 and November 2018). Average vehicle speed dropped on both streets in all time periods. The largest decrease in average speed occurred on Market Street during the midday peak (14% decrease). In addition to average speed, average travel times along Market Street and JFK Boulevard were evaluated. **Table 4** shows the average travel time on JFK Boulevard and Market Street in both the AM and PM peak hour based on multiple vehicle runs through the corridor. The exact time the travel time studies were conducted is unknown. In the AM peak hour, average travel time increased on both streets, with a 26% increase on JFK Boulevard and a 15% increase on Market Street. However, in the PM peak, average travel time decreased, 21% decrease on JFK Boulevard and 8% decrease on Market Street. In both time periods, the change in average travel time was greater on JFK Boulevard than on Market Street.

Figure 1. Average Vehicle Speed on JFK Boulevard (Source: City of Philadelphia)

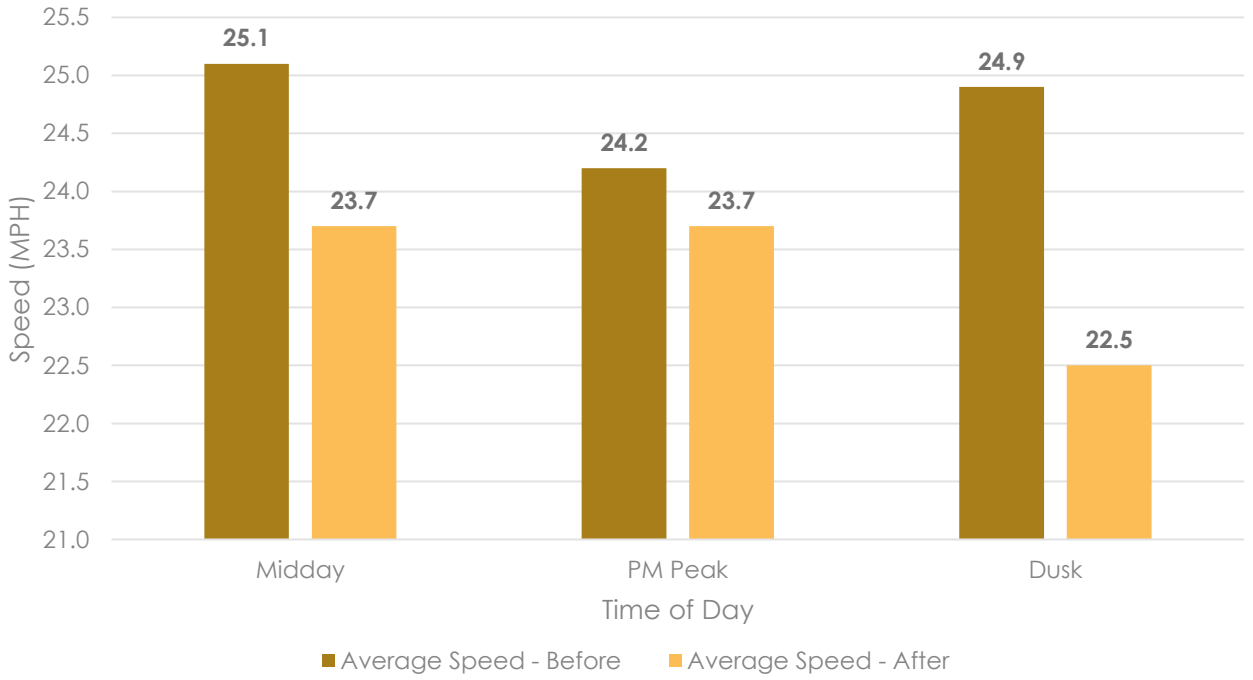


Figure 2. Average Vehicle Speed on Market Street (Source: City of Philadelphia)

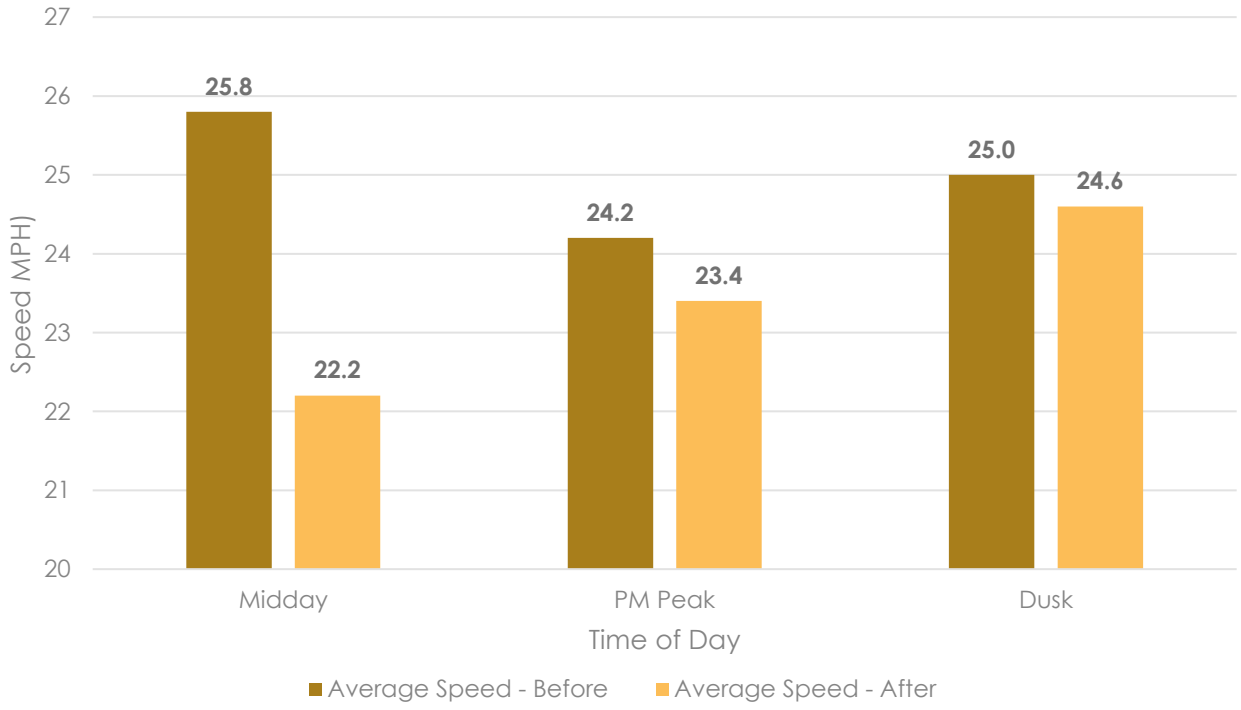


Table 4. Average Travel Time (Source: City of Philadelphia)

JFK Boulevard from 15th Street to 20th Street				
Travel Time Run	**AM**		**PM**	
	Before (min)[1]	**After (min)[1]**	**Before (min)[1]**	**After (min)[1]**
Run #1	1.67	2.26	2.36	2.23
Run #2	1.86	2.33	2.06	2.33
Run #3	2.32	2.10	3.20	2.13
Run #4	1.98	3.20	2.15	2.18
Run #5	-	-	4.16	2.16
Average	**1.96**	**2.47**	**2.79**	**2.21**
Percent Change		**+26%**		**-21%**

Market Street from 15th Street to 20th Street				
Travel Time Run	**AM**		**PM**	
	Before (min)	**After (min)**	**Before (min)**	**After (min)**
Run #1	1.52	1.27	2.58	1.55
Run #2	1.32	2.06	2.63	2.32
Run #3	1.53	1.58	1.58	2.98
Run #4	1.53	1.90	1.67	1.53
Run #5	-	-	2.83	1.95
Average	**1.48**	**1.70**	**2.26**	**2.07**
Percent Change		**+15%**		**-8%**

1. Exact dates the data were collected is unknown.

Bike Counts

Bikes counts from the Delaware Valley Regional Planning Commission (DVRPC) were used to measure how many people are using the PSBLs. Counts were taken on the bike lane side and the non-bike lane side of both JFK Boulevard and Market Street in March 2018, before installation, and then again in August 2018 and October 2018, after installation. **Figure 3** and **Figure 4** show the number of bikes observed on the bike lane and non-bike lane side, respectively. As shown in **Figure 3** the number of bikes increased on the bike lane side of the street on both JFK Boulevard and Market Street. The only exception is the 1900 block of JFK Boulevard, which saw a 40% decrease in the number of bikes between March and October. On Market Street, the number of bikes increased nearly 300% and 100% on the 1900 block and 1500 block, respectively. **Figure 4** shows a consistent decrease in the number of people biking on the non-bike lane side of the road. These two findings suggest a large share of people biking on JFK Boulevard and Market Street are taking advantage of the PSBLs.

Figure 3. Bike Counts on Bike Lane Side of Street (Source: DVRPC)

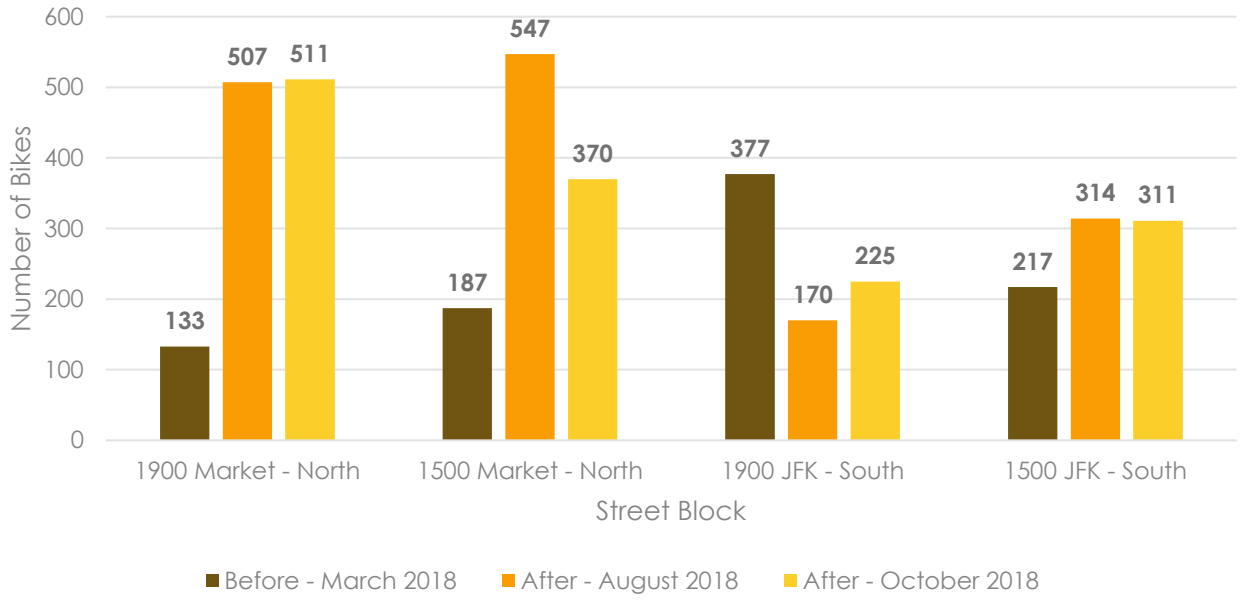
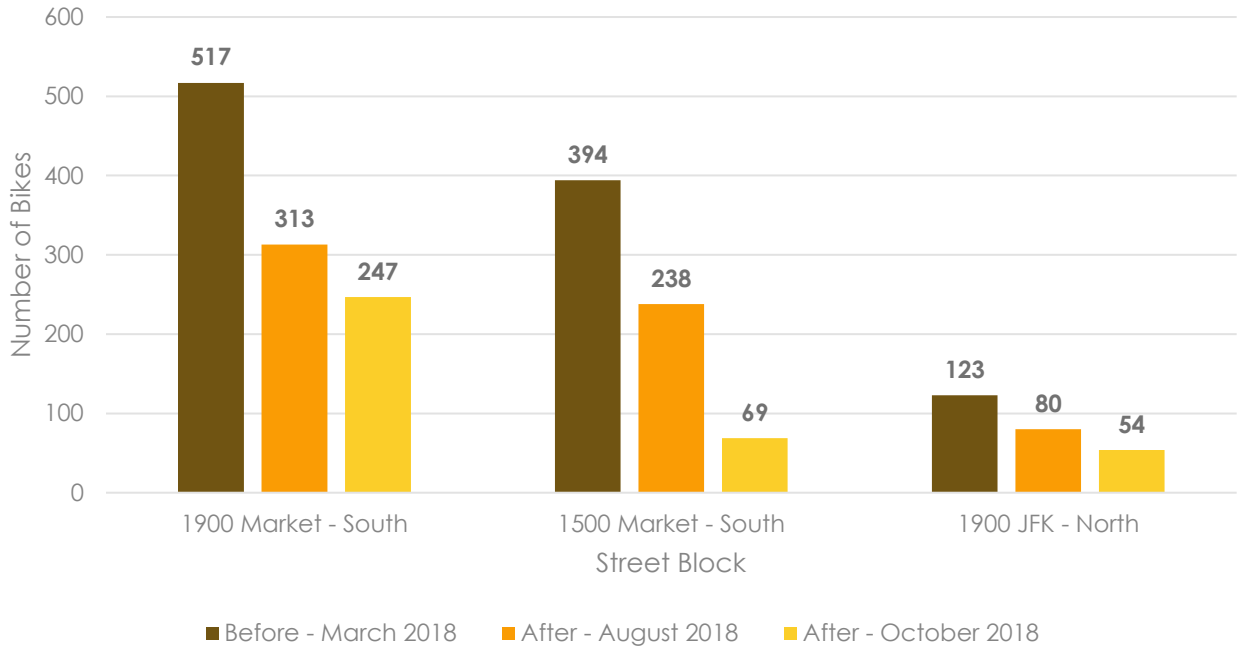


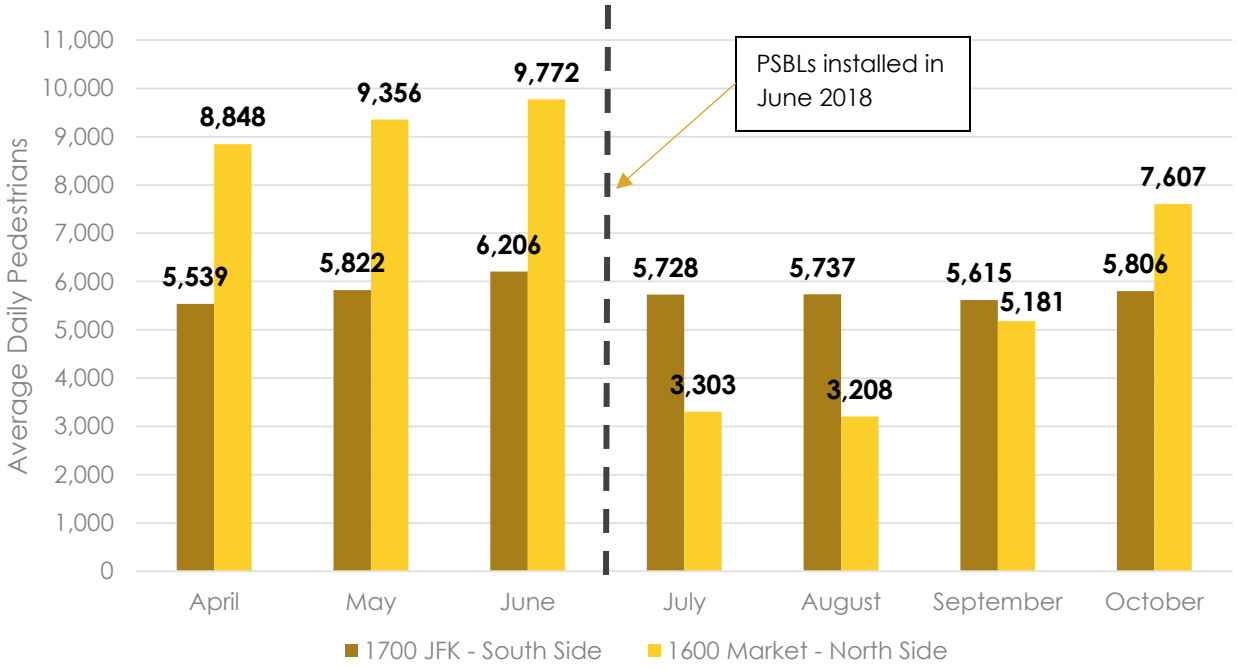
Figure 4. Bike Counts on Non-Bike Lane Side of Street (Source: DVRPC)



Pedestrian Counts

Figure 5 shows pedestrian counts on the PSBL side of the street for both JFK Boulevard and Market Street from April 2018 to October 2018. The PSBLs were installed in June 2018. Pedestrian counts on JFK Boulevard remained consistent and shows little change after installation of the PSBLs. However, pedestrian counts on Market Street decrease by 66% between June and July. While the pedestrian counts increase from July, pedestrian volumes on Market Street do not reach the same level as before the PSBL was installed.

Figure 5. Pedestrian Counts - 2018 (Source: Center City District)



Transit Vehicle Speeds

Table 5 and **Table 6** show average transit vehicle speeds on JFK Boulevard and Market Street, respectively. Similar to passenger vehicles, transit vehicles saw a modest decreased in average speed on both JFK Boulevard and Market Street. The change in transit vehicle speed is greater on JFK Boulevard than on Market Street.

Table 5. Average Transit Vehicle Speed on JFK Boulevard (Source: SEPTA)

JFK Boulevard Between	Average Speed (mph)		
	Before[1]	After[2]	Percent Change
19th Street & 18th Street	9.3	8.2	-11.8%
18th Street & 17th Street	10.3	8.7	-15.5%
17th Street & 15th Street	9.5	6.9	-27.4%
Average	**9.7**	**7.9**	**-18.2%**

1. Data time range: 3/5/2018 to 3/30/2018
2. Data time range: 8/20/2018 to 9/14/2018

Table 6. Average Transit Vehicle Speed on Market Street (Source: SEPTA)

Market St Between	Average Speed (mph)		
	Before[1]	After[2]	Percent Change
20th Street & 19th Street	7.6	7.4	-2.6%
19th Street & 18th Street	8.6	7.9	-8.1%
18th Street & 16th Street	7.3	7.1	-2.7%
16th Street & 15th Street	11.4	10.9	-4.4%
Average	**8.7**	**8.3**	**-4.5%**

1. Data time range: 3/5/2018 to 3/30/2018
2. Data time range: 8/20/2018 to 9/14/2018

CMF METHODOLOGY

CMF Background

The evaluation of Philadelphia's Parking Separated Bike Lanes was used to inform initial research on how a Crash Modification Factor (CMF) could be developed to quantify the potential safety benefits of PSBLs. A CMF is a multiplicative factor that indicates the proportion of crashes that would be expected after implementing a countermeasure, such as a pedestrian crossing island or a road diet. CMFs with a value less than 1.0 indicate an expected decrease in crashes; CMFs greater than 1.0 indicate an expected increase in crashes.

Typical sources for CMFs include the Crash Modification Factors Clearinghouse and FHWA's Proven Safety Countermeasures. FHWA promotes the use and widespread implementation of safety treatments and strategies that have proven effective at reducing crash rates. There are 20 FHWA Proven Safety Countermeasures, none of which include PSBLs or Separated Bike Lanes (SBLs).

The CMF Clearinghouse does include several countermeasure listings for "Install Separated bicycle lane"; all of these are based on the 2016 Separated Bike Lane Crash Analysis paper highlighting the methodology and results of a safety data analysis undertaken as part of the study process for the Federal Highway Administration's (FHWA) Separated Bike Lane Planning and Design Guide. These CMFs are given a 1-star quality rating (out of 5), suggesting low quality or confidence in the results of the study producing the CMF. Two of these CMFs directly reference outcomes in separated bike lanes that use parking as the method of separation; however, since the reference report used to develop the CMFs did not report the number of crashes in the after period, the Project Team determined that these CMFs should not be used.

CMF Development

Development of a high quality PSBL-specific CMF will be critical to more widespread implementation and adoption by state and federal agencies. Due to the relatively recent implementation of PSBLs in the US,

comprehensive research reports that can be used for CMF development are still not available However, two ongoing research projects are currently evaluating the safety implications of separated bicycle facilities and will be very helpful to this effort once completed:

- **FHWA Development of Crash Modification Factors for Different Separated Bike Lane Configurations:** The Study will "determine the influence of separated bike lanes/bikeways (SBLs) on the total number and severity level of crashes with particular attention to crashes that involve bicycles". Phase I of the study evaluated the feasibility and requirements for developing crash modification factors (CMFs) for intersection-related crashes separately from crashes occurring at midblock locations. Phase II, currently underway, will focus on how to perform the analysis, collecting data through video recordings of crashes or recording the way bicyclists behave on the road with motor vehicles. Phase II will also focus on developing CMFs for midblock SBL locations.

- **NCHRP 15-74 Safety Evaluation of On-Street Bicycle Facility Design Features:** The objective of this research is to provide practitioners at state DOTs and other transportation agencies with data-driven guidelines for selecting context-appropriate design features for safety improvements to existing separated and non-separated on-street bicycle facilities and for the planning of new facilities. The guidelines will be based on an up-to-date, quantitative analysis of crash patterns as well as an evaluation of the roadway characteristics, land use patterns, and human factors that increase conflicts and the risk and severity of midblock crashes that involve bicyclists.

The Philadelphia PSBL pilot projects are insufficient to develop a high-quality CMF, due to the small sample size, lack of control sites, and limited years of after data. However, a project-specific CMF was developed based on the before and after crash data for the Market Street and JFK Boulevard corridors. The overall reduction in crashes post installation results in a CMF of 0.775.

Best practice data considerations for development of a PSBL CMF are as follows:

- Identify a variety of PSBL sites and comparable roads without PSBLs. 30 sites are needed, but a corridor can be broken up into segments (i.e., 30 different PSBLs corridors are not required)
- Collect before and after data on PSBL and non-PSBL sites (traffic volumes, bicycle volumes, crash data)
- Document the following for each site:
    - Facility location + extents
    - Length of facility
    - Before/after roadway typical section
    - Number of signalized intersections
    - Before/after traffic and bicycle volumes
    - Before/after crash data
    - Date of installation

CONCLUSION

The Philadelphia PSBL Pilot Project successfully implemented PSBL facilities on Market Street and JFK Boulevard that operate appropriately and serve a variety of bicycle users. The facilities have been implemented mostly in line with best practices and national guidance. Vehicles are typically parking, loading, and turning in designated locations, especially where there are delineator posts. Cyclists are using the facilities, which are typically clear of debris and obstructions. The daylighting areas are creating adequate sight lines, which is necessary at driveways as well. The facilities are most useful as through facilities for cyclists; right turns can be more problematic. Increased signage may improve operations and awareness of the facilities.

Per meetings with City Operations and Maintenance Staff, there are drawbacks and additional considerations required to properly maintain PSBLs. Frequent replacement of flexible delineator posts in the buffer zones and daylighting areas is required after being run over and scuffed, particularly when the reflective tape is damaged. Snow, leaf, and debris removal require specialized equipment and significant testing to ensure they are functional. Installing PSBLs as part of resurfacing may make the project more economical and result in longer lasting thermoplastic paint. Due to limited maintenance funding and capacity, it is important to consider which streets would make strong candidates for PSBLs and their corresponding maintenance, and which ones may be less ideal.

Public stakeholder feedback indicates that the facilities are being used and are effective. Cyclists feel safer on Market Street and JFK Boulevard following PSBL installation. The bike signals are more comfortable intersection treatments for cyclists as compared to the transition zones. Delineator post maintenance is important to branding the facility as being official and useful.

Based on analysis before and after installation of PSBLs, the following key findings are summarized below:

- **Crashes** – Small decrease in total crashes and decrease in number of fatalities. However, more crash data are needed due to uncertainties from COVID-19.
- **Vehicle Speeds** – Decrease in average speed in all time periods. An increase in travel time during the AM peak hour and a decrease in travel time during the PM peak hour.
- **Bike Counts** – Increase in the number of bikes on the PSBL side of JFK Boulevard and Market Street, and a decrease in the number of bikes on the non-PSBL side.
- **Pedestrian Counts** – No meaningful change in pedestrian counts on JFK Boulevard. Large decrease in pedestrian counts on Market Street right after installation, but pedestrian counts increase again.
- **Transit Vehicle Speeds** – Modest decrease in average transit vehicle speeds.

A high-quality PSBL-specific CMF that is approved by FHWA and state and local transportation agencies is needed to encourage the implementation of PSBLs in Pennsylvania. Ongoing research efforts by FHWA and NCHRP will provide useful analysis that will either directly result in Separated Bike Lane/PSBL CMFs or data that can be used to develop PSBL-specific CMFs.