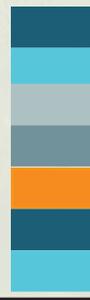


Federal Highway Administration

SEPARATED BIKE LANE PLANNING AND DESIGN GUIDE



APPENDIX



U.S. Department of Transportation
Federal Highway Administration

MAY 2015

APPENDIX

Appendix A: Literature Review

Appendix B: Lessons Learned Report

Appendix C: Crash Analysis Report

Appendix D: Project Evaluation Checklist

Appendix E: Data Collection Information

Appendix F: Future Research Needs

For Federal Highway Administration

Separated Bike Lanes Planning and Design Guide
Literature Review
Prepared December 2013

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Introduction

Many U.S. cities have recently incorporated separated bike lanes (also known as separated bikeways) as a component of their bicycle networks. Separated bike lanes are separated bicycle facilities that run alongside a roadway separated from automobile traffic by a physical barrier, such as parked cars, bollards, a landscaped buffer, or a curb. Several studies have been conducted on separated bike lanes in the U.S., showing a mix of safety benefits and negative safety effects, but many of these studies have had significant limitations due to lack of “after” data and low sample sizes. In addition to the need for more quality safety research on separated bike lanes, there is a strong need for geometric design and safety guidance for these facilities in the U.S.

Given the interest and implementation in separated bike lanes throughout the country and the need for safety research and design guidance, the objective of this research is to:

- Provide a robust and contemporary assessment of crash data (and proxy data, if needed) for operational separated bike lanes in the U.S.;
- Develop separated bike lane planning and design information based on safety studies and qualitative input that provides information to transportation professionals to accommodate bicycle transportation and promote safety for all transportation users; and
- Support the goal of ensuring that separated bikeway facilities are designed to the highest possible degree of safety, while encouraging their implementation in the appropriate context.

This document reviews relevant literature on separated bike lane operations and safety for all street users. Some studies were excluded if they only expressed the author’s opinion or if they employed inappropriate research methods or analyses. Papers meeting the screening criteria were critically reviewed and synthesized. Three primary objectives of the literature review were identified:

1. Provide insight as to how the team can create a separated bike lane safety study methodology that adds to the current body of knowledge.
2. Learn from the limitations of the existing studies of separated bike lanes and try to address them in our methodology.
3. Understand existing separated bike lane design guidance / best practices being recommended internationally today.

While the purpose of this literature review was focused on existing safety research and/or design of separated bike lanes, the review also identified some papers in other related areas of study, such as the perceived safety of separated bike lanes (as opposed to observed); the mode shifting effect of a network of separated bike lanes (Pucher and Buehler 2008) and the route selection effect of more isolated separated bike lanes (Jensen et al. 2010; Lusk et al. 2011; Goodno et al. 2013) related to bicyclist preferences for separated facilities; and the operational implications (delay, queuing, signal timing) of separated bike lanes related to both bikes and cars at intersections. Summaries of the studies reviewed are included herein, following the main body of the literature review. Studies that we considered, but not reviewed, are listed in Appendix 2.

The document is organized into four sections:

1. Separated Bike Lane Safety Performance Studies
2. General Bicycle Safety Studies
3. Design Guidance
4. Areas for Future Review

There are no existing separated bike lane studies that have satisfied best practices for analyzing the safety of separated bike lanes. With this in mind, the research team will use this information to 1) create a separated bike lane safety study methodology; 2) learn from the limitations of the studied separated bike lanes; and 3) incorporate separated bike lane best practices.

Separated Bike Lane Safety Performance Studies

The safety performance of separated bike lanes (SBL) has been studied extensively in recent years, both in the U.S. and abroad. However, the relative newness of these facilities and the rarity of bicycle collisions contribute to small sample sizes to accommodate crash data review. The overwhelming majority of separated bike lanes in the U.S. were installed within the past five years. Furthermore, sharp rises in overall bicycle ridership in many of the cities limit the ability of the research to draw strong conclusions.

Much of the highest quality research comes from outside the U.S. Studies from Canada, the Netherlands, and Denmark offer the greatest detail into the safety effects of various features, driver and cyclist behaviors, and other elements. These authors' findings must be carefully considered before applying directly to a U.S. context. The transportation experience in other countries may be different, especially when considering the differences in transportation infrastructure, land use development, and expectations about different user types in the roadway.

Safety Study Methods

The study methods used in the research can be divided into several categories.

Case-Control Analysis – Bicycle crash and volume data were collected and reviewed at facilities and other “control” sites. Some researchers compared roadways with SBLs to roadways with no bicycle infrastructure, while others compared them to other types of facilities, such as bike lanes and sidepaths. Within this group, there are two subsets.

Crash Incidence Analysis –Crash data were reviewed to determine if the installation of bicycle facilities had an impact on the number of crashes.

Crash Severity Analysis –Crash data were evaluated to determine the impact SBLs had on the severity of crashes.

Before-and-After Studies – Bicycle crash and volume data were collected before and after installation of a separated bike lane. In most cases, significant increases in bicycle volume were observed following installation of the s. These studies tend to lack sufficient “after” data to allow for meaningful conclusions.

Case Studies/Interviews –Interviews with individuals admitted to emergency rooms following bicycle crashes yielded information on the infrastructure and behavioral events related to each crash incident.

Video Observations – Video recordings of SBLs were collected and reviewed to identify bicycle, pedestrian, and vehicle volumes; crash incidents; and near-miss crashes/maneuver events to evaluate the safety performance of the facility.

Conflict Path Analysis – At an intersection or other conflict point, each type of conflict is analyzed using conflict path analysis, which considers the actual path of a bicyclist and the relative location of the bicyclist to surrounding automobiles.

The literature reviewed was limited by an inconsistency of the study methods to determine the safety benefits of separated bike lanes. Ideally, four components are needed to conduct a robust safety analysis:

- Before/After Study
 - Similar to the Highway Safety Manual methods and most applicable to existing roadways
- Network of Streets
 - Distinguish between intersection and segment crashes, which may differ between streets and bike lane streets
 - Cyclists may use parallel streets prior to a separated bike lane installation, as separated bike lanes are typically installed on large high volume roads, where cyclists would not have been cycling otherwise
- Control for Exposure
 - The number of bicyclists may increase when a separated bike lane is constructed so controlling for this variable is important. It is also important to account for the change in vehicular volumes
- Severity of Crashes
 - The severity of bicycle crashes on segments and intersections may be different as crashes on segments classified as overtaking/sideswipe have been generally found to be more severe than intersection crashes

Safety Themes

Due to the variety of study methods and small data samples, some disagreement exists within the literature reviewed on separated bike lanes. Still, some themes were revealed through the review:

- Separated bike lanes exhibit crash reductions when compared with similar streets without bicycle infrastructure (Nosal, et al. 2011; Winters, et al. 2012; Lusk, et al. 2013; and Harris, et al. 2013).
- Separated bike lanes have not been found to increase crash incidence compared with roads with bike lanes (Nosal, et al. 2011; Teschke, et al. 2012; and Jensen, et al. 2007).
- Separated bike lanes reduce the incidence of vehicle overtaking crashes (Thomas and DeRobertis, 2013).
- Turning movement crashes at intersections with trucks, especially right-turning vehicles across the separated bike lanes (“right hooks”), pose the greatest threat to bicyclists (Collection of Cycle Concepts, 2012).

Some of the literature found increases in bicycle crashes following the installation of separated bike lanes, but this increase is likely due to greater ridership following the provision of a dedicated bicycle facility, given that this literature did not control for exposure.

Key Questions

Several questions emerged from the literature review.

- **What are the effects of on-street parking along separated bike lanes?**
Preliminary findings in Montreal (Jensen, et al. 2008 and Nosal, et. al 2011) found the presence of on-street parking between the separated bike lane and roadway reduced crashes.
- **What is the safety performance difference between one-way and bidirectional separated bike lanes?**
There is some evidence that bidirectional separated bike lanes exhibit higher crash rates (Schepers, et al. 2010 and Nosal, et al. 2011), potentially as drivers are unaccustomed to yielding to two directions of traffic.
- **How do separated bike lanes affect the types of crashes and crash severity?**
The introduction of separated bike lanes reduces some types of crashes (e.g. vehicle overtaking, “dooring,” and cyclist turning events) while increasing others (e.g. cars turning right or left, cyclist-pedestrian crashes).

General Bicycle Safety Studies

Some literature did not directly study separated bike lanes but rather focused on subjects useful to advancing research in separated bike lanes. These papers are described below.

Carter et al. (2006) focused on roadway characteristics that increase the risk of pedestrian or bicycle crashes. This study analyzed over 60 intersections and collected operational and geometric data, including pedestrian/bicycle crashes, vehicular volume, posted speed, number of through lanes, etc. The study also collected video clips to subjectively evaluate pedestrian/bicycle and motorist conflicts. Then a prioritization model was developed based on pedestrian/bicycle experts’ input to determine which intersection characteristics present the highest risk to pedestrians/bicyclists. From this model, the study developed safety indices practitioners can use to better identify intersections which may have a higher risk of pedestrian/bicycle crashes.

Focusing on bicycles, one study performed a meta-analysis on common characteristics of bicycle crashes (Reynolds et al. 2009), which is similar to FHWA’s *Factors Contributing to Pedestrian and Bicycle Crashes on Rural Highways*(2010). Reynolds et al. found that sidewalks, multi-use trails, and high-volume roadways present the highest risk to bicyclists. The lowest risk facilities are on-road bike routes, marked bike lanes, and off-road bicycle paths. However, many of the reviewed studies did not control for bicycle volumes.

Chen et al. (2011) studied the before/after safety effects of bicycle lanes in New York City. The study inventoried before/after roadway characteristics, (intersection or segment, number of travel lanes, signalized intersection, etc.)The authors collected five years of before and two years of after crash data and used a generalized estimating equation (GEE) methodology to analyze the safety impacts of bike lanes. Results indicate there was no increase in bicycle crashes despite the likely increase in the number of bicyclists after the addition of the bicycle lanes; however, consistent volume data were not available so the study did not control for bicycle volumes.

Lastly, Loo & Tsui (2010) conducted a bicycle safety study in Hong Kong, but it is unclear whether they evaluated separated bike lanes or multi-use paths, as the paper did not contain a specific description of

the facilities. The results find that there are more crashes close to the facilities, but these crashes are less severe than elsewhere in the City.

Design Guidance

Design guidance for separated bike lanes comes from cities and countries in North America and Europe. The Dutch CROW Manual and Danish Collection of Cycle Concepts are the most comprehensive in terms of segment, intersection, and operational design characteristics, but none incorporate all features and considerations. Since much of the guidance comes from abroad, many specific issues with construction and design of American separated bike lanes are not captured in the literature.

Overview of Separated Bike Lane Design Guidance

The following separated bike lane design guides were reviewed which are organized by origin:

- U.S. – NACTO Urban Bikeway Design Guide
- England – London Cycling Design Standards
- Canada – Planning and Design for Pedestrians and Cyclists: A Technical Guide
- Canada– Bicycle Facilities Design Course Manual
- Denmark – Collection of Cycle Concepts
- The Netherlands – CROW Manual (Design Manual for Bicycle Traffic)

These design guides cover a wide range of separated bike lane planning, engineering, and design subjects. Table 1 summarizes the guidance by reference and subject according to the following criteria:

- Ridership – the impact of separated bike lanes on bicycle or auto ridership
- Separated bike lane speed/volume thresholds –vehicle speed and average volume thresholds for determining whether a separated bike lane is appropriate
- Bicycle volume-based width requirements –width requirements for separated bike lanes based on bicycle volume
- Dimensions – minimum design requirements for separated bike lane width
- Intersection Approach – guidance for separated bike lane treatments at intersections, including recommended horizontal displacement from the roadway vehicle lane
- Separated Bike Lane Construction – preferred separated bike lane materials and height of curb from roadway-separated bike lane and separated bike lane-sidewalk

Table 1: Subjects Discussed by Separated Bike Lane Design Guides

Design Guide	Ridership	Speed/Volume Thresholds	Bicycle Volume-Based Width Requirements	Dimensions	Intersection Approach	Construction
NACTO Urban Bikeway Design Guide (America)	N/A	N/A	N/A	Relatively narrow	Separated bike lane should 0-6.5 feet from vehicle lane, but prefers 0 feet from vehicle lane. Provides guidance on bike boxes.	N/A
London Cycling Design Standards (London)	N/A	Contains volume and speed thresholds to use separated bike lanes.	N/A	Relatively narrow	Cars required to use advanced stop bars, which show a 35% crash reduction.	N/A
Planning and Design for Pedestrians and Cyclists (Montreal)	N/A	N/A	N/A	Relatively narrow	Provides guidance on bike boxes.	N/A
Bicycle Facilities Design Course Manual (British Columbia)	Separated bike lanes are preferred on-street facilities. Separated bike lanes increase ridership by 20%.	N/A	N/A	Relatively wide	Provides guidance on bike boxes.	N/A
Collections of Cycle Concepts (Denmark)	Auto trips can be replaced with Bike Trips. Separated bike lanes can increase bike traffic while reducing auto traffic. Comfort important for bicycling; separated bike lanes are more comfortable than mixed traffic.	Contains volume and speed thresholds to use separated bike lanes.	Contains guidance on how to size width of one way and two way separated bike lane based on hourly bicycle ridership. Discusses "Conversational Cycling" as a width justification.	Relatively wide.	Separated bike lane should be horizontally positioned 16.5-23 feet away from intersection to allow turning vehicles to queue when there is heavy overtaking traffic	Guidance provided on construction materials and cost. Provides guidance on height of separated bike lane curb: Roadway-Separated bike lane = 2.75-4.75 in. Separated bike lane-Sidewalk = 2-3.5 inches. [Typical bicycle pedal clearance = 3 in.]
CROW Manual (Netherlands)	Separation from traffic (with separated bike lanes) increases bicyclist comfort which is important.	Contains volume and speed thresholds to use separated bike lanes.	Contains guidance on how to size width of one way and two way separated bike lane based on hourly bicycle ridership.	Relatively wide	Separated bike lane should be 0-23 feet away from intersection to allow turning vehicles to queue. The Dutch frequently use corner refuge island	Guidance provided on construction materials.



Separated Bike Lane Setbacks at Intersections/Driveways - The setback prevents bicyclists from riding more than 12.4 mph and allows turning vehicles a place to queue while simultaneously leaving the main road.



A Dutch Corner Refuge Island.

Separated Bike Lanes in AASHTO's Guide for the Development of Bicycle Facilities

AASHTO's Guide for the Development of Bicycle Facilities (2012) does not explicitly cover separated bike lanes, but rather provides a discussion about sidepaths. Sidepaths are similar to two-way separated bike lanes and guidance is provided to minimize the number of driveways and intersections alongside paths, which is similar to other preferred treatments of two-way separated bike lanes. The AASHTO guide provides many sidepaths considerations which cite safety, operations, and legal concerns. However, the guidelines to utilize sidepaths do not discuss safety improvements for the bicyclist because of the sidepath.

General Separated Bike Lane Operations

A review of the design guidance literature yielded the following observations related to separated bike lane design and operations:

- Directness of bicycle routes is a high priority as it will cause the least confusion and provide the most attractive route.
- Separated bike lanes may reduce speeds: The Danish have observed automobile speed reduction of 1-3 mph and a 1 mph speed reduction for bicyclists.
- In downhill situations, separated bike lanes should merge with vehicle traffic prior to intersections.
- Bus stops should be positioned between the roadway and separated bike lanes
- Two cargo bikes will not be able to pass each other on a two-way separated bike lane of 8.2 feet, and therefore is the absolute minimum dimension.
- Account for cyclists in signal timing. Advance green time for bicycle can provide greater safety and comfort. Consider phasing to separate right-turning auto travel and through cyclists
- Consider extra buffer space between separated bike lanes and parked vehicles for door-swinging and loading/unloading passengers.
- Consider grates and other obstacles on cycle routes. Smooth road surfaces are important as bicycles are disproportionately affected by potholes and other imperfections.
- Regularly maintain separated bike lanes. Keep the routes clear of snow, debris, and potholes.

The Danish and Dutch design guides do not provide much information on what type of buffered protections to use; however, these European countries are known to typically use parked cars as their protective barrier.

Key Questions to Inform Future Design Guidance

There are general inconsistencies between design guides about the specific subjects that should be considered to provide best practices for future separated bike lane design guides.

- What are the general ridership benefits from separated bike lanes?
- What are the preferred speed and volume thresholds to recommend separated bike lanes?
- What is the preferred width for typical one-way and two-way separated bike lanes to accommodate a specified bicycle design vehicle (conversational cyclist)?
- What is the best practice for the horizontal alignment of separated bike lanes and the intersection?
- How tall should separated bike lanes be constructed relative to the roadway and sidewalk?

Preferences, Perceptions and Operations

Bicyclist preferences for separated bike lanes

This literature review did not comprehensively explore the question of bicyclist preferences for different types of infrastructure, which relates directly to the potential for increased bicycle ridership in the US. A separate body of work exists on the topic of bicyclist preferences, and several existing papers have reviews of this work (Pucher, Dill, and Handy, 2010; Pucher and Buehler, 2008; Heinen, et al. 2010). Overall, these reviews noted a lack of studies designed to test the impact of a specific intervention – a before and after evaluation of both a “treatment” and “control” group.

Pucher and Buehler (2008) analyzed data from fourteen countries around the world, including European and North American examples, as well as Australia. The authors compared data at a national level for overall ridership, trip lengths, trip purpose, gender of bicyclists, and crashes. Their research found much higher ridership in some European countries (the Netherlands and Denmark) and a much lower cyclist fatality rate when compared with the U.S.

Pucher and Buehler concluded that a multi-pronged approach, with similar measures to these European countries, may help to increase bicyclist mode share in the US. They conclude that the most important measure in making cycling attractive is the provision of separate cycling facilities along heavily traveled routes and intersections, plus traffic calming in residential areas. Notably, Pucher and Buehler’s work assesses data at the national level – at this scale, it is indeed a *network* of separated bike lanes and other separated and traffic-calmed infrastructure that contributes to their results – their findings were not related to specific installations of a separated bike lanes or other infrastructure.

Pucher, Dill, and Handy reviewed 139 studies looking at the effects of various interventions with bicycling as the dependent variable, including both observed and stated preference studies. In North American examples, they found a prevalence of literature related to bike lanes as an intervention. The aggregate level studies (for example, those assessing the citywide level) showed a statistically significant and positive relationship between bike lanes and levels of cycling, but individual level studies (for example, assessing the impact of a person living near a bike lane) were less conclusive. Their reviews of stated preference literature all concluded that both bicyclists and non-bicyclists prefer bike lanes over a lack of bike lanes. Fewer studies included in their review directly addressed separated bike lanes, although one before-after study, found an 18 to 20 percent increase in cycle/moped traffic on streets where separated bike lanes were installed (Jensen, et. al., 2006; detailed review included herein).

However, Pucher, Dill, and Handy provide in-depth studies of 14 cities related to cycling mode share and conclude that cities with high (or rapidly increasing) bike mode share have implemented a series of encouragement measures to increase cycling, of which on-street infrastructure is only one part. Other measures include education, bike-specific programming, provision of bike parking and related facilities, transit and bike-sharing access, and land use policies. As part of this comprehensive approach, they emphasize the need for a complete network of facilities and note the limitations with existing studies attempting to assess the impact of a particular isolated intervention.

Since Pucher, Dill, and Handy’s work was published in 2010, other studies have found an increase in bicycling on routes with separated bike lanes. Lusk, et al. (2011) found bicycle volumes were 2.5 times higher on routes with separated bike lanes compared to parallel routes without separated bike lanes (however, Lusk et. al. was not able to assess the volumes on the separated bike lane routes prior to installation). Goodno et al. (2013) studied two routes with separated bike lanes in Washington D.C., including bicyclist volumes before and after the installation of the separated bike lanes, and found an

increase in volumes of over 200 percent in both locations after the separated bike lanes were installed, compared to a city-wide increase of 36 percent increase over the same time period.

Bicyclist perceptions of separated bike lanes

This literature review also did not comprehensively explore the question of bicyclist *perceptions* of separated bike lanes with regards to safety. While observed safety of separated bike lanes has been shown to vary according to a number of design factors, this review does not reveal how bicyclists perceive safety on separated bike lanes or other facilities, although some work has been done in this arena. One recent paper by Monsere, et al. conducted a survey of separated bike lane users on Broadway Ave in Portland, OR, and found that 71 percent of the cyclists surveyed felt that the separated bike lane made bicycling safer and easier. Goodno, et al. also surveyed separated bike lane users and found that bicyclists feel safer riding on the separated bike lane, while pedestrian perceptions are more mixed.

Other studies of user perceptions of separated bike lane safety were not reviewed as part of this literature review; instead, this review focuses on studies of observed safety impacts. However, bicyclist perceptions of safety may be observed in their behavior while using separated bike lanes.

Operational impacts of separated bike lanes on auto and bicycle travel

Finally, this literature review does not attempt to explore operational characteristics of vehicles and bicycles in areas with separated bike lanes, with regards to intersections, delay for travelers, queuing for bikes or cars, or traffic signal progression. However, operational issues may have implications for jurisdictions seeking to balance auto- and bicycle-mobility in time- and space-constrained environments. At least four of the papers in this initial review included some assessment of the operational characteristics of separated bike lanes. Monsere, et al. found a relatively low red signal compliance of cyclists using the separated bike lane (44 percent stopped). However, this study noted that this low compliance is more likely due to a lack of conflicting auto traffic, rather than the separated bike lane, given that compliance was at 41 percent prior to installation of the separated bike lane. Monsere, et al. found no significant impacts on auto operations – intersections operated with 2 to 7 seconds of delay per vehicle on average after installation of the separated bike lane.

Goodno, et al. evaluated the operations of the separated bike lane routes in Washington D.C. using methods outlined by the Danish LOS, Bicycle Environmental Quality Index, and Highway Capacity Manual methods. Their analysis found that motor vehicle and pedestrian levels of service (per the HCM 2000 Urban Streets and 2010 MMLoS methodologies, respectively) remained nearly constant, and bicycle levels of service improved (using the Danish LOS and BEQI methods, because the HCM methodology does not evaluate separated bike lanes). The authors found that cyclists on the separated bike lanes experienced a significant delay when traveling in the non-dominant direction, noting that signal progression had not been adjusted for cyclist progression, but was still timed for the dominant auto movements. Goodno, et. al. also noted other operational issues arising from their survey, such as higher delays for left turning vehicles (crossing the separated bike lane) into alleys and potential conflicts with pedestrians in the crosswalk.

Two other papers, while not directly addressing separated bike lanes, raised operational issues that are relevant in considering separated bike lane operations and design. Cherry, et al. (2012) used micro-simulation to examine the impacts on auto delay and queuing of different signal timing and geometric configurations of existing intersections with bike lanes. While they selected interventions that would decrease conflicts at the intersections, some interventions (such as right turn lanes for autos) did not

remove the conflicts, but rather displaced them. Wolfe, et al. (2006) examined the impacts of a bicycle scramble signal in Portland, and found that illegal bicyclist crossing movements decreased substantially (from 72 percent to four percent) with the introduction of the scramble signal.

The literature reviewed on these topics did not provide a broad enough survey to support strong conclusions, but are included to provide additional context to the safety and design guide reviews.

Review of Current State of Practice

In early 2013, the Institute of Transportation Engineers (ITE) published an informational report on separated bike lanes (called separated bikeways in the ITE report) in the United States and Canada. This report examines the current state-of-the-practice in for separated bike lanes through an extensive literature review focused on research studies and design guidance in North America and Europe. The report also includes case studies of applications in nine North American cities.

The ITE report arrives at similar conclusions to the literature review for this study regarding the need for additional data and research to inform design decisions. In particular, the report highlights six areas where specific research is needed. These areas are 1) appropriate locations for separated bike lanes, 2) types of buffers to delineate separated bike lanes, 3) operational and design features for intersection safety, 4) appropriate signing and marking, 5) specifics on traffic controls, and 6) factors road user behaviors and mode share shifts.

The literature review for this study builds on the findings of the ITE report to further demonstrate the need for additional separated bike lane planning and design information based on safety research and practical applications.

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Appendix 1

Literature Review Summaries

Title *Guide for the Development of Bicycle Facilities*
 Author AASHTO
 Year 2012

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
 Case Study Design Guide International

Separated bike lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

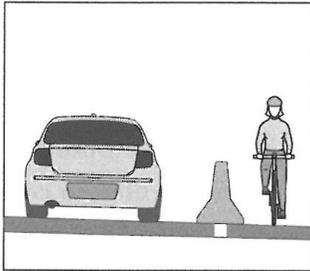
Summary

The AASHTO Guide for the Development of Bicycle Facilities provides information on sidepaths, not specifically pertaining to separated bike lanes. Sidepaths are similar to two-way separated bike lanes and guidance is provided to minimize the number of driveways and intersections along sidepaths, which is similar to other preferred treatments of two-way separated bike lanes. A number of sidepath conflicts are cited:

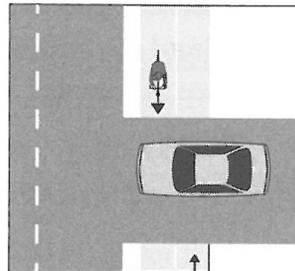
1. Motorists may not see the bicyclists in both directions when turning across the sidepath
2. Bicyclists crossing intersections at intersections may be at unexpected speeds (speeds faster than pedestrian speeds), which may increase crash frequency
3. Motorists waiting to enter roadway may block the sidepath crossing
4. Stopping the bicyclist at cross-street driveways are inappropriate and typically not effective
5. When sidepath ends, one direction of bicyclists will be going the wrong way
6. A sidepath may need additional road crossings
7. Signs posted for roadway users are backwards for contra-flow riders
8. Barriers are sometimes needed to keep roadway traffic from conflicting with sidepath cyclists, which may obstruct view of each other
9. Sidepath is sometimes constrained by fixed objects
10. Some bicyclists will use the roadway instead of the sidepath because of operational issues described. Furthermore, some states prohibit bicyclists using roadway when sidepath is present
11. Bicyclists can only make a pedestrian-style left, which will increase crossing delay
12. Bicyclists may not be in the view of drivers turning left or ride from adjacent roadway/driveway
13. Bicycle-motor vehicle crashes may still occur at sidepath crossing locations
14. Signs and markings have not been shown to be effective at changing road or path behavior at sidepath intersections

“For these reasons, other types of bikeways may be better suited to accommodate bicycle traffic along some roadways”

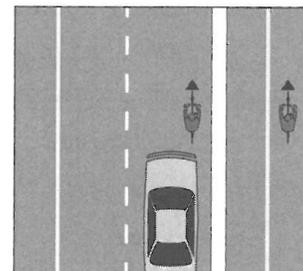
Exhibits illustrating sidepath conflicts:



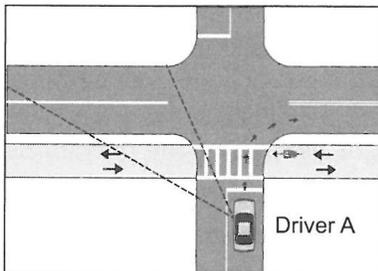
Barriers, while needed in tight spaces, can narrow both roadway and path, and create hazards.



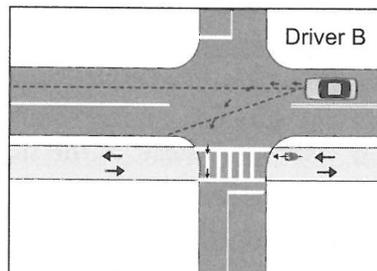
Stopped motor vehicles on side streets or driveways may block the path.



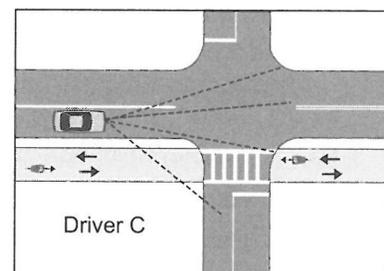
Some bicyclists may find the road cleaner, safer, and more convenient. Motorists may believe bicyclists should use a sidepath.



Right turning Driver A is looking for traffic on the left. A contraflow bicyclist is not in the driver's main field of vision.



Left turning Driver B is looking for traffic ahead. A contraflow bicyclist is not in the driver's main field of vision.



Right turning Driver C is looking for left turning traffic on the main road and traffic on the minor road. A bicyclist riding with traffic is not in the driver's main field of vision.

The AASHTO guide provides many sidepaths considerations which cite safety, operations, and legal concerns. However, the guidelines to utilize sidepaths do not discuss safety improvements for the bicyclist because of the sidepath.

There is some guidance on the minimum recommended distance between the sidepath and the roadway (5 feet). If there is not enough space, then a barrier should be provided between the roadway and sidepath.

On highways, crashworthy barriers should be provided if separation is not greater than 5 feet.

Comments

Some of the number design considerations have been confronted in the European separated bike lane design guides.

Also, the section on sidepaths is generally negative and does not recommend sidepaths.

Rating (quality of research, relevance) Medium

Title *Traffic safety on bicycle paths – results from a new large scale Danish study*

Author Agerholm, Niels, Sofie Caspersen, and Harry Lahrmann

Year 2008

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

Danish researchers conducted a safety study for one-way raised separated bike lanes in “built-up” areas of Denmark, not including Copenhagen, constructed between 1989 and 2000. The before-and-after study looked at crash frequency for vulnerable road users (including mopeds) on facilities with separated bicycle paths (defined as one-way paths next to the traffic lane, in the same direction as the traffic lane, and separated by a curb and elevated by 2.7 to 4.7 in). Crash performance was evaluated with a comparison group.

Bicycle paths selected for this study were limited to those on larger roads in built-up areas with bicycle paths on both sides of the street.

The researchers found that implementing bicycle paths resulted in a statistically insignificant increase in the number of injury accidents (14 percent) overall, but a significant increase (34 percent) in injury accidents at intersections. The effect was worst for moped riders, with a similar but lower trend for bicyclists and pedestrians.

Comments

Study includes mopeds. Crash data were not controlled for exposure (change in bicycle volume).

Rating (quality of research, relevance) Medium Failure to account for changes in bicycle volume may discredit findings; questionable research methods

Title *Bicycle Facilities Design Course Manual*

Author British Columbia Recreation and Parks Association (BCRPA) and British Columbia Ministry of Transportation and Infrastructure (BC MOT)

Year 2011

Research Type

- | | | |
|--|--|---|
| <input type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input checked="" type="checkbox"/> Case Study (secondary) | <input checked="" type="checkbox"/> Design Guide (primary) | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|--|---|---|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input checked="" type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|--|--|---|---|

Summary

The manual was designed for a one-day course for design professionals around issues involving the design and implementation of cycling infrastructure. It also serves as a reference guide. The manual defines separated bike lanes as physically separated from motor vehicle travel lanes but located within the road right-of-way.

User outcomes: Separated bike lanes have been found to be the most preferred type of on-street facility and combine benefits of increased comfort offered by off-street pathways with benefits of route directness provided by on-street facilities. Separated bike lanes can increase bicycle ridership by 18 to 20 percent, compared with a 5 to 7 percent increase from bicycle lanes, according to Danish research.

Separated bike lane design issues: Motorists may not see cyclists when they are not directly alongside motor vehicles (increasing cyclist vulnerability at intersections); conflicts with pedestrians can occur, especially on separated bike lanes that are less well-differentiated from the sidewalk or are located between a sidewalk and a transit stop; regular street sweeping or snow removal trucks cannot navigate the narrow roadway of many separated bike lanes. Separated bike lanes are not recommended on streets with many major and closely spaced intersections. Separated bike lanes should only be installed where there is adequate right-of-way; sidewalks should not be narrowed to a point where pedestrians will be likely to walk in the separated bike lane.

Separation from motor vehicle travel lanes can be achieved through parking placement, channelization, elevation from roadway, and/or bollards/delineators. A separated bike lane between the parking lane and sidewalk can be at street level or elevated and should have drainage inlets to handle run-off. In addition to physical medians, channelization can be achieved through the use of planters or bicycle parking. Elevated separated bike lanes should be two to three inches above street-level with a hard curb, and the sidewalk should be an additional two to three inches above the separated bike lane. Signage, pavement markings, and pavement colors / textures should be used to indicate the separated bike lane's role for bicycle use. Signage, in addition to bollards, can also add to physical separation elements.

Widths: One-way separated bike lanes should typically be 6.5 feet wide but may be as narrow as 5 feet in certain places. High demand separated bike lanes can be as wide as 10 feet. Two-way separated bike lanes should range from eight feet to 13 feet wide, depending on bicycle volumes. The separated bike lane's buffer should range from two feet (fence) to 3.5 feet (physical barriers or lamp posts) to 7.5 feet (vegetation) in built-up areas. A two-way separated bike lane should have a minimum buffer width of 3.5 feet.

One-way vs. two-way: Most separated bike lanes are one-way; two-way separated bike lanes increase complications at intersections, where turning vehicles and bicyclists cross paths. Two-way separated bike lanes are appropriate on a street without intersections or without access on one side and on one-way streets (or two-way streets where left turns are prohibited) with limited intersections or driveways (ideally less than one every 300 meters). Two-way separated bike lanes should allow for a variety of turning movements at intersections through a separated signal for bicycles and motor vehicles.

Transit: Separated bike lanes should not be located along major transit routes; where bus stops are present there should be adequate room in the buffer area so disembarking passengers do not walk directly into the separated bike lane. Cyclists should be instructed through signage or markings to yield to disembarking passengers. Pedestrians should be provided adequate visibility to safely cross the separated bike lane.

Intersections: Most intersection conflicts occur when a right-turning vehicle crosses a separated bike lane. Protected or advanced signal phases with dedicated bicyclist signals can reduce conflicts at high-volume intersections. Removing on-street parking prior to an intersection can raise visibility and awareness of cyclists. Restricting access or certain turning movements to reduce the potential number of conflict points can increase safety at intersections. At intersections where many cyclists turn right, a separate right-turn lane within the separated bike lane should be provided. Motor vehicles must be prohibited from turning right on red when cyclists continuing straight through an intersection have a separate signal phase. Cyclists making left turns off a separated bike lane should be encouraged through on-street markings to make a "Copenhagen Left" or two-stage maneuver.

Implementation: Installing separated bike lanes can be challenging on existing roads and may require the removal of on-street parking and/or a motor vehicle travel lane. Separated bike lanes provide significant cost savings benefits in terms of increased ridership and crash reduction if properly designed. However, the cost of installation is higher than bicycle lanes or shared lanes, and can be highly variable based on existing conditions and design.

Comments

Clear guide that describes many relevant issues related to separated bike lanes. Design guidance is simple to read and lacks significant technical depth, but would be highly useful for urban planners and designers seeking to inform themselves on major separated bike lane issues. The manual also covers other bikeway types and provides an excellent introduction / context chapter on cycling. [Note –metric widths were converted to their approximate feet equivalents in this memo]

Rating (quality of research, relevance) High

Title *Pedestrian and Bicyclist Intersection Safety Indices: Final report*

Author Carter, D.L., Hunter, W.W., Zegeer, C.V., Stewart, J.R. and Huang, H.F.

Year 2006

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

The primary objective of this study was to develop safety indices to allow engineers, planners, and other practitioners to proactively prioritize intersection crosswalks and intersection approaches with respect to pedestrian and bicycle safety. The study involved collecting data on pedestrian and bicycle crashes, conflicts, avoidance maneuvers, and subjective ratings of intersection video clips by pedestrian and bicycle experts. There were a total of 68 intersection crosswalks selected for the pedestrian analysis from the cities of Philadelphia, PA; San Jose, CA; and Miami-Dade County, FL. The bicycle analysis included 67 intersection approaches from Gainesville, FL; Philadelphia, PA; and Portland and Eugene, OR. Prioritization models were developed based on expert safety ratings and behavioral data. Indicative variables included in the pedestrian safety index model included type of intersection control (signal or stop sign), number of through lanes, 85th percentile vehicle speed, main street traffic volume, and area type. Indicative variables in the bicycle safety models (for through, right-turn, and left-turn bike movements) included various combinations of: presence of bicycle lane, main and cross street traffic volumes, number of through lanes, presence of on-street parking, main street speed limit, presence of traffic signal, number of turn lanes, and others. Practitioners will be able to use the safety indices to identify which crosswalks and intersection approaches have the highest priority for in-depth pedestrian and bicycle safety evaluations and subsequently use other tools to identify and address potential safety problems.

Comments

The research models did not include separated bike lanes.

Rating (quality of research, relevance) High The relevance to the current study would be the data gathering methods using video clips.

Title *Design Manual for Bicycle Traffic*
Author *CROW*
Year Dutch version in 2006, English in 2007

Research Type

Safety Study Ridership/Operations/Perceptions Study Design Guide

Separated Bike Lanes Considered

Buffered, Street-Level Raised One-Way Two-Way

Summary

The research organization named CROW published a design guide to plan, design, and maintain bicycle facilities for Dutch jurisdictions. The manual is comprehensive and even delves into anecdotes of cyclist comfort such as avoiding placing bicycle routes on hilly terrains. However, the Dutch have not performed empirical safety studies of their own separated bike lanes for safety at about the time of wide-spread separated bike lane constructions in the 1980s due to seeing relatively high increases of ridership from because of wide-spread construction during the 1980s. In any case, there is valuable guidance on separated bike lanes contained in this manual.

The manual outlines principles of safety in three main categories and comfort in five:

Separate Vehicle Types – when speeds differ considerably, modes should be separated completely. When speed differences in traffic aren't too great, then separation isn't essential, however separation will result in better comfort and subject safety which is an important for bicycle friendly facilities.

Reduce Speed at conflict points – when serious conflicts at intersections occur the speed of motorists should be reduced to the speed of cyclists.

Avoid cyclists being forced off the road – The road surface should be smooth devoid of obstacles such as grates so maneuvers may be made.

Prevent lost time – Bicycles should not be forced to cycle at speeds below the design speed

Avoid turns – Turns will confuse riders and create a less attractive route

Maintain a smooth road surface – This include transitions

Minimize inclines – Routes which go on steep hills should be avoided because they'll detract from rider comfort

Minimize weather nuisance – In some cases trees may be planted to shelter bicyclists from high wind areas or storms

Urban Areas:

Table 14. Option diagram for road sections inside the built-up area

Road category	Max. speed of motorised traffic (km/h)	Motorised traffic intensity (pcu/day)	Cycle network category		
			basic network ($I_{\text{bicycle}} > \text{work } 750/\text{day}$)	cycle route ($I_{\text{bicycle}} 500-2500/\text{day}$)	main cycle route ($I_{\text{bicycle}} > 2000/\text{day}$)
Estate access road	n/a	0	solitary track		
	walking pace or 30 km/h	1 - 2.500	combined traffic		cycle street or cycle lane (with right of way)
		2.000 - 5.000	cycle lane or cycle track		
District access road	50 km/h	irrelevant	cycle track or parallel road		
			2x1 lanes	cycle track, moped/cycle track or parallel road	
	70 km/h	2x2 lanes			

Rural Areas:

Table 16. Option diagram for road sections outside the built-up area

Function	Speed (km/h)	Intensity (pcu/day)	Bicycle traffic road section function	
			basis network	(main)cycle route ($I_{\text{cycle}} > 2,000/\text{day}$)
Motorised traffic road section function	Estate access road	60	combined traffic	cycle street, if $I_{\text{pcu}} < 500 \text{ pcu/day}^1$
			cycle lane or cycle track	cycle track, or perhaps lanes
		> 3000	cycle track	
District access road	80	irrelevant	cycle/moped track parallel road	

¹ Plus any additional requirements in the area of safety

In other words:

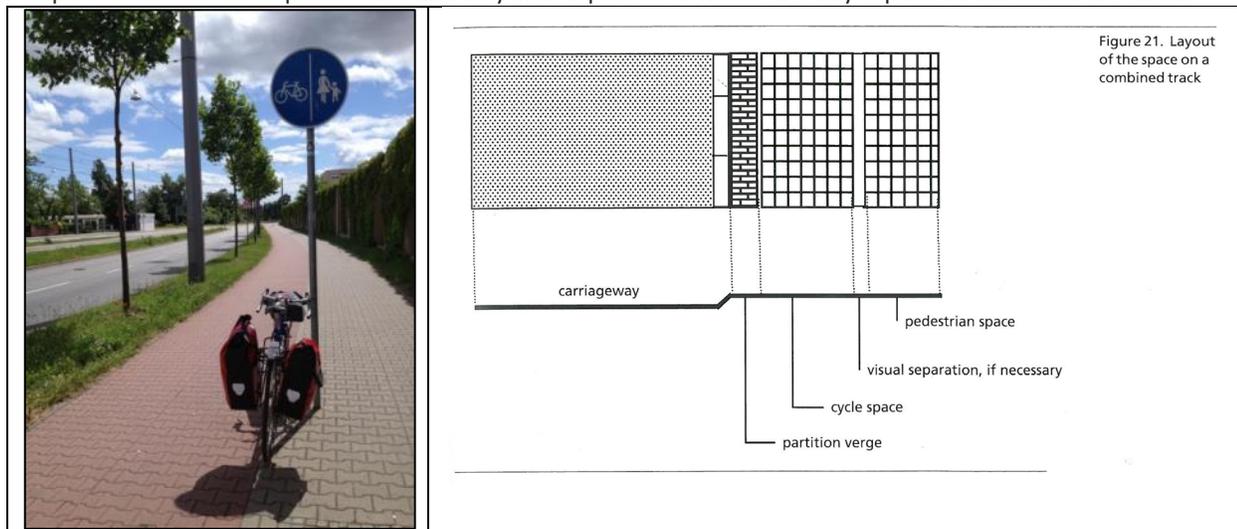
- In urban areas, a separated bike lane is preferred over 4,000 ADT and/or when vehicle speeds reach 30 mph.
- In rural areas, a separated bike lane is preferred over 3,000 ADDT and/or when speeds reach 35 mph. When vehicle speeds reach 50 mph a separated bike lane is recommended irrelevant of traffic volumes.

There is also guidance on how wide to size separated bike lanes based on bicyclist volume:

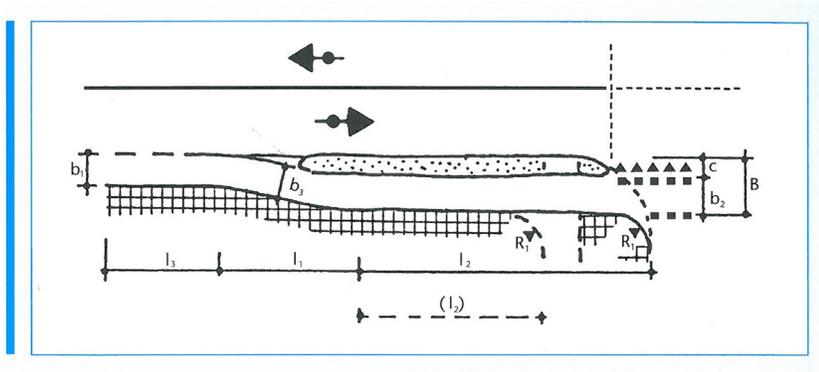
One Way Separated Bike Lane		Two-Way Separated Bike Lane	
Rush Hour Intensities (one direction), bicycles/hour	Width (Feet)	Rush Hour Intensities (two directions), bicycles/hour	Width (Feet)
0-150	6.5	0-50	8.2
150-750	9.8, (8.2 of path)	50-150	8.2-9.8
>750	13 (11.5 of path)	>150	11.5-13

In addition to the separated bike lanes themselves, there is guidance on what kind of intersection treatment to use based on volume.

A separate delineation of pedestrians and bicyclists is preferred when two way separated bike lanes are used.



Example diagram of separated bike lane approach to an intersection:



		Rural Areas			
Hourly Vehicle Volumes		< 500		> 450	
Urban Areas		No Cycle Route	Cycle Route	Main Cycle Route	All Situations
	< 1,000	Built up intersection	Built up intersection with supplementary measures	Built up intersection with supplementary measures or roundabout	Roundabout
	800-1,500	Built up intersection with supplementary measures			
	1,200-1,750	Built up intersection with Supplementary Measures, with Traffic Signal or grade separated intersection			
	> 1,500	Traffic Signal or grade-separated (only for main cycle routes where appropriate)			Roundabout, traffic signal, or grade separated

Guidance is provided for how to deal with separated bike lanes at intersections:

- When speeds exceed 35 mph, bending the separated bike lane toward the vehicle traffic is not recommended. In this case, separated bike lanes should be situated 15 to 25 feet away from the roadway so vehicles can queue between the roadway and the separated bike lane when performing right turns
- Inside the built up areas a 15-25 foot bend out may not be possible, therefore the separated bike lane should be bent out 6.5 to 8 feet away from the roadway.

The manual then discusses various operational guidance for how to design traffic signals, how to create queuing areas for cyclists, and what preferred maintenance practices to provide consistent cycling environments are.

Construction:

- A red asphalt color for a separated bike lane color is preferred
- If a curb is used to separate the roadway and separated bike lane, it should be 2 inches high. If the curb is 3 inches high, then a sloping profile should be used to avoid a bicycle pedal striking the curb.

Description	Narrow paved separation of cycle track and main carriageway
Function	physical separation of motorised and bicycle traffic
Application	<ul style="list-style-type: none"> on separate cycle track inside the built-up area if insufficient room for partition verge
Implementation	<ul style="list-style-type: none"> ((1), (2), (3) and (4) for cycle track with element paving (5) and (6) with continuous asphalt paving interruption of paving for drainage interruption at side roads and exits kerbs or edge may be painted white or black and white
Dimensions	<ul style="list-style-type: none"> width varies $h_1 \leq 0.10$ to 0.12 m $h_2 = 0.05$ (0.07) m; if 0.07 m, choose a profile that prevents pedals striking the separation
Considerations	<ul style="list-style-type: none"> separation of motor vehicles and bicycles is safe on narrow profiles, separate cycle track is still possible limited crossing options for cyclists (only at side roads, exits and gaps in the partition verge) incorrect dimensioning causes dangerous edge for cyclists motorised traffic may cross
Combination options	combined track (soft separation between cycle track and pavement)

Comments

Some select measurements have been converted to US customary units from metric units for the purposes of this review.

Rating (quality of research, relevance) High

Analysing and Managing the Cyclist-Driver Interface using "Conflict Path Analysis"

Title

Author B. Cumming

Year 2012

Research Type

- | | | |
|--|---|---|
| <input checked="" type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input type="checkbox"/> Case Study | <input type="checkbox"/> Design Guide | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|---------------------------------|----------------------------------|----------------------------------|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input type="checkbox"/> Raised | <input type="checkbox"/> One-Way | <input type="checkbox"/> Two-Way |
|--|---------------------------------|----------------------------------|----------------------------------|

Summary

This study analyzes four types of roadway conflict scenarios where there is a particularly high crash risk for bicyclists. Each type of conflict is analyzed using conflict path analysis, which considers the actual path of a bicyclist and the relative location of the bicyclist to surrounding automobiles. Certain paths may cause a bicyclist to be less visible and less predictable to drivers. Results show that left-turn side-swipes can be reduced by encouraging left-turning vehicles to move to the left edge of the road before turning left. The risk of a car door opening into a cyclist or forcing a cyclist into moving traffic can be reduced by painted buffer areas between parked cars and bicycle lanes (i.e., buffered bicycle lanes). Roundabout crashes can be reduced by placing bicycle marking symbols in the center of the roundabout lanes so that bicyclists are encouraged to position themselves centrally. Most relevant to separated bike lane safety is the use of this analysis technique to address “keep clear” area crashes. This is the area where on-street parking is prohibited near a driveway or intersection perpendicular to a parking-separated separated bike lane. Separated bike lane intersection or driveway crashes can be reduced by extending intersection clear areas further upstream (increasing sight lines between drivers and bicyclists).

Comments

It appears that conflict path analysis could be promising for analyzing bicycle crashes associated with separated bike lane facilities, especially at intersections and driveways. However, this study focuses on the conflict method rather than evaluating the safety of specific bicycle facility or roadway designs.

Rating (quality of research, relevance) Medium

Title *Collection of Cycle Concepts*

Author Cycling Embassy of Denmark

Year 2012

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

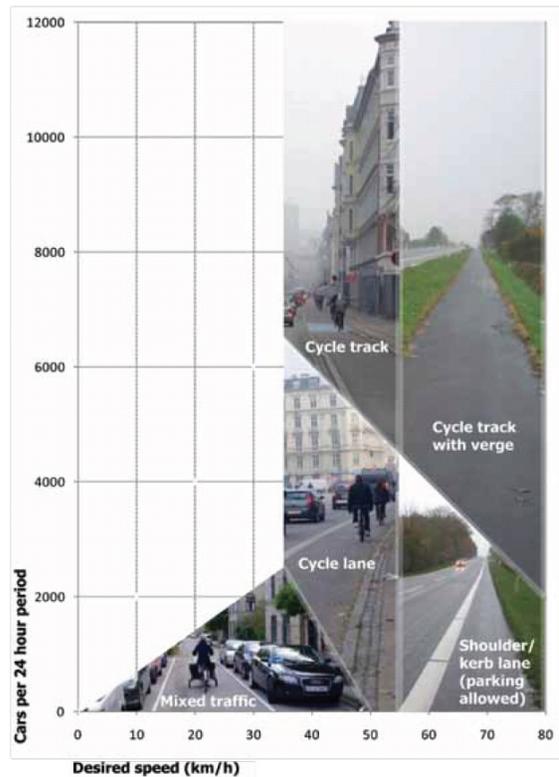
Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

The Collection of Cycle Concepts is the second edition design guide for bicycling in Denmark. There is extensive information in bicycling planning and behavioral studies about what bicyclists like or dislike about facility types. Furthermore, there are cost estimates of a range of facilities. The design guide cites numerous studies about the perceived and actual safety of separated bike lanes. Here are some key findings:

Volume/Posted Speed Thresholds



On major arterials, one way separated bike lanes on both sides of the street is the preferred solution

When a separated bike lane was installed in Copenhagen, bicycle traffic increased 20% and auto traffic dropped by 10%

Cargo bikes cannot pass each other on a 8.2 feet (2.5m) two-way separated bike lane

9 of 15 bicyclists experience conflicts in mixed traffic where 5 of 15 bicyclists experience conflicts on separated bike lanes

When cars pass bicyclists by 20-30 mph, separated bike lanes are favored

Separated bike lanes contributed to a 1-3 mph speed reduction for automobiles and a 1mph speed reduction for bicyclists

The bicyclists perceived comfort for separated bike lanes is significantly higher as compared with bike lanes

The crash rate of urban separated bike lanes greatly depends on the traffic volumes. A Copenhagen study showed that separated bike lanes increase the total number of crashes by 10%, but that this covers a drop in road section crashes and an increase in intersection crashes

Construction:

- Curb height of separated bike lane to roadway should be 2.75 - 4.75 inches
- Curb height of separated bike lane to sidewalk should be 2 – 3.5 inches
- The American pedal clearance is typically 3 inches, where it's 4.25 inches for a Dutch style bike
- The separated bike lane should be set back by 16.5 – 23 feet at a driveway or intersection when there is dense cross traffic

When setting back the stop bar back has shown a 35 percent crash reduction with cars turning right and bikes moving straight and 50 percent reduction of bike fatalities'

In fatal right hook crashes 90 percent of the time the vehicle is a truck

Comments

None

Rating (quality of research, relevance) High

Evaluation of Innovative Bicycle Facilities in Washington, DC: Pennsylvania

Title *Avenue Median Lanes and 15th Street Cycle Track*

Author Goodno, Mike, Nathan McNeil, Jamie Parks, and Stephanie Trainor

Year 2013

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
- Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

The Washington, DC Department of Transportation (DDOT) evaluated the effectiveness of two separated bike lane installations in the District: Pennsylvania Avenue and 15th Street NW. Data were collected before and after installation of the bicycle facilities, including bicycle and motor vehicle counts, crash data, video observations, and intercept surveys. Each facility was evaluated for facility use, “efficient operations,” convenience, safety, and comfort. Several level-of-service analyses were employed to understand efficient operations: Danish Bicycle Level of Service and the Bicycle Environmental Quality Index (BEQI). The HCM’s Multimodal Level of Service does not include methods for evaluating separated bike lanes, and was not used for this investigation.

Both separated bike lanes are at street level and separated by a buffer. Pennsylvania Avenue is a center median-running two-way separated bike lane with Zebra bumps. 15th Street NW is a two-way separated bike lane on a one-way street, protected with flex-post bollards and on-street parking. Bicycle signals are provided for the southbound (contraflow) bicyclists.

The researchers found increased bicycle volumes (nearly quadrupled), level of service (mostly A or B), and comfort (overwhelmingly favor separated bike lane facilities). The safety results were inconclusive given the limited sample of data, but bicycle crashes increased following installation of the facilities. Convenience, as measured by signal progression, was mixed, with contraflow bicycles on 15th Street NW experiencing low travel time performance. The effects of these facilities on motorists and pedestrians were also evaluated, and were found to be neutral or positive.

Comments

Robust research method, but lacking conclusive safety findings. Includes good detail of design of two Washington, DC separated bike lanes.

Rating (quality of research, relevance) High

Title *Comparing the Effects of Infrastructure on Bicycling Injury at Intersections and Non-intersections using a Case–crossover Design*

Author M. Anne Harris, Conor C.O. Reynolds, Meghan Winters, Peter A. Crompton, Hui Shen, Mary L. Chipman, Michael D. Cusimano, Shelina Babul, Jeffrey R. Brubacher, Steven M. Friedman, Garth Hunte, Melody Monroe, Lee Vernich, and Kay Teschke

Year 2013

Research Type

- Safety Study
- Case Study
- Operations Study
- Design Guide
- Perceptions Study (Survey)
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

This study, conducted in Vancouver and Toronto, compared the bicycle facilities (and roadway design, as it relates to bicycling) at locations where bicyclists were injured versus the bicycle facilities at other, randomly-selected control sites on their bicycling route. Study participants included 690 bicyclists aged 19 and over who had been treated in hospital emergency rooms. A total of 210 intersection injury sites were compared to 272 intersection control sites. In addition, a total of 478 non-intersection (roadway segment) injury sites were compared to 801 non-intersection control sites. Intersections of two major (multi-lane) streets had five times the risk of intersections of two minor (two-lane) streets. Slower-speed streets had lower risk, but traffic circles were actually associated with higher risk at intersections of minor streets. For non-intersection locations, separated bike lanes (separated by a barrier from traffic) along major streets were found to be safer than major streets with no bicycle infrastructure. Local streets with traffic diverters (e.g., bicycle boulevards) were revealed as the safest non-intersection facilities. Steep grades were associated with higher risk at both intersection and non-intersection locations.

Comments

This study included only 2 injury locations and 17 control locations for separated bike lane facilities.

The researchers did not analyze one-way versus two-way separated bike lanes, although it is likely that both were included, given the facilities available in Vancouver and Toronto.

The case-crossover study design compares the location where a crash (and injury) occurred with other locations on a bicyclist’s route where the crash could have occurred but did not. This technique gets around the problem of collecting accurate exposure data at different locations. Using a single individual for analysis of different types of locations also controls for personal factors, such as age, gender, and bicycling experience, as well as weather, safety equipment, and other contextual factors.

Rating (quality of research, relevance) High

Title *Commuting by Bicycle: An Overview of the Literature*

Author Evan Heinen, Bert Van Wee, and Kees Maat

Year 2010

Research Type

- | | | |
|--|---|---|
| <input type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input checked="" type="checkbox"/> Case Study | <input type="checkbox"/> Design Guide | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|---|---------------------------------|----------------------------------|----------------------------------|
| <input type="checkbox"/> Buffered, Street-Level | <input type="checkbox"/> Raised | <input type="checkbox"/> One-Way | <input type="checkbox"/> Two-Way |
|---|---------------------------------|----------------------------------|----------------------------------|

Summary

This paper provides an overview of the different determinants for bicycle commuting through a review of the existing literature. They categorized determinants into one of five groups:

1. The built environment
2. The natural environment
3. Socio-economic variables
4. Psychological factors
5. Cost, time, effort, and safety

In terms of the built environment, authors noted that various studies have revealed that the type of infrastructure present for bicycles does impact the number of people cycling and the type of cyclists – women and younger people prefer dedicated facilities. Authors also noted that countries with a higher level of separated facilities also have a higher mode share of cyclist and higher levels of safety.

The authors noted that objective and subjective safety should not be confused – while studies still dispute the objective safety of certain types of bicycle infrastructure, the subjective safety levels are higher on dedicated bicycle facilities. The authors also cited a number of studies finding that more bicycle paths results in higher cycling mode shares and found that cyclists tend to have a negative perception of traffic control (including signals and stop signs), but that they did not find a clear effect of traffic control on mode choice.

Comments

This is a comprehensive literature review spanning broader topics than concern the FHWA study. However, there are some citations potentially worth exploring further related to infrastructure and mode share.

Rating (quality of research, relevance)	Medium	Thorough lit review encompassing a wide variety of potential determinants of cycling.
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Title *Road Safety and Perceived Risk of Cycle Facilities in Copenhagen*

Author Soren Underliien Jensen, Trafitec, Claus Rosenkilde, City of Copenhagen, Niels Jensen, City of Copenhagen

Year 2007

Research Type

- | | | |
|--|---|--|
| <input checked="" type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input checked="" type="checkbox"/> Perceptions Study (Survey) |
| <input type="checkbox"/> Case Study | <input type="checkbox"/> Design Guide | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|--|---|---|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input checked="" type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|--|--|---|---|

Summary

This paper summarizes three different studies, looking at the effects of separated bike lanes and cycle lanes; effects of raised exits and colored lanes through intersections; and cyclist's perception of bicycle facilities. The study found that the construction of separated bike lanes led to an overall increase in crashes of nine to 10 percent. Midblock crashes decreased, however, and intersection crashes rose more quickly. In terms of specific types of crashes, statistically significant decreases were found in the following:

- Cars hitting cyclists from behind
- Cyclists turning left
- Cyclists hitting parked cars

The following types of crashes increased:

- Bike on bike crashes
- Crashes with cars turning right
- Crashes with cars turning left
- Crashes between bikes and bus riders boarding and alighting

The prohibition of parking was seen to cause a greater increase in crashes, as the policy led to an increase in turns in order to find parking on side streets.

The construction of cycle lanes did not result in a statistically significant change in overall crashes or injuries. However, there was an increase of crashes involving cars turning right.

Separated bike lanes led to an increase in bicycle and moped traffic of 18-20% and a decrease in vehicle traffic of 9-10%. Cycle lanes led to an increase of 5-7% of bicycle and moped traffic.

Cyclists were the most comfortable on separated bike lanes, followed by cycle lanes, and least comfortable in mixed traffic.

The study found that the safety varied among the separated bike lanes and the level of safety could be tied to certain characteristics:

- Avoid reducing possibilities for parking
- Avoid entry lanes without turn lanes at signalized intersections
- Create one blue crossing at signalized intersections
- Continue separated bike lanes on a raised crossing at non-signalized intersections

Comments

Separated bike lanes and cycle lanes were not defined in this paper, but it should be noted that the photo provided as an example of a cycle lane shows a bike lane between parked cars and the curb.

Rating (quality of research, relevance) High

Title *Bicycle Tracks and lanes: A before-after study*

Author Søren Underlien Jensen

Year 2008

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

In this before/after study, Jensen examined crash, injury, and traffic data for separated bike lanes and marked bike lanes in Copenhagen. The 12.8 miles of one-way separated bike lanes studied were constructed in 1978 through 2003. The 3.5 miles of one-way bike lanes were marked in 1988 through 2002. This observational study used a stepwise regression methodology. Correction factors for changes in traffic volumes and crash/injury trends were developed using a general comparison group (as opposed to a matched comparison group, like the one in Chen et al 2011). The length of time of before and after periods analyzed was the same for individual segments; it ranged from one to five years.

This study revealed increases in most types of crashes and injuries on roadway segments and at intersections with bicycle lanes; however, none of these increases were statistically significant at the 5 percent level.

Comments

This study groups moped riders and bicyclists together in crash, injury, and volume data.

Rating (quality of research, relevance) Medium This study benefits from the availability of volume data, but Chen et al (2011) is a higher-quality example of a before/after study since it accounts for built environment factors and uses more rigorous statistical techniques.

The tables and narrative in Jensen (2008) are often hard to follow.

Title *Sidepath Facility Selection and Design*

Author Landis, B. Petritsch, T., Huang, H., McLeod, P., and Challa, S.

Year 2005

Research Type

- Safety Study
 Operations Study
 Perceptions Study (Survey)
- Case Study
 Design Guide
 International

Separated Bike Lanes Considered

- Buffered, Street-Level
 Raised
 One-Way
 Two-Way

Summary

Some bicyclists prefer to ride on facilities separated from the roadway. In this study a methodology was developed to determine if a sidepath would be an appropriate facility and included design, operational considerations, and safety. A seven-step procedure included the following factors: bicycle level of service on adjacent roadway, a determination of whether a sidepath would be a safe alternative, a determination of whether parallel roadways would offer an alternative route, availability of right-of-way for a sidepath, access provided to likely destinations by the sidepath, sidepath length and termini, level of service of the proposed sidepath. The FDOT's model for bicycle level of service on a roadway was modified to develop a model for a sidepath. Analysis of twenty-one roadway sections in Florida was done to compare on-street versus sidepath crash rates for bicycle-motor vehicle crashes.

Comments

Separated bike lanes were not a part of the research.

Rating (quality of research, relevance) High

Title *Cycling Safety Update (2007-2009)*

Author Transportation Research Laboratory (United Kingdom)

Year 2010

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
 Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

This summary is provided by the Independent Transportation Research laboratory based in the United Kingdom which outlines various bicycle safety studies performed from 2007 to 2009. This review covers some of those studies which are relevant to separated bike lanes.

The Safety Effects of Blue Cycle Crossings: A Before-After Study by Jensen has been cited in other separated bike lane works. This paper discusses the effectiveness of blue pavement through intersections to reduce crashes. One blue crossing was found to have a 10% reduction, and two and four blue crossings reduce crashes by 23% and 60%, respectively.

Another source called ‘Cycling for Everyone: Lessons from Europe’ by Pucher and Buehler was cited which is also part of the research team’s review. This paper incorporates country level statistics from countries with high cycling percentages of The Netherlands, Denmark and Germany and explains reasons behind their high cycling percentages.

Otherwise, this compendium of papers does not contain information about separated bike lanes and mostly focuses on helmet safety.

Comments

None

Rating (quality of research, relevance) Low

Title *Bicycle crash casualties in a highly motorized city*

Author Becky P.Y. Loo, K.L. Tsui

Year 2010

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

The paper examines bicycle collisions in Hong Kong, a “highly motorized” city where “cycling is often considered as a recreational activity.” The study focuses on where in the right-of-way did the crash happen and whether the cyclists were entering or exiting the bicycle facility. The authors examine how bicycle crashes are spatially dispersed in Hong Kong, what circumstances lead to bicycle crashes, and how injury patterns appear based on various characteristics of the cyclist and the environment in which the crash occurred.

Bicycle crashes have increased as a percentage of total traffic crashes in Hong Kong from 2.9% of all crashes in 1993 to 12.7% in 2004 (and 10.3% in 2007, the most recent year of data in the study). The relative number of bicycle crashes compared to their mode share of 0.85% of all trips is also very high (2001 data).

While only 8.2% of bicycle crashes occurred on separated bike lanes themselves, 38.6% occurred within 100 meters and 70.6% occurred within 500 meters of separated bike lane facilities. These latter two values are high relative to the shares of the total road network lying within 100 or 500 meters of separated bike lanes, which are 10.3% and 23.6% respectively. The authors speculate that these spatial findings can be attributed to difficulties in accessing separated bike lanes and navigating the many breaks between the bicycle network segments.

The mean age of all cyclists involved in crashes was 32; however, those that died from crash injuries had a mean age of 45. Those that died were also more likely to be cycling on public roads with traffic and thus appeared at highest frequencies in the “over 500 meters from a separated bike lane” parameter. The authors speculate these cyclists are likely using bicycles as a primary mode of transport, rather than recreationally on the separated bike lanes.

Although the risk of crashing within 500 meters of a separated bike lane is relatively high, the severity of resulting injuries is much lower. Crashes on or near separated bike lanes are less likely to cause severe injury than those far away from them. Cyclists are 2.4 times more likely to become disabled as a result of crashes that occur over 500 meters from any separated bike lane than crashes that occur on or within 500 meters of a separated bike lane.

Comments

Hong Kong’s “Cycle Tracks” under the authors’ study may not fit NACTO’s definition of separated bike lanes and are more analogous to AASHTO’s “sidepath” definition. Although the authors never explicitly define “separated bike lane,” they say that they are suited for recreational use and describe them as very much separate from the traditional road network. Research on Google Streetview confirms this. Nevertheless, the authors’ conclusions provide valuable information on the safety effects of protected bicycle facilities.

Rating (quality of research, relevance) Medium (quality of research is high; however relevance to separated bike lanes – as defined by NACTO – is low)

Title *Risk of injury for bicycling on separated bike lanes versus in the street*

Author Anne Lusk, et al

Year 2011

Research Type

- | | | |
|--|---|---|
| <input checked="" type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input checked="" type="checkbox"/> Case Study | <input type="checkbox"/> Design Guide | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|--|----------------------------------|---|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|--|--|----------------------------------|---|

Summary

Methodology: Authors studied six two-way separated bike lanes in Montreal. They selected reference streets considered alternative routes without cycling facilities to compare with the separated bike lane routes. They tried to select routes with similar characteristics and similar cross-streets; they also calculated the “relative traffic danger” of the reference streets by comparing the total motor-vehicle occupant (MVO) crash injuries with the MVO injuries on the separated bike lane streets. Authors considered this ratio a surrogate for traffic danger a bicyclist would face on a street without accounting for the bicycling facility.

Authors accessed crash data from police reports from 2002-2006 for the months of April-November and injury data from emergency medical response from 1999-2008 for the same months, and calculated average annual rates of each on the streets with separated bike lanes. They also collected this data for the reference routes.

Authors estimated bike-kilometers ridden based on automatic counter volumes at a point on each separated bike lane (multiplied volumes by a fraction of each separated bike lane’s length), and then calculated crashes per million bike-km. They did simultaneous two-hour counts at the separated bike lanes and reference routes in order to determine the relative exposure.

Finally, authors calculated the relative risk of injury while riding on the separated bike lanes compared to the reference routes, using the reported injuries and the bike volumes. They did *not* incorporate the relative traffic danger ratios into the calculation of relative risk.

Findings:

The authors concluded that two-way separated bike lanes have either lower or similar injury rates compared with bicycling on streets without bicycle facilities. According to their results, three of the six separated bike lanes had statistically significant comparisons, and each of these showed a decreased relative risk on the separated bike lane streets. Overall, they found a statistically significant lower relative risk. They did calculate higher relative risks on some of the separated bike lane streets but found that these were not statistically significant.

The authors also found that the relative vehicle traffic danger, in aggregate, between separated bike lane streets and reference streets was close to 1.0 (same traffic danger), but the relative traffic danger of each of the six study streets ranged from 0.09 (much less traffic danger than reference street) to 1.69 (more traffic danger than reference street).

Table 2 shows their relative risk results and table 3 shows the relative traffic danger calculations:

Table 2 RR of injury for cycle tracks compared to similar on-street routes for Montreal, Quebec*

Cycle track†	Reference street‡	Limiting cross streets	Length (km)	Cycle track		Reference street		RR (95% CI)¶
				2-h bike count	EMR-reported injuries§	2-h bike count	EMR-reported injuries§	
1. Brébeuf	St Denis (N)	Rachel – Laurier	1.0	1193	37	437	32	0.42 (0.26 to 0.6)
2. Rachel	Mont Royal	St Urbain – Marquette	3.5	990	120	613	63	1.18 (0.87 to 1.6)
3. Berri	St Denis (S)	Cherrier – Viger	1.4	763	74	134	27	0.48 (0.31 to 0.7)
4. Maisonneuve	Both	Claremont – Wood	1.9	547	18	176**	18	0.32 (0.17 to 0.6)
	Sherbrooke (W)					129	14	0.30
	Ste Catherine					47	4	0.39
5. Christophe Colomb	Both	Gouin – Jarry	3.7	407	64	122	19	1.01 (0.61 to 1.6)
	Saint-Hubert					45	9	0.79
	Christophe Colomb (S)	Villeray – Rosemont				77	10	1.21
6. René Levesque	Sherbrooke (E)	Lorimier – St Hubert	1.3	109	27	130	32	1.01 (0.60 to 1.6)
All			15.1	4009	340	1612	191	0.72 (0.60 to 0.8)

*Statistically significant comparisons are shown in bold.
 †All cycle tracks are two-way on one side of the street.
 ‡An on-street bike route on a parallel street in close proximity of the cycle track.
 §Injuries recorded by emergency medical response (EMR) services between 1 April 1999 and 31 July 2008 for the season 1 April to 15 November.
 ¶95%CI calculated using the variance of log(RR) based on a Poisson distribution.
 **For comparisons having two reference streets, the total number of bicyclists is used from both streets.

Table 3 Relative danger from vehicular traffic*

Cycle track street	Reference street	MVO injuries†		Relative traffic danger of cycle track street (95% CI)‡
		Cycle track street	Reference street	
1. Brébeuf	St Denis (N)	8	90	0.09 (0.04 to 0.18)
2. Rachel	Mont Royal	86	69	1.25 (0.91 to 1.73)
3. Berri	St Denis (S)	127	116	1.09 (0.85 to 1.41)
4. Maisonneuve	Both	13	59§	0.22 (0.12 to 0.40)
	Sherbrooke (W)		72	
	Ste Catherine		46	
5. Christophe Colomb	Both	367	217§	1.69 (1.43 to 2.00)
	Saint-Hubert		268	
	Christophe Colomb (S)		166	
6. René Levesque	Sherbrooke (E)	196	205	0.96 (0.79 to 1.16)
	All	797	756	1.05 (0.95 to 1.16)

*Statistically significant comparisons are shown in bold.
 †Injuries to motor vehicle occupants recorded by emergency medical response (EMR) services between 1 January 1999 and 31 July 2008.
 ‡95% CI calculated using the variance of log(RR) based on a Poisson distribution.
 §For comparisons having two reference streets, the average number of injuries of the reference streets is used.
 MVO, motor vehicle occupant.

Comments

The study does not attempt to evaluate different design characteristics of the separated bike lanes included in the study (all of which are two-way), nor does it differentiate between crashes related to intersections as opposed to segments. Therefore, it doesn't provide any insight as to which design elements may be desirable in terms of safety. The data in the study does show higher volumes of cyclists on the routes with separated bike lanes compared to the reference routes with no cycling facilities, but the study does not attempt to control for other factors or variables potentially associated with this finding.

This study has been thoroughly critiqued by a number of other authors, many of whom are active vehicular cycling advocates. Their critiques include the following points:

- Motor vehicle occupant (MVO) injuries is not an acceptable proxy for the level of traffic danger on a street because it does not take into account other cycling specific design variables, such as the presence of a parking lane wide enough to invite cyclists to ride in the door zone.
- The calculation of relative traffic danger (MVO ratios) does not normalize for total auto volumes.
- The relative traffic danger (MVO ratios) of the separated bike lane street compared to the reference street is not incorporated into the calculation of relative risk of injury for the separated bike lane streets,

even when the relative traffic danger is significantly different than 1.0. The MVO ratios vary by factors of up to 25.

- Several critics noted ways in which the selected reference streets are dissimilar from the streets with cycle-tracks, including number of travel lanes, number of intersections, adjacent land uses, presence of parking, and speed limits, questioning the validity of a comparison with these routes.
- A significant portion of one separated bike lane passes through a park, operating outside the roadway ROW.
- The determination of the length of each cyclist's trip in order to calculate bike-km traveled is subjective and according to the authors' judgment. In case the length of the separated bike lane is incorrectly listed in the paper (Rachel is 1.8 instead of 3.5 km)
- The study does not consider a before-after comparison of the streets with separated bike lanes.
- The exposure calculations for the reference streets over the 1999-2008 study periods are based on a single two-hour count. The ratio of the count with the reference street to separated bike lane street was applied to the longer study period to estimate exposure for the reference streets. This ignores fluctuations or differences due to roadway construction, traffic congestion, potholes, etc. that may affect a cyclist's route choice.
- The statistical methods used in the analysis are also criticized for a number of reasons, including whether the event probability follows a Poisson distribution.
- The authors' conclusion is not supported by their statistical analysis, given that only three of the eight comparisons were statistically significant.

Rating (quality of research, relevance)

Medium

Title *Multiuser Perspectives on Separated, On-Street Bicycle Infrastructure*

Author Monsere, C. M, McNeil, N., and Dill, J.

Year 2011

Research Type

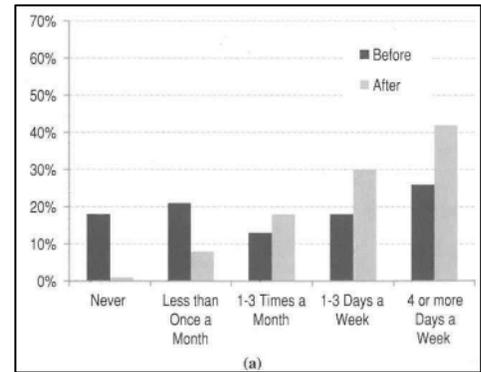
- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

In 2009, the City of Portland installed a separated bike lane and a pair of buffered bike lanes in downtown. The protected separated bike lane was installed on a one way street that originally had three travel lanes, two parking lanes, and a bike lane. One travel lane was eliminated to create a protected lane between a row of parked cars and the sidewalk. This study examined before and after perceptions of bicyclists, motorists, and pedestrians for both of these facilities. Surveys were conducted between August and September 2010, approximately one year after installation. Here are results from the survey that focused on the separated bike lane:



- Bicyclists
 - 71% agree the new facility is safer
 - Reported separated bike lane facility use for before and after (see image)
- Motorists
 - 48% agree that the separated bike lane has made driving safer
 - 78% like that bikes and cars are more separated because of the separated bike lane

When the same questions were asked of both samples, cyclists on the buffered bike lanes generally had more positive perceptions of those facilities than cyclists on the separated bike lane, through both groups were generally very positive.

Comments

None

Rating (quality of research, relevance) Medium

Title *Urban Bikeway Design Guide*

Author National Association of City Transportation Officials (NACTO)

Year 2012

Research Type

- | | | |
|--|--|---|
| <input type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input checked="" type="checkbox"/> Case Study | <input checked="" type="checkbox"/> Design Guide | <input type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|--|---|---|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input checked="" type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|--|--|---|---|

Summary

The NACTO Urban Bikeway Design Guide covers all of the predominant separated bike lane configurations and provides context for facilities within U.S. design guidance, such as the MUTCD and AASHTO Green Book. Each type of facility includes a high-level description, enumerated benefits, and typical applications. Design guidance is divided into three categories: required, recommended, and optional elements. Additionally, consideration is given to the ADA/PROWAG and maintenance issues.

Guidance was developed through a worldwide literature review and professional experience. The authors worked closely with a panel of urban bikeway planning professionals from NACTO member cities, as well as traffic engineers, planners and academics with experience in urban bikeway applications.

The NACTO Guide is available online (<http://nacto.org/cities-for-cycling/design-guide/>) to allow for frequent updates in response to the rapidly evolving state of innovative bicycle facility design.

Case studies of several US separated bike lanes are provided, including one-way, two-way, and raised separated bike lanes in San Francisco, Brooklyn, Washington, DC, Portland, Missoula, Montana, and Cambridge, Massachusetts.

Comments

The NACTO Guide is the only national resource for separated bike lane design guidance. As such, many cities are using the NACTO Guide as they begin installing separated bike lanes.

Rating (quality of research, relevance) High

Separated bike lanes, bike lanes, and on-street cycling in Montreal: A

Title *preliminary comparison of the cyclist injury risk*

Author Nosal, Thomas, Luis F. Miranda-Moreno, Anne C. Lusk, and Patrick Morency

Year 2011

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
- Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

The researchers present a control-case study to determine the relative cyclist injury risk of various bicycle facilities: separated bike lanes; bicycle lanes; and streets without bicycle facilities. The cyclist injury rates for a set of four separated bike lanes and four bicycle lanes in the City of Montreal are compared to injury rates for corresponding control streets using relative risk ratios. In addition, the injury rates for the bicycle facilities are compared to each other. Overall, it was found that most bicycle facilities in the analysis exhibit lower cyclist injury rates than the corresponding control streets.

The method consisted of three steps:

1. Selection of facilities and control sites
2. Obtaining bicycle counts, expansion factors and injury data
3. Data assembly and definition of analysis method

Crashes were segregated between intersections and segments

Design features that affect safety were identified, including whether or not a given facility is bidirectional, visibility, presence and location of parking, vehicular traffic and the roadway's built environment. Nearly every separated bike lane section with parking has a lower injury risk than the sections without parking. Bidirectional separated bike lanes were identified as potentially less safe because drivers were unaccustomed to yielding to two directions of traffic when turning. Further research is required to determine the exact effect of these factors.

Comments

Very relevant to the FHWA research with similar methods and valuable findings.

Rating (quality of research, relevance) High

Title *Sidepath Safety Model – Bicycle Sidepath Design Factors Affecting Crash Rates*

Author Petritsch, T. A. et al.,

Year 2006

Research Type

- | | | |
|--|---|---|
| <input type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input checked="" type="checkbox"/> Case Study | <input type="checkbox"/> Design Guide | <input type="checkbox"/> International |

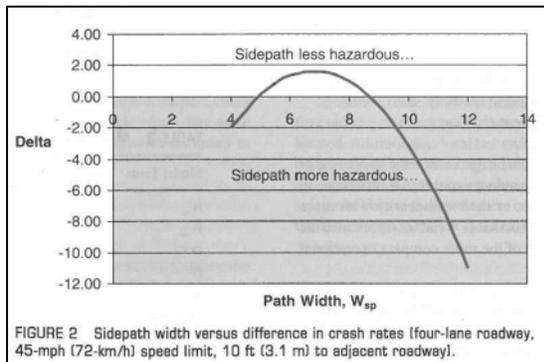
Separated Bike Lanes Considered

- | | | | |
|---|--|---|---|
| <input type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input checked="" type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|---|--|---|---|

Summary

FDOT conducted a study to determine whether sidepaths are safer than on-roadway facilities. This study utilizes operational and geometric roadway data for facilities which have sidepaths; 21 locations were selected. Bicycle counts were collected for this study at the sidepath locations. Bicycle-auto crashes were also collected at the sidepaths.

A crash model was constructed to represent the relative crash rates for on-roadway facilities and sidepath facilities. Four main variables were modeled: sidepath width, distance between sidepath and roadway, posted speed, and number of lanes in which there was an overall R2 of 0.81.



The authors then discuss how the value of the variable (sidepath width, distance between sidepath and roadway, etc.) impacts the relative safety between on-roadway bike facilities and sidepaths. For example, the effect of path width is graphed against a 4-lane roadway, 45 mph posted speed, and 10 foot distance adjacent to the roadway. The results show a bell curve where a narrow 4 foot sidepath is hazardous (delta of -2, more hazardous), a 7 foot sidepath is optimal (delta of +1.8, less hazardous), and a 12 foot sidepath is hazardous (delta of -11, more hazardous). See figure 2 for example.

The optimal configuration of a sidepath is uncertain because of the results from other variables. For example, the safest sidepath is one where adjacent posted speed is 70, which is contrary to intuition. Furthermore, the safest sidepath with a posted speed of 55 mph is one which is 23 feet away from the roadway, which is not realistic.

Despite the limitations of the model, the variables were found to be statistically significant to predict the difference in auto-bicycle crashes for on-roadway facilities and sidepaths.

Comments

The results from this crash model do not appear to be realistic as the optimal safest facility would be the following:

- 2 lane
- 70mph
- 0 foot separation to roadway in 35 mph speed
- 23' separation from roadway in 55 mph speed
- 7' path width

Rating (quality of research, relevance) Medium

Title *Cycling for Everyone: Lessons from Europe*

Author John Pucher and Ralph Buehler

Year 2007

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

The authors discuss the different policies and programs that have succeeded in creating relatively high bicycle mode shares in the Netherlands, Denmark, and Germany in comparison with other countries that have not implemented these policies and programs to the same degree. The authors compiled data on cycling mode share from different countries; Figure 1 summarizes this data. The authors also compared trip lengths and found that Europeans have a higher portion of trips less than 1.5 miles, and they make a much higher percentage of these short trips by bike than Americans.

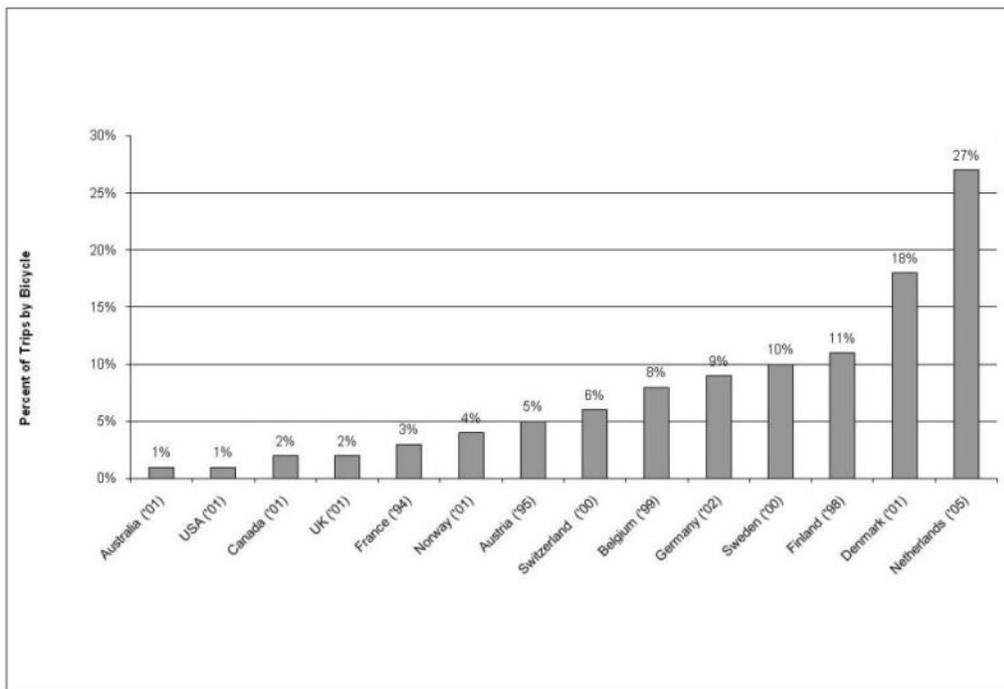


Figure 1. Bicycle Share of Trips in Europe, North America, and Australia (percent of total trips by bicycle) (1), (2), (3), (5)

The authors also found the Europeans are more likely to make utilitarian trips by bicycle, and in Denmark, Germany, and the Netherlands, women and men cycle at about equal rates, and people of all ages use bikes for transportation.

With regards to safety, fatality and injury rates for cyclists are much higher in the U.S. when compared with the

European countries, by a factor of 4-5. Figure 3 compares fatality rates. The authors also found that cycling fatalities are declining faster in European countries than in the U.S., following the same trend as overall traffic fatalities. Finally, the authors cite the “safety in numbers” phenomenon, and note that perceived danger is a deterrent to more widespread cycling. The authors found that the use of helmets is generally very low.

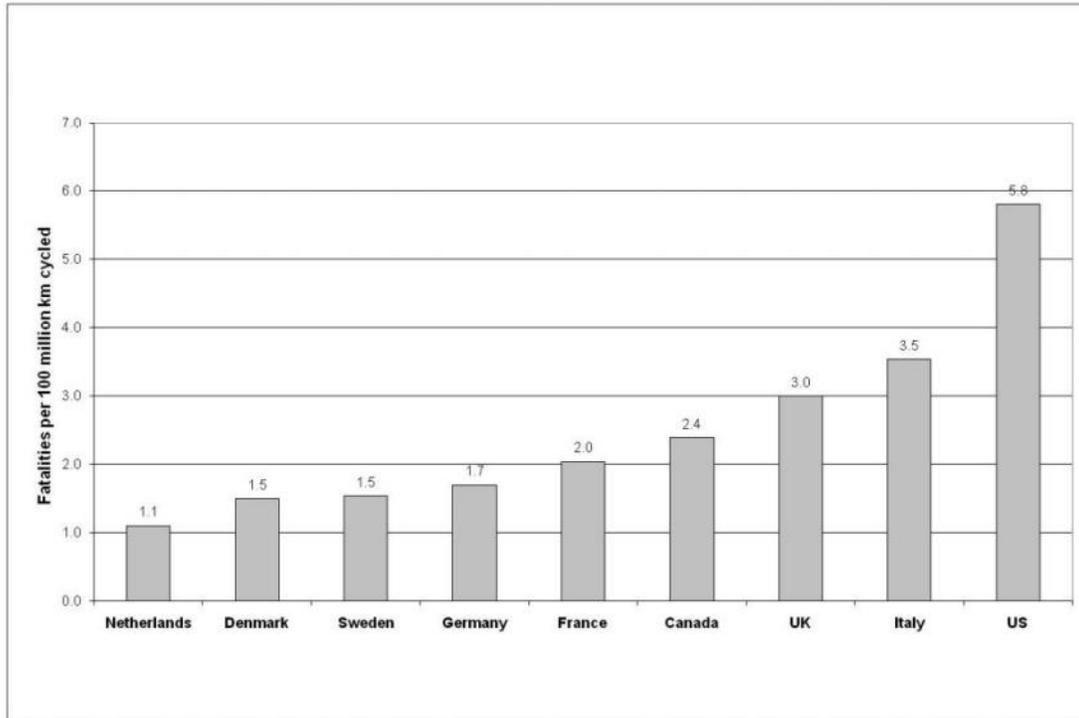


Figure 3. Cycling Fatality Rates in Europe and North America, 2002/2005 (Cyclist deaths per 100 million km cycled) (1), (2), (5), (9), (17)

The authors identified eight categories of measures that have been widely adopted in cities in Denmark, Germany, and the Netherlands, and suggest that a coordinated, multi-pronged approach including these measures may prompt an increase in the bicycle mode share in U.S. cities. Those categories are:

1. Bike paths and lanes
2. Traffic calming
3. Intersection modifications (to provide protection and priority for cyclists)
4. Bike parking
5. Integration with public transport
6. Training and education
7. Promotional events
8. Complementary taxation, parking, and land-use policies

In their conclusions, the authors state that the most important measure in making cycling safe and attractive, in the case studies of their research, is the provision of separate cycling facilities along heavily traveled routes and intersections, plus traffic calming in residential areas.

Comments

This is a high level overview paper with a good compilation of data across different countries. The overall data tell us that cycling is not safe or a well-used mode in the US, in comparison to other European countries.

Rating (quality of research, relevance)

Medium

Very high level – only good for background info.

Infrastructure, programs, and policies to increase bicycling: an international review

Title

Author John Pucher, Jennifer Dill, and Susan Handy

Year 2010

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
 Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

The authors sought to understand the effects of various interventions on levels of bicycling, including infrastructure; integration with public transport; education and marketing; bicycle access programming; and legal issues. In this paper, the authors conduct a broad-based literature review to collect relevant studies pertaining to one of more of these types of interventions. Overall, the authors identified 139 studies from both peer-reviewed and non-peer-reviewed research and noted that the research methods and quality varied considerably. They found that very few papers meet rigorous standards of study design.

Specific to infrastructure interventions, they reviewed a number of papers related to bicycle lanes and found that the aggregate level studies showed a statistically significant and positive relationship between bike lanes and levels of cycling. They also reviewed one study directly relating to separated bike lanes that showed an increase in ridership after their installation.

In addition, they did comprehensive case studies of 14 cities that have succeeded in achieving high bicycle mode share or have experienced rapid increases in bicycle mode share.

Overall, the authors found that most studies found a positive correlation of the various types of interventions with cycling rates, and noted that any “lack of evidence of a positive effect of some specific intervention is not the same as evidence of a lack of positive effect.” Based on their case studies and reviews of the literature, the authors concluded that “Some individual interventions can increase bicycling to varying degrees, but the increases are not usually large. That does not mean that individual interventions are not important, but they are most effective as a part of a more comprehensive effort. Substantial increases in bicycling require an integrated package of many different, complementary interventions, including infrastructure provision and pro-bicycle programs, as well as supportive land use planning and restrictions on car use.”

Comments

Rating (quality of research, relevance)

High

Comprehensive literature review.

Title *The Impact of Transportation Infrastructure on Bicycling Injuries and Crashes:
A Review of the Literature*

Author Conor C.O. Reynolds, M. Anne Harris, Kay Teschke, Peter A. Crompton, and Meghan Winters

Year 2009

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
 Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

[Multilane Roundabout Intersections]

Summary

This literature review summarizes studies on the relationship between bicycle facilities (and roadway design, as it relates to bicycling) and bicyclist safety. Safety was measured in terms of crashes, injuries, and injury severity. The studies were divided into intersection and segment (between intersections) categories. While there were only 23 bicycle safety studies identified in the literature review, the authors concluded that infrastructure influences bicyclist injuries and crash risk. Types of facilities with the highest risk to bicyclists included sidewalks, multi-use trails, and high-volume roadways. On-road bike routes, marked bike lanes, and off-road bicycle paths were associated with the lowest risk. Street lighting, paved surfaces, and low-angle grades were also factors associated with reduced risk. The only result specific to separated bike lane facilities was that the high risk at multi-lane roundabouts can be reduced if a separated bike lane is included at the roundabout. The authors noted that many of the studies were limited because the data that were used to control for bicyclist exposure on particular facilities were inadequate.

Comments

The article identifies the need for more bicycle safety studies, and the authors call for additional research on a greater variety of bicycle facilities, including separated bike lanes. The literature review, published in 2009, found no cycle-track-specific studies published in English (though the authors alluded to several studies published in other languages).

Rating (quality of research, relevance) High

*Road factors and bicycle-motor vehicle crashes at unsignalized priority*Title *intersections*

Author J.P. Schepers, P.A. Kroeze, W. Sweer, J.C. Wust

Year 2010

Research Type

- | | | |
|--|--|---|
| <input checked="" type="checkbox"/> Safety Study | <input checked="" type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input type="checkbox"/> Case Study | <input type="checkbox"/> Design Guide | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|--|---|---|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input checked="" type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|--|--|---|---|

Summary

Methods:

The study examined bicycle-motor vehicle crash data for four years at 540 unsignalized intersections in the Netherlands. Their analysis included 339 failure-to-yield crashes. They divided crashes into two categories:

- Type I: through bicycle related collisions where the cyclist has right of way (i.e. bicycle on the priority road);
- Type II: through motor vehicle related collisions where the motorist has right of way (i.e. motorist on the priority road).

They used a negative binomial regression to examine the relationship between the number of crashes per intersection and the independent variables (road design factors), while controlling for bicycle and automobile volumes. The variables they tested were as follows:

For Type I Crashes:

- **type of bicycle facility:** cycle lane, one-way bicycle path, two-way bicycle path, or no bicycle facility (i.e. cyclists mixed with other traffic);
- **distance between the separated bike lane and the side of the main carriageway:** 0–2 m, 2–5 m, over 5m;
- **visibility from the minor road:** unrestricted view over 100m or more at 2m before the main road or its adjacent cycle path, or restricted (i.e. worse visibility);
- **marking and use of colors:**
 - color: reddish colored crossing, or else;
 - quality of (other) markings (white painted rectangles to delineate separated bike lanes; or white stripes or continuous lines to delineate cycle lanes): well-visible; hardly visible, or no marking;
- **presence of a speed reducing measure for motorists that enter or leave the priority road** (e.g. a raised bicycle crossing);
- **number of lanes of the side road** (i.e. entry width);
- **presence of a left-turn lane** or left-turn section on the main road;
- **type of intersection:** three-armed, or four-armed.

For Type II Crashes:

- number of lanes of the main road;
- presence of middle islands:
 - no raised middle islands;
 - raised middle islands that enclose a left-turn section, i.e. cyclist are enabled to cross the main road in two phases and share the space with left-turning motorists;
 - raised middle islands with a separate space for cyclists;

- presence of speed-reducing measures for through motor vehicles on the main road, e.g. speed humps;
- type of intersection: four-armed, three-armed, or single separate bicycle crossings (i.e. where a solitary separated bike lane crossed the priority road).

Findings:

The authors found that the most effective safety-improving measure was the use of speed-reducing measures for drivers leaving or entering the main road. They also found that one-way separated bike lanes between 2 and 5 meters from the intersection is safer than a lane passing through the intersection. They found a higher risk for cyclists on two-way paths and in intersections with red color and high quality markings through the intersection. Table 2 presents the statistical results.

Table 2
Estimation results for the type I accident risk model.^a

Parameter	Number of intersections	Regression parameter (95% Wald CI)	Exponential of the regression parameters (95% CI)	Wald χ^2	P-value
Constant		-9.43 (-12.21 to -6.65)		44.22	<0.001
Volume of motorized vehicles entering or leaving the major road		0.73 (0.50 to 0.96)		38.30	<0.001
Volume of through cyclists		0.48 (0.24 to 0.73)		13.56	<0.001
Two-way versus one-way cycle track					
One-way cycle path or other provision	423	0 (reference)	1 (reference)		
Two-way cycle path	67	0.56 (0.01 to 1.11)	1.75 (1.01 to 3.03)	4.00	0.046
Distance between the bicycle facility and the side of the main carriageway					
Cycle lane or no cycle facility	232	0 (reference)	1 (reference)		
Cycle track 0-2 m	43	0.03 (-0.69 to 0.74)	1.03 (0.50 to 2.10)	0.01	0.944
Cycle track 2-5 m	127	-0.61 (-1.20 to -0.01)	0.55 (0.30 to 0.99)	4.01	0.045
Cycle track over 5 m	88	-0.07 (-0.71 to 0.57)	0.93 (0.49 to 1.76)	0.05	0.823
Use of a red colour and quality of markings for bicycle crossings					
None	137	0 (reference)	1 (reference)		
Red colour	190	0.38 (-0.16 to 0.93)	1.47 (0.85 to 2.52)	1.93	0.165
High quality markings	80	0.55 (-0.13 to 1.24)	1.74 (0.88 to 3.45)	2.52	0.112
Red colour and high quality marking	83	0.93 (0.33 to 1.53)	2.53 (1.39 to 4.60)	9.16	<0.01
Raised bicycle crossing or other speed reducing measure for vehicles entering or leaving the side road					
Not present	277	0 (reference)	1 (reference)		
Present	213	-0.70 (-1.15 to -0.26)	0.49 (0.32 to 0.77)	9.49	<0.01
Visibility from the minor road					
Good	341	0 (reference)	1 (reference)		
Restricted	115	0.32 (-0.15 to 0.78)	1.37 (0.86 to 2.19)	1.75	0.186
Bad	34	-0.62 (-1.78 to 0.54)	0.54 (0.17 to 1.72)	1.09	0.297
Number of lanes of the side road					
One	22	0 (reference)	1 (reference)		
Two	456	-0.89 (-1.84 to 0.06)	0.41 (0.16 to 1.07)	3.35	0.067
Three	12	-0.76 (-2.21 to 0.68)	0.47 (0.11 to 1.98)	1.07	0.300
Left-turn lane or left-turn section on the main road					
Not present	341	0 (reference)	1 (reference)		
Present	149	0.11 (-0.33 to 0.56)	1.12 (0.72 to 1.74)	0.26	0.612
Type of intersection					
Three-armed	314	0 (reference)	1 (reference)		
Four-armed	176	-0.16 (-0.58 to 0.26)	0.56 (0.46 to 0.85)	0.56	1.295

^a Log likelihood is -337.55.

Comments

Notably, the authors found that intersections with one-way separated bike lanes have the same or less bicycle crashes than intersections with no bicycle facilities, a result differing from other studies (Elvik and Vaa 2009). The authors note that this may be due to the fact that they did control for volumes, while many other studies did not.

A noted limitation of this study includes the fact that it does not account for crash severity, which may be influenced by intersection design.

Rating (quality of research, relevance) High

Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study

Title *Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study*

Author Kay Teschke, M. Anne Harris, Conor C. O. Reynolds, Meghan Winters, Shelina Babul, Mary Chipman, Michael D. Cusimano, Jeff R. Brubacher, Garth Hunte, Steve M. Friedman, Melody Monro, Hui Shen, Lee Vernich, and Peter A. Crompton

Year 2012

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
- Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

The study gathered data from 690 Toronto and Vancouver bicyclists who had been injured while bicycling to compare the bicycle injury risk along 14 types of bicycle routes (with specific infrastructure features). Roadway characteristics at locations where bicyclists were injured were compared to roadway characteristics at other, randomly-selected control sites on their bicycling route. Study participants included bicyclists aged 19 and over who had been treated in hospital emergency rooms. Separated bike lanes had the lowest risk of all types of bicycle facilities (nine times lower than on major streets with on-street parking and no bicycle infrastructure). Bicycle injury risk was higher on major streets when they had on-street parking, but bicycle injury risk was lower on major streets when they had bicycle lanes. In general, local streets had lower bicycle injury risk than major streets. Higher risks were associated with streetcar and train tracks, downhill grades, and construction.

Comments

This study included only 2 injury locations and 10 control locations for separated bike lane facilities.

The researchers did not analyze one-way versus two-way separated bike lanes, although it is likely that both were included, given the facilities available in Vancouver and Toronto.

This particular study did not specifically address separated bike lane safety at intersection versus roadway segment locations, although it examined intersection versus segment location for the full set of bicycle crashes and did not find a significant relationship.

The case-crossover study design compares the location where a crash (and injury) occurred with other locations on a bicyclist's route where the crash could have occurred but did not. This technique gets around the problem of collecting accurate exposure data at different locations. Using a single individual for analysis of different types of locations also controls for personal factors, such as age, gender, and bicycling experience, as well as weather, safety equipment, and other contextual factors.

Rating (quality of research, relevance) High

Title *London Cycling Design Standards*

Author Transport for London

Year 2005

Research Type

- Safety Study
- Operations Study
- Perceptions Study (Survey)
- Case Study
- Design Guide
- International

Separated Bike Lanes Considered

- Buffered, Street-Level
- Raised
- One-Way
- Two-Way

Summary

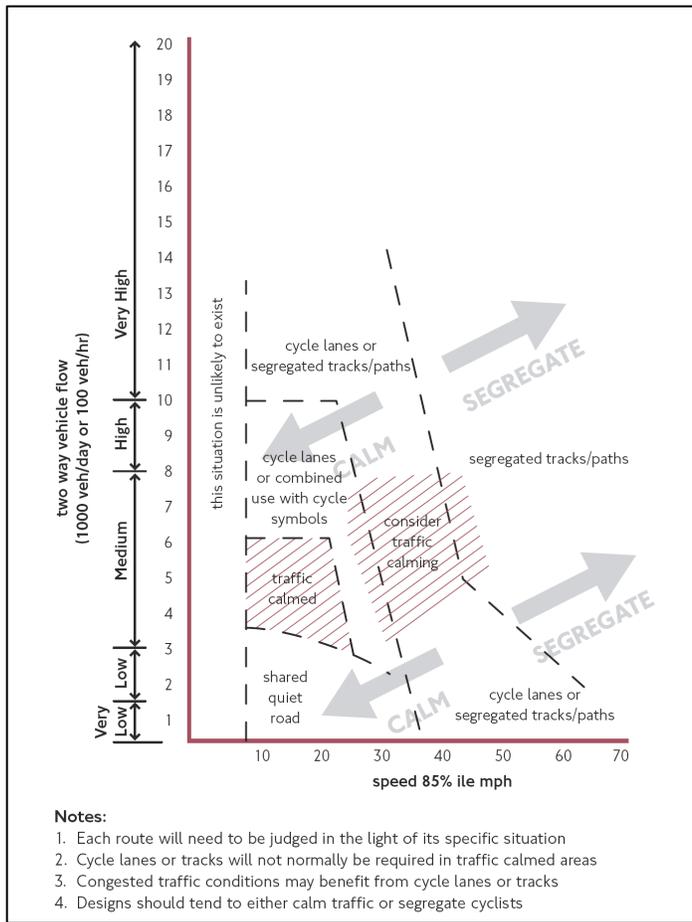
This design guide provides a range of bicycle facility types and treatments for the City of London. There is guidance on when to use facilities based on traffic volumes and 85th percentile speeds as shown below:

Figure 4.1
Matrix of cycle facility solutions based on motor traffic volume and speed

	85 th ile Speed			
	<20mph Very Low	20-30mph Low	30-40mph Medium	>40mph High
Very High >10,000VPD	Lanes or Tracks/paths	Lanes or Tracks/paths	Lanes or Tracks/paths	Tracks/paths
High 8,000-10,000VPD 800-1,000VPH	Lanes	Lanes	Lanes or Tracks/paths	Tracks/paths
Medium 3,000-8,000VPD 300-800VPH	Lanes or combined use with cycle symbols	Lanes or combined use with cycle symbols	Lanes or Tracks/paths	Tracks/paths
Low 1,500-3,000VPD 150-300VPH	Combined use with cycle symbols	Combined use with cycle symbols	Lanes or Tracks/paths	Lanes or Tracks/paths
Very Low <1,500VPD <150VPH	Combined use – no symbols necessary	Combined use with cycle symbols	Combined use with cycle symbols	Lanes or Tracks/paths

Notes:

1. This table assumes current conditions and trends.
2. Additional protection to lanes should be used in medium or high speed/flow situations (see drawing CCE/B12 for options)
3. Where Lanes OR Tracks/paths are shown, Lanes should be considered as the first option
4. "symbols" are the cycle symbol road marking to Diagram 1057 of TSRGD. Their use in association with route numbers may be appropriate
5. VPD = number of motor vehicles in typical 24hour weekday
6. VPH = number of motor vehicles in typical morning peak hour
7. In congested areas cycle lanes may be desirable where they are not justified on traffic volume and speed



These design standards also provide some guidance on separated bike lane widths:

Type of Separated Bike Lane	Desirable Minimum (feet)	Absolute Minimum (feet)	Safety Strip to Roadway Curb Edge Minimum Width (feet)
One Way	6.5	5	0.5
Two Way	9.8	6.5	0.5

As for intersections, the British have set a policy to require advanced stop lines at signalized intersections. Otherwise, there is not much other information regarding separated bike lanes such as transitions, safety, or comfort.

Comments

None

Rating (quality of research, relevance) Medium

Title *Planning and Design for Pedestrians and Cyclists: A Technical Guide*

Author Vélo Québec

Year 2010

Research Type

- | | | |
|---------------------------------------|--|---|
| <input type="checkbox"/> Safety Study | <input type="checkbox"/> Operations Study | <input type="checkbox"/> Perceptions Study (Survey) |
| <input type="checkbox"/> Case Study | <input checked="" type="checkbox"/> Design Guide | <input checked="" type="checkbox"/> International |

Separated Bike Lanes Considered

- | | | | |
|--|--|---|---|
| <input checked="" type="checkbox"/> Buffered, Street-Level | <input checked="" type="checkbox"/> Raised | <input checked="" type="checkbox"/> One-Way | <input checked="" type="checkbox"/> Two-Way |
|--|--|---|---|

Summary

Vélo Québec is an organization that promotes active transportation. This document, which includes guidance on pedestrian facilities, is an update to previous editions that focused only on bikeways. It covers the planning, design, and maintenance of the public way and incorporates the latest in roadway design in Canada, the US, and Europe.

Separated bike lanes are referred to as on-road bike paths and can be on the pavement or at sidewalk level. The guidance includes basic geometry of the separated bike lanes and guidance such as spacing from parked cars, parking restrictions at corners, and the recommended spacing between delineators.

Guidance on where it may be appropriate to have a bi-directional separated bike lane is included, such as along a waterway, and where a sidewalk-level separated bike lane could be considered. However, the guide does not address general guidance on where to install a separated bike lane overall.

Comments

This is a nice guide with good, but basic information. It doesn't get very in-depth on design or safety issues of separated bike lanes.

Rating (quality of research, relevance) Medium

Bicyclists' Injuries and the Cycling Environment: The impact of route infrastructure

Title

Winters, M., M. A. Harris, C. C. O. Reynolds, P. A. Crompton, M. Chipman, M. D. Cusimano,

Author J. Brubacher, S. M. Friedman, M. Monro, L. Vernich, H. Shen, G. Hunte, and Kay Teschke

Year 2012

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
- Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

Methods:

The authors designed a case-crossover study in which they obtained study participants from emergency rooms at major hospitals in Toronto and Vancouver, Canada. Study participants included people that visited the emergency room as a result of a cycling crash while cycling for recreation or utilitarian purposes, but excluded people injured while racing, mountain biking, and “trick” riding. To collect data, the authors interviewed each study participant to determine the exact location of their crash, the time of day and conditions, and the route they were traveling at the time of the crash. They then recorded the following data about each crash site:

- type of street or path;
- whether the site was at an intersection;
- presence of junctions, street lighting, streetcar or train tracks;
- slope of the surface
- distance visible along the direction of
- counts of motor vehicle, cyclist and/or pedestrian traffic volume in 5 minutes;
- average motor vehicle traffic speed

Researchers then randomly selected another control site along the cyclists’ trip route and collected the same data. They used a logistic regression model to test the associations between characteristics of the cycling environment and the dependent variable (injury site or control site).

Findings:

Figures 1 and 2 show the authors’ main findings.

Overall the authors found that bike-specific infrastructure was associated with lower injury risk, with cycle-tracks showing one-ninth the risk compared to the reference route (arterial/collector route with parking and no bike facility). Authors found that downhill slopes, streetcar/train tracks, and presence of construction are associated with a higher crash risk.

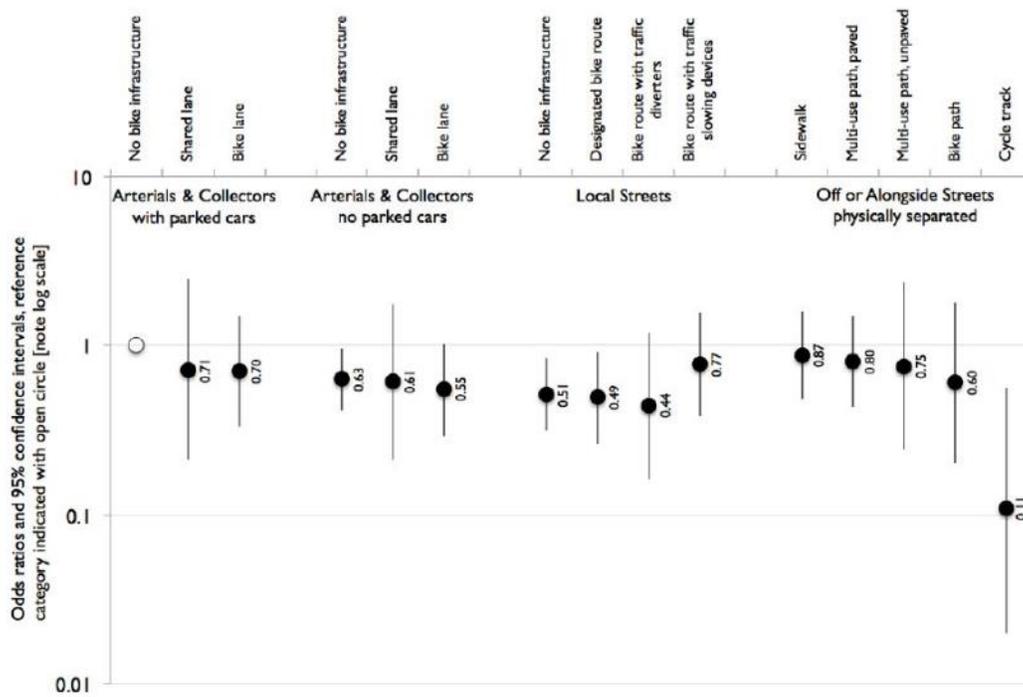


FIGURE 1 Relative risks for 15 route types; adjusted odds ratios and 95% confidence intervals estimated using multiple logistic regression.

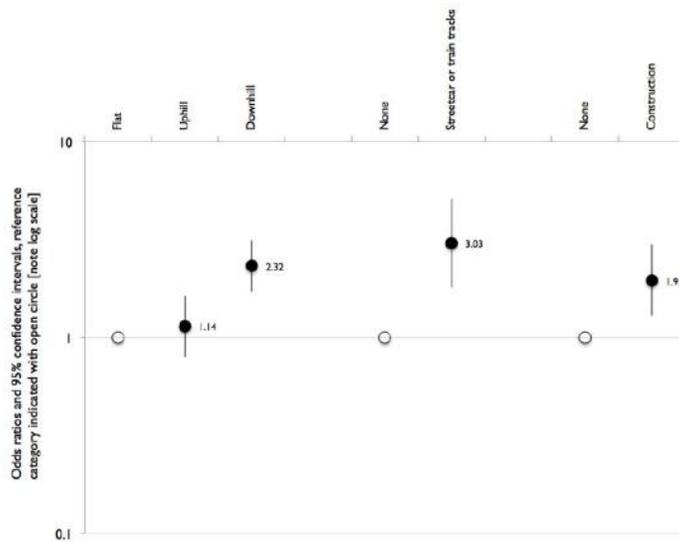


FIGURE 2 Relative risks for other infrastructure components, including grade, rail tracks and construction; adjusted odds ratios and 95% confidence intervals estimated using multiple logistic regression; same model as routes types (results in Figure 1).

Comments

The study did not differentiate between different types of cycle-tracks – one-way or two-way, street-level or raised, etc.

Rating (quality of research, relevance)

High

Title *Bike scramble signal at N Interstate & Oregon*

Author Michael Wolfe, Jared Fischer, Chris Deslauriers, Stephen Ngai, & Matt Bullard

Year 2006

Research Type

- Safety Study Operations Study Perceptions Study (Survey)
 Case Study Design Guide International

Separated Bike Lanes Considered

- Buffered, Street-Level Raised One-Way Two-Way

Summary

This report was an academic exercise for a civil engineering course at Portland State University. Students conducted a before/after study of one intersection in Portland where the state DOT installed a bicycle scramble signal. When activated, the signal stops motor vehicle traffic in all directions and allows bicyclists to cross the intersection diagonally. Observational data came from physical counts and surveillance video collected during peak hours in a two-week period in early November 2006. The Portland DOT collected peak hour cyclist data in July 2003 (before signal installation) and again two months and four months after installation (June and August 2004, respectively).

Observations used for this study include the total users of the bicycle scramble and their direction of travel; total number of bicyclists using the intersection; number of users crossing the intersection illegally; and the number of drivers who make illegal right turns during the scramble phase.

PDOT's 2003 counts found that 71.8 percent of all cyclists passed through the intersection illegally. The November 2006 counts found that this number had fallen to 4.2 percent.

Comments

No crash data were mentioned or used. They seem to be using illegal crossings as a proxy for safety.

Rating (quality of research, relevance) Low Interesting treatment, but this study includes only one site that was observed during limited hours over one two-week period.

Appendix 2

Excluded Literature

Author	Title	Year	Journal/Publisher
UNC HSRC	Tech Brief: Evaluation of Shared Lane Markings	2010	FHWA
Chicago DOT	CDOT Bicycle Program Design Guidelines	2012	
Transport for London	London Cycling Design Standards		
FHWA	BIKESAFE: Bicycle Countermeasure Selection System		
Jensen, S.U.	Safety Effects of Blue Cycle Crossings: A Before-After Study	2008	Accident Analysis & Prevention
Ministry of Transport, Public Works and Water Management	Cycling in the Netherlands	2007	
Eva Heinen, Bert van Wee & Kees Maat	Commuting by Bicycle: An Overview of the Literature	2010	
Krizek KJ, El-Geneidy A, Thompson K.	A detailed analysis of how an urban trail system affects cyclists' travel	2007	<i>Transportation</i> . 34:611–624
Justen P. O'Connor, Trent D. Brown	Riding with the sharks: Serious leisure cyclist's perceptions of sharing the road with motorists	2010	Vol. 13, Issue 1, p53-58
John Pucher and Ralph Buehler	City Cycling. Chapter 7: Cycling Safety	2012	MIT
Cherry, Hill, and Xiong	Assessing Countermeasures Designed to Reduce Hazards Between Bike Lane Occupants and Right-Turning Automobiles in China	2012	Vol. 4, Issue 4
Wang and Nihan	Estimating the risk of collisions between bicycles and motor vehicles at signalized intersections	2004	Accident Analysis and Prevention. 36(3): 313-321
Becky P.Y. Loo and K.L. Tsui	Bicycle crash casualties in a highly motorized city	2010	Vol. 42, Issue 6. p1902-1907

Author	Title	Year	Journal/Publisher
Miranda-Moreno et al.	Disaggregate Exposure Measures and Injury Frequency Models of Cyclist Safety at Signalized Intersections	2011	TRR 2236
Nicaj et al.	Bicyclist Fatalities in New York City: 1996 - 2005	2009	Traffic Injury Prevention. Vol. 10, No 2
Schepers et al.	Road Safety and Bicycle Usage Impacts of Unbundling Vehicular and Cycle Traffic in Dutch Urban Networks	2013	European Journal of Transport and Infrastructure Research
Russo, Ryan, Benson, Joshua, Lucas, Christopher	Ninth Avenue Bicycle Path and Complete Street	2008	ITE 2008 Annual Meeting and Exhibit
Nicole Romanow et al.	Environmental Determinants of Bicycling Injuries in Alberta, Canada	2012	Journal of Environmental and Public Health. Vol. 2012. Issue number 487681
Zegeer, C. V., et al.	Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines	2005	FHWA
Eilert-Petersson, E. and L. Schelp	An Epidemiological Study of Bicycle Related Injuries.	1997	Accident Analysis & Prevention. 29 (3). 363-372
Garder, P., L. Leden and U. Pulkinnen,	Measuring the Safety Effect of Raised Bicycle Crossings Using a New Research Methodology.	1988	TRR 1636, 64-70
Jennifer Dill	Bicycling for Transportation and Health: The Role of Infrastructure	2009	Journal of Public Health Policy
Christine M. Kendrick, Adam Moore, Ashley Haire, Alexander Bigazzi, Miguel Figliozi, Christopher M. Monsere, Linda George	Impact of Bicycle Lane Characteristics on Exposure of Bicyclists to Traffic-Related Particulate Matter	2011	Volume 2247 / 2011 Bicycles 2011
Douglas Shinkle	Transportation Review: Bicycle and Pedestrian Safety	2012	National Conference of State Legislatures
Reynolds, Conor CO et al.	Active Transportation in Urban Areas: Exploring Health Benefits and Risks	2010	

Author	Title	Year	Journal/Publisher
Harridge, M.	Shared paths: minor investments for major gains	2012	A safe system: expanding the reach: Australasian College of Road Safety national conference, 9-10 August 2012, Sydney
Cumming, B.	Analysing and managing the cyclist-driver interface using "conflict path analysis"	2012	A safe system: expanding the reach: Australasian College of Road Safety national conference, 9-10 August 2012, Sydney
Bach, O, O Rosbach and E. Jorgensen	Cykelstier i byer: den sikkerhedsmaessige effekt. Cyclists in cities: The Safety Effect	1988	Vejdirektoratet, Denmark

For Federal Highway Administration

**Separated Bike Lanes Planning and Design Guide
Lessons Learned Report
Prepared May 2014**

University of North Carolina Highway Safety Research Center

Sam Schwartz Engineering, DPC

Kittelson & Associates, Inc.

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Executive Summary

Separated bike lanes are still an innovative design treatment, one with little accepted design guidance. Engineers and planners in the US have taken upon themselves to implement this type of facility to provide more protection for bicyclists in their municipalities. Each municipality has unique experiences with regards to the planning, design and implementation of separated bike lanes. The purpose of the Lessons Learned analysis was to collect all of these experiences and provide a summary that could be shared with anyone interested in any aspect of a separated bike lane. The research team spoke to 35 U.S. municipalities to build this analysis. Though answers varied for each municipality, a number of key themes were heard throughout the process.

- There currently exists much variability in separated bike lane design. Many municipalities expressed a strong desire to continue to have design flexibility with separated bike lanes; others expressed an immediate need for a set of separated bike lane design guidelines to assist with the design and approval process.
- Roadway space is a major constraint for planning and building separated bike lanes. Planning for separated bike lanes often starts in places where there is excess capacity (i.e. “low hanging fruit”). The levels of current bicycle volumes tend to be secondary for a majority of municipalities interviewed.
- Municipalities are seeking a balance between separated bike lanes providing connectivity within the bicycle network and interference with roadway circulation for motor vehicles.
- Municipalities employ varying strategies on intersection design. Strategies include mixing zones, lateral shifts, and/or dedicated bicycle signalization. Most municipalities use a combination of strategies and adjust based on context. Some favor one over others.
- Municipalities have had success installing non-permanent or pilot separated bike lanes. These installations can be used to test the public’s reaction to the separated bike lane concept, save money upfront on materials, promote a more streamlined implementation process, and are more easily altered or removed if the reaction is negative (widespread negative reactions were found to be very rare among all municipalities interviewed; most complaints were isolated and temporary in nature).
- Municipalities should strive to ensure that the first separated bike lane project is a success.
- Partnerships with business improvement districts (BIDs) have been instrumental in advancing separated bike lanes in many municipalities, especially as local business groups come to understand the potential economic benefits associated with bicycle infrastructure and increased walk-in (“bike-by”) traffic.
- Separated bike lane costs vary extensively due to the wide variety of treatments and materials used.

- Municipalities that creatively employ multiple funding sources and aggressively seek out private or third-party funding will be more likely to succeed in building out separated bike lane networks.
- Snow plowing and street sweeping issues associated with the width of separated bike lanes relative to the width of sanitation vehicles have been an issue for most municipalities. In some cases, lack of coordination between planning and maintenance agencies and a lack of funding have undermined separated bike lane maintenance, but agencies have attempted to work around these challenges through equipment retrofits, new purchasing, or business association cooperation.
- Decisions on one-way versus two-way separated bike lanes depend on context. One-way separated bike lanes are generally a simpler design, but two-way facilities provide advantages: they are wider and therefore easier to maintain, they perform well when adjacent to uninterrupted curbs with few intersections or driveways, and they limit wrong-way cycling. However, turning movements, intersections, and heavy pedestrian activity are elements that introduce design challenges for two-way separated bike lanes.

Introduction

The practice related to the planning, design, construction, and maintenance of separated bike lanes has evolved considerably over the last few years in the U.S. Municipalities have been implementing one-way and two-way separated bike lanes on streets across the country. These facilities all share many similar traits, but the design details can vary widely. Separated bike lanes are still an innovative treatment, one with little accepted design guidance. This has led to engineers and planners to experiment with different designs, processes, treatments, and materials. These projects have provided a tremendous amount of insight and experience to the practitioners that have worked on them.

One of FHWA’s goals for this project was to tap into this knowledge and share it widely. The scope of the Lessons Learned analysis focuses on speaking to those that have worked on separated bike lane projects in different municipalities and documenting their experiences. Some of this has been shared by NACTO and the Green Lane project and between municipalities; however, there is no public resource that documents all of this information. A comprehensive set of in-person and telephone interviews were conducted by knowledgeable members of the research team with municipalities that have designed and constructed separated bike lanes across the country, as well as municipalities that are planning to implement separated bike lanes and those that have considered separated bike lanes but determined them to not be the appropriate treatment.

The intent of this analysis is to share information on all aspects of separated bike lanes. This information is useful to all practitioners, but particularly for municipalities who are just beginning to build separated bike lanes and those that are still considering them. There are many examples of successes that can be replicated and challenges that can be avoided. While there is still a lack of consensus on a number of aspects of how separated bike lanes are planned and built, the analysis does describe how these decisions are being made and where additional research is necessary. The information gathered as part of this process was used to inform the Planning and Design Guide.

The project teams thanks all the individuals that volunteered their time to be part of this analysis.

Alameda, CA	Gail Payne
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Atlanta, GA	Joshua Mello
Austin, CO	Nathan Wilkes
Baltimore, MD	Nate Evans, Caitlin Doolin
Boston, MA	Vineet Gupta, Nicole Freedman, Jonathan Greeley
Boulder, CO	Marni Ratzel
Cambridge, MA	Cara Seiderman
Charleston, SC	Phillip Overcash, Stephen Risse
Chicago, IL	Mike Amsden, Nathan Roseberry
Davis, CA	Dave Kemp
Eugene, OR	John Bonham, Lee Shoemaker
Evanston, IL	Rajeev Dahal
Indianapolis, IN	Jamison Hutchins

Jackson, WY	Brian Schilling
Long Beach, CA	Nathan Baird, Steve Tweed
Los Angeles, CA	Tim Fremaux
Madison, WI	Arthur Ross
Miami, FL	Collin Worth
Milwaukee, WI	Kristin Bennett
Minneapolis, MN	Simon Blenski
Missoula, MT	Ben Weiss
New York, NY	Josh Benson, Ryan Russo
Philadelphia, PA	Charles Carmalt
Phoenix, AZ	Joseph Perez
Pittsburgh, PA	Stephen Patchan
Portland, OR	Rob Burchfield, Roger Geller
Salt Lake City, UT	BeckaRoolf, Colin Quinn-Hurst
San Jose	ZahiKattab, Paul Smith
San Francisco, CA	Luis Montoya, Mike Sallaberry
Seattle, WA	Reiner Blanco, Dongho Chang, Sam Woods, Sara Zora
Spartanburg, SC	Laura Ringo
St. Petersburg, FL	Cheryl Stacks
Syracuse, NY	Paul Mercurio
Washington, DC	Mike Goodno, Jim Sebastian

Lessons Learned Interview Process

The research team interviewed staff from the U.S. municipalities listed below that have constructed separated bike lanes. The purpose of the interviews was to document the lessons that these municipalities have learned during the separated bike lane planning, design, and implementation process. The interviews were each led by a senior member of the research team over one to two hours and solicited responses on a broad range of topics related to separated bike lanes. This report synthesizes comments received, presents notable case studies, and makes suggestions for further research based on the lessons learned by U.S. municipalities that have started to include separated bike lanes as part of their bicycle planning toolkit.

Alameda, CA	Madison, WI
Atlanta, GA	Milwaukee, WI
Austin, TX	Minneapolis, MN
Boston, MA	Missoula, MT
Boulder, CO	New York City, NY
Davis, CA	Portland, OR
Cambridge, MA	Salt Lake City, UT
Chicago, IL	San Francisco, CA
Evanston, IL	San Jose, CA
Eugene, OR	Seattle, WA
Frankfort, KY	St. Petersburg, FL
Indianapolis, IN	Spartanburg, SC
Jackson, WY	Syracuse, NY
Long Beach, CA	Washington, DC

The research team also interviewed staff at the following locations that do not have separated bike lanes to identify challenges to separated bike lane implementation:

Arlington County, VA	Los Angeles, CA
Baltimore, MD	Miami, FL
Charleston, SC	Philadelphia, PA
Denver, CO	Phoenix, AZ
Houston, TX	Pittsburgh, PA

The project team developed an interview plan and a list of proposed municipalities that was reviewed by FHWA and the Technical Working Group (TWG). We then worked with bike coordinators in each jurisdiction to identify appropriate personnel that should be part of the interview process. In addition to the engineers that have designed these facilities, interviews included planners, construction personnel, and resident engineers.

Each interview lasted approximately one to two hours and covered a range of topics about separated bike lanes, including those shown in Figure 1.

Figure 1:

Topic Areas	Topics
Planning	<ul style="list-style-type: none"> • Cross sections for different facilities • Selection of separated bike lane locations • Traffic volumes and speed • Measuring parking usage and parking removal • Land use including truck and industrial uses • Existing bike ridership and demographics • Lane reductions • Curb use
Design	<ul style="list-style-type: none"> • Intersection design (channelization, bike boxes, mixing zones, etc.) • Sight distance at unsignalized intersections • Types of protection (parking, striping, bollards, curb, etc.) • Incorporating other engineering improvements into designs (pedestrian safety, stormwater management, traffic signal upgrades, etc.) • Turning movements at intersections, including bus and truck maneuvers • Bus/light rails stops • Bike signals • Traffic signal phasing • Transition to standard bike lanes/shared lanes • Designing with cost in mind • Drainage and pavement conditions • Signage • Curb access design for loading and accessible parking/special curb uses • Right-side, center and left- side separated bike lanes • Colored pavement
Outreach/Agency	<ul style="list-style-type: none"> • Public involvement
Coordination	<ul style="list-style-type: none"> • Business outreach • Coordination with transit agencies • Coordination with enforcement (keeping separated bike lanes clear of vehicles, etc.) • Coordination with state/county DOTs • Public education (for motorists, cyclists, and pedestrians)
Operations	<ul style="list-style-type: none"> • Data collection • Design modification • Illegal parking • Integrating counters
Construction	<ul style="list-style-type: none"> • Contractor education • Materials used
Maintenance	<ul style="list-style-type: none"> • Street sweeping • Snow removal • Potholes/Pavement conditions
Funding	<ul style="list-style-type: none"> • Cost of projects • Cost of individual elements • Funding sources

Lessons Learned

Planning

Section: Planning – 1

Topic: Choosing Successes

Lesson: Separated bike lane planning is best accomplished when municipalities can anticipate a successful project. U.S. municipalities strategically select corridors for separated bike lanes that will attract cyclists and face relatively few engineering or political challenges. Some municipalities undertake pilot projects to identify successes with less risk.

Detail: Roadway space is a major constraint – planning for separated bike lanes often starts in places where there is excess capacity (i.e. “low hanging fruit”). Levels of current bicycle volumes tend to be secondary for a majority of municipalities interviewed. Some municipalities have found that it is politically difficult at best to implement road diets where the roadway is already close to or at capacity, and are choosing separated bike lane corridors based on excess vehicle capacity and minimizing impacts for motorists (LOS or otherwise). These municipalities seek a balance between locating separated bike lanes on major arterials – where they may be most valuable from a connectivity standpoint – and avoiding streets where vehicle volumes are so high that implementing a separated bike lane (and associated road diet) may be considered infeasible from an engineering and/or political standpoint. Other municipalities are not as far along with separated bike lane implementation and have thus focused on obvious streets for road diets before tackling more difficult streets.

In addition, some municipalities are installing non-permanent or pilot separated bike lanes to test the public’s reaction to the separated bike lane concept. These pilot projects often use flexible delineators and paint as opposed to installation of permanent curbs and other infrastructure. Municipalities see pilot projects as beneficial because their approvals are typically more streamlined, resulting in quicker implementation times, and are more easily altered or removed if the reaction is negative.

Examples: Salt Lake City’s first separated bike lane on 300 East was introduced as a pilot project and generated significant media attention and feedback. Almost two years later, the pilot project remains installed and the city is investigating a more permanent design.

New York City and others have deployed separated bike lanes using non-permanent treatments that allow for flexibility and the ability to make changes

as needed if certain user groups encounter problems as a result of separated bike lane installation and as the city improves upon earlier separated bike lane designs.

Los Angeles’s plan for a separated bike lane along Figueroa Street carefully considered its potential effects on the ability of the street to handle existing motor vehicle volumes. As a result, the current design plan has some sections of the corridor revert from a protected separated bike lane alignment to a standard bicycle lane in order to maintain this capacity. The city is hopeful that its thorough engineering analysis will result in a successful project for all users upon implementation.

Exceptions: Some municipalities reported not considering roadway availability first; instead they look at benefits to the bicycle network first and foremost. Austin has embarked on separated bike lane implementation in its downtown while knowingly accepting potential reductions—real or perceived—in vehicle level of service. In Washington DC, planners sited the L Street separated bike lane in a corridor with essentially no excess roadway capacity.

Further Study: Most municipalities are unsure of what type of decrease in vehicular capacity should be considered acceptable when a separated bike lane is installed. How can this balance be better defined? For example, is a reduction from LOS A to LOS C on a roadway with ADT of 10,000 acceptable if the separated bike lane carries 1,000 cyclists per day? Can these types of tradeoffs be quantified? How should “excess capacity” be defined?

Choosing locations for separated bike lanes and defining what makes a successful separated bike lane should include analysis of who would benefit from separated bike lane construction. Currently, most municipalities interviewed do not comprehensively address issues of transportation equity or health impacts when planning for separated bike lanes. Studies comparing the demographic characteristics of separated bike lane users with the characteristics of surrounding communities would benefit municipalities as they move forward in planning and building out their separated bike lane networks. Similarly, Health Impact Assessments (HIA’s) might be appropriate to advocate and plan for separated bike lanes for communities in need.

Call Out / Case Study: Pilot Programs in Boulder, CO: Boulder, CO, uses pilot projects extensively on many infrastructure projects through its “Living Laboratory” program. A separated bike lane on Baseline Road was installed in summer 2013 using this program, and another for University Avenue is scheduled for fall 2014. The “Living Laboratory” program intentionally involves limited public outreach to begin with and a concentrated effort to follow-up with the public to determine if the project should be made permanent. The program benefits the city by minimizing much of the upfront costs of public outreach that might be spent for naught if a project is ultimately rejected. Boulder prides itself on its active citizen participation in civic projects, and pilot programs allow the city to be more experimental while still maintaining its responsive reputation before

permanent separated bike lane designs are finalized. Boulder’s planners use the program to actively identify potential successful separated bike lanes and test these perceptions in real-time.

Photo:



Boulder’s Baseline Road separated bike lane was installed with inexpensive treatments as part of the city’s Living Laboratory pilot program. *Source: City of Boulder*

Section:	Planning – 2
Topic:	Separated Bike Lanes and Complete Streets
Lesson:	Planning for separated bike lanes is often part of planning for Complete Streets. ¹ Municipalities incorporate separated bike lanes as part of a toolkit of strategies to serve all road users, calm traffic, and improve safety outcomes.
Detail:	Municipalities typically conveyed that separated bike lane planning should be accomplished through a Complete Streets approach that balances the needs of all street users (motorists, cyclists, pedestrians, transit users). Design and engineering practitioners often modify separated bike lane plans and designs to comprehensively accommodate the needs of these groups. Municipalities that focus on planning for separated bike lanes in the context of traffic calming, Complete Streets, potential safety benefits, and improved mobility for all street users, along with municipalities that can show these benefits (with data to back up the claims), will likely have an advantage in the planning and implementation of separated bike lanes.
Examples:	<p>Seattle has framed separated bike lane projects within the context of total street capacity (versus motor vehicle capacity alone) and potential safety benefits for all users, particularly children, the elderly, and other groups vulnerable to roadway dangers.</p> <p>Philadelphia’s Center City Business District (a local business improvement district (BID)) embarked on a traffic calming and safety campaign and found that separated bike lane installation would be a way to accomplish these goals; separated bike lanes are currently planned for Market Street and JFK Boulevard.</p> <p>Missoula’s downtown BID made a similar case for North Higgins Street, and a separated bike lane was constructed as a result in 2010.</p> <p>Planning for separated bike lanes has evolved in Chicago to include policy level discussions between the City’s bicycle program and planners at the Chicago Transit Authority. Chicago considers its growing separated bike lane network as a way to improve access to transit, facilitate multi-modal connections, and build Complete Streets.</p>
Call Out / Case Study:	<u>Evaluation of Cycle Tracks using a Complete Streets Approach in Seattle and New York</u> : Seattle conducts thorough technical analyses under existing and forecasted conditions prior to engaging the public on its separated bike lane projects. The analyses assess the following for the entire corridor:

¹ Complete Streets are those designed and operated to enable safe access and travel for all users, regardless of mode choice. For additional information, see the National Complete Streets Coalition website at <http://www.smartgrowthamerica.org/complete-streets>.

1. parking utilization,
2. collisions,
3. land use,
4. growth projections,
5. travel time, and
6. Level of Service (LOS).

Seattle takes a comprehensive perspective in assessing corridor performance, with the goal of improving access for all modes. The City sees LOS as one factor, but takes a holistic view towards mobility and is willing to make sacrifices – for example, Seattle may accept increased side street delays to provide lower delay on major streets with high transit ridership. In addition to movement along the corridor, Seattle evaluates crossing opportunities for pedestrians and cyclists, and tries to eliminate barriers and enhance crossing opportunities in areas with low vehicle turning volumes. Applying these treatments in concert with a separated bike lane installation can increase public buy-in and represents a true Complete Street approach to roadway redesigns.

Seattle then engages stakeholders and the public to discuss the design changes, presenting the analysis about how the street will function in the future, including potential impacts on travel time. The City publicly projects possible increases in travel time, and advocates such changes as a trade-off for the implementation of a more Complete Street that accommodates all modes. After the implementation of each project, the City performs a follow-up evaluation using the same metrics. This open process helps instill confidence in the City's analysis methods and its forecasts for future projects.

New York City evaluates its separated bike lane projects by reporting its effects on all users of the roadway. Framing these projects as both mobility enhancements and as traffic calming tools, the City publishes before- and after-travel time and safety outcome figures as they relate to cyclists, pedestrians, and motor vehicle occupants. The City looks at separated bike lanes as a tool in its Livable Streets toolkit, and has combined such projects with pedestrian plaza programs and Select Bus Service transit corridors, all under the umbrella of comprehensive redesigns to create Complete Streets.

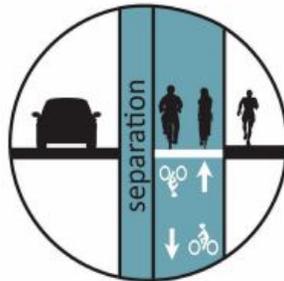
Photos:

SDOT **Westlake Cycle Track Project** March 2014

What is the Westlake Cycle Track project?

The Westlake Cycle Track is a project to design and build a cycle track along Westlake Avenue North between Lake Union Park and the existing Ship Canal Trail in front of Diamond Marina (south of the Aurora Bridge overpass).

A cycle track, or protected bike lane, is physically separated from motor vehicle traffic and either separated or delineated from pedestrian traffic – it helps people on bikes access places safely and conveniently.



Why a cycle track?

The Westlake Cycle Track's overarching goal is to improve safety for all modes of travel in the right-of-way. An additional goal is to improve accessibility, connecting northwest Seattle with Seattle's fast-growing South Lake Union and downtown neighborhoods. Another is to further the City's broader goal of having a safe bicycle route within a quarter mile of all residents.

What are the project goals?

- Safety** Improve safety for bicycle riders, for pedestrians and for motor vehicles.
- Connectivity** Create a high-quality bicycle connection between South Lake Union, Westlake and the Ship Canal Trail.
- Equity** Improve opportunities for bicycle riders of all ages and abilities.
- Livability** Support the Westlake, South Lake Union and northwest Seattle communities by creating a welcoming environment for business, recreation and transit.
- Ridership** Increase amount and mode share of bicycles riding on Westlake for commuters, residents, workers, and tourists.



The Westlake Cycle Track will be constructed within the publicly-owned 150-foot-wide City-owned right-of-way along Westlake Avenue North, between Lake Union Park and the Ship Canal Trail south of the Aurora Bridge overpass.

Seattle's plan for a separated bike lane on Westlake Avenue involves extensive before- and after- analysis and public outreach. This fact sheet highlights the Complete Street benefits for all users that will arrive with project implementation, currently slated for 2015. *Source: City of Seattle Department of Transportation*



New York City has found that separated bike lane installations generally improve safety outcomes for all users, including along 1st Avenue. This image includes a left-side one-way separated bike lane, pedestrian islands resulting in shorter crossing distances, and a dedicated Select Bus Service bus lane on the right.
Source: New York City Department of Transportation

Section: Planning – 3

Topic: Planning for Bicycle Networks

Lesson: Separated bike lanes have great potential to fill needs in creating “low-stress” bicycle networks in U.S. municipalities. However, most municipalities interviewed have yet to integrate separated bike lanes into their bicycle master plans – a trend that is likely to change as separated bike lanes become more mainstream.

Detail: Municipalities use various approaches in planning separated bike lanes, with some focusing on site-specific improvements while others plan a more comprehensive, high-quality bicycle network. The former use separated bike lanes to solidify certain connections at nodes where physical separation may improve bicycling comfort (for example, near highway exits or high-volume chokepoints such as approaches to bridges). Others, also including some municipalities targeting specific sites, view separated bike lanes as a conduit for the creation of a separate “2.0 bicycle network”. Such a network might be overlaid on and around – or even replace – an existing bicycle network, but pays particular attention to higher-quality, lower-stress connections, even if this results in some backtracking or extra distance requirements for cyclists using the enhanced network. The goal of a “2.0 network” is to create a set of low-stress connections that essentially covers a municipality while emphasizing the quality of bicycle facilities over their quantity. Depending upon the context of the corridor (motorist volumes and speeds, roadway alignment, etc.), municipalities may find separated bike lanes provide great benefits in moving towards building out such a network.

Most municipalities do not specifically address or include separated bike lanes in their bicycle master plan (if they have a bicycle master plan at all). Instead, they tend to identify separated bike lane projects opportunistically. Resurfacing projects, roadway reconstruction, and projects that can be implemented easily are often drivers of separated bike lane corridor choices.

Examples: New York City has applied site specific separated bike lane treatments at bridge entrances such as the Sands Street median separated bike lane approach to the Manhattan Bridge.

Municipalities such as Austin, TX, Boulder, CO, and Portland, OR, have begun to view separated bike lanes as implementation tools in the creation of low-stress bicycle networks that appeal to cyclists of all skill levels.

New York City’s de facto bicycle master plan is represented by a map of potential bicycle routes that are generally undifferentiated by route type. The city’s bicycle improvements vary from year to year based on a variety of factors such as bicycling demand, community requests, available funds, upgrading more stressful or less safe facilities, etc. There is no explicit long-term plan for city-wide separated bike lanes. As is the case in many U.S. municipalities, bicycle

volumes are increasing significantly and the needs of bicyclists are quickly evolving, and this approach is a reflection of that.

Exceptions:

Some municipalities are including separated bike lanes in their bicycle master plans already. Atlanta’s bicycle master plan identifies five core travel corridors critical for bicycle network connectivity for priority bike improvements, including separated bike lanes.

Portland’s Bicycle Plan for 2030 explicitly identifies routes to be treated with “separated in-roadway” (i.e. separated bike lane) treatments, and forecasts the percentages of the City’s population that would live within ½ and ¼ mile of low-stress bikeways in future years as the plan is implemented. The City’s three existing separated bike lanes on Broadway, Cully Avenue and Multnomah Street were identified in the 2030 Plan as needing a separated roadway treatment. They were then selected for construction opportunistically and implemented as demonstration projects.

Seattle’s next master plan will specifically refer to separated bike lanes.

Los Angeles’s Department of Transportation intends to identify corridors for protected bicycle facilities (in some cases separated bike lanes) in its forthcoming strategic transportation plan.

Only a small subset of locations indicated that their planning of separated bike lanes was not site-specific or does not point towards creation of a low-stress network of bicycle facilities. One such city is St Petersburg, FL, which has planned separated bike lane routes to connect existing greenway and trail facilities within its downtown. As opposed to using separated bike lanes to supplement or be a part of a traditional downtown bicycle network, the city’s existing and planned separated bike lanes are generally seen as an extension of and connection to larger facilities within the city’s recreational trail network.

Further Study:

Low-stress bicycle networks are important for the future expansion of cycling, as cyclists in the “interested but concerned” group tend to represent the majority of potential users of bicycle facilities in the United States. Attempts to create low-stress, connected networks are still in their infancy domestically, so it may be worthwhile to study how such networks abroad (for example, in Copenhagen) induce greater demand for cycling. The Mineta Transportation Institute has outlined the benefits of creating a low-stress bicycle network, and has shown how even marginal improvements to bicycle facilities in San Jose would greatly expand the reach of a bicycle network that even novices would be comfortable using.² In many instances, separated bike lanes could play a key role in providing the upgraded facilities needed to create low-stress networks along with bicycle boulevards, neighborhood greenways and other off-street paths and trails.

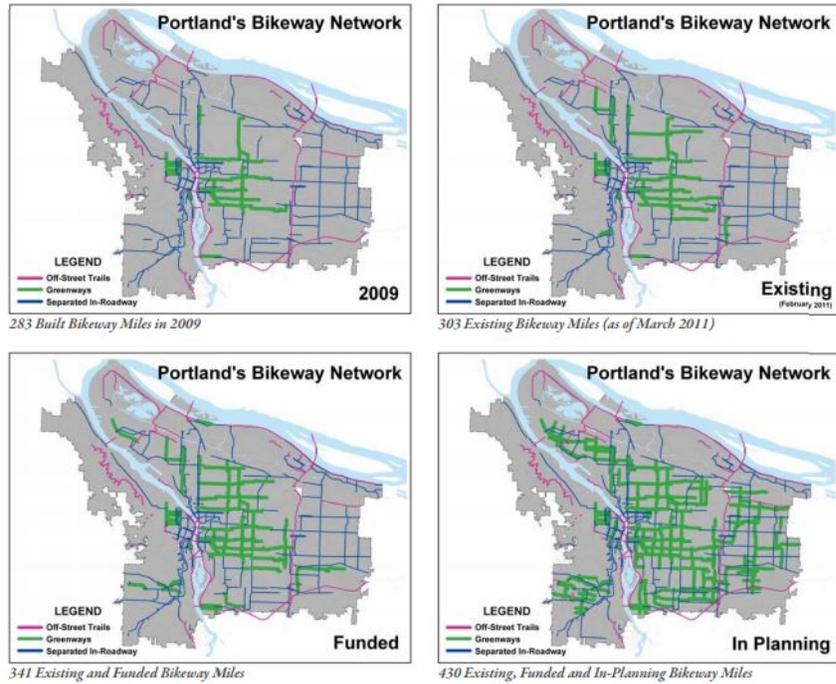
² See Firth, Mekuria, and Nixon: Low-Stress Bicycling and Network Connectivity. Published May 2012 and available at <http://transweb.sjsu.edu/project/1005.html>

Call Out / Case Study: “2.0 Networks” in Austin and Boulder: Low-stress bicycle networks – already common in European municipalities – may become more widespread in the United States in coming years as cycling becomes a legitimate transportation option and municipalities seek to attract riders who might not be comfortable on higher-stress facilities that face significant interaction with motor vehicle traffic. Two municipalities leading the push in creating these networks – and using separated bike lanes as a major component of building them out – are Austin, TX, and Boulder, CO. Boulder has an extensive network of on-street bicycle lanes (along with trails and sidepaths) but is looking towards creating a “2.0 network” to provide a means to bicycle to points throughout the city in a low-stress environment. Separated bike lanes will be tested in corridors where off-street facilities don’t yet exist and are not a realistic option, such as Baseline Drive and University Avenue. Similarly, Austin, TX, is combining its greenways, sidepaths, low-volume streets and, in some cases, on-street separated bike lanes, to move toward a goal of creating an “all ages network,” or one that provides even novice cyclists the ability to travel extensively by bicycle in the city via lower stress facilities. The City’s highly popular Bluebonnet Lane separated bike lane runs adjacent to an elementary school and is frequently populated with young children commuting to and from school on two wheels.

Photos:



Austin’s Bluebonnet Lane separated bike lane is part of the City’s expanding “all-ages” network. *Source: City of Austin*



Portland's BIKEWAY MILES				PORTLANDERS LIVING NEAR LOW-STRESS BIKEWAYS - Number / (%)		
Year	Neighborhood Greenways	Separated In-roadway	Off-street Trails	Total	Within 1/2 Mile	Within 1/4 Mile
2009	30	175	78	283	277,300 / (51%)	159,700 / (29%)
Existing (March 2011)	46	179	78	303	342,200 / (62%)	212,800 / (39%)
Existing & Funded	71	187	83	341	399,600 / (73%)	268,200 / (49%)
Existing, Funded & In-Planning	149	198	83	430	493,900 / (90%)	390,900 / (71%)

Portland's Bike Plan for 2030 targets an expansion of a low-stress network, which includes separated bike lanes. *Source: One Year Progress Report on Portland Bicycle Plan for 2030, published April 2011*

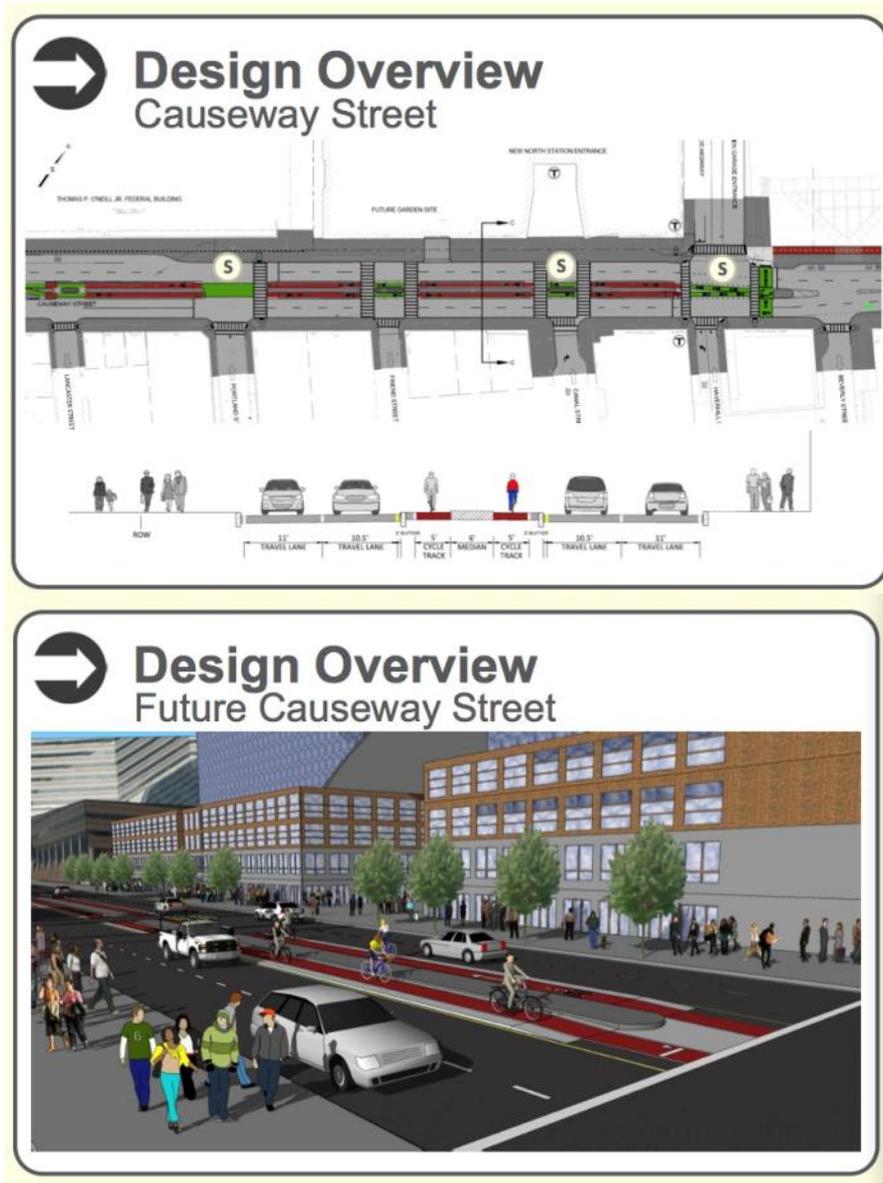
Section:	Planning – 4
Topic:	One-Way vs. Two-Way Separated Bike Lanes
Lesson:	Decisions on one-way versus two-way separated bike lanes depend on context. One-way separated bike lanes are generally a simpler design, but two-way facilities provide advantages in certain situations. Intersections and termini create configurations that introduce design challenges.
Detail:	One-way separated bike lanes minimize the dangers that come from motorists or pedestrians not expecting a cyclist to cross their path from an unanticipated direction. They also will result in simplified turning movements at intersections, which create fewer conflicts. Two-way separated bike lanes provide benefits, however: they are wider than one-way facilities, which helps with plowing and maintenance difficulties in narrow one-way facilities that were brought up by a majority of municipalities interviewed. They can be especially beneficial when adjacent to an uninterrupted curb with few or no intersections or driveways. Two-way separated bike lanes also provide the benefit of reducing wrong-way cycling.
Examples:	<p>Boston is designing a two-way separated bike lane on the outside edge of Commercial Street (adjacent to the harbor) because it has many fewer intersection and curb cut conflicts. The City is also designing a median-running two-way separated bike lane on Causeway Street to avoid heavy pedestrian activity on both sides of the street.</p> <p>Washington, DC’s Pennsylvania Avenue features a center two-way separated bike lane/buffered bike lane to avoid heavy tour bus curbside activity. The City also installed two-way separated bike lanes on 15th Street and L Street to provide bi-directional bicycle travel on one-way streets, but has since found that unexpected intersection conflicts reduce the benefits of providing cyclists these two-way options. The City will not likely place two-way separated bike lanes on one-way streets again.</p> <p>Long Beach, CA, installed a pair of one-way separated bike lanes on parallel one-way streets in its downtown, on Broadway and 3rd Street. The City has found that wrong-way cycling occurs frequently, as cyclists avoid adding extra distance especially on short trips through downtown.</p>
Call Out / Case Study:	<u>Planning for a Two-Way Separated Bike Lane in Boston, MA:</u> As part of its Connect Historic Boston bicycle trail initiative, planners in Boston faced a challenge in designing a segment along Causeway Street, which runs adjacent to high-volume pedestrian attractors like North Station and the TD Bank Garden. With numerous intersections on the south side of the street, and high pedestrian volumes on the north, the City has decided to use an existing median to build a center-running two-way separated bike lane in this section. The two-way alignment allows crossing pedestrians to contend with crossing only one rather than two separate bicycle facilities, and also provides a median that

decreases exposure to motor vehicle traffic. Cyclists will enjoy the benefit of a protected facility that is well-marked and easily identifiable.

Photos:



Washington DC's center-running two-way separated bike lane on Pennsylvania Avenue reduces conflicts with pedestrians along the curbs. *Source: Federal Highway Administration*



Boston plans a center-running two-way separated bike lane on Causeway Street as part of its Connect Historic Boston bicycle trail initiative. *Source: Connect Historic Boston*

Design

Section: Design – 1

Topic: Standards / Lack of Standards

Lesson: Separated bike lane design varies significantly, depending on local context and design preferences. Municipalities use various resources to assist in their design processes, but developing a menu of separated bike lane design options would likely be beneficial for U.S. municipalities. Any design guidance should allow municipalities to maintain design flexibility, as encouraged by FHWA.

Detail: Many factors playing a role in separated bike lane design. These include ensuring access for pedestrians and meeting accessibility requirements under the Americans with Disabilities Act of 1990 (ADA) and the Rehabilitation Act of 1973 (Section 504), the presence of on-street parking and potential parking impacts, freight delivery and loading considerations, land uses, available roadway space, community and political priorities, maintenance concerns, and others.

Many municipalities are looking to the National Association of City Transportation Officials' Urban Bikeway Design Guide ("NACTO guide") for design ideas, and even to other municipalities for design inspiration. Others have sought guidance from design consultants or even NACTO's 18 member cities. Municipalities have generally not looked to international design publications for guidance.

The lack of detailed separated bike lane design guidelines has deterred some municipalities from pursuing separated bike lanes, typically because existing guidance is unclear or unavailable for certain design features, the municipality lacks the necessary in-house capacity to design separated bike lanes, and/or the lack of guidelines makes reaching design consensus between staff and agencies difficult.

Municipalities with more experience with separated bike lanes are able to develop and modify local practices that can be applied to future projects, with the design process becoming more streamlined with each project. As a result, the best practices for some municipalities may be their own, developed incrementally and over time. The unique conditions of every municipality, with different street networks, diversity of land uses, specific local regulations, varied geometric design practices, and other factors, could make the development of detailed design guidelines difficult. While counter to a philosophy of uniform national design guidelines based on engineering consensus, the issue warrants further discussion, as expressed by many municipalities.

Federal guidance on separated bike lane design already encourages municipalities to practice flexibility in their design choices. A memo released by

FHWA in August 2013 speaks to the agency’s support for flexible designs for bicycle and pedestrian facilities, along with relationships among existing guidance from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and NACTO.³

Examples:

Portland, OR, has relied on the NACTO guide for conceptual designs and made adjustments where required. New York City’s early separated bike lane designs influenced the development of the NACTO guide, and several municipalities interviewed, including Boulder, CO, mentioned using New York City’s designs as a reference point. Atlanta submitted a specific design problem related to a hotel loading zone at a proposed separated bike lane to NACTO, and its members from other municipalities provided design advice; this service is available to NACTO member cities.

San Francisco has developed its own set of guidelines called the Innovative Bicycle Treatment Toolbox. These guidelines provide more details than the NACTO guide, but are also tailored to San Francisco and California’s specific bicycle regulations and may not be applicable to other municipalities.

Phoenix has considered separated bike lanes but a lack of guidelines for designs at driveways and curb cuts has slowed the planning and design process on certain corridors. Charleston, SC, stated that a lack of national guidelines results in a lengthy design-exception approval process with the South Carolina Department of Transportation. (Note – approximately 85% of Charleston streets are under the jurisdiction of the State). Because separated bike lane designs are not included in the State’s design guidelines (such as the AASHTO *Guide for the Development of Bicycle Facilities*), they require approval as an exception. Madison, WI, looked to the NACTO guide but city engineers would be more comfortable with more detailed design guidelines.

Seattle, San Francisco, New York, Chicago, and Washington, DC, have all installed multiple separated bike lanes and have several years’ experience doing so. All reported that they look to their past designs for their development of future projects and modify the designs based on lessons learned from the past projects. New York, for example, built out its 9th Avenue separated bike lane (a one-way facility) with a 9 foot lane but observed motor vehicles entering and even parking on the facility. Latter separated bike lanes were reduced to approximately 6 feet.

Exceptions:

Some municipalities, such as Salt Lake City, UT, and Cambridge, MA, expressed doubts that official guidelines would always help advance separated bike lane planning and implementation. Since roadway and intersection alignments can vary so much from municipality to municipality, and even within the same municipality, any guidelines are unlikely to address every unique design issue that may be involved with a separated bike lane plan. As a result, separated bike

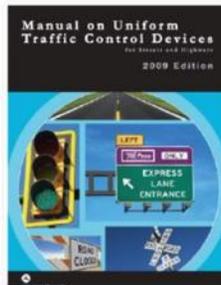
³ See http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/design_guidance/design_flexibility.cfm

lane guidelines that are too prescriptive could restrict the flexibility that some municipalities currently enjoy in the absence of official guidelines.

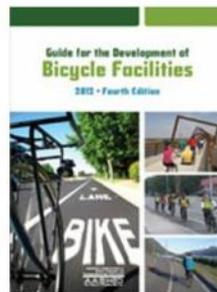
Further Study:

Should separated bike lane design be standardized? Some municipalities have requested common design guidelines. Other municipalities indicate that the flexibility that comes from not being pinned down to a limited set of design options allows for designs tailored to local conditions and context. This flexibility may be important given the many elements that differ within each corridor or even between blocks or intersections. In general, municipalities are seeking guidance that is more detailed than the NACTO guide but not restrictive to the point of limiting flexibility that is needed to accommodate local conditions and context. While a “one size fits all” approach to separated bike lane guidelines may have limited value given the issues described above, a more appropriate approach may be to develop a menu of separated bike lane options that vary based on density, street network connectivity, development patterns, and related factors.

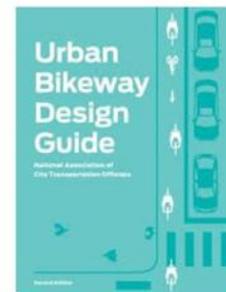
Photo:



MUTCD, 2009
Edition



AASHTO Bike
Guide, 4th Edition
(2012)



NACTO Urban
Bikeway Design
Guide

Existing standards that touch on elements of separated bike lane design include these documents, but no comprehensive design guidelines exist for separated bike lanes.

Source: Sam Schwartz Engineering

Section:	Design – 2
Topic:	Intersection Design
Lesson:	Intersections are the most difficult design challenge. Intersection design strategies such as mixing zones, lateral shifts, dedicated bike signalization, and others are used by municipalities differently in different contexts.
Detail:	Municipalities employ varying strategies on intersection design. Municipalities using a mixing zone approach (where the separated bike lane ends prior to an intersection and the travel lane is shared with turning motor vehicles) praise it because it is generally cheaper (there is no need for signal modifications). Some municipalities appear less eager to adopt mixing zones, however, because of perceived comfort or safety issues or the volume of vehicles turning across the separated bike lane being too high. As a result these municipalities struggle with costs associated with more complicated intersection signalization. Many municipalities use a combination of mixing zones and intersection treatments with less exposure, depending on conditions. Other municipalities are using a design in which the separated bike lane shifts laterally to a location between the motor vehicle turn lane and the motor vehicle through lane, rendering the onus of yielding to through cyclists on right-turning motorists.
Examples:	<p>Portland, OR, uses mixing zones in some locations, but believes they are not appropriate for all situations, and that these designs may deter novice or “interested but concerned” cyclists. The city also is eager for guidance on traffic volume and speed levels in which mixing zones are acceptable and those where a separate signal phase is more appropriate.</p> <p>Salt Lake City is using the lateral shift design on a pilot separated bike lane project and has received positive nationwide feedback from planners and designers.</p>
Further Study:	A matrix of design options would ideally address the intersection design question as it relates to traffic volumes (particularly turning vehicles), traffic speeds, cycling volumes, and other factors.
Call Out / Case Study:	<p><u>Intersection Treatments in New York City:</u> New York City generally favors mixing zones at most intersections and uses less prescriptive signage and street markings in these areas relative to other large municipalities such as Chicago and Washington, DC. The City believes the zone functions mostly as a negotiation between cyclists and drivers, regardless of who has the legal right of way. The City does, however, abandon mixing zones in favor of dedicated bicycle signals when separated bike lanes cross multi-lane or two-way streets and/or streets with high traffic volumes (for example 14th, 23rd and 34th Streets).</p> <p>The City views intersections in three levels:</p> <ol style="list-style-type: none"> 1. Intersecting streets with low volumes – a mixing zone is applied.

2. Intersecting streets with mid-level volumes – a split phase with a dedicated bicycle green signal phase followed by a motor vehicle turn phase is applied. The split is useful because it segregates through cyclists from turning vehicles.
3. Intersecting streets with high volumes – a mixing zone is applied. In these situations, a split phase with a dedicated bike signal would cause the intersection to lose its ability to process high volumes of turning motor vehicles, with congestion ensuing.

The City applies a general rule that the first category includes streets with fewer than 150 turns per hour, the second includes streets with 150 to 250 turns per hour, and the third includes streets that see over 250 turns per hour. However, agency officials stressed that these values are extremely context sensitive and rarely if ever should be considered as specific criteria for intersection design type.

Photo:



A lateral shift approach on the 300 East separated bike lane in Salt Lake City. Cyclists move to the left of the motor vehicle right-turn lane in advance of any opportunity for vehicles to move right. This approach places the onus of yielding to cyclists squarely on motor vehicles that need to make a right turn. *Source: City of Salt Lake City*



New York City applies mixing zones on streets with relatively low intersecting and turning volumes. Above, a typical mixing zone along the 1st Avenue separated bike lane. *Source: New York City Department of Transportation*



An intersection with a split phase and dedicated bicycle signal on the 9th Avenue separated bike lane in New York City. *Source: New York City Department of Transportation*

Section:	Design – 3
Topic:	Curb Cuts / Driveways
Lesson:	Designing separated bike lanes to interact with curb cuts or driveways becomes more difficult as their frequency increases, due to increased potential for motor vehicle and cyclist conflict within the separated bike lane.
Detail:	Curb cuts and driveways are a significant problem in some municipalities, especially those with more suburban development patterns. Municipalities question both what is best from a design standpoint and at what point does driveway/curb-cut frequency render potential separated bike lane benefits moot. It appears no consensus has yet been reached on the issue.
Examples:	Salt Lake City treats major commercial driveways in the manner that the NACTO guide prescribes to intersections, with appropriate daylighting ⁴ distances. The city is also considering applying green paint to separated bike lanes in these locations to alert cyclists and motorists to the potential for conflicts, as is practiced at certain locations on separated bike lanes in Washington, DC.
Further Study:	<p>Design alternatives that reduce the number of conflicts at driveways could be useful, especially for municipalities with corridors that feature large scale commercial development with off-street parking lots or in suburban areas with many residential driveways. One option may be a median separated bike lane, such as New York’s Allen and Pike streets separated bike lane and the Pennsylvania Avenue bikeway in Washington, DC.</p> <p>In areas with generous rights-of-way, another option may be a service road that collects traffic entering and existing driveways, with a separated bike lane located between the service road and the adjacent main roadway. Phoenix, AZ, has considered such designs due to the high number of residential and commercial driveways along its streets, but not yet at a detailed design level.</p>

⁴Daylighting refers to the removal of on-street parking near intersections or adjacent to curb cuts in order to improve sightlines for motorists, cyclists, and pedestrians.

Photo:



Median running separated bike lanes, such as this one along Allen Street in New York City, can reduce cyclist-motor vehicle conflicts at curb cuts and driveways. *Source: New York City Department of Transportation*

Section:	Design – 4
Topic:	Parking and Loading
Lesson:	<p>Parking alignment changes (generally from curbside to floating) may see initial resistance but most municipalities report few problems as the driving public conquers the learning curve. Proactive consideration of loading and unloading requirements for individuals and businesses is beneficial to separated bike lane planning and design.</p>
Detail:	<p>Separated bike lanes are often implemented through the removal of a parking lane or by moving the parking lane between the separated bike lane and motor vehicle lanes. As additional separated bike lanes are installed in a municipality, the public – motorists, businesses, residents, and separated bike lane users alike – better understands effects on parking and achieves more familiarization with the implementation process. As a result, the first separated bike lane may often be the most difficult to plan in terms of effects on parking and the public’s reaction to those changes. Furthermore, a separated bike lane’s effect on curbside parking often depends on the local context and prevailing regulations.</p> <p>Municipalities apply varying strategies to address loading zones, with flexibility between spaces dedicated to loading vs. parking playing a key role. Separated bike lanes that pass through commercial corridors need to be carefully planned to accommodate loading, especially in municipalities where off-street loading is unavailable. Issues with loading adjacent to residential land uses are generally not as problematic, but can occur especially when framed with accessibility (see following section). Municipalities have found that as more separated bike lanes are installed, loading issues are less contentious as the public becomes more accustomed to floating parking / floating loading zones.</p> <p>Several municipalities reported that illegal parking or loading in the separated bike lane often occurs when motorists are not prepared for the change in the streetscape. However, most of the time, drivers quickly learn how the facility functions and municipalities report this problem dissipates over time. This is especially true for municipalities with multiple separated bike lanes, where the driving public becomes more and more accustomed to new street cross sections with each facility.</p>
Examples:	<p>New York City has found that as additional separated bike lanes are installed, the public reaction to a change in parking alignment and/or decreases in number of available on-street parking spaces (due to daylighting at intersections, etc.) has not been as severe and has become less reactionary. This comes from a combination of past experience and knowing what to expect with a floating parking lane along with more refined and targeted outreach practices by the city.</p> <p>In Chicago, city officials have strived to remove as little parking as possible due to the public’s general opposition to such practices and the city’s privatization of</p>

metered parking – losses of parking spots would result in revenue losses for the private operator.

In New York City, detailed parking/curbside loading analyses are conducted during design stages, and parking regulations are modified to prioritize the needs of businesses along separated bike lane corridors.

Exceptions:

Some municipalities face few issues regarding on-street parking because most parking is provided off-street. Atlanta reports having little trouble planning separated bike lanes around parking, for example. Other municipalities with less compact, more suburban development patterns, such as Alameda, CA, also report a similar experience.

Section:	Design – 5
Topic:	Accessibility
Lesson:	Municipalities must take measures to address accessibility and/or not reduce access as a result of implementing separated bike lanes. Requirements fall under the Americans with Disabilities Act (ADA) but may also include specific supplemental State or local legislation.
Detail:	Separated bike lane installations often impede access to the curb for alighting motor vehicle passengers or transit users. In many cases, access to the curb for cars parking or unloading in a floating parking lane has been addressed by installing mid-block curb ramps and buffers wide enough to accommodate wheelchair lifts.
Examples:	San Francisco made adjustments to its Market Street separated bike lane by increasing the width of the buffer between the floating parking lane and curbside separated bike lane. The city installed additional mid-block curb ramps and adopted a policy allowing taxis and other vehicles serving those with disabilities to legally pull into the separated bike lane where necessary to make pick-ups and drop-offs. The city also deployed signage to clearly indicate allowable actions within the separated bike lane regarding accessibility and curb access.
Further Study:	Separated bike lanes can complicate accessibility issues, particularly at intersections. Further guidance on the impact of raised islands (and the need for push buttons, truncated domes, etc.), access to bus stops, placement of accessible parking space signing, and signal timing is needed.

Section:	Design – 6
Topic:	Transit Stops
Lesson:	Municipalities have deployed a variety of treatments to accommodate bus stops and separated bike lanes.
Detail:	<p>Some municipalities where one-way streets are common locate the separated bike lane on the left side of one-way streets to avoid bus stops. Other municipalities have built “bus bulbs” in the street beyond the separated bike lane. Such treatments typically place a physical separation between the bus bulb and the separated bike lane, such as a railing, to direct bus riders to enter and exit the bus bulb via the adjacent crosswalk. Alternately, some bus bulbs include curb ramps closer to where the front of the bus would be located, or at stops at mid-block. Others apply similar designs without the physical concrete bus bulb – buses stop in the travel lane and include wheelchair lifts that lower fully to the carriageway. Although bus riders must cross the separated bike lane to access the bus stop, most municipalities that have used bus bulbs did not report problems from an operations or safety standpoint where such solutions were implemented.</p>
Examples:	<p>Philadelphia and New York City have many one-way streets; on these corridors separated bike lanes are located on the left side of the roadway while transit stops are placed on the right, eliminating potential cyclist-transit user conflicts.</p> <p>St. Petersburg, FL, uses bus bulbs both near crosswalks and at mid-block locations. Atlanta applies a similar treatment without a raised bulb; instead buses stop at street level but offset from the separated bike lane. In both cases transit users cross the separated bike lane for bus boarding and alighting.</p>

Section:	Design – 7
Topic:	Colored Lanes
Lesson:	For almost all municipalities interviewed, the use green colored pavement is limited to bicycle-motor vehicle conflict areas.
Detail:	Municipalities apply colored paint (almost exclusively green) in separated bike lanes to designate areas of potential bicycle-motor vehicle conflict. The intention of colored paint is to alert both cyclists and motorists to the potential for conflict, and to provide cyclists with a sense of increased visibility in such areas. Only two municipalities use colored pavement in low-conflict, rather than high-conflict, areas. All municipalities are concerned about the high cost and maintenance required for colored pavement.
Examples:	All municipalities but two interviewed use colored paint in high-conflict areas. Chicago and Washington DC in particular have a long history (in terms of recent US separated bike lane construction periods) of applying green paint to high-conflict areas of their separated bike lanes.
Exceptions:	Of the municipalities interviewed, Evanston, IL, and New York City are unique in their use of colored pavement in low-conflict areas of separated bike lanes. New York's reasons include cost considerations (paint in intersections is worn off by turning automobile traffic much faster than paint within the separated bike lane), visibility/safety concerns (the green paint that is applied cannot be easily seen by motorists at night), and data showing cyclists are less likely to check for conflicts in colored areas.
Further Study:	New York City expressed a desire to study the true effects of colored paint on cyclists and motorists to determine its benefits, if any. For example, does the presence of green paint make it more likely a cyclist will check for motor vehicles, or less so because of a perceived safety benefit of having paint on the ground?

Photo:



Colored paint is applied in conflict areas near intersections on the Milwaukee Avenue separated bike lane in Chicago. *Source: Chicago Department of Transportation*

Outreach and Coordination

Section: Outreach and Coordination – 1

Topic: Building Support

Lesson: Municipalities build support for separated bike lane projects through targeted public outreach and support from local businesses or Business Improvement Districts (BIDs). Notwithstanding these efforts, municipalities rarely engage in public education campaigns to accompany separated bike lane rollouts.

Detail: Outreach for separated bike lanes is generally project specific. Generally, the more complex the project in terms of impact, the more outreach that is required. In many cases, municipalities are literally going door-to-door to affected businesses or, in some cases, residences. Most municipalities report that the most successful public outreach is started as early as possible and provides the public with transparent information on changes that are proposed to the streetscape. Some municipalities will make design changes (or even cancel or remove a project entirely) because of local opposition.

Local business support within municipalities that have or are planning for separated bike lanes is mixed. Partnerships with BIDs have been instrumental in advancing separated bike lanes in many municipalities. Businesses see separated bike lanes as a tool for traffic calming and generators of increased activity in front of storefronts. Still, other municipalities have very little support from the business community. Based on the municipalities interviewed, the trend seems to be pushing towards acceptance, especially as local businesses come to understand the potential economic benefits associated with bicycle infrastructure.

Few municipalities have engaged in large-scale public education efforts related to separated bike lane implementation or operations.

Examples: Municipalities differ on levels of public outreach on separated bike lanes depending on the typical political process. In Boulder, CO, every permanent separated bike lane project is subject to an alternatives analysis that the public is heavily involved in. Seattle, WA, also conducts a very robust public outreach process that includes clear communication to the public, supported by data analysis, both before and after a project's implementation.

Examples of support from local businesses includes the Higgins St. separated bike lane in Missoula, MT, which emerged through a downtown master plan that was conceived of and paid for by the local downtown business improvement association. The plan focused heavily on improving walking and cycling, which included separated bike lane facilities. While a few local businesses vocally opposed the project because of losses of curbside parking spots, the vast majority, along with the association's director and the director of

the downtown redevelopment agency, supported the project to bring safer cycling activity to downtown Missoula.

As bicycle facilities and separated bike lanes have become more popular in Chicago, the city is finding that small businesses are typically welcoming adjacent separated bike lanes because of their traffic calming effect and propensity to produce more walk-in traffic. In Salt Lake City, two future separated bike lanes are planned downtown, and a brewpub at the intersection of the proposed facilities has spearheaded support among the local business community to welcome the coming changes to the streetscape and to work with the city on adjustments to design elements as needed. Washington, DC, found that most businesses on L Street were supportive of a separated bike lane on the corridor; however, they did need to reach out extensively to a small number of opponents. In St. Petersburg, where some parking spaces were removed in conjunction with a separated bike lane, business opposition was largely tempered when the city offered to install bike racks at businesses adjacent to the lost parking.

Exceptions:

Unlike most municipalities interviewed, Indianapolis reports doing little in the way of cycle-track specific public outreach because of the simplicity of its designs and the lack of disruption to normal street functions downtown on its Cultural Trail.

Jackson, WY, plans to launch a public education campaign associated with its Broadway separated bike lane that will be implemented in 2014 and 2015. The campaign will include a partnership with a local advocacy organization, advertisements in the local newspaper, and temporary signage along the corridor during the initial rollout period. This type of education effort was rare among municipalities interviewed, and could serve as a model for education during implementation, especially in municipalities building their first separated bike lane facility.

A subset of municipalities reported that outreach to businesses is limited, in some cases due to lack of funding. Other municipalities, including Alameda, CA, have found that outreach to businesses is unnecessary in a less urban setting where business do not directly front the separated bike lane and ample off-street parking is provided.

Further Study:

As separated bike lanes grow in popularity and appear in municipalities unfamiliar with them, guidance on appropriate educational tools aimed at cyclists, motorists, and pedestrians may prove beneficial in reducing collision rates and providing the general public with a sense of comfort around new separated bike lanes.

Call Out / Case Study:

Separated Bike Lane Support from BIDs in Philadelphia and Miami: Business districts recognize that vibrant, thriving commercial spaces are characterized by walkability and activity. Philadelphia's Center City BID initiated a traffic calming project to slow traffic and make street crossings safer on JFK Boulevard and

Market Street. The BID worked with the City, neighborhood building owners, and retail tenants, and determined that a separated bike lane design would be the best method of calming traffic. The plan particularly appealed to business owners because it introduced two-way traffic, an outcome for which they had been advocating. During Park(ing) Day, the City enacted a temporary closure of one lane, and showed that traffic would still flow with a lane reduction.

Likewise, the Downtown Development Authority (DDA) in Miami led the planning and concept development of several separated bike lane facilities. The DDA is enthusiastic about separated bike lanes because of their ability to attract “interested but concerned” riders and draw new people to their district. Specifically, they are hoping to attract senior citizens, who often ride on the sidewalk in downtown.

In both cases, business districts will assume responsibility for cleaning and regular maintenance of the separated bike lanes.

Section:	Outreach and Coordination – 2
Topic:	Agency Coordination
Lesson:	Successful planning, design, and implementation of separated bike lanes are often contingent on cooperation by municipalities with state or county departments of transportation. Additionally, municipalities must ensure that coordination with street maintenance divisions occurs before and after separated bike lanes are constructed.
Detail:	<p>Coordination with State and county departments of transportation may be difficult due to the lack of national separated bike lane guidelines. Many municipalities expressed wishes to have more formal design guidance for separated bike lanes in order to ease the design review and approval process with State agencies.</p> <p>Coordination with street maintenance divisions has been mixed. Many municipalities cited examples of problems associated with street sweeping and snow removal in separated bike lanes. Municipalities have learned to coordinate with sanitation departments or other sister agencies prior to and during the planning and design process, rather than after, in order to minimize coordination challenges. Nevertheless, most municipalities still report that this issue is problematic.</p>
Examples:	<p>Charleston, SC, indicated that more formalized guidelines for separated bike lanes, such as via future editions of the AASHTO bike guide, would be very helpful in gaining approvals for separated bike lanes on its many roadways under State jurisdiction.</p> <p>Missoula’s downtown BID has assumed responsibility for cleaning and regular maintenance of the North Higgins Street separated bike lane. Its activities include snow removal and sweeping, and the BID owns vehicles that can fit into the separated bike lane.</p>
Exceptions:	Massachusetts is the first US state intending to publish a separated bike lane design guide.
Further Study:	Recommendations for coordination with various local municipal departments relative to a separated bike lane design and implementation timeline might reduce maintenance problems.

Photo:



The city of Boulder’s Transportation Division coordinates with its Public Works division to remove snow from the pilot separated bike lane on Baseline Road.
Source: City of Boulder

Construction and Maintenance

Section: Construction and Maintenance – 1

Topic: Debris and Snow Removal

Lesson: When building separated bike lanes, municipalities must consider how they will be swept and, if applicable, plowed during snow events. 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.

Detail: Snow plowing and street sweeping issues associated with the width of separated bike lanes relative to the width of sanitation vehicles have been an issue for most municipalities. Common issues are the lack of coordination between planning and maintenance agencies before building the separated bike lane and a lack of funding to purchase smaller sanitation equipment to fit the separated bike lane. Plowing and sweeping problems are exacerbated in many municipalities due to their separate departments for planning and maintaining separated bike lanes.

Examples: Portland, OR, and Austin, TX, both recognized the challenge of effective separated bike lane maintenance and have not let it delay their separated bike lane implementation processes. Portland has purchased a sweeper that can fit into 7.5' wide spaces. This dimension has become the standard minimum width for separated bike lanes in Portland. Austin has not yet purchased a special sweeper, but can sweep as narrow as 8.5' with existing equipment. The city may purchase new equipment in the future, as needed.

Further Study: Several municipalities mentioned that they are pursuing funding for smaller sweepers that can be used in separated bike lanes.

Photo:

The city of Milwaukee can clear snow from its raised Bay Street separated bike lane using its standard road-clearing equipment, as the separated bike lane provides sufficient width to do so. However, Milwaukee officials indicated that the rolled curb (at right) can present problems for its plowing equipment.

Source: City of Milwaukee

Section: Construction and Maintenance – 2

Topic: Materials

Lesson: Municipalities prefer cheaper, temporary materials for their flexibility and ease of installation. However, in the long run permanent solutions may result in sturdier facilities and potential cost savings.

Detail: With separated bike lanes quite new for many U.S. municipalities, many report using cheaper and/or temporary materials to reduce construction costs and speed implementation. For example, Chicago has reported using shorter flexible delineators and a reduced amount of paint in its newer designs in order to lower costs. However, some municipalities report that such treatments may be cheaper up front but more expensive to maintain in the long run.

Examples: St. Petersburg, FL, has had a separated bike lane in place downtown on 1st Ave South for several years and several more planned using more permanent materials and landscaping. The city finds that the resulting reduction in long-term maintenance costs results in projects that are ultimately cheaper overall.

Further Study: Additional information regarding the short- and long-term costs of varying materials would aid municipalities in their long-term separated bike lane planning.

Photo:



The 15th Street separated bike lane in Washington DC uses inexpensive flexible bollards and relatively minimal amounts of green paint. *Source: Federal Highway Administration*

Funding

Section: Funding – 1

Topic: Typical Costs

Lesson: Costs for separated bike lanes vary extensively due to the wide variety of treatments and materials.

Detail: Costs are highly dependent on materials used. Permanent build-outs with raised curbs and/or dedicated bicycle signalization require more labor and material costs than pilot separated bike lanes that consist only of paint, flexible bollards and moderate amounts of signage. Funding is always an issue and affects the quality of the facility. Numerous municipalities reported scaling back initial designs due to a lack of funding.

Examples: Costs for separated bike lanes are highly variable; one recent estimate provides a range of \$50,000 to \$500,000 per mile for facilities in Austin, TX (Source: Beaudet, Annick, AICP, and Katherine Gregor. "Austin Rides to the Front." *Planning*. May 2014: 17-19. Print.)

Further Study: Further investigation is needed to develop a range of costs for different treatment options, including costs for ongoing maintenance (painting, landscaping, sweeping, etc.).

Section:	Funding – 2
Topic:	Funding Sources
Lesson:	Municipalities are creatively searching for funding sources through public programs, private investment, and nonprofit contributions.
Detail:	<p>Funding for separated bike lanes comes from a mix of Federal grants, local contributions, and other sources. Federal programs responsible for separated bike lane funding among municipalities interviewed include the Congestion Mitigation and Air Quality Improvement Program (CMAQ), Surface Transportation Program (STP), Transportation Alternatives Program (TAP) (replaced the Transportation Enhancement (TE) Activities), Transportation Investment Generating Economic Recovery grants (TIGER), and others. Several municipalities interviewed use development or impact fees and/or local sales tax ordinances to generate local funding dedicated to separated bike lanes.</p> <p>Some municipalities are considering or have already received funding for separated bike lanes from local businesses, or groups of businesses through BIDs, or other private entities that consider investments in bicycle infrastructure to be economically beneficial and to improve employee satisfaction.</p> <p>Third party funding from nonprofit organizations represents another funding method that several of the municipalities interviewed have taken advantage of. Bicycle advocacy organizations (along with other general health organizations) can provide incremental funding that a municipality might need to bring a separated bike lane concept from planning and design stages to implementation.</p>
Examples:	<p>Boulder, CO, has a one-mill sales tax dedicated solely to transportation and has aggressively allocated more funding to new bikeways than to new roadway projects over the last decade. The city also passed a ballot initiative to support transportation maintenance funding that includes additional full-time bikeway staff. Dedicated local funding ensures that Boulder can expand and maintain its separated bike lane network in the future.</p> <p>Amazon, one of the Seattle’s larger corporate residents, will pay for construction of the portion of a proposed separated bike lane on 7th Ave adjacent to the company’s new corporate headquarters – an arrangement that other municipalities may wish to consider in the absence of public funds.</p> <p>Indianapolis’s downtown Cultural Trail, although constructed with Federal funds, is maintained by a nonprofit organization. The trail includes bicycle facilities but is also geared toward tourism, providing a route that traces the city’s local history for visitors.</p>

Call Out / Case Study: San Francisco and Chicago’s use of Value Capture – San Francisco has provided variances above existing height limits in the local zoning code to developers in exchange for impact fees that flow directly to the city’s transportation budget.

Chicago has also used value capture through Tax Increment Financing (TIF) mechanisms, in which portions of increased tax revenue from development rights are used to fund neighborhood improvements such as separated bike lanes. The City is also using TIF programs to fund expansion of its popular Divvy bike share program.

Photo:



Chicago employs TIF schemes to fund separated bike lane infrastructure and its Divvy bike share program. Above, Divvy users pictured on the Milwaukee Avenue separated bike lane. *Source: Chicago Department of Transportation*

Additional Resources

Additional resources on separated bike lanes can be found in the following publications:

- NACTO Urban Bikeway Design Guide
- AASHTO Guide for the Development of Bicycle Facilities (4th Edition)
- ITE Separated Bikeways Report
- CROW Design Manual for Bicycle Traffic
- Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S. (Portland State University report for National Institute for Transportation and Communities, June 2014)

Suggestions for Future Research

Suggestions for future research, as mentioned in the Lessons Learned analysis:

- Benefits of separated bike lanes measured against reductions in vehicular capacity of roadway
- Separated bike lane location decisions within a transportation equity framework
- Separated bike lane planning and Health Impact Assessments
- Separated bike lane effects on transit access (i.e. growth of transit catchment areas)
- Low-stress bicycle networks, and impacts from separated bike lanes
- Menu of separated bike lane design options (Note: also refer to Design Guide within September 2014 FHWA Separated Bike Lanes Planning and Design Guide)
- Specific safety-related outcomes from different intersection alignments
- Best practices for curb cuts / driveways
- Effectiveness of various accessibility elements
- Effects of colored paint on cyclist and motorist behavior and on safety-related outcomes
- Effectiveness of educational tools on safety-related outcomes
- Best practices for agency coordination
- Study of material costs and cost effectiveness of permanent vs. temporary treatment options

Lessons Learned Appendices

Lessons Learned Appendix 1 – Question List for Separated Bike Lane Municipalities

Introduction

The goal of our “Lessons Learned” report is to gain local knowledge of how your city has addressed separated bike lanes, to compare those experiences with the experiences of other cities, and to ultimately provide transportation professionals guidance to more easily and safely accommodate bicycle transportation. This is the ultimate goal of the study, so please answer the questions with that in mind as we proceed through the interview.

Planning

Primary Questions

- How have you selected streets for separated bike lane? Master plan or individually?
- How does your separated bike lane planning relate to the larger bike route network? Do you consider the overall bike route network relative to separated bike lane planning/implementation?
- Have you selected separated bike lanes on where activity is now, where demand could be in the future, or where roadway space is available?
- How do you balance the needs of cyclists/pedestrians/motorists when planning for a separated bike lane?
- Do you have an example of when you considered a separated bike lane but then determined it was not the appropriate type of bicycle facility?

Potential Follow-ups/Written Questions

- What are the different cross sections you’ve chosen?
- Do you have guidelines for vehicle traffic volumes/speeds?
- Has parking factored into planning for separated bike lanes?
- Has land use factored into planning for separated bike lanes?
- What other factors have you considered for separated bike lane selection (safety, economic development, demographics)?
- Are there locations you would stay away from (arterials, high truck use, industrial land use, etc.)?
- Do you consider reducing the number of lanes to add a separated bike lane? Or removing parking?
- Since you have implemented separated bike lanes, what has been the overall crash trend across your city? [Asked in order to compare overall crash trends to separated bike lane-specific crashes, not to determine if separated bike lanes have affected overall crash trends.]

Design

Primary Questions

- What have your experiences been with design? What issues have you had (lack of standards, intersections, right-turns, types of protect, etc.)?
- Do you have design standards for separated bike lane design? If not, what do you use?
- Please comment on each of these key design issues:
 - a. Alignment and physical features (islands, curbs, chicanes, etc.)

- b. Sight distance requirements
- c. Parking vs. landscaping near conflict points
- d. Traffic control devices – signing, striping, delineators, etc.
- e. Intersection control and timing – do you have a standard intersection design or standards as to when to include specific features? (bike boxes, channelization, mixing zones, etc.)
- Do you vary your designs based on context? If so, how do they vary?
- How do your designs take into consideration accessibility issues (blind pedestrians, buffer wide enough for wheel chair lift, etc.)?
- Does the lack of official separated bike lane design standards stop or discourage your city from planning and/or implementing separated bike lanes?

Potential Follow-ups/Written Questions

- Do you have any sight distance/corner clearance standards at intersections?
- How do you design for right-turns? What are your experiences with the design?
- What type of protection have you used? What are your experiences from a safety, utility, and aesthetic point of view?
- Have you incorporated other engineering improvements into design/construction?
- What design vehicle do you use for turns?
- How have you designed for bus and light rail stops?
- Have you used bike signals? If not, was it because they weren't in MUTCD?
- Have you changed traffic signal phasing (leading bicycle intervals, changing turns from permitted to protected)? What affects has it had?
- How have you transitioned from separated bike lanes to standard bike lanes?
- How have you transitioned from two-way separated bike lanes back to one-way?
- Are your designs done with cost in mind? What would you add to your designs if cost was not a factor?
- Have you designed improvements to drainage/pavement condition?
- What type of signage do you use? (bike-oriented and driver-oriented)
- Do you have design to provide curb access for loading?
- Do you have design to provide curb access for accessible parking?
- How do you incorporate colored lanes into the design? What material do you use for color? Do you use them at high or low conflict locations?

Outreach/Agency Coordination/Legal Issues

Primary Questions

- What types of public involvement have you done for separated bike lane projects? How has it gone?
- Do local cyclists prefer separated bike lanes over other facility types?
- Have you done any type of public education efforts for motorists, bicyclists, or pedestrians? How successful has it been?
- Are there any unique legal issues in your city or state that affect separated bike lane implementation? Do any such issues dissuade you from implementing separated bike lanes?
- Do you find there are legal liability issues that stem from less conventional or new separated bike lane designs? Do any such issues dissuade you from implementing separated bike lanes?

Potential Follow-ups/Written Questions

- Do non-cyclists attend public meetings? Have they been supported?

- How have you reached out to businesses? What type of feedback do you get from them?
- How have you coordinated with transit agencies? What type of feedback do you get from them?
- How have you coordinated with state/county DOTs? What type of feedback do you get from them?
- How have you coordinated with elected officials? What type of feedback do you get from them?

Operations

Primary Questions

- How have you monitored operations? What has been your experience in the short-term and over time?
- How, if at all, do you coordinate with police for enforcement related to separated bike lanes (obeying bike signals, motorists yielding to cyclists, pedestrians in the separated bike lane, etc...)? Have there been issues with illegal/unsafe behavior of drivers, pedestrians or cyclists?
- Have you made changes to previously installed separated bike lanes to improve their performance (from a safety perspective or any other perspective)?

Potential Follow-ups/Written Questions

- Have you had to remove any separated bike lanes? If so, why?
- How have you evaluated each separated bike lane project?
- What type of data collection have you done post-construction?
- Have you had issues with pedestrian/bicycle conflict, for instance where a parking lane separates the separated bike lane from traffic? If so, if you done anything to address this?
- Have you noticed changes in driver behavior subsequent to installing separated bike lanes?
- Have you had issues with illegal parking?
- How have businesses reacted after installation?
- Have you had any issues with ADA?
- Have you had any issues with colored pavement?

Construction

Primary Questions

- What have your experiences been with construction? What issues have you had (materials, contractors, purchasing)?

Potential Follow-ups/Written Questions

- What are the standard materials you use for construction (striping, barrier, etc.)? What are your experiences with each?
- What materials have you had success with?
- What materials have you stopped using?
- Have you had any issues working with contractors?
- Have you provided any education/information to contractors?
- Have you had any issues with purchasing unique elements?

Maintenance

Primary Questions

- What have your experiences been with maintenance? What issues have you had (snow, leaves, debris, glass, etc.)?

Potential Follow-ups/Written Questions

- What do you do to plow/sweep your separated bike lane?
- Was your Department of Sanitation/Public Works department involved in discussions during planning/design of separated bike lanes? How have you involved them since? Have they come up with solutions?
- How have you addressed potholes/pavement/drainage issues in separated bike lanes?
- Do you include maintenance concerns with current planning/design of separated bike lanes?
- Would you do anything differently to better plan for maintenance?

Funding

Primary Questions

- How much, per mile, has your separated bike lane construction cost?
- How are you funding separated bike lane design/construction?
- What are unique local (city or state) issues that affect funding?

Potential Follow-ups/Written Questions

- How much of that cost is “new” infrastructure and how much is improving existing infrastructure (stop bars, crosswalks, etc.)?
- Have costs gone down on construction or design since you started?
- Are there individual costs that you have added/removed for any reason?

Conclusion

What could be done differently on future separated bike lane projects?

Lessons Learned Appendix 2 – Question List for Non-Separated Bike Lane Municipalities

Introduction

The goal of our “Lessons Learned” report is to gain local knowledge of how certain cities have addressed separated bike lanes – including why some, such as yours, have not yet adopted them – and to compare those experiences with experiences of other cities. The study will ultimately provide transportation professionals guidance to more easily and safely accommodate bicycle transportation.

Planning

- Are you considering separated bike lanes? If not, why not?
- Does your city have a bicycle master plan? Does the plan identify locations for future separated bike lanes?
- How were locations for potential future separated bike lanes (if any) determined? (Based on where bicycle activity is now, where demand could be in the future, or where roadway space is available?)
- Would your city’s bike network benefit from separated bike lanes? What parts of the network would benefit most?
- Do the needs of pedestrians and/or motorists prevent you from implementing separated bike lanes, due to roadway space constraints?
- Has the potential loss of parking spaces or the public’s reluctance for a change in parking culture (from curbside to floating) prevented you from planning separated bike lanes?
- Do you have an example of when you considered a separated bike lane but then determined it was not the appropriate type of bicycle facility?

Design

- Has a lack of standards or guidance on separated bike lane design dissuaded you from considering or installing them?
- Have you consulted any guidance on separated bike lanes (NACTO Urban Bikeway Design Guide, FHWA guidance, international standards, etc.)? Is there specific information that does not exist that would help you consider separated bike lanes?
- What’s the most troublesome design element that has prevented you from installing separated bike lanes? Intersection control and timing? Roadway alignment? Interaction between separated bike lanes and transit stops? Curb access? Accessibility issues?

Funding

- Have a lack of funding and/or the relatively higher costs of separated bike lanes compared with on-street bike lanes prevented you from considering/installing separated bike lanes?

Outreach

- Have you tried to promote separated bike lanes but pulled back due to public opposition? And/or opposition from local businesses?
- Is there latent demand for separated bike lanes in your city’s cycling community?
- Would you need a political champion in order to install a separated bike lane?

Legal

- Do potential legal liabilities prevent you from installing separated bike lanes, especially facilities with unconventional designs?

Construction / Maintenance

- Do construction challenges (contractors unfamiliar with separated bike lanes, material procurement challenges, etc.) prevent you from considering/installing separated bike lanes?
- Do maintenance challenges (i.e. snow, leaves, debris, and glass) prevent you from considering/installing separated bike lanes?

For Federal Highway Administration

**Separated Bike Lanes Planning and Design Guide
Crash Analysis Report**

Prepared August 2014

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Introduction

As cities look to improve cycling facilities, several have opted to incorporate separated bike lanes as part of their bicycle networks. This analysis, one component of a larger effort to understand opportunities and challenges associated with separated bike lane implementation, examines safety data in an effort to identify potential safety impacts associated with separated bike lanes. Specifically, crash data (total crashes and bicycle crashes) were analyzed in conjunction with bicycle volume data to understand bicycle crash frequencies before and after separated bike lane implementation. All reported crashes (not only serious injury or fatal crashes) involving bicyclists and/or motor vehicles at the study sites were used in this analysis.

The crash analysis results are presented in the tables below, divided in two sections:

- The first section provides results of analysis by separated bike lane site, grouped by city. Results are included only for those separated bike lanes that had *before and after crash and volume* data.
- The second section provides the results of analyses by separated bike lane characteristics. Included in these analyses are separated bike lanes with *before and after crash* data.

As described in this report, some general findings were identified:

- The inconsistent nature of data collection, especially bicycle volumes, makes analyses – especially before and after analyses – difficult. This needs to be taken into account when interpreting results.
- Separated bike lanes were generally associated with a decrease in total crashes and an increase in total bicycle crashes. When accounting for exposure, separated bike lanes were also associated with a decrease in the rate of bicycle crashes per bicycle volume.
- Increases in bicycle crashes after separated bike lanes were built were especially pronounced at intersections. The inconsistent nature of data collection, especially bicycle volumes, makes analyses – especially before and after analyses – difficult. As noted throughout this appendix, there are limits to interpreting these data because of issues such as sample size, confounding variables, lack of statistical testing, what constitutes a crash, and other factors. This needs to be taken into account when interpreting results.

Crash Data Analysis by Site

This section provides results of crash data analysis by separated bike lane site, grouped by city. In cases where additional information on intersection and midblock crashes was available, that data has also been included on a site-by-site basis. Similarly, information for comparison sites is provided in summary table for each city.

As described in the methodology section, acquiring data was a significant challenge for these analyses, especially with respect to bicycle volume data. Ultimately, 17 sites in 8 States provided data. In some cases, a site provided bicycle crash and bicycle volume data, but did not provide total crashes. These sites were included since they provided bicycle volume data, a critical component often not available. Crash data includes only reported crashes involving a bicycle and a motor vehicle.

Unlike general highway safety data which is routinely reported as crashes per hundred million vehicle miles traveled, bicycle volume data is not collected in any standardized format. As a result, this analysis relied on whatever data could be provided. Bicycle volume data may have been provided as peak hour bicycle count or average hourly bicycle count for a period ranging from 2 hours to 24 hours. Given the dearth of bicycle volume data, accommodations were made to include whatever bicycle volume data was provided. For this reason, the rate of annual bicycle crashes per any particular volume metric should not be compared from one site to another since the volume metric is not standardized.

New York City provided both peak hour and average hourly bicycle volume data for their sites. This information was used to understand the potential implications of using one measure of exposure over the other, as shown in Table 1. Although the specific numbers may differ, the before-after impact (decrease or increase) is similar. In most cases, the degree of that impact is greater when using peak hour volume than when using average hourly volume. Since the use of either peak hour volume or average hourly volume yielded the same general result, average hourly volume was used when available but peak hourly volume was deemed a reasonable proxy for sites where only peak hour volume was available.

Table 1: Comparison of Rate of Bicycle Crashes per Bicycle Volume Using Peak Hour Bicycle Volume and Average Hourly Bicycle Volume as Exposure Metric

Site	% Change Before-After	
	Peak Hour Volume	Average Hourly Volume
1st Avenue	+54%	+34%
2nd Avenue	+8%	+12%
8th Avenue	+72%	+57%
9th Avenue	-72%	-65%
Broadway	+21%	+7%
Sands Street	-80%	-67%

It is also important to note, that for many sites, the number of bicycle crashes was very low. In some instances, the number of average annual bicycle crashes was less than one. The small number of average annual bicycle crashes for these sites may lead to results that appear to be noteworthy as a result of a relatively small change in crashes.

For each site, a summary table includes the following information for before and after periods:

- Average Annual Total Crashes which includes crashes between motor vehicles; motor vehicles and pedestrians; and motor vehicles and bicycles;
- Average Annual Crashes Involving a Bicycle; and
- Average Annual Bicycle crashes per Volume.

In some cases, data was provided to consider whether crashes occurred at intersections or midblock. Additionally, for sites where a suitable comparison site was identified and crash data provided, the comparison analysis results are included in a summary table. A summary of data for all sites with information on bicycle crashes that allows for some substantive analysis is included at the end of this section.

AUSTIN, TEXAS

In Austin, the Rio Grande Street separated bike lane saw an increase in the average annual crashes involving a bicycle from the before to the after period. However, there was a decrease in the average annual bicycle crashes per bicycle volume; bicycle volume alone more than doubled from the before period to the after period. During the same period, there was also a decrease in the number of average annual total crashes. It is important to note that the small number of average annual bicycle crashes for this site may lead to results that appear to be noteworthy as a result of a relatively small change in crashes.

Rio Grande Street

Austin, TX: Rio Grande	Before	After
	2004-2011	2013
Average Annual Total Crashes	10.9	3.0
Average Annual Crashes Involving Bicycle	0.3	1.0
	Before	After
	2011	2013
Average Hourly Bicycle Volume	11.8	31.9
Average Annual Bicycle Crashes per Average Hourly Volume (x1,000)	84.8	31.3

CHICAGO, ILLINOIS

Only one Chicago site provided data that could be used for analysis. At the 18th Street separated bike lane site, the average annual total crashes slightly increased while the average annual crashes involving a bicycle and the annual bicycle crashes per bicycle volume decreased since there were no bicycle crashes during the only “after” year for which data was provided. Bicycle volume increased from the construction year to the after year. It is important to note that the number of average annual bicycle crashes for this site was small, so small changes in number of bicycle crashes could result in before-after changes that appear to be more noteworthy than they actually are.

18th Street

Chicago, IL: 18 th Street	Before	After
		2008-2010
Average Annual Total Crashes	25.0	26.0
Average Annual Crashes Involving Bicycle	0.7	0.0
	Before	After
	2011*	2012
Average Peak Hours Bicycle Volume	145	172
Annual Bicycle Crashes per Peak Hour Count	6.9	0.0

*2011 is construction year.

Comparison Sites

The average annual number of bicycle crashes decreased at both the 18th Street separated bike lane site as well as the comparison for this site, Damen Avenue. Again, it is important to note that the small number of crashes, especially at the 18th Street site, may lead to results that appear to be noteworthy as a result of a relatively small change in crashes. In addition, this comparison doesn’t account for possible differences in bicycle volumes between the two sites.

Site	Separated bike lane or Comparison	Average Annual # Bike Crashes	
		Before	After
18 th Street	Separated bike lane	0.7	0.0
Damen Avenue	Comparison	4.7	3.0

EUGENE, OREGON

Eugene provided data for the Alder Street separated bike lane. At this site, there was a decrease in average annual total crashes. However, there was an increase in average annual crashes involving a bicycle and in annual bicycle crashes per bicycle volume. Bicycle volume increased from the before period to the after period.

Alder Street

Eugene, OR: Alder Street	Before	After
	2008-2010	2012-2013
Average Annual Total Crashes	21.3	19.0
Average Annual Crashes Involving Bicycle	3.0	4.5
	Before	After
	2010	2012
Average 2 Hour Bicycle Count Volume	132.6	186.7
Annual Bicycle Crashes per Average 2 Hour Count Volume (x1,000)	15.1	21.4

LONG BEACH, CALIFORNIA

Long Beach provided data for two sites and their comparison sites. At the Third Street separated bike lane site, there were no crashes for the 1 year of “after” data provided. As a result, there was a decrease from the before periods (which included 3 years) to the one year after period for both average annual crashes involving a bicycle and average annual crashes involving a bicycle per bicycle volume. Bicycle volume at the Third Street separated bike lane site increased from the before period to the after period. It should be noted that small numbers, and the single year of after data, may lead to results that appear to be noteworthy as a result of a relatively small change in crashes.

At the Broadway separated bike lane, there was also a decrease in average annual bicycle crashes and average annual bicycle crashes per bicycle volume from the before period to the after period. As was the case with the Third Street separated bike lane site, bicycle volume at the Broadway separated bike lane site increased from the before period to the after period. It should be noted that small numbers, and the single year of after data, may lead to results that appear to be noteworthy as a result of a relatively small change in crashes.

3rd Street

Long Beach, CA: 3 rd Street	Before	After
	3 years*	1 year*
Average Annual Total Crashes	5.0	NA
Average Annual Crashes Involving Bicycle	2.3	0.0
	Before	After
	2010	2012
Average Hourly Bicycle Volume	10.3	16.3
Average Annual Bicycle Crashes for Period per Average Hourly Volume for Stated Year (x1,000)	37.1	0

*Actual years not provided

Broadway

Long Beach, CA: Broadway	Before	After
	3 years*	1 year*
Average Annual Total Crashes	7.0	NA
Average Annual Crashes Involving Bicycle	4.0	3.0
	Before	After
	2010	2012
Average Hourly Bicycle Volume	22.7	33.7
Average Annual Bicycle Crashes for Period per Average Hourly Volume for Stated Year (x1,000)	43.0	25.4

*Actual years not provided

Comparison Sites

Both separated bike lane sites saw decreases in average annual number of bicycle crashes while both of the comparison sites saw increases. Similar to the other analyses for these two sites, it should be noted that small numbers, and the single year of after data, may lead to results that appear to be noteworthy as a result of a relatively small change in crashes.

Site	Separated bike lane or Comparison	Average Annual # Bike Crashes	
		Before	After
3rd Street	Separated bike lane	2.3	0.0
6 th Street	Comparison	0.0	3.0
Broadway	Separated bike lane	4.0	3.0
7 th Street	Comparison	2.0	4.0

MISSOULA, MONTANA

Higgins Avenue saw an increase in bicycle crashes at the separated bike lane site from the before period to the after, though this is a prime example of the challenges of small numbers. There were zero bicycle crashes during the before period and one average annual bicycle crash during the after period. During the same timeframe, there was a decrease in the average annual total crashes. Before data for bicycle crashes per bicycle volume was not available, however bicycle crashes per bicycle volume data is available for the construction year. There was a decrease in this number from the construction year to the after period. There was an increase in the bicycle volume from the construction year to the after period.

Higgins Avenue

Missoula, MT: Higgins Avenue	Before	After
	2008-2009	2011-2013
Average Annual Total Crashes	17.5	16.0
Average Annual Crashes Involving Bicycle	0.0	1.0
	Before	After
	2010*	2011-2013
Bicycle Average Annual Daily Traffic	255.0	673.7
Average Annual Bicycle Crashes per Average Annual Daily Bicycle Traffic (x1,000)	3.9	0.5

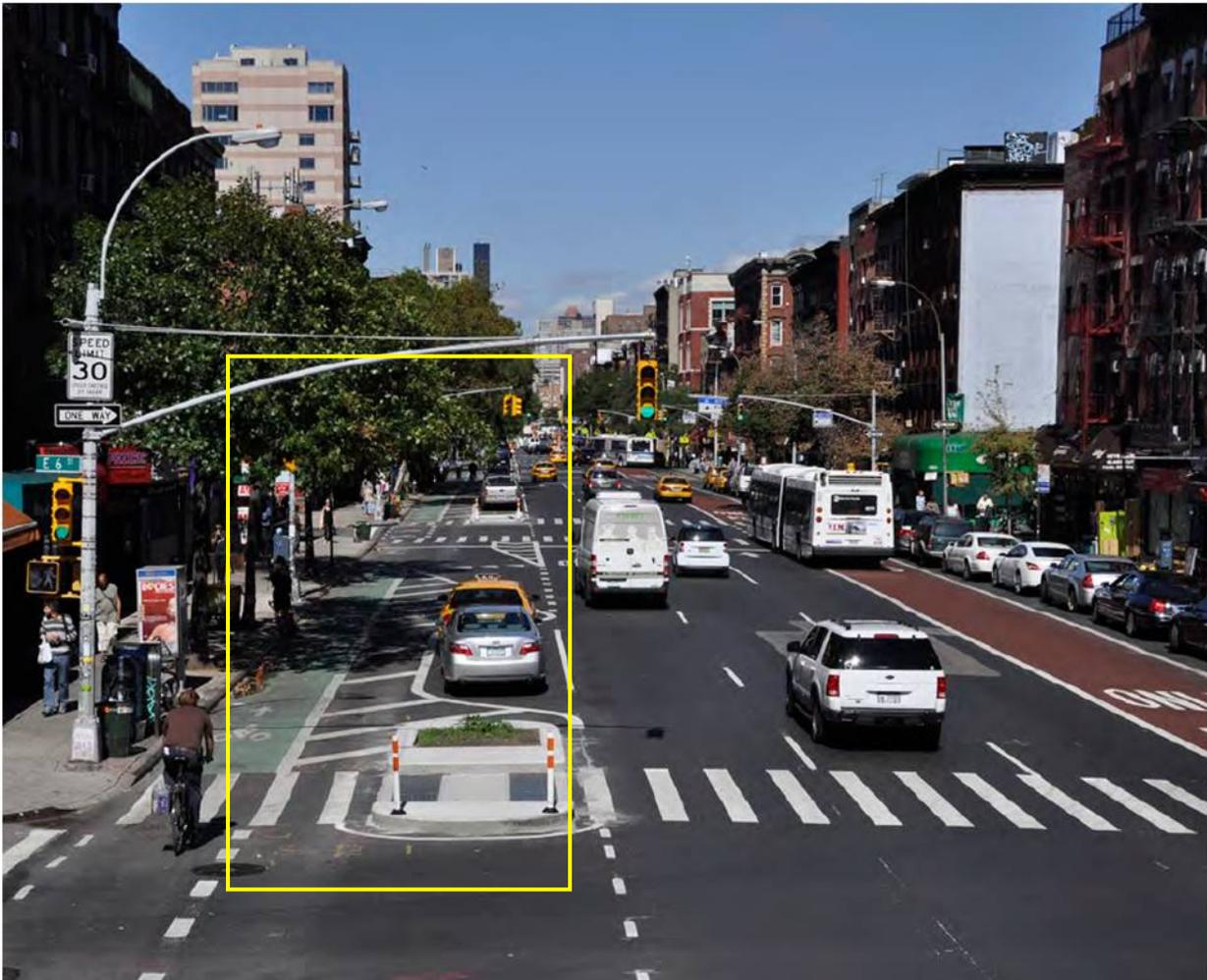
*2010 is construction year.

NEW YORK, NEW YORK

New York City provided data for six separated bike lane sites. In addition to having the most separated bike lane sites, New York sites also had the highest numbers for crashes and volume, yielding potentially more meaningful analysis results.

1st Avenue

The photo below shows the 1st Avenue separated bike lane.



The number of average annual total crashes decreased from the before period to the after period, while the average annual bicycle crashes increased during the same time. Additionally, the average annual bicycle crashes per bicycle volume decreased from the before period to the after period. Bicycle volume increased from the before period to the after period.

New York, NY: 1 st Avenue	Before	After
		2000-2009
Average Annual Total Crashes	189.8	171.0
Average Annual Crashes Involving Bicycle	15.8	29.0
	Before	After
	2007-2008	2012
Average Hourly Bicycle Volume	63.6	100.6
Average Annual Bicycle Crashes per Average Hourly Volume (x 1,000)	290.7	288.3

The increases in bicycle crashes and availability of additional data led to an analysis of the locations of bicycle crashes. Interestingly, the percentage of crashes that occurred at an intersection increased from the before period to the after period, for bicycle crashes as well as those crashes not involving a bicycle.

Average Annual Crashes

Phase	Crash Type	Intersection	Midblock	% Intersection
Before	Other	144.8	32.6	82%
	Bike	13.0	2.8	82%
After	Other	222.0	6.0	97%
	Bike	53.0	2.0	96%

2nd Avenue

The 2nd Avenue separated bike lane saw increases in all two of the three crash measures – average annual total crashes and average annual crashes involving a bicycle. There was a decrease in average annual bicycle crashes per bicycle volume. Bicycle volume increased from the before period to the after period.

New York, NY: 2 nd Avenue	Before	After
	2000-2009	2011-2012
Average Annual Total Crashes	138.2	139.5
Average Annual Crashes Involving Bicycle	14.8	22.5
	Before	After
	2008	2012
Average Hourly Bicycle Volume	106.1	152.6
Average Annual Bicycle Crashes per Average Hourly Volume (x 1,000)	282.7	170.3

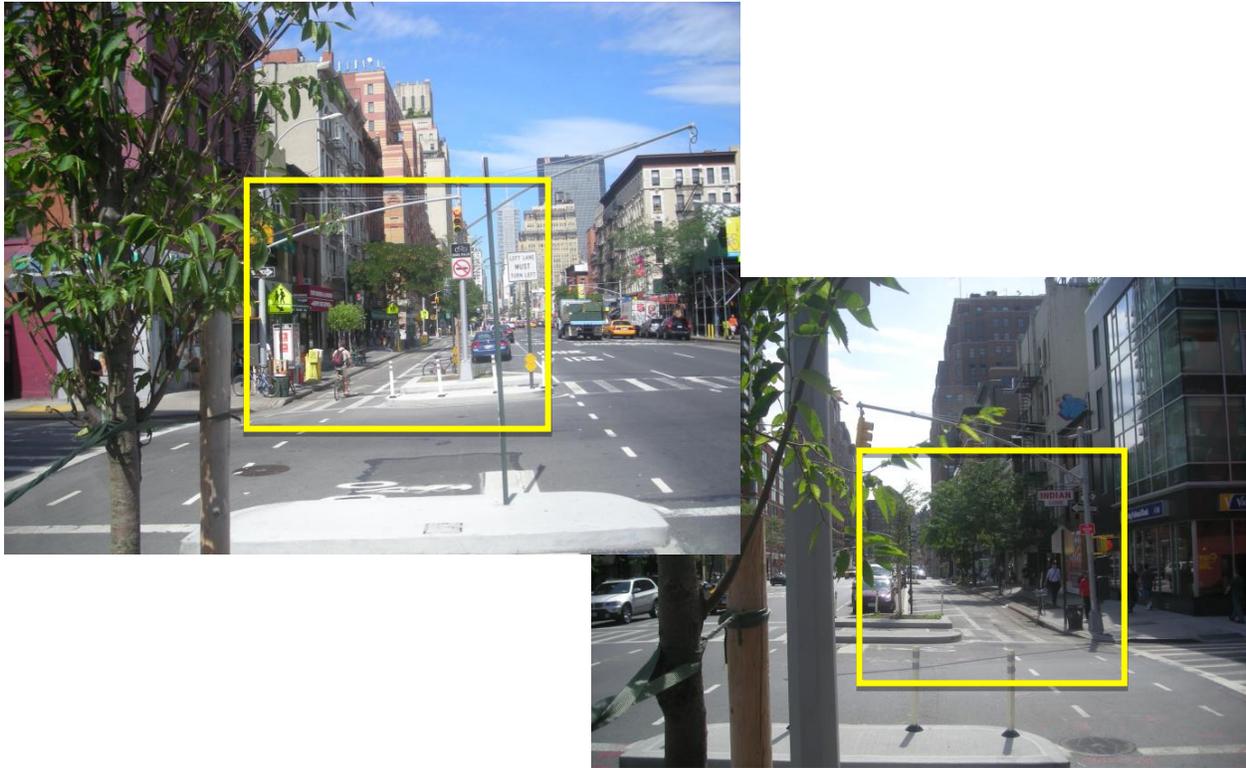
Similar to the 1st Avenue site, the 2nd Avenue site saw an increase in the percentage of crashes that occurred at intersections for both bicycle crashes and those not involving a bicycle.

Average Annual Crashes

Phase	Crash Type	Intersection	Midblock	% Intersection
Before	Other	215.0	39.6	84%
	Bike	21.0	3.2	87%
After	Other	117.5	4.5	96%
	Bike	21.0	1.5	93%

8th Avenue

These photos show the 8th Avenue separated bike lane.



The 8th Avenue separated bike lane site saw a decrease in average annual total crashes as well as a decrease in average annual bicycle crashes and average annual bicycle crashes per bicycle volume from the before period to the after period. Bicycle volume increased from the before period to the after period.

New York, NY: 8 th Avenue	Before	After
	2000-2007	2011-2012
Average Annual Total Crashes	151.1	134.5
Average Annual Crashes Involving Bicycle	13.8	20.5
	Before	After
	2006-2007	2011-2012
Average Hourly Bicycle Volume	100.1	125.2
Average Annual Bicycle Crashes per Average Hourly Volume (x 1,000)	164.9	163.8

Again, there was an increase in the percentage of crashes that occurred at intersections for bicycle crashes and other crashes. Nearly all of the bicycle crashes during the after period occurred at an intersection.

Average Annual Crashes

Phase	Crash Type	Intersection	Midblock	% Intersection
Before	Other	139.4	22.8	86%
	Bike	14.6	2.6	85%
After	Other	141.0	6.0	96%
	Bike	27.5	0.5	98%

9th Avenue

The 9th Avenue separated bike lane is pictured in the photograph below.



The 9th Avenue separated bike lane site saw decreases in all three crash measures – average annual total crashes, average annual crashes involving a bicycle, and average annual bicycle crashes per bicycle volume. Bicycle volume increased from the before period to the after period.

New York, NY: 9 th Avenue	Before	After
	2000-2006	2009-2012
Average Annual Total Crashes	80.6	57.5
Average Annual Crashes Involving Bicycle	6.6	4.5
	Before	After
	2006-2007	2011-2012
Average Hourly Bicycle Volume	65.2	105.60
Average Annual Bicycle Crashes per Average Hourly Volume (x 1,000)	199.5	42.6

The percentage of crashes that occurred at intersections increased for both bicycle crashes and other crashes. All bicycle crashes during the after period occurred at intersections.

Average Annual Crashes

Phase	Crash Type	Intersection	Midblock	% Intersection
Before	Other	75.8	15.7	83%
	Bike	7.3	0.8	90%
After	Other	54.0	3.5	94%
	Bike	4.8	0.0	100%

Broadway

The image below is a photograph of the Broadway separated bike lane.



There was a decrease from the before period to the after period in the average annual total crashes and average annual bicycle crashes at the Broadway separated bike lane. There was also a decrease in average annual bicycle crashes per bicycle volume. There was a decrease in bicycle volume from the before period to the after period.

New York, NY: Broadway	Before	After
	2000-2008	2011-2012
Average Annual Total Crashes	110.6	67.5
Average Annual Crashes Involving Bicycle	10.1	9.0
	Before	After
	2006-2008	2011-2012
Average Hourly Bicycle Volume	62.9	80.2
Average Annual Bicycle Crashes per Average Hourly Volume	132.5	112.2

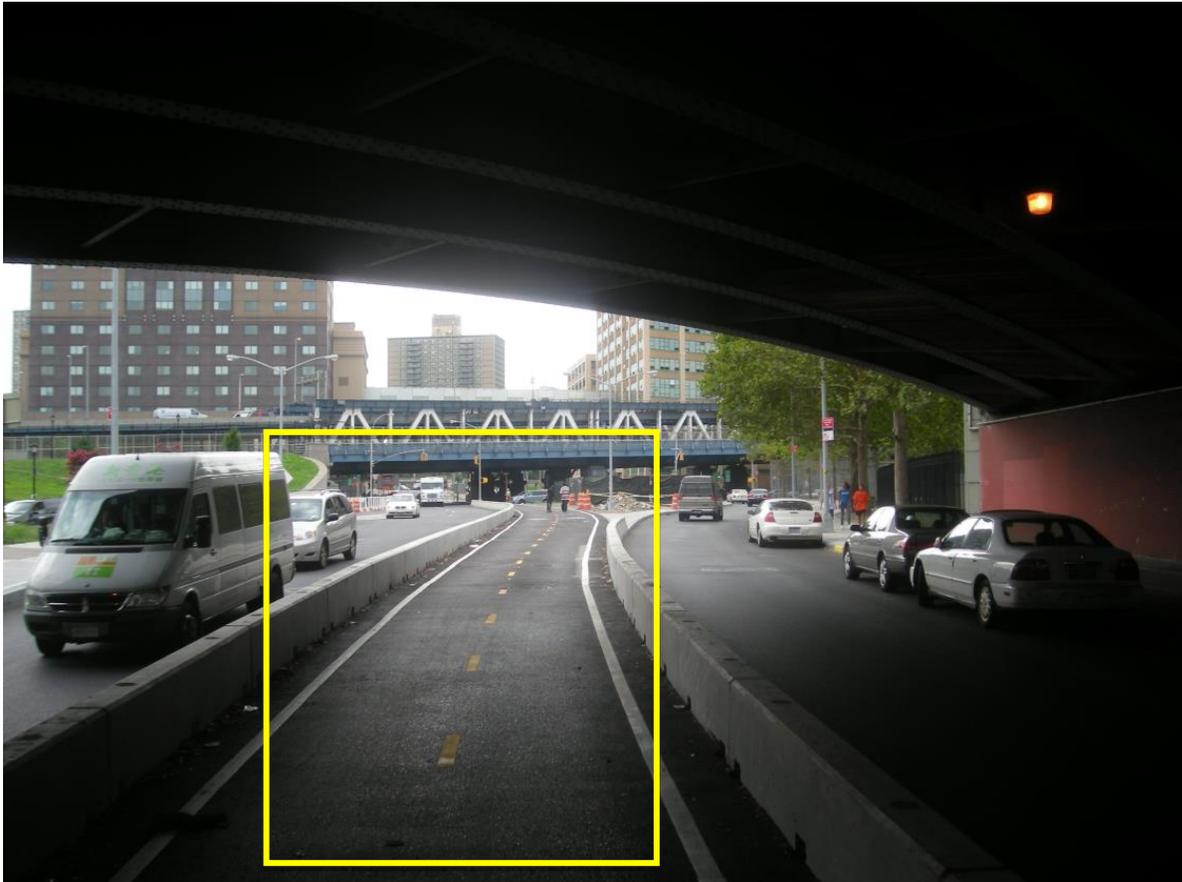
The percentage of crashes that occurred at intersections increased for Broadway, as it did for other separated bike lanes in New York. This is true for both bicycle crashes and other crashes.

Average Annual Crashes

Phase	Crash Type	Intersection	Midblock	% Intersection
Before	Other	89.9	12.9	87%
	Bike	9.4	1.2	89%
After	Other	77.0	1.5	98%
	Bike	12.0	0.5	96%

Sands Street

The photo below shows the Sands Street separated bike lane.



There was an increase in average annual total crashes and average annual bicycle crashes from the before period to the after period for the Sands Street separated bike lane. However, there was a decrease in the average annual bicycle crashes per bicycle volume. Bicycle volume more than tripled from the before period to the after period.

New York, NY: Sands Street	Before	After
	2000-2008	2010-2012
Average Annual Total Crashes	8.9	9.7
Average Annual Crashes Involving Bicycle	0.4	2.0
	Before	After
	2007	2010-2012
Average Hourly Bicycle Volume	32.3	129.4
Average Annual Bicycle Crashes per Average Hourly Volume (x 1,000)	62.0	15.5

There was an increase from the before period to the after period in the percentage of crashes that occurred at intersections for bicycle crashes and other crashes.

Average Annual Crashes

Phase	Crash Type	Intersection	Midblock	% Intersection
Before	Other	123.9	20.2	86%
	Bike	13.0	2.3	85%
After	Other	94.0	4.0	96%
	Bike	18.3	0.3	98%

Comparison Sites

The table below provides a summary of average annual bicycle crashes at New York separated bike lanes with their respective comparison sites. Two of the separated bike lane sites (2nd Avenue and 8th Avenue) saw increases in average annual bicycle crashes, as did their comparison sites. The 1st Avenue separated bike lane saw an increase while its comparison saw a decrease. The reverse was true for the 9th Avenue separated bike lane and its comparison; there was a decrease at the separated bike lane site and an increase at the comparison site.

Site	Separated bike lane or Comparison	Average Annual # Bike Crashes	
		Before	After
1st Avenue	Separated bike lane	15.8	29
10th Avenue	Comparison	1.2	1.0
2nd Avenue	Separated bike lane	14.8	22.5
7th Avenue	Comparison	4.0	7.0
8th Avenue	Separated bike lane	13.8	20.5
6th Avenue	Comparison	29.8	35.5
9th Avenue	Separated bike lane	6.6	4.5
7th Avenue	Comparison	4.1	5.8

SAN FRANCISCO, CALIFORNIA

San Francisco provided data for the Market Street separated bike lane.

Market Street

There was an increase from the before period to the after period in the average annual crashes involving a bicycle as well as all average annual crashes at the Market Street separated bike lane. There was a noteworthy increase in bicycle volume at the separated bike lane location from the before period to the after period which contributed to a decrease in the rate of bicycle crashes per bicycle volume from the before period to the after period.

San Francisco, CA: Market Street	Before	After
	2002-2008	2011
Average Annual Total Crashes	45.4	61.0
Average Annual Crashes Involving Bicycle	10.9	24.0
	Before	After
	2006-2008	2011
Average Annual Bicycle Volume for 1.5 hour peak period	618.7	1,173.0
Average Annual Bicycle Crashes per Average Annual Bicycle Volume for 1.5 hour Peak Period for Year Stated (x1,000)	23.7	20.5

ST. PETERSBURG, FLORIDA

St. Petersburg provided bicycle crash data for the separated bike lane on 1st Street South.

1st Avenue South

There was a decrease from the before period to the after period in average annual crashes involving a bicycle at the 1st Avenue South separated bike lane. There was also a decrease in the average annual bicycle crashes per bicycle volume. It should be noted that small number of crashes may lead to results that appear to be noteworthy as a result of a relatively small change in crashes. Bicycle volume more than quadrupled from the before period to the after period.

St. Petersburg, FL: 1 st Avenue South	Before	After*
	2003-2007	2008-2012
Average Annual Total Crashes	NA	NA
Average Annual Crashes Involving Bicycle	2.0	1.6
	Before	After
	2006	2011
Average Daily Bicycle Volume	23.0	108.0
Average Annual Bicycle Crashes per Average Daily Volume for Year Stated (x1,000)	86.9	14.8

*Includes construction year and after

The 1st Avenue South separated bike lane saw a decrease in average annual bicycle crashes from the before period to the after period while its comparison site saw an increase during the same time.

Comparison Sites

Site	Separated bike lane or Comparison	Average Annual # Bike Crashes	
		Before	After
1 st Avenue South	Separated bike lane	2.0	1.6
1 st Avenue North	Comparison	1.4	1.8

WASHINGTON, DC

Washington, DC provided data for three separated bike lane locations: 15th Street NW, Pennsylvania Avenue, and L Street NW.

15th Street NW

The 15th Street NW separated bike lane saw an increase in average annual total crashes and average annual bicycle crashes from the before period to the after period. There was a decrease in the average annual bicycle crashes per bicycle volume from the before period to the after period. Bicycle volume more than quadrupled from the before period to the after period.

Washington, DC: 15 th Street NW	Before	After
	12/2006-10/2009	12/2010-09/2013
Average Annual Total Crashes	131.3	159.3
Average Annual Crashes Involving Bicycle	4.7	14.3
	Before	After
	2009	2011-2013
Average Hourly Bicycle Volume	31.8	148.5
Average Annual Bicycle Crashes for Period per Average Hourly Volume for Stated Years (x1,000)	147.7	96.3

Pennsylvania Avenue

The separated bike lane on Pennsylvania Avenue saw increases in all three crash measures from the before period to the after period. Average annual total crashes, average annual crashes involving a bicycle, and average annual bicycle crashes per bicycle volume all increased from the before period to the after period. Bicycle volume more than doubled from the before period to the after period. It should be noted that the Pennsylvania Avenue separated bike lane is in the middle of roadway and is separated by plastic flexible posts only immediately before and after intersections.

Washington, DC: Pennsylvania Avenue	Before	After
	07/2007-06/2010	07/2010-09/2013
Average Annual Total Crashes	126.0	148.0
Average Annual Crashes Involving Bicycle	4.3	12.0
	Before	After
	2007-2010	2011-2013
Average Hourly Bicycle Volume	45.3	104.1
Average Annual Bicycle Crashes for Period per Average Hourly Volume for Stated Years (x1,000)	94.9	115.3

L Street NW

The L Street NW separated bike lane saw a decrease in all three crash measures from the before period to the after period. Average annual total crashes, average annual crashes involving a bicycle, and average annual bicycle crashes per bicycle volume all decreased from the before period to the after period. Bicycle volume increased from the before period to the after period.

Washington, DC: L Street NW	Before	After
	11/2009-10/2012	11/2012-09/2013
Average Annual Total Crashes	125.0	101.0
Average Annual Crashes Involving Bicycle	8.7	2.0
	Before	After
	2009-2011	2013
Average Hourly Bicycle Volume	38.4	70.0
Average Annual Bicycle Crashes for Period per Average Hourly Volume for Stated Years (x1,000)	221.0	28.6

Comparison Sites

The 15th Street NW and Pennsylvania Avenue separated bike lanes, as well as their respective comparison sites, saw increases in the number of average annual bicycle crashes from the before period to the after period. The L Street NW separated bike lane saw a decrease in average annual number of bicycle crashes while its comparison site saw an increase.

Site	Separated bike lane or Comparison	Average Annual # Bike Crashes	
		Before	After
15 th Street NW	Separated bike lane	4.7	14.3
12 th Street NW	Comparison	1.3	3.0
Pennsylvania Avenue	Separated bike lane	4.3	12.0
Connecticut Avenue	Comparison	4.0	9.7
L Street NW	Separated bike lane	8.7	2.0
19 th Street NW	Comparison	4.7	6.0

SUMMARIES OF SEPARATED BIKE LANE SITE CRASH DATA ANALYSES

As shown in Table 2, 8 of the 14 sites that provided before and after crash data for all crashes saw decreases in total crashes from the before period to the after period. All 17 sites provided before and after bicycle crash data. Of those 17 sites, 8 saw decreases in bicycle crashes from the before period to the after period. Four of the 14 sites that provided before and after crash data for total crashes and bicycle crashes saw decreases in both from the before period to the after period. It is important to note, however, that some of these sites had average annual bicycle crash numbers of less than 1 per year.

Table 2: Summary of Site Crash Changes Before-After

Site	Average Annual Bicycle Crashes	
	Before	After
Austin, TX: Rio Grande Street	0.3	1.0
Chicago, IL: 18th Street	0.7	0.0
Eugene, OR: Alder Street	3.0	4.5
Long Beach, CA: 3rd Street	2.3	0.0
Long Beach, CA: Broadway	4.0	3.0
Missoula, MT: Higgins Avenue	0.0	1.0
New York, NY: 1st Avenue	15.8	29.0
New York, NY: 2nd Avenue	14.8	22.5
New York, NY: 8th Avenue	13.8	20.5
New York, NY: 9th Avenue	6.57	4.5
New York, NY: Broadway	10.1	9.0
New York, NY: Sands Street	0.44	2.0
San Francisco, CA: Market Street	10.9	24.0
St. Petersburg, FL: 1st Street South	2.0	1.6
Washington, DC: 15th Street NW	4.7	14.3
Washington, DC: Pennsylvania Avenue	4.3	12.0
Washington, DC: L Street NW	8.7	2.0

Table 3 shows the same information as Table 2, limited only to those sites where the average annual bicycle crashes for the before period were 4 or more. For these sites, 5 of the 9 sites that provided before and after crash data for all crashes saw decreases in total crashes from the before period to the after period. All 10 sites provided before and after bicycle crash data. Of those 10 sites, 4 saw decreases in bicycle crashes from the before period to the after period. Three of the 9 sites that provided before and after crash data for total crashes and bicycle crashes saw decreases in both from the before period to the after period.

Table 3: Summary of Changes in Before-After # of Crashes: Limited to Sites with Four or More Average Annual Bicycle Crashes During Before Period

Site	Average Annual Bicycle Crashes	
	Before	After
Long Beach, CA: Broadway	4.0	3.0
New York, NY: 1st Avenue	15.8	29.0
New York, NY: 2nd Avenue	14.8	22.5
New York, NY: 8th Avenue	13.8	20.5
New York, NY: 9th Avenue	6.57	4.5
New York, NY: Broadway	10.1	9.0
San Francisco, CA: Market Street	10.9	24.0
Washington, DC: 15th Street NW	4.7	14.3
Washington, DC: Pennsylvania Avenue	4.3	12.0
Washington, DC: L Street NW	8.7	2.0

When accounting for exposure, as demonstrated in Table 4, the general trends are similar. For those sites with 4 or more average annual bicycle crashes before, 4 of the 9 sites saw a decrease in the average annual bicycle crashes per bicycle volume from the before period to the after period. Note that 8 of the 9 sites had a similar exposure metric, allowing for this type of comparison.

Table 4: Summary of Changes in Before-After Bicycle Crashes per Bicycle Volume: Limited to Sites with Four or More Average Annual Bicycle Crashes During Before Period

Site	Average Annual Bicycle Crashes per Average Hourly Volume	
	Before	After
Long Beach, CA: Broadway	43.0	25.4
New York, NY: 1st Avenue	290.7	288.3
New York, NY: 2nd Avenue	282.7	170.3
New York, NY: 8th Avenue	164.9	163.7
New York, NY: 9th Avenue	199.5	42.6
New York, NY: Broadway	132.4	112.2
San Francisco, CA: Market Street*	23.7	20.5
Washington, DC: 15th Street NW	147.7	96.3
Washington, DC: Pennsylvania Avenue	94.9	115.3
Washington, DC: L Street NW	221.0	28.6

*Volume is measured as 1.5 hour peak volume.

Crash Data Analysis by Separated Bike Lane Characteristic

In addition to considering each of the separated bike lane sites, the crash analyses examined the collective group and sought to identify potential benefits associated with specific separated bike lane characteristics, summarized in Tables 5 and 6. Four categories of characteristics were considered: 1) separation, 2) intersection treatment, 3) green pavement, and 4) previous presence of a bicycle lane. For separation and intersection treatment, each characteristic was examined based on whether it was applied on its own or whether it was applied in conjunction with other treatments. Number of crashes is for that separated bike lane as a whole, not only the sections where that particular treatment occurs, e.g., crashes for particular intersection treatment types are for separated bike lanes where that intersection treatment is used, not just intersection crashes. Note that application in conjunction with other treatments only takes into account treatments from the same category of characteristic (i.e., separation or intersection treatment). Also note that specific descriptions of these treatments will be found in the Planning and Design Guide for this project.

In addition to considering characteristics for all sites, Table 6 includes only those separated bike lane characteristics that were implemented at 10 or more sites included in this analysis. This provides the opportunity to consider the impacts of these characteristics across a sample size that has greater potential to be demonstrative of potential safety impacts when implemented at other sites. Given the recognized statistical limitations of the data set, it is important to note that even characteristics with the larger number of sites for implementation may not be sufficient to state with certainty that a particular characteristic is most effective in improving bicycle safety.

Average Annual Bicycle Crashes

As shown in the table below, only two of the characteristics were associated with a decrease in average annual bicycle crashes from the before period to the after period. Using only concrete/curb for separation resulted in a decrease. It should be noted that this was applied at only 5 sites. The intersection treatment of mixing zones without another treatment resulted in a decrease; however it should be noted that this was applied only at 3 sites and the number of crashes occurring at these sites was small.

Average Annual Total Crashes

While the number of average annual bicycle crashes increased for most of the characteristics considered, the number of average annual total crashes decreased for most characteristics.

Separation

- Average annual total crashes decreased when parking lanes were used in combination with another treatment.
- Concrete/curb applied in conjunction with other characteristics, which were applied at 14 sites, were associated with a decrease in average annual total crashes as was concrete/curb only. However, it is important to note that concrete/curb in combination with another treatment was applied at 14 sites while concrete/curb without another treatment was only applied at only 5 sites.
- Plastic bollards applied in conjunction with other characteristics, which were applied at 13 sites, were associated with a decrease in average annual total crashes while plastic bollards applied on their own were associated with an increase.
- Other treatments were difficult to quantify since there is only one site that applied other treatments only.

Intersection Treatment

The following observations are offered to inform future analysis. This future analysis will need to include more robust statistical testing.

- Mixing zones in combination with other treatments was associated with a decrease in average annual total crashes. Mixing zones in conjunction with other intersection treatments was applied at 10 sites.
- Lateral shift was associated with a decrease in average annual total crashes when applied on its own. When applied in conjunction with other treatments, there was an increase in total crashes. There were only 2 sites where it was applied on its own and 4 where it was applied in conjunction with another intersection treatment.
- Separate bike signals applied in conjunction with another treatment was associated with a decrease in average annual total crashes (applied at 9 sites).
- Markings through the intersection were associated with decreases in average annual total crashes when applied with other intersection treatments and when applied alone. The decrease in average annual total crashes was greater when applied in conjunction with other intersection treatments. Both applications – alone and in conjunction with other intersection treatments – were applied at more than 10 sites.

Green Pavement

All applications of the green pavement are associated with decreases in average annual total crashes. Green pavement only at conflict points was associated with the greatest decrease in average annual total crashes. This treatment was applied at 13 sites.

Previous Bicycle Lane

The existence of a painted bike lane prior to the installation of a separated bike lane is associated with greater decrease in average annual total crashes than where there was no painted bike lane prior to separated bike lane installation.

Table 5: Before-After Crashes by Separated Bike Lane Characteristics (Note: This does not account for changes in bicycle volume)

	# of Sites	Average Annual Bike Crashes		Average Annual Total Crashes	
		Before	After	Before	After
Separation					
Parking Lane Only	11	6.84	10.36	77.92	78.79
Parking Lane Plus	15	1.81	2.78	24.33	17.36
Concrete/Curb Only	5	8.05	6.78	75.90	52.15
Concrete/Curb Plus	14	1.83	2.49	24.75	18.33
Plastic Bollards Only	6	3.22	7.86	37.62	48.94
Plastic Bollards Plus	13	2.84	4.42	45.05	40.90
Other (including Other Bollards) Only	1	0.50	2.00	9.70	9.00
Other (including Other Bollards) Plus	8	4.33	5.93	4.33	5.93
Intersection Treatment					
Mixing Zones Only	3	2.10	0.00	13.6	NA
Mixing Zones Plus	10	7.60	9.93	99.73	85.60
Lateral Shift Only	2	0.45	3.00	12.25	10.00
Lateral Shift Plus	4	1.00	2.20	15.83	18.00
Separate Bike Signals Only	1	NA	9.30	NA	59.00
Separate Bike Signals Plus	9	8.61	11.27	130.2	107.8
Markings through Intersection Only	15	2.44	3.39	23.89	22.71
Markings through Intersection Plus	12	6.76	10.29	84.70	77.78
Green Pavement					
Continuous	4	2.65	4.43	34.25	32.2
Only at Conflict Points	13	1.95	2.17	18.21	15.67
Except at Conflict Points	8	8.76	12.29	99.04	85.01
None	10	3.04	5.28	31.54	42.87

Previous Bike Facility					
Bike Lane	16	4.14	6.45	45.66	41.92
None	30	3.38	4.92	52.00	50.07

Table 6: Before-After Crashes by Separated Bike Lane Characteristics Limited to Treatments Applied to 10 or More Locations

	# of Sites	Average Annual Bike Crashes		Average Annual Total Crashes	
		Before	After	Before	After
Separation					
Parking Lane Only	11	6.84	10.36	77.92	78.79
Parking Lane Plus	15	1.81	2.78	24.33	17.36
Concrete/Curb Plus	14	1.83	2.49	24.75	18.33
Plastic Bollards Plus	13	2.84	4.42	45.05	40.90
Intersection Treatment					
Mixing Zones Plus	10	7.60	9.93	99.73	85.60
Markings through Intersection Only	15	2.44	3.39	23.89	22.71
Markings through Intersection Plus	12	6.76	10.29	84.70	77.78
Green Pavement					
Only at Conflict Points	13	1.95	2.17	18.21	15.67
None	10	3.04	5.28	31.54	42.87
Previous Bike Facility					
Bike Lane	16	4.14	6.45	45.66	41.92
None	30	3.38	4.92	52.00	50.07

OBSERVATIONS

- It is imperative to include volume data as well as crash data in safety analyses related to separated bike lanes. The implementation of a separated bike lane is likely to result in increased bicycle ridership which, in turn, increases the number of bicyclists who might be involved in a collision with a motor vehicle. Considering only crashes, without accounting for exposure or crash severity, has the potential to result in over-reporting of negative safety impacts of separated bike lanes.
- Challenges associated with obtaining bicycle volume data make it difficult to understand the true impacts on safety of separated bike lanes.
 - Many separated bike lanes sites had volume data for the construction year and years after construction but no volume data for before separated bike lane installation.
 - There is no standardized volume metric for bicycle volume data as there is for motorized vehicle travel. This makes it difficult to understand separated bike lane impacts across multiple sites.
- The small number of bicycle crashes occurring at some separated bike lanes yield analysis results with very large percentage changes (increases or decreases) since a change of one or two crashes can effectively double or triple the crash count for that site.
- The impact of separated bike lanes on safety should consider changes in total crashes as well as changes in bicycle crashes. Of the 14 sites that provided both, 8 saw a decrease in total crashes. Five sites saw a decrease in bicycle crashes. This translates to 9 of 14 sites demonstrating a decrease in crashes of some sort. Four of the 14 sites saw decreases in both bicycle and total crashes.
- Similar trends are seen when considering bicycle exposure at sites with at least 4 average annual bicycle crashes. Nine of the 10 sites saw decreases in average annual bicycle crashes per average hourly bicycle volume.
- It appears that the introduction of separated bike lanes may result in increased challenges at intersections, relative to separated or protected midblock locations. All six of the sites where the analysis included consideration of intersection vs. midblock crashes saw an increase in the percentage of crashes that occurred at an intersection relative to crashes at midblock. This was true for bicycle crashes as well as those not involving a bicycle. However, these comparisons did not control for changes in bicycle volumes between the before and after periods.
- The consideration of separated bike lane sites against a comparison site yielded mixed results. In some cases both the separated bike lane and comparison site saw similar trends in number of bicycle crashes; in other cases, there were differences between the two. Overall, there were inconsistent trends in these comparisons. Note that these comparisons did not control for changes in bicycle volumes between the before and after periods.
- Analysis of separated bike lane crashes by characteristic yielded several observations. Note that these results are based on analyses of total crashes and overall bicycle crash numbers. They did not control for changes in bicycle volumes between the before and after periods.

- The impact on total crashes is generally more positive (i.e., yielding more crash reductions) than the impact on bicycle crashes.
- Separated bike lanes installed in locations where there had previous been a painted bike lane had more positive safety outcomes than those that were not preceded in time by a painted bike lane.
- Future efforts may consider the following:
 - Analysis of crash severity and other crash characteristics including time of day, day of week, contributing circumstances, weather and lighting conditions, etc.;
 - Analysis on the safety impacts of the many options and combinations of options for separated bike lane intersection design;
 - A detailed examination of each of the sites to better understand which factors may have contributed to changes in crash and volume data from the before period to the after period; and
 - The development of a separated bike lane data collection guide to provide definitive information on the type of data that would be most beneficial for future analyses, along with information on collection methodologies (how, when, etc.).
 - The need for using rolling averages to assess before and after data trends.
 - Revision of crash typing based on the presence of separated bike lanes. Updated crash typing would allow for the ability to code crashes based on the characteristics of a specific facility, for example to distinguish a crash that happened on a one-way facility versus a two-way facility.

For Federal Highway Administration

**Separated Bike Lanes Planning and Design Guide
Project Evaluation Checklist
Prepared September 2014**

University of North Carolina Highway Safety Research Center
Sam Schwartz Engineering, DPC
Kittelson & Associates, Inc.

Project Evaluation Checklist

Use the following checklist to perform a holistic project evaluation of a separated bike lane facility. The items provided below represent a range of evaluation suggestions; not all are required and other measures not on the list are also available to practitioners for evaluation.

By evaluating a separated bike lane project using a wide range of criteria, planners will be better able to communicate the wide range of benefits that such facilities provide beyond improvements to cyclist safety. This checklist should be used in conjunction with Appendix E, which provides detailed instructions on volume and crash data collection pre- and post-implementation.

Safety

1. Crashes – Measure pre-/post-SBL statistics for all users (cyclists, pedestrians, motor vehicle occupants)
2. Injuries / Serious injuries – Measure pre-/post-SBL statistics for all users (cyclists, pedestrians, motor vehicle occupants)
3. Fatalities – Measure pre-/post-SBL statistics for all users (cyclists, pedestrians, motor vehicle occupants)
4. Excessive Speeding – Measure pre-/post-SBL percentages of motorists exceeding speed limit

Mobility

1. Volumes – Measure pre-/post-SBL volume data for all users (cyclists, pedestrians, motorists, transit)
2. Travel Time – Measure pre-/post-SBL effects on all users through travel time runs (cyclists, motorists, transit)
3. Level of Service – Measure pre-/post-SBL Level of Service for all users (cyclists, pedestrians, motorists, transit – consider a multi-modal LOS measure or specific bicycle and pedestrian LOS criteria)
4. Simplification of roadway network and changes to complicated intersections – Number of nodes simplified; Percentage of conflicting movements reduced
5. Pedestrian Mobility – Number of intersections with reduced crossing distances; Percentage of crossing distance reductions; Number of pedestrian refuge islands installed

Economic Vitality / Street Vitality + Quality of Life

1. Beautification – Number of street trees planted; Number of landscaped medians constructed; Number of street planters installed
2. Sidewalk Cycling – Reduction in number of cyclists using sidewalk
3. Parking Availability – Number of spaces lost or gained; Changes to parking demand and utilization; Changes to parking pricing

4. Effects on Loading and Unloading – Number of dedicated loading zones created; Effects of changes to loading and unloading regulations
5. Public Space – Square footage of new pedestrian plaza or public space created; Changes in usage of public space (quantitative and/or qualitative studies of changes – i.e. percentage change in number of users of public space or pre-/post-SBL surveys on public space changes)
6. Economic Effects – Compare pre-/post-SBL retail or other sales metrics along separated bike lane corridor (with before/after of comparison corridor); Compare pre-/post-SBL values of commercial rents along separated bike lane corridor (with before/after of comparison corridor); Perform pre-/post-SBL surveys or testimonials of merchants along separated bike lane corridor
7. Perception of Safety – Perform pre-/post-SBL surveys on all street users (cyclists, pedestrians, motorists, transit users)

For Federal Highway Administration

**Separated Bike Lanes Planning and Design Guide
Data Collection Information
Prepared September 2014**

University of North Carolina Highway Safety Research Center
Sam Schwartz Engineering, DPC
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Appendix E: Recommended Separated Bike Lane (SBL) Data Collection Protocol

This appendix contains data collection recommendations for practitioners at the local, regional, and state level that have implemented or are considering Separated Bike Lanes. It describes the counts to be collected, and the type of information that should be supplied to properly identify the location and the nature of the count. Counts should be collected at selected locations before commencing SBL construction, and again at the same location several months to a year after the facility has been opened. It is recommended that counts be repeated at periodic intervals after the facility is constructed, as usage of many facilities does not develop immediately upon project completion.

Minimum Requirements

The minimum parameters in the table on the following page will yield useful data for documenting the success of a SBL project with respect to its use and safety. The recommended parameters will generate data that will allow comprehensive evaluation of the SBL as an element in a larger network of bicycle facilities.

Best Case Scenario

In the best case scenario, discussed in the pages after the minimum data collection table, the before-and-after counting will generate data that can be imported into the forthcoming bicycle and pedestrian element of the FHWA Traffic Monitoring Analysis System (TMAS). To import data in TMAS, it must support all the critical (required) data elements laid out in the FHWA Traffic Monitoring Guide (the TMG format). The remainder of this document explains the relevant elements of the TMG format, as well as the programmatic elements required to gather high quality counts (for example, the duration of counts, and the number of days). Note that all of the information provided after the table on the following page applies to the best case scenario.

Minimum Data Collection Before and After Construction of Separated Bike Lane

Before and After Construction of Separated Bike Lane	Data Element	Minimum	Preferred	After Construction Data Consideration	Notes
Volume of Bicyclists	Manual count duration/day	4 hours/day	All Daylight Hours	Ensure compatible time periods as before counts	Suggested times: 4 hours in a row; do not split morning and evening
	Manual count days	3 days	14 Days	Ensure comparable weather conditions and days of the week as before counts	
	Automatic count duration	24 hours/day	24 hours/day	Ensure compatible time periods as before counts	
	Automatic count days	7 days	14 Days	Ensure comparable weather conditions and days of the week as before counts	
	Documentation of count locations	All	All	Same count locations as before counts	Adequate documentation of all count locations (see document text)
Travel Characteristics	Traveling direction	All bicyclists in any direction	Each direction separately		
	Wrong way riding	Not counted separately	"Wrong" and "Right" directions separately		Which side of the road the wrong way riders were on is essential, so there might be two counts (wrong way in each direction)
	Facility on which bicyclists are traveling	All lanes together	Each lane separately		e.g. Shared Lane, Bike Lane, Sidewalk
Crashes	Identify and compile all available crash records in the project vicinity	All available	All available		Ideally data will include coded locations of crashes, date/time of crashes, severity of crash, and documentation of circumstances

Where to Count

The recommended location for counts is at a mid-block location along the alignment of the proposed Separated Bike Lane at some distance from major entry and exit points. In addition, if desired, counts may be collected mid-block on intersecting facilities near the Separated Bike Lane. If major intersections occur within the project boundary, agencies should collect counts on segments of the proposed Separated Bike Lane on each side of such intersections. Counting at intersections is not necessary if sufficiently detailed mid-block counts are collected (see the section on “What to count”). Finally, if the Separated Bike Lane is being built in a context with nearby parallel roadways (or parallel multiuse off-road trails) that may carry bicycle traffic to similar destinations and for similar purposes as the Separated Bike Lane, it will be desirable to count traffic on those parallel roadways as well, both before and after Separated Bike Lane construction. The purpose of the parallel roadway counts is to evaluate the volume of “new” traffic as well as trips that have simply re-routed from the adjacent roadway.

What to Count

Counts of bicyclists should be conducted in sufficient detail to provide information about changes of behavior of existing cyclists as well as presence of new cyclists. It is not sufficient simply to report a count of all bicyclists traveling in all directions near the count location. At a minimum, the following counts should be provided for each direction of motorized traffic at each count location prior to constructing the Separated Bike Lane:

- Cyclists traveling in the same direction as legal traffic in the same lane
 - In lanes shared with motor vehicles
 - In a dedicated bicycle lane (if one exists)
 - On the right side sidewalk (if one exists)
- Cyclists traveling in the direction opposite to the posted direction (wrong way) as adjacent traffic
 - In lanes shared with motor vehicles
 - In a dedicated bicycle lane (if one exists)
 - On the left side sidewalk (if one exists)

It is important to record separately bicycles traveling in each direction on the “correct” or “wrong” side of the road because one of the potential benefits of Separated Bike Lanes is reduction of “wrong way” bicycling.

After the Separated Bike Lane has been constructed, the same set of counts should be performed:

- Cyclists traveling in the same posted direction as adjacent traffic
 - In lanes shared with motor vehicles
 - In the Separated Bike Lane
 - On the right side sidewalk (if one exists)
- Cyclists traveling in the direction opposite to the posted direction (wrong way) as adjacent traffic
 - In lanes shared with motor vehicles

- In the Separated Bike Lane
- On the left side sidewalk (if one exists)

Note that the direction of travel with respect to “adjacent traffic” in a two-way Separated Bike Lane should refer to intended direction of bicycle traffic on each side of that facility. Also note that if a contraflow Separated Bike Lane or bicycle lane is being counted, the adjacent traffic again refers to the intended direction of bicycle traffic in the lane. In a shared lane, the direction of adjacent traffic is the direction that motor vehicles would legally move if they were operated on the same side of the street as the bicycle. If a bicycle lane is not marked with directional indicators, the direction of adjacent traffic is determined by the direction in which legal motorized traffic would be traveling in the next adjacent lane. On a sidewalk, the direction of adjacent traffic is the direction of motorized traffic in the nearest motorized lane (not the nearest bicycle lane).

If counts are conducted on parallel roadways or trails, the same level of detail should be collected as for the Separated Bike Lane roadway. Such counts are not required, but are strongly encouraged if an anticipated effect of the Separated Bike Lane is to divert existing bicyclists from these alternate facilities.

If counts are conducted on intersecting facilities, the same level of detail may be sought as for the Separated Bike Lane facility itself, but it is not expected. Agencies may conduct more aggregate counts (e.g. all traffic without regard to lane or direction) on those facilities for limited time periods, or may elect not to do any such counts.

Notes on the Traffic Monitoring Guide

These recommendations are designed to support coding data in the format recommended in the current (September 2013) edition of the Traffic Monitoring Guide (TMG). While that format allows for very detailed specification of count type and location, the current format does NOT distinguish between paint-separated and physically-separated facilities (see the Crosswalk variable). A coding extension will be supplied to distinguish painted lanes from Separated Bike Lanes.

Further note that the TMG does not have formal codes to distinguish male or female riders or other observable demographic characteristics (age, helmet use, type of bicycle, auxiliary equipment such as lights or panniers, etc.). It may be interesting to collect such data for the Separated Bike Lane study, but agencies are not expected to do so as the resources required may be onerous (due to the cost of manual or video collection, and the difficulty of covering sufficient time periods as requested in the next section).

When to Count

Counts should ideally be conducted for a 24-hour period over a consecutive stretch of two or three weeks. Such counts are generally only feasible with automated equipment (either automatic counters or video collectors). If manual counts are conducted, then at a minimum, per the Traffic Monitoring Guide, counts should be conducted for 4 hour peak periods over a full week (weekdays and weekends). The same four hours should be counted each day. Ideally, a full 24-hour count will be conducted on at least one weekday to verify that the 4-hour counts occur during reasonable peak periods of use. Site

observation may be conducted prior to the formal count to identify a reasonable peak period, but it is important to recognize that the construction of the facility may also shift the peak period (e.g. by helping bicyclists feel more comfortable riding during peak hours of motorized traffic).

Forms for Data Collection

This section describes the information that should be gathered during data collection, and includes a sample form. The data elements support all required elements of the data format published in the September 2013 edition of the FHWA Traffic Monitoring Guide (<http://www.fhwa.dot.gov/policyinformation/tmguide/>).

Station Location

The following information should be gathered for each count location (or in traffic monitoring parlance, for each “station”). Some of these elements will be constant for the entire project and may not need to be collected on a location-by-location basis. The acronym “HPMS” in this discussion refers to the “FHWA Highway Performance Monitoring System”. The reader is referred to the TMG for additional information on detailed coding of each field, including valid field values.

- State and County (TMG “L” fields 2 and 3)
 - Valid codes for State and County are described in the TMG and derive from FIPS standards used to describe Census geography
 - Additional jurisdiction information such as City or Town may be included if relevant
- Longitude and Latitude (TMG “L” fields 25 and 26)
 - GPS coordinates of the location where the data collection master device (or person) is placed
 - This is NOT sufficient to fully describe the location of tubes or individual sensors. The individual collection locations must also be described structurally using fields explained in the following sub-section (“Subject of Count”)
 - **Note:** Longitude and latitude may be provided separately for each subject of count at the agency’s discretion. However only a single set of longitude and latitude values to identify the overall station location is required.
- Station ID (TMG “L” field 4)
 - A six-character identifier for this geographic location; this ID is arbitrary but should be unique within a given State and County
 - If counting on a wide street, there may be a perceptible difference in longitude or latitude from one side to the other. The Station ID is used to unite counts of different uses at the same “place”.
- Direction of Route (TMG “L” field 6)
 - This is a conventional compass direction (N, NE, E, SE, S, SW, W, NW) describing the orientation of the adjacent motorized roadway; it does NOT imply a direction of travel (see the “Subject of the Count” section below)
 - For one-way facilities it is the posted direction of travel. For two-way facilities, it is the increasing “milepost” direction which can be obtained from the HPMS Linear Reference System (preferred if available), from physical mileposts on the roadside, or from the direction of increasing house or block numbers on the roadway.

- If the count is on a trail or road with no conventional direction (such as mileposts), the direction is arbitrary but the same choice should be used for counts taken later at the same location (e.g. after the Separated Bike Lane is constructed)
- Functional Classification of the Roadway (TMG “L” field 5)
 - A table of valid codes is presented in the TMG, including a code for off-road trail facilities that might be counted as a parallel facility

The following station location elements are optional, but strongly encouraged if they are available:

- Posted Speed Limit (TMG “L” field 21)
 - Speed posted in miles per hour on the adjacent motorized roadway
- National Highway System (TMG “L” field 24)
 - True or false if the road is part of the National Highway System
- Posted Route Signing (TMG “L” field 27)
 - TMG contains a table of valid codes
 - Code the highest classification route number appearing on signs posted along the facility
- Route Number (TMG “L” field 28)
 - Record the route number appearing in the posted sign (previous field)
- HPMS Segment Identification (TMG “L” fields 29 and 30)
 - See the TMG and HPMS documentation for the LRS segment identification format
 - Useful if motorized counts on this roadway segment are also collected for HPMS
- Station Location (TMG “L” field 31)
 - A short (50 character) plain English description of the location
- Other Information (TMG “L” field 32)
 - Any special circumstances can be documented.

Note that the TMG allows entry of up to five “Factor Groups” which are used to identify comparable facilities when factoring short term counts to seasonal or annual averages. Factor Groups are a “future enhancement” and need not be collected for the Separated Bike Lane studies. If reported, however, they will be recorded.

Subject of the Count

The “Subject of the Count” data elements describe in detail what counts are going to be collected at the station location. The actual numeric counts reported are technically the counts of these “subjects”. As noted above in the Section “What to Count”, bicyclists traveling in different directions or positions on the roadway are considered different “subjects” and separate count sets should be reported for each.

The following elements are required to define the subject of a count:

- Roadway Facility (TMG “L” field 9)
 - TMG calls this field “Crosswalk”
 - This field identifies which part of the roadway is being counted: bike lane/Separated Bike Lane, lanes shared with motor vehicles, a sidewalk, or a separate off-road facility. The field will also identify crosswalks, overpasses or underpasses, though none of those are likely relevant to the Separated Bike Lane study.
- Direction of Facility (TMG “L” field 7)
 - TMG calls this “Location of Count Relative to Roadway Orientation”

- This element records which “side” of the road the counted Roadway Facility is on (same or opposite).
- To determine Direction of Facility: Face in the Direction of Route. If the Roadway Facility is “on the right” it is “same” direction, and if it is “on the left” it is “opposite” direction
- TMG supports crossing counts, but parallel counts are recommended for the Separated Bike Lane study
- TMG also supports “both” directions, which would be appropriate if you were counting a trail that did not have a directional center stripe, or a narrow neighborhood street without a center line.
- Direction of Travel (TMG “L” field 8)
 - To determine Direction of Travel: Face in the Direction of Route. Record “same” if the bicyclists you are counting in front of you are traveling in the direction of route (away from you), and “opposite” if the bicyclists will be traveling opposite the direction of route (toward you).
 - Notice that this element has nothing to do with the Direction of Facility (the distinction is “actual” direction of travel in this field, versus “intended” direction of travel in the Direction of Facility field).
 - TMG can accept counts of “both” travel directions, but it is recommended that directional counts be collected (same/opposite), even on facilities such as trails that are intrinsically bi-directional.
 - If Direction of Travel is opposite the Direction of Facility, the bicyclist is traveling the “wrong way”
- Type of Count (TMG “L” field 11)
 - TMG supports “bicyclists” or “pedestrians” or “both” (future TMG extensions may allow for “male/female/either sex/indeterminate”, and those subjects may be counted separately if desired). For the Separated Bike Lane study, only “bicyclists” are required.
- Sensor Installation Type (TMG “L” field 12)
 - TMG calls this field “Method of Counting”
 - This should be “permanent”, “portable” or “manual” and describes how the Type of Sensor technology is installed. Permanent counters are built into the physical environment and intended to operate continuously over long periods. Portable counters are installed just for the duration of the count study. Manual counts are conducted by human beings holding portable equipment (clipboards, tablets, smartphones, etc.)
 - Note that video counts (type of sensor) should be either “permanent” or “portable” unless the video was recorded by a hand-held camera (which is unusual)
- Type of Sensor (TMG “L” field 13)
 - This element states whether a manual or automated count was collected, and what specific kind of technology was used. The TMG has a table of valid codes for different technologies and methods.
 - It is legitimate to collect manual and automated counts of the same facility at the same location, but these counts should be reported as separate “subjects”.

Note: The TMG data format is new, and there may be some situations that can’t be fully accounted for using the directional elements described here. Such situations will be rare in practice. Contact FHWA project staff if you cannot figure out how to collect data for your particular situation.

Count Information

The following data items should be reported to describe and submit the counts:

- Station Location
 - This can be all the items in the first sub-section above (“Station Location”), or a conventional identifier can be used to refer to another page that contains the required information
- Subject of Count
 - This can be all the items in the second sub-section above (“Subject of Count”), or a conventional identifier can be used to refer to another page that contains the required information
- Date of Count (TMG “N” fields 17, 18 and 19)
- Duration of reported intervals (TMG “N” field 21)
 - Only certain interval durations are acceptable: 5 minute, 10 minute or 15 minute. Counts should be collected for the shortest feasible intervals (shorter if automated equipment is used, longer if manual counts are conducted)
 - Ideally, all count subjects will be counted over the same intervals (that is, if any type of bicycle traffic is counted in 5 minute intervals, then all counts should be reported in 5 minute intervals)
- Start time of first Count Interval (TMG “N” field 20)
 - Start times for each interval can be reported if desired
 - **Important:** If a count session continues past midnight, a new form with a new date should commence at midnight.
- Counts for each interval (TMG “N” fields 21 through 309 as appropriate)
 - The number of distinct “subjects” observed during the interval

The following elements are optional but strongly encouraged:

- Precipitation (TMG “N” field 14)
 - Was it raining or snowing during any count interval?
- High Temperature (TMG “N” field 15)
 - The highest temperature recorded at the station location during any count interval
- Low Temperature (TMG “N” field 16)
 - The highest temperature recorded at the station location during any count interval

For Federal Highway Administration

**Separated Bike Lanes Planning and Design Guide
Future Research Needs
Prepared September 2014**

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This appendix highlights future research needs identified in the development of the *Separated Bike Lane Planning and Design Guide*. These research needs are provided to inform the activities of the full range of research stakeholders, including local and state partners, University Transportation Centers, pooled research fund managers, and the National Cooperative Highway Research Program.

A: Safety

1. Develop Crash Modification Factors for Different SBL Configurations

The crash analysis conducted as part of the development of this guide is a first step towards understanding the safety trends related to separated bike lanes. However, to truly understand the safety effects of separated bike lanes, it will be necessary to collect more robust crash data (e.g., crash severity) and bicyclist volume data. Future research should be conducted to develop crash modification factors for different SBL configurations. To facilitate this process, a mechanism to receive and compile new and updated data on separated bike lanes will be needed and, to the extent possible, this effort should be coordinated with ongoing efforts to modify FHWA's Traffic Monitoring Analysis System (TMAS) based on the Traffic Monitoring Guide format so that exposure rates for SBLs can be properly assessed. Future research identified in Appendix F, and also by other stakeholders such as the Transportation Research Board's Bicycle Transportation Committee, should also be undertaken and should involve stakeholders and partners at all levels, including cities, MPOs, States, advocacy organizations, University Transportation Centers, private nonprofit institutions, foundations, and the Federal government.

2. Improve Crash Reporting Practices

- Research leading to clearer and more consistently applied thresholds and practices for reporting crash data is needed. This research will lead to more standardization of crash reporting so key information is captured and there is less variability in what is reported between facilities and geographic locations. Research may examine potential bias in reporting systems, for example, a minimum property damage requirement may encourage under-reporting and the definition of injury may be too vague. Research could also identify a reporting threshold used by a specific community that can serve as a model or best practice.

3. Conduct Conflict Analyses

- Detailed conflict analyses on existing separated bike lanes will help planners and designers better understand operational issues and make more informed design decisions. Research will provide insights on general potential conflicts between, for example, turning and through vehicles and between bicyclists, pedestrians, and transit users. Conflict analysis also needs to include observed conflict, for example by tracking evasive maneuvers via video analysis. Ultimately, this research on conflict analysis could lead to a conflict measure, which would document the rate of conflicts between through and turning vehicles. This would help practitioners to break out low conflict scenarios from high conflict scenarios and could eventually be linked to specific design choices. For example, a mixing zone may be acceptable in low conflict scenarios, but less desirable when the conflict rate goes up.

4. Expand Safety Analyses by Design Elements and Intersection Characteristics

- As higher quality data become available, additional research is needed comparing crash and injury statistics with specific physical design characteristics. This research should incorporate the

results of the conflict analyses discussed above. This research will enable designers to understand safety implications of specific design choices and this will result in improved designs over time. As one example, research on safety implications of different intersection alignments and design choices will enable practitioners to design safer intersections. A more detailed examination of each of the sites examined in this study would help to better understand which factors may have contributed to changes in crash and volume data from the before period to the after period. It also may help to better understand what factors are contributing to a higher rate of bike crashes but a lower rate of overall crashes. This research might eventually lead to an understanding of Crash Modification Factors for different Separated Bike Lane configurations. In addition to providing insights on critical design elements and safety performance of intersections, this research should include human factors components.

B. Planning

5. Improve the Consideration of Separated Bike Lanes in the Planning Process

- There is a need to improve consideration and understanding of separated bike lanes in various planning processes, for example by pursuing the following research:
 - Additional research is needed to examine the relationship between network connectivity and the quality of networks and other policy priorities such as mode share goals, storm water management, green streets, and emergency evacuation. This research will provide insights into strategies for measuring network quality, connectivity, and changes over time, while also highlighting best practices for agency coordination.
 - Additional research is needed to examine the impact of separated bike lanes on trip purpose, for example to highlight the extent to which they increase utilitarian bike trips. This analysis could also evaluate the extent to which separated bike lanes expand the cross section of people bicycling for transportation.
 - A detailed examination of material cost and cost effectiveness of permanent versus temporary treatment options would be helpful.
 - Additional research is needed on equity implications (positive and negative) of separated bike lanes, which could highlight, for example, process oriented best practices and case studies.
 - Research is needed to scan and synthesize how each state treats lane/parking reductions for the purpose of installing a separated bike lane under the NEPA process to ensure there are no significant environmental impacts. Considerations might include LOS intersection standards, requirements for future-year LOS and AQ analysis, any state-specific streamlining policies (e.g. below AADT thresholds, or separated bike lane network scenario analyses in lieu of project-specific analysis), documentation requirements, and suggestions for streamlining separated bike lane implementation.
 - Research is needed on strategies for streamlining the design exceptions process.

6. Evaluate Targeted Education and Awareness Strategies

- Research is needed on the effectiveness of educational tools on safety-related outcomes, specifically for separated bike lanes. This research can also identify and evaluate effective strategies for teaching drivers and bicyclists about new interaction expectations (e.g. merging, mixing, etc.). This research will also provide insight on changes in behavior of drivers, bicyclists, and pedestrians over time. Including additional research on whether separated bike lanes attract a different, likely less experienced or confident, type of bicyclist could assist in further

targeted measures for education, marketing, design and crash analyses. This research would provide insight into multifaceted approaches to improving safety and could include things such as drivers' education courses, classes for children, and the most effective enforcement strategies.

C. Design

7. Improve Design and Operations

- Research is needed on best practices for curb cuts and driveways. This research would provide guidance on questions such as the number of driveways that are desirable or acceptable on a given block. The effectiveness of various accessibility elements and colored paint on cyclist and motorist behavior and on safety-related outcomes would be helpful to practitioners, as would additional guidance on thresholds (e.g. when to signalize, when to provide protected turns, etc.). The MUTCD experimentation process can provide a venue to evaluate a range of separated bike elements such as signal strategies, two-stage stage turn queues, bike boxes, and green paint in conflict areas.
- The recent report *Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S.* provided an overview of different mix zone geometries and markings, but did not provide any details on if or how cities are signing these new (and potentially confusing) conflict points. Furthermore, there are few obvious options to provide signs to cue how and where motorists must enter to turn, and also indicate their requirement to yield (except for [the proposed R10-15a](#) in a few cases). Research could survey how cities are signing their separated bike lane mixing zones, test effectiveness of any/all schemes in improving yielding behavior and entering the turn stall, and/or create and experiment with a new design (such as an adapted r10-15a).
- The *Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S.* report provides a comparison of mixing zone designs, but there is a stated preference among users surveyed for bike-specific phases at signal-controlled intersections in lieu of mixing. Additionally, where turning volumes of vehicles are low, the lack of queuing makes the mixing zones unnecessary. Research could provide some factors to consider (accounting for both vehicle LOS and bicycle user perception and safety) in selecting an intersection design, including some quantitative analysis of turning vehicles versus separated bike lane users as a guide.
- Additional research is needed to evaluate speed-time progressions of bicyclists in separated bike lanes. This research would provide average speed data for use in changing signal timing, and demonstrate/quantify the potential value to separated bike lane users in reducing their intersection delay.
- Placing a separated bike lane forces a number of changes to allow other road users access to the curb. Future research should include a scan of how separated bike lane planning, designs, policies, regulations, and outreach programs are mitigating the impact of separated bike lanes on curbside access for a variety of other users, such as taxis, curbside vendors, freight, transit vehicles, and facilities with high drop-off demand (such as hotels).

D. Evaluating Performance

8. Develop a Holistic Project Evaluation Framework for Separated Bike Lanes

- More research is needed on the broad based benefits of separated bike lanes, above and beyond just safety. These benefits can be measured against reductions in vehicular capacity of a roadway. The effect of separated bike lanes on transit access can be researched, for example to determine the impact on transit catchment areas and effect on first/last mile challenges. This research can lead to a more holistic project evaluation framework that documents the impact of separated bike lanes and the local economy, environment, emissions reductions, and single occupancy vehicle commuting. A more holistic project evaluation framework will help practitioners and others make decisions with a larger and more informed context.



For More Information

Visit http://www.fhwa.dot.gov/environment/bicycle_pedestrian

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