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FINAL REPORT

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

NITC-RR-583

June 2014

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LESSONS FROM THE GREEN LANES:
EVALUATING PROTECTED BIKE LANES IN THE U.S.

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by

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16. Abstract

This report presents finding from research evaluating U.S. protected bicycle lanes (cycle tracks) in terms of their use, perception, benefits, and impacts. This research examines protected bicycle lanes in five cities: Austin, TX; Chicago, IL; Portland, OR; San Francisco, CA; and Washington, D.C., using video, surveys of intercepted bicyclists and nearby residents, and count data. A total of 168 hours were analyzed in this report where 16,393 bicyclists and 19,724 turning and merging vehicles were observed. These data were analyzed to assess actual behavior of bicyclists and motor vehicle drivers to determine how well each user type understands the design of the facility and to identify potential conflicts between bicyclists, motor vehicles and pedestrians. City count data from before and after installation, along with counts from video observation, were used to analyze change in ridership. A resident survey (n=2,283 or 23% of those who received the survey in the mail) provided the perspective of people who live, drive, and walk near the new lanes, as well as residents who bike on the new lanes. A bicyclist intercept survey (n= 1,111; or 33% of those invited to participate) focused more on people's experiences riding in the protected lanes. A measured increase was observed in ridership on all facilities after the installation of the protected cycling facilities, ranging from +21% to +171%. Survey data indicates that 10% of current riders switched from other modes, and 24% shifted from other bicycle routes. Over a quarter of riders indicated they are riding more in general because of the protected bike lanes. A large majority of drivers and bicyclists stated that they understood the intent of the intersection designs and were observed to use them as intended, though specific designs perform better than others on certain tasks. No collisions or near-collisions were observed over 144 hours of video review for safety at intersections, including 12,900 bicyclists. Residents and bicyclists indicated that any type of buffer shows a considerable increase in self-reported comfort levels over a striped bike lane, though designs with more physical separation had the highest scores. Buffers with vertical physical objects (those that would be considered protected lanes - e.g. with flexposts, planters, curbs, or parked cars) all resulted in considerably higher comfort levels than buffers created only with paint. Flexpost buffers got very high ratings even though they provide little actual physical protection from vehicle intrusions— cyclists perceive them as an effective means of positive separation. Support for the protected lanes among residents was generally strong with 75% saying that they would support building more protected bike lanes at other locations, and 91% of surveyed residents agreed with the statement, "I support separating bikes from cars." This agreement was high among primary users of all modes (driving, walking, transit, and bicycling), though motorists expressed concerns about the impacts of protected lanes on congestion and parking. Most residents also agreed with the statement "I would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier," with "*Interested but Concerned*" residents expressing the highest level of agreement at 85%. Nearly three times as many residents felt that the protected bike lanes had led to an increase in the desirability of living in their neighborhood, as opposed to a decrease in desirability (43% vs 14%).

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Finally, thanks to anonymous peer reviewers who provided immensely helpful insights and corrections to this report (including suggesting the term “turning zone” which we adopted).

DISCLAIMER

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EXECUTIVE SUMMARY

As cities move to increase levels of bicycling for transportation, many practitioners and advocates have promoted the use of protected bike lanes (also known as "cycle tracks" or "protected bikeways") as an important component in providing high-quality urban infrastructure for cyclists. These on-street lanes provide more space and physical separation between the bike lane and motor vehicle lane compared with traditional striped bike lanes. However, few U.S. cities have direct experiences with their design and operations, in part because of the limited design guidance provided in the past. Until recently there was limited research on protected bike lanes in North American. Researchers have been working to make up for this shortfall, with findings suggesting that protected bike lanes can both improve bicyclists' level of comfort and safety, and potentially increase the number of people cycling.

Our research evaluates protected bike lanes in five distinct contexts varying in population, driving and cycling rates and cultures, and weather: Austin, Texas; Chicago, Illinois; Portland, Oregon; San Francisco, California; and, Washington, District of Columbia (see map, Figure 1). These five cities participated in the inaugural "Green Lane Project" (GLP) sponsored by People for Bikes (formerly known as Bikes Belong).

Figure ES-1. Map of Study Cities

This evaluation focused on six questions:

1. Do the facilities attract more cyclists?
2. How well do the design features of the facilities work? In particular, do both the users of the protected bicycle facility and adjacent travel lanes understand the design intents of the facility, especially unique or experimental treatments at intersections?
3. Do the protected lanes improve users' perceptions of safety?
4. What are the perceptions of nearby residents?
5. How attractive are the protected lanes to different groups of people?
6. Is the installation of the lanes associated with measureable increases in economic activity?

Study Sites

The study includes nine new protected bike lanes in the five cities (Figure ES-2 and Table ES-1). The projects were completed between spring 2012 and summer 2013.

Austin, Texas

The **Barton Springs Road** protected bike lane is a one-way, half-mile long lane separated by flexposts and a 1.5' buffer. Space was created by narrowing the motor vehicle lanes. There is a shared-use path on the other side of the street.

The **Bluebonnet Lane** protected bike lane is a two-way lane on a low-traffic primarily residential two-way street with an elementary school. The 0.7 mile lane is separated by flexposts and a 2' buffer, and provides an alternative commuter route to the busy Lamar Boulevard. On-street parking was removed to provide room for the protected lane.

The **Rio Grande Street** protected bike lane is a two-way, half-mile long lane on the left side of a one-way street a few blocks the University of Texas-Austin campus. The street has a mix of residential, retail, and office uses. A motor vehicle lane and limited on-street parking were removed to provide room for the protected lanes and 4' buffer with flexposts.

Chicago, Illinois

The **Dearborn Street** protected bike lane is a two-way lane on a one-way street through Chicago's 'Loop.' One motor vehicle lane was removed to provide space for the lane, which is separated by parking, flexposts, and a 3' buffer zone, with bicycle signals at each intersection.

The **N. Milwaukee Avenue** protected bike lanes, along a major radial route between central Chicago with neighborhoods to the northwest connect existing protected bike lanes on W. Kinzie Street and N. Elston Avenue. The protected bike lanes are on both sides of the street along the 0.8 mile route, buffered by a mix of a 2-3' painted buffers with posts and parking protected areas.

Portland Oregon

The **NE Multnomah Street** protected bike lanes run 0.8 miles along a commercial street. The five-lane street with standard bike lanes and no on-street parking was "dieted" down to one travel lane in each direction, a two-way left-turn lane, and bike lanes protected by a mix of parking, painted buffers, flexible bollards, and/or planters, depending on the road segment.

San Francisco, California

The **Oak and Fell Street** protected bike lanes run three blocks along a one-way street couplet, connecting bike routes from downtown to Golden Gate Park and neighborhoods to the west. Parking was removed to accommodate the lanes with 5' buffers and flexposts.

Washington, District of Columbia

The **L Street** protected bike lane is half of a planned protected bike lane couplet along two one-way streets in downtown. L Street was decreased from 4 to 3 motor vehicle lanes in places, to make room for the 1.12-mile long, one-way left-side lane separated by a 3' striped buffer zone with plastic flex-posts.

Figure ES-2. Protected Bike Lanes included in the research

Austin, TX: Barton Springs Road

One-way protected bike lane on the south side of the road

Bluebonnet Lane

Two-way protected bike lane on a two-way street

Rio Grande Street

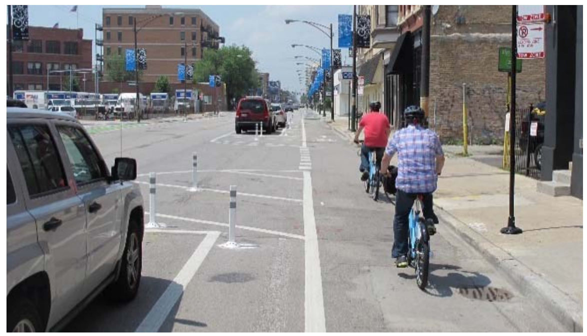
Two-way protected bike lane on one-way street

Chicago, IL: N/S Dearborn Street

Two-way protected bike lane on one-way street

N Milwaukee Avenue

Pair of one-way protected bike lanes on a two-way street



Portland, OR: NE Multnomah Street

Pair of one-way protected bike lanes on a two-way street

San Francisco, CA: Oak Street

One-way right-side lane on a one-way street

Fell Street

One-way left-side protected lane on a one-way street

Washington, DC: L Street NW

One-way protected bike lane on a one-way street

Table ES-1. Protected Bike Lane Elements

Data Element	Austin			Chicago		Portland	San Francisco		Washington DC
	Barton Springs Road	Bluebonnet Lane	Rio Grande St	N/S Dearborn St	N Milwaukee Ave	NE Multnomah St	Fell St	Oak St	L Street NW
Protected Lane Description	One-way EB protected lane on south side (+WB shared path on north side)	Two-way protected lanes on two-way street	Two-way protected lanes on one-way street	Two-way protected lanes on one-way street	Pair of one-way protected lanes on either side of two-way street	Pair of one-way protected lanes on either side of two-way street	One-way protected lane on one-way street	One-way protected lane on one-way street	One-way protected lane on one-way street
Standard / Striped Bike Lanes (pre)	None	1 nb, 1 sb	1 nb	None	1 nb, 1 sb	1 eb, 1 wb	1 wb	None	None
Standard Traffic Lanes (pre)	2 eb, 1 ctr turn lane, 2 wb	1 nb, 1 sb	2 nb	3-4 nb	1 nb, 1 sb	2 eb, 1 center turn lane, 2 wb	3 wb	3 eb	3 eb
Loss of MV Travel Lane	No	No	In places	One lane	Dedicated turn or bus lane in places	One lane in each direction	No	No	In places
Parking Allowed (pre)	No	Both sides	Left Side	Left side	Both sides	No	Both sides	Both sides	Right side, Left side (flex)
Net Loss of Parking	No	~150	No	21	69	+27 gained	~28	~27	~150
Length (miles)	0.5	0.7	0.4	1.2	0.8	0.8	0.3	0.3	1.12
# Signalized Intersections	4	0	2	12 to 13	7	10	4	4	15
# Unsignalized Intersections	2	15	5	0	5	3	0	0	0
ADT (pre)	23-28,000	3,500	5,000	8-18,000	11,000	10,000	10-20,000	10-20,000	10,000
Construction Timeframe	Spring 2013	August 2012	April 2012	Nov./ Dec. 2012, May 2013	April/May 2013	Fall 2012/ Winter 2013	Spring /summer 2013	Spring /summer 2013	October 2012
Bike Lane Width (representative)	5'-7'	5' + 5'	6.5' + 5.5'	5' + 4'	7'	4'-7'	7'3"	7'3"	8'
Buffer Type	Flexposts	Flexposts	Flexposts	Flexposts; MV parking	Flexposts; MV Parking	Concrete Planters; MV Parking	Flexposts	Flexposts	Flexposts
Typical Buffer Width	1.5'	3'	4'	3'; 8' parking strip	2-4'; 9' parking strip	2'-8'	5'	5'	3'
# Bicycle Signals	2	0	1	12 to 13	1	0	0	0	0
Typical MV Lane Width	10'-10.5'	10'	14'	9'-10'	10'-11'	10'	9'6"	9'6"	11'
# Mixing or Turning zones	0	0	0	0	0	11	3	3	11

Data and Methods

The primary data collection methods were video collection and observation at selected intersections, surveys of intercepted bicyclists, and mail-out surveys of nearby residents. The data sources were supplemented with count data provided by each city. Due to facility characteristics and available data, some protected lanes only lent themselves to certain types of data collection and analysis (Table ES-2).

Table ES-2. Data used in Analysis, by Site

	Austin			Chicago		Portland	San Francisco		Washington DC
	Barton Springs	Bluebonnet Lane	Rio Grande	Dearborn	Milwaukee	NE Multnomah	Fell	Oak	L Street
Video Data				●	●	●	●	●	●
Bicyclist Survey	●		●	●	●	●	●	●	●
Resident Survey	●	●		●	●	●	●	●	●
Count Data	●	●	●	●	●	●	●		●

Note: Due to construction activity and routes with relatively low traffic volumes at intersections, no video data were collected for the Austin locations

The video data help to assess *actual behavior* of bicyclists and motor vehicle drivers to determine how well each user type understands the design of the facility and to identify potential conflicts between bicyclists, motor vehicles and pedestrians. Cameras were mounted for a minimum of 2 days at 16 locations. A total of 168 hours of video were analyzed, in which 16,393 bicyclists and 19,724 turning vehicles were observed.

The resident survey (n=2,283 or 23% of those who received the survey in the mail) provided the perspective of people who live, drive, and walk near the new lanes, as well as residents who bike on the new lanes. The bicyclist intercept survey (n= 1,111 or 33% of those invited to participate) focused more on people's experiences riding in the protected lanes. Selected demographic information from survey respondents in shown in Figure ES-3. The intercepted bicyclists were younger and more likely to be male than the residents.

In contrast to the video data, the surveys collect data on *stated* behavior and perceptions. In instances where the two analyses overlap, the video review and survey results can be contrasted to compare how individuals behave to how they say they do, or should, act (Table ES-3).

Table ES-3. Overview of Data used in Analysis

Research Element	Video Data	Bicyclist Survey	Resident Survey	Count Data
Change in Ridership	●	●	●	●
Design Evaluation	●	●	●	
Safety	●	●	●	
Perceptions of Residents			●	
Appeal to Different Groups		●	●	
Economic Activity		●	●	

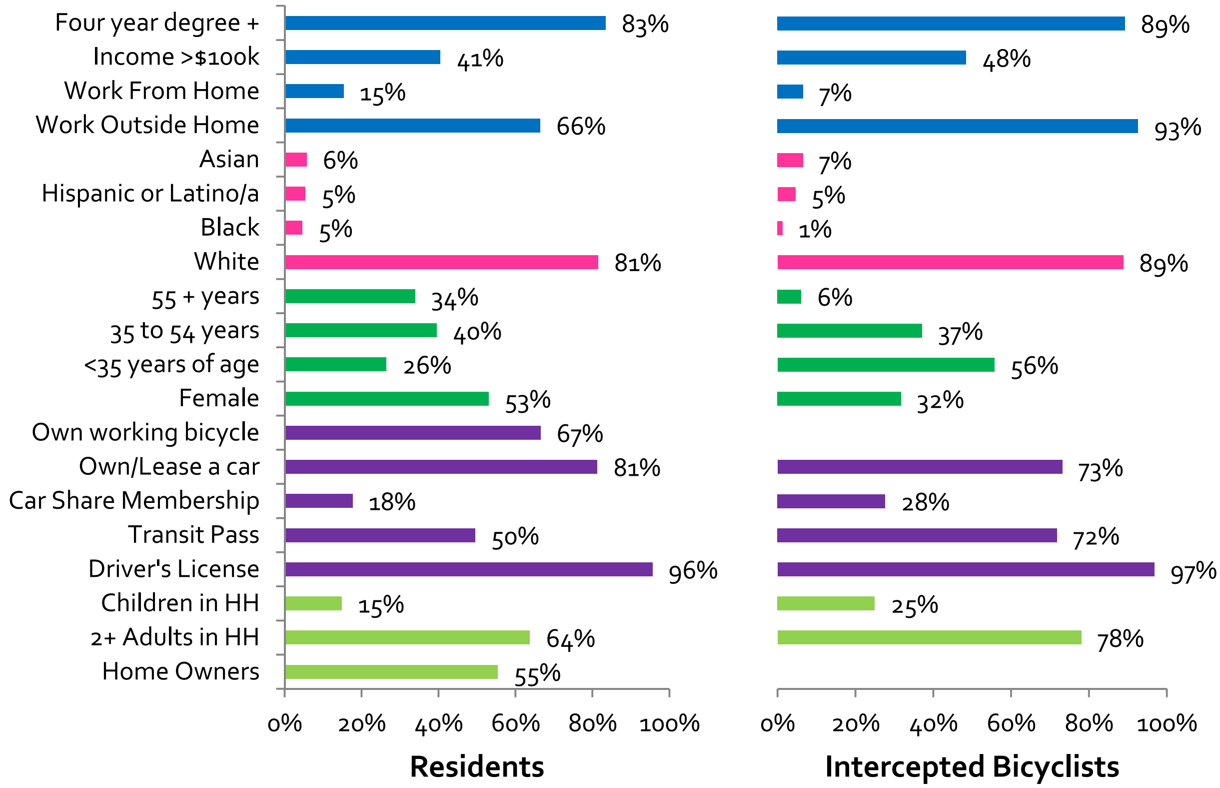


Figure ES-3. Resident and Bicyclist Survey Respondent Demographics

Findings: Changes in Ridership

We found a measured increase in observed ridership on all facilities within one year of installation of the protected bike lanes, ranging from +21% to +171% (Figure ES-4). The increases appear to be greater than overall increases in bicycle commuting in each city. Some of the increase in ridership at each facility likely came from new riders (i.e. riders who, absent the protected bike lane, would have travelled via a different mode or would not have taken the trip) and some from riders diverted from other nearby streets (i.e. riders who were attracted to the route because of the facility, but would have chosen to ride a bicycle for that trip regardless).

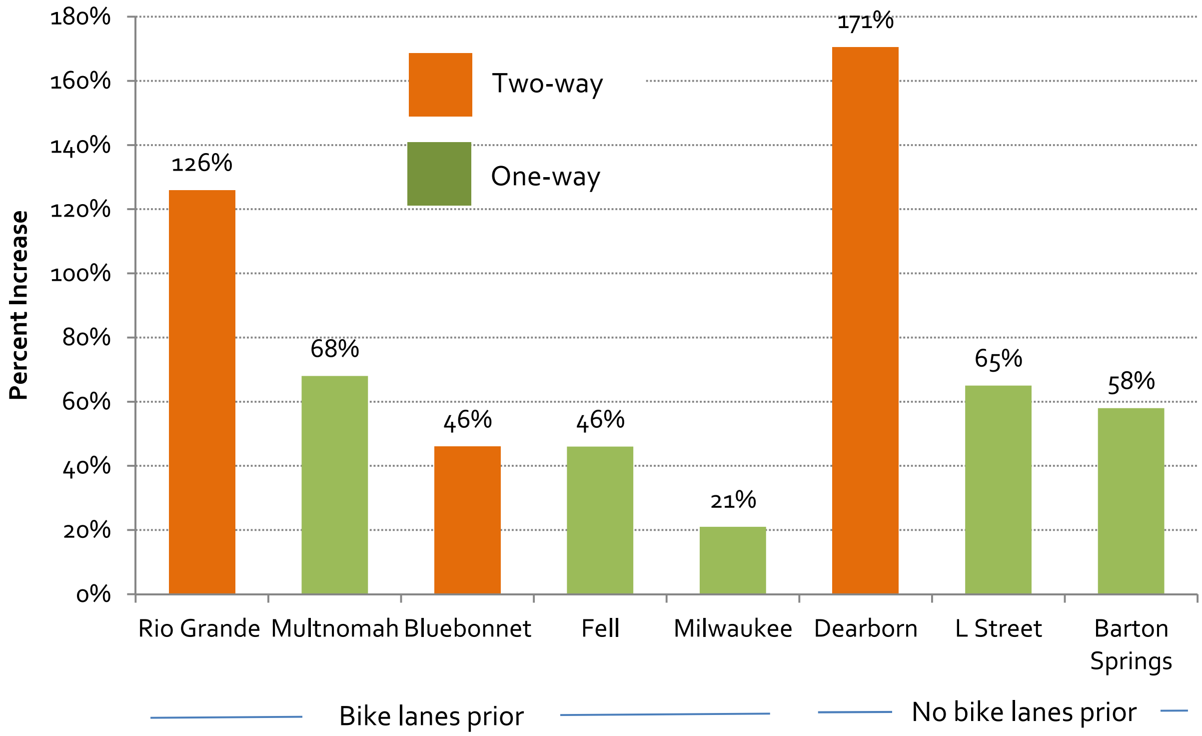


Figure ES-4. Change in Observed Bicycle Volumes

Our intercept survey of bicyclists found that 10% would have made the trip by another mode and 1% would not have made the trip, indicating that there are some new riders attracted to the facilities. The remainder would have bicycled on a different route (24%) or the same route (65%).

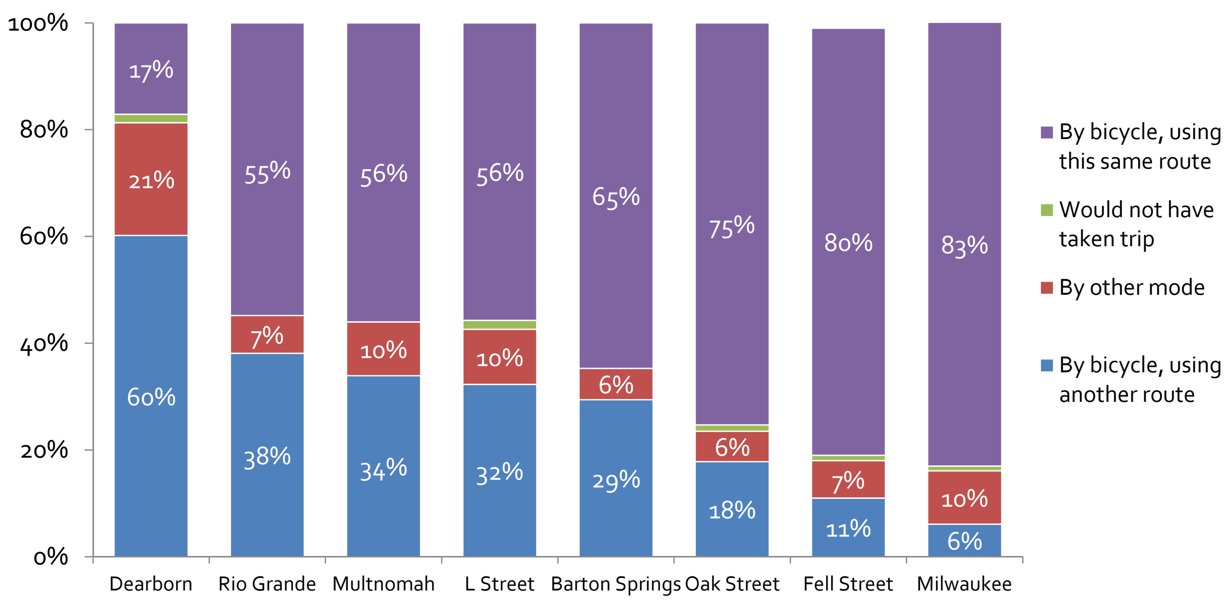


Figure ES-5. Before the new facility was built, how would you have made this trip?

- Bicyclists self-reported that they rode more frequently on the facility after installation. Just over 49% of bicyclists indicated that they are traveling on the respective routes more frequently than they were prior to protected lanes. The percentage ranged between 28% for Fell Street in San Francisco to 86% for Dearborn Street
- Nearly a quarter of bicyclists intercepted on the facilities stated that their overall frequency of bicycling increased because of the new protected lanes. The increase was higher among women.

Findings: Effectiveness of the Intersection Designs

A primary focus of our analysis was on intersection design—a critical component of making the protected lane concept function. Each of the facilities evaluated used different designs for through bicycles to mix with turning motor vehicle traffic. Three different design approaches were evaluated. First, some designs require the bicycles and turning vehicles to "mix" in the same space. These designs are called "mixing zones." The second approach moves the through bicycle from the protected lane near the curb to the left or right of the turning traffic into a narrow through bike lane. These are called "turning zones." There is a defined turn/merge gap for this maneuver and the lanes are marked with dotted lines recognizing that larger vehicles may encroach on the bike lane due to the narrow widths of the turning lanes. The third design involves signalization to separate the bicycle and turning vehicle movements.

With some exceptions noted below and in the main text, the large majority of drivers and bicyclists stated that they understood the intent of the mixing zone designs and were observed to use them as intended. In addition, a majority of bicyclists using the intersections stated feeling safe.

- For the turning zones, the design using the through bike lane (TBL) works well for its intended purpose. The TBLs help position cyclists and reduce confusion compared to sharrows in mixing zones. The design in Washington D.C. (where vehicles have a limited entry into the turning lane) had high correct lane use by turning vehicles (87%) and by through bicyclists (91%, Table ES-4). This suggests a clear benefit of the restricted entry approach and creating a semi-protected through bicycle lane.
- For the mixing zones, the highest compliance of any design was at the *Mixing Zone with Yield Markings* design in Portland, OR, where nearly all (93%) of the turning vehicles used the lane as intended. However, only 63% of observed bicycles correctly used the mixing zone when a car was present (they chose to go around vehicle in the buffer space to left). This is not necessarily a critical issue and hatching this space would likely change this observed behavior. However, the observed behavior does suggest a preference of giving cyclists space with a TBL.
- A low of 1% to a high of 18% of the turning vehicles at mixing zones actually turned from the wrong lane. The *Mixing Zone with Yield Markings* design in Portland and the *Turning Zone with Post-Restricted Entry and TBL* in Washington, D.C. had the fewest vehicles observed turning from the wrong lanes, indicating that clear marking of the vehicle entry point to the turning lane is beneficial.
- Based on observed behaviors, green pavement marking is effective at communicating the space that should be used by bicycles and that over use of green marking may result in some drivers avoiding the space.

Table ES-4. Turning Motor Vehicle and Through Bicycle Use of Intersections

Image	Design Type	Video: Correct Lane Use		Survey: % of Bicyclists Agreeing They Feel Safe
		Turning Motorist	Through Bicyclist	
	Turning Zone with Post Restricted Entry and Through Bike Lane (TBL): L Street	87%	91%	64%
	Mixing Zone with Yield Entry Markings: NE Multnomah / 9th	93%	63%	73%
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Oak/ Divisadero	66%	81%	74%
	Mixing Zone with Sharrow Marking: Oak/Broderick	48%	30%	79%
	Mixing Zone with Green Skip Coloring: Fell/Baker	49%	-	84%

Findings: Use of Traffic Signals to Separate Movements

One design approach is to separate the conflicting movements of turning motor vehicles and through bicycles using signal phasing. By doing so, if all road users comply, there should be no conflicts. This option was used on Chicago's two-way facility. Compliance rates by drivers and bicycles to the traffic control were comparable and users appeared to comprehend the design.

- At the three intersections studied, 77-93% of observed bicyclists complied with the bicycle signal and 84-92% of observed motorists complied with the left-turn signal.
- Nearly all cyclists (92%) who used the intersections with separate bicycle signal phases agreed that they felt "safe" when riding through the intersection. This exceeded all other intersection designs and is the only design evaluated where the protected lane carries all the way to the intersection.

Figure ES-6. Bicyclists wait at a bike signal on Dearborn Street.

Findings: Buffer Designs Influence Cyclist Comfort

We assessed bicyclists' perceptions of different buffer designs based upon their stated preferences for the actual facilities where they rode and some hypothetical designs presented in diagrams. One clear takeaway is that designs of protected lanes should seek to provide as much protection as possible to increase cyclists' comfort.

- Designs with more physical separation had the highest scores. Buffers with objects (e.g. flexposts, planters, curbs, or parked cars) had higher comfort levels than buffers created only with paint (Figure ES-7).
- Flexpost buffers got very high ratings even though they provide little actual physical protection
- Any type of buffer shows a considerable increase in self-reported comfort levels over a striped bike lane.

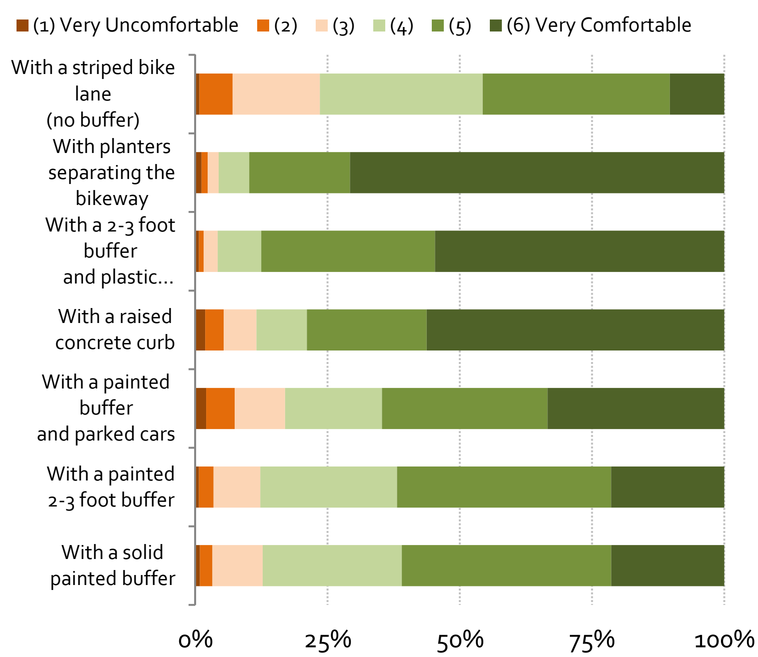


Figure ES-7. Bicyclists' Stated Comfort Level with Hypothetical Buffer Options

Findings: Perceived Safety for All Users

There was consistent evidence that the protected facilities improved the perception of safety for people on bicycles. Perceptions of the change to the safety of driving and walking on the facility were more varied.

- Nearly every intercepted bicyclist (96%) and 79% of residents stated that the installation of the protected lane increased the safety of bicycling on the street. These strong perceptions of improved safety did not vary substantially between the cities, despite the different designs used (Figure ES-8).
- Nearly nine out of 10 (89%) intercepted bicyclists agreed that the protected facilities were "safer" than other facilities in their city.

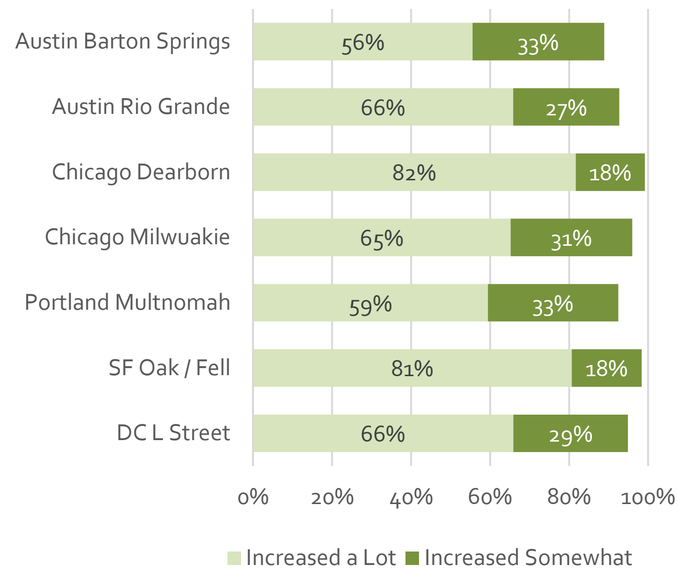


Figure ES-8. Bicyclists: "I feel the safety of bicycling on _____ has . . ."

- Perceptions of the safety of driving on the facility were more varied. Overall, 37% thought the safety of driving had increased; 30% thought there had been no change; 26% thought safety decreased; and 7% had no opinion. The perceptions varied by facility (Figure ES-9).
- Perceptions of the safety of the walking environment after the installation of the protected lanes were also varied, but were more positive than negative. Overall, 33% thought safety increased; 48% thought there had been no change; 13% thought safety decreased; and 6% had no opinion. These perceptions varied by facility.

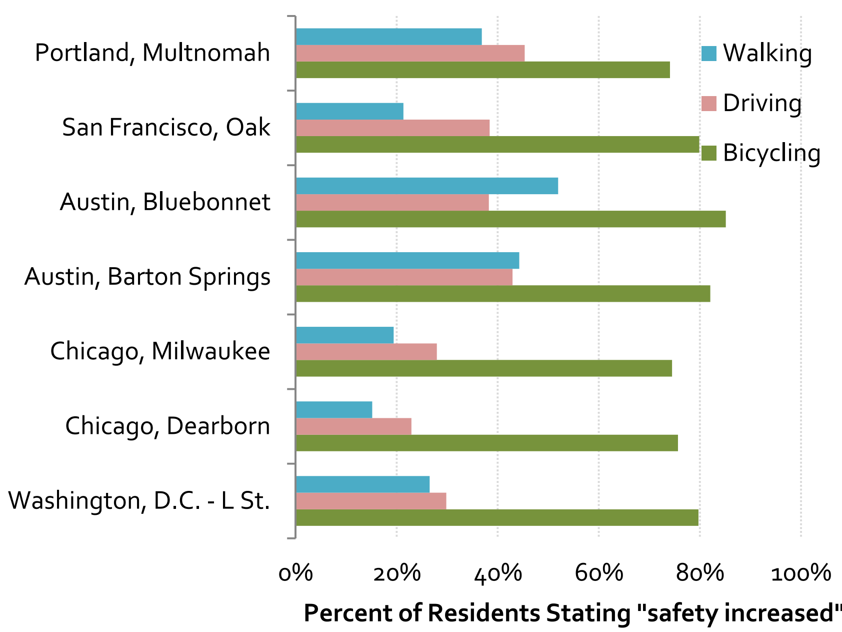


Figure ES-9. Residents: "Because of the protected bike lanes, the safety of ____ on the street has increased"

Findings: Observed Safety

Due to the very recent installation dates, reported crash data were not available for analysis on most of the facilities. Overall, we did not observe any notable safety problems and survey respondents had strong feelings that safety had improved. Taken together, these findings (when combined with the results of prior work) suggest that concerns about safety should not inhibit the installation and development of protected bike lanes—though intersection design does matter, and must therefore be carefully considered.

- In the 144 hours of video analyzed for safety in this research, studying nearly 12,900 bicycles through the intersections, no collisions or near collisions were observed. This included both intersections with turn lanes and intersections with signals for bicycles.
- In the same video analysis, only 6 minor conflicts (defined as precautionary braking and/or change of direction of either the bicycle or motor vehicle) were observed. At the turning and mixing zones analyzed there were 5 minor conflicts in 6,100 though bicycles or 1 minor conflict for every 1,200 though bicycles.
- There was generally a higher rate of conflicts observed in the mixing zone designs than in the turning zone designs.

Findings: Overall Support for the Protected Lane Concept

Overall, residents supported the protected lanes.

- Three in four residents (75%) said they would support building more protected bike lanes at other locations (Figure ES-10). This support was strong even among residents who reported "car/truck" as their primary commute mode — 69% agreement)
- Overall, 91% of surveyed residents agreed with the statement "I support separating bikes from cars". This includes primary users of all modes (driving, walking, transit, and bicycling).

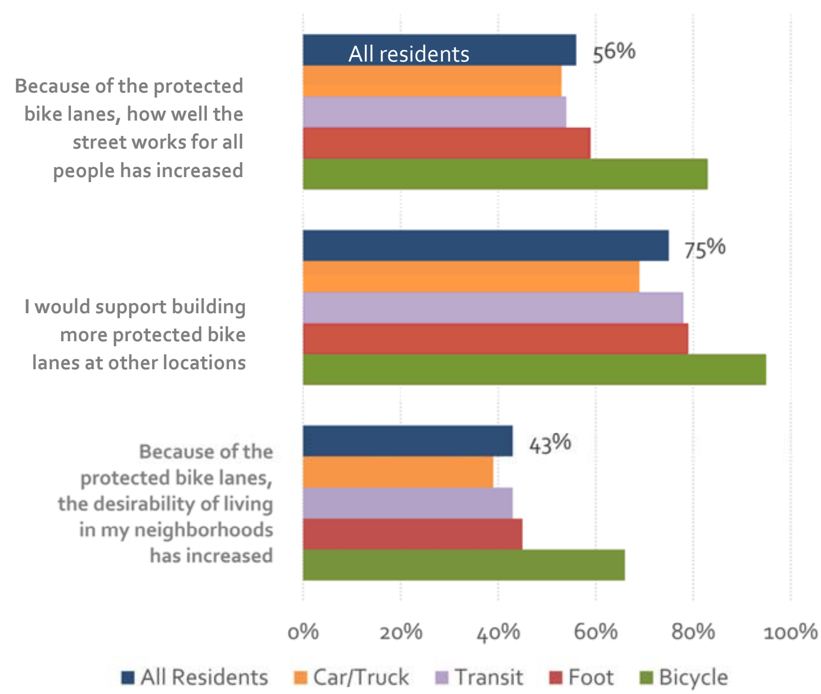


Figure ES 1. Residents' Opinions of Protected Bike Lanes, by Commute Mode

- Over half the residents surveyed (56%) felt that the street works better for "all people" due to the protected bike lanes, while only 26% felt the street works less well.

Findings: Neighborhood Desirability and Economic Activity

On the resident and bicycle surveys, questions were asked to provide insight into the impact of the protected lanes on neighborhood desirability and economic activity.

- Nearly three times as many residents felt that the protected bike lanes had led to an increase in the desirability of living in their neighborhood, as opposed to a decrease in desirability (43% vs 14%) - the remainder stated there had been no change in desirability.
- Approximately 19% of intercepted bicyclists and 20% of residents who bicycled on the street stated that how often they stop at shops and businesses increased after the installation of the protected bike lanes. Few respondents indicated their frequency decreased (1% and 6%, respectively)—most indicated no change.
- Similarly, approximately 12% of the residents stated that they are more likely to visit a business on the corridor since the protected bike lanes were built—9% indicated they were less likely, most self-reported no change.

Findings: Potential to Attract New Riders

Protected bike lanes could increase bicycling among people who do not currently ride regularly for transportation.

Nearly 2 in 3 residents agreed with the statement "I would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier." Agreement was higher for residents in the *Interested but Concerned* segment (Figure ES-11). *Interested but Concerned* residents had the highest perception of improved safety due to the installation of the protected lanes and the highest agreement with the statement, "I support separating bikes from cars."

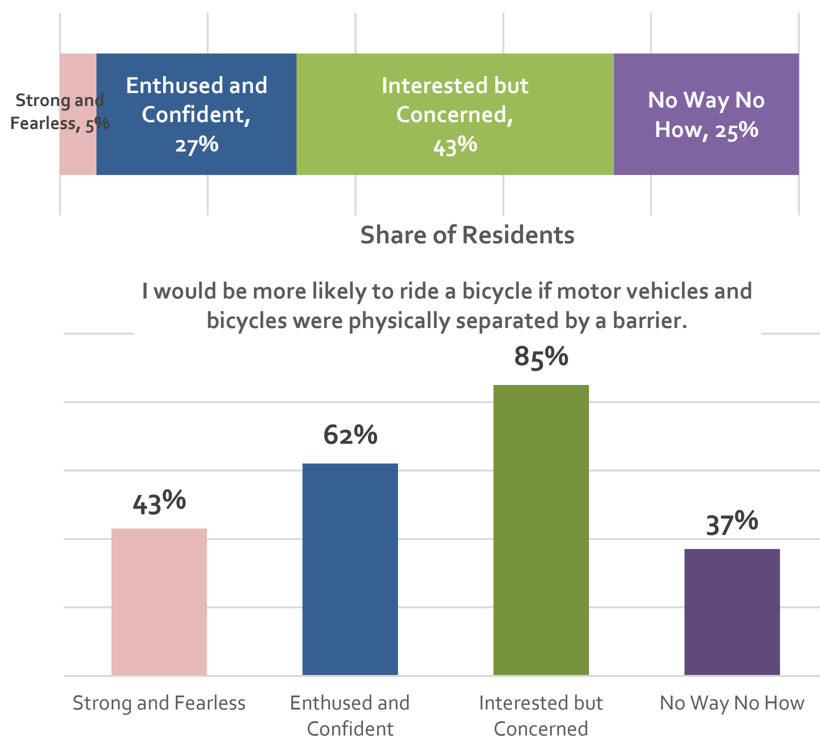


Figure ES-2. Residents' Likelihood of Riding with Physical Separation by Type of Cyclist

Findings: Perceptions of People Driving on the Street

The specific impacts to motor vehicle travel vary between the cities, depending on the before-and-after context.

- Over half (53%) of residents who had driven a motor vehicle on the street stated the predictability of bicycles and motorists had increased – only 12% felt predictability had decreased. We interpret this as support for the clear ordering of the street space for all users.
- Only 14% of respondents indicated that they ever avoided driving on the street because of the protected bikeway.
- About 31% of residents who drove on the street stated that since the protected bike lanes were built the amount of time it takes to drive on this street has increased, 10% indicated it decreased, and 59% indicated no change.
- Parking is a key issue when street space is reassigned and cities. The impact to parking was the most negative perception, with about 30-55% of residents indicating the impacts to parking were negative, even in cases where a minimal amount of parking was removed, or parking was increased.

1 INTRODUCTION

Cycle-friendly infrastructure has the potential to increase bicycling (*Pucher et al., 2010)*. However, levels of cycling in the U.S. remain low compared to international peers *(Pucher et al., 2011).* At the city level, several studies have demonstrated a positive association between miles of bike facilities and bicycle commuting *(Nelson and Allen, 1997; Dill and Carr, 2003; Buehler and Pucher, 2011)*. In the U.S., the most common types of bicycle facilities are striped bike lanes on streets and separate paths exclusive to bicycles and pedestrians. Increasingly, U.S. cities are adopting more innovative infrastructure options, similar to those found in many European cities. One type of innovative facility gaining attention is a protected bike lane, also known as a cycle track. These on-street lanes provide more space and physical separation between the bike lane and motor vehicle lane compared with traditional striped bike lanes.

The National Association of City Transportation Officials (NACTO) defines "cycle track" in its urban bikeway design guide as an "exclusive bike facility that combines the user experience of a separated path with the on-street infrastructure of a conventional bike lane" (*NACTO, 2011*). In this report cycle tracks more generically referred to as "protected bike lanes," protected cycling facilities," or "protected bikeways." Cycle tracks come in a variety of designs, but can generally be characterized as one- or two-way bike lanes with physical separation from motor vehicles. The physical separation may be flexposts (safe hit) or bollards, parked cars, curbs, raised pavement or other vertical physical barriers.

One motivation for the installation of these facilities is the hypothesis that they are more likely to attract new bicyclists—particularly those who have an interest in bicycling more but are concerned for their safety—because of an increased perception of safety and higher level of comfort while riding in the lane. Attracting large shares of these potential cyclists is essential to realizing many of the potential benefits of bicycling that cities are aiming for at an impactful scale, such as better health and reduced pollution. Early evidence from recently constructed protected bike lanes suggests that they do provide greater comfort (*Winters and Teschke, 2010; Monsere et al., 2012; Goodno et al., 2013*) and improved safety (*Lusk et al., 2011; Harris et al., 2013; Lusk et al., 2013; Thomas and DeMartis, 2013*).

The interest in innovative facilities is evident in a number of ways. In 2011, NACTO published the *Urban Bikeway Design Guide*, which was developed in part due to a lack of guidance on cycle tracks and other innovative bicycle facilities in typical state and national design standards manuals. The Green Lane Project, sponsored by People for Bikes (formerly known as Bikes Belong), aims to increase implementation of protected bike lanes and attracted applications from over 40 cities in its first year and letters of interest from over 100 cities in its second phase in 2014. The number of protected bike lanes is increasing quickly. Just over 60 facilities had been built by 2011, but 52 such facilities were built in the following two years, an increase of over 85% *(Bikes Belong, 2013)*.

Evaluations of protected bike lanes in the U.S. are sparse, and many cities are waiting for more empirical evidence of the effects of such facilities before constructing them. Of particular concern is the design and safety of the facilities at intersections, where conflicts and collisions can occur between through-moving cyclists and turning motor vehicles. In constrained urban areas, installing new protected lanes often requires reallocation of space that was previously used for motor vehicle traffic, parking, or transit activities. Thus, cities are interested in better knowing the benefits of installing the protected lanes, including increasing the level of people using cycling for transportation, impacts to economic activity, and changes to perceptions of safety and actual safety.

1.1 Research Objectives

The overall objective of this research is to evaluate U.S. protected bicycle lanes (cycle tracks) and intersection treatments in terms of their use, perception, benefits and impacts. This research examines protected bicycle lanes in five cities: Austin, TX; Chicago, IL; Portland, OR; San Francisco, CA; and Washington, D.C. These five cities participated in the inaugural "Green Lane Project" (GLP). The research had planned to evaluate Memphis, TN, but construction delays put the facilities outside the project window.

The research was designed to gather information and data about a number of relevant questions related to protected infrastructure. The project is the first in the U.S. that evaluates protected bike lanes in multiple cities and contexts, employing a consistent methodology and timeframe, using both observation of use and user and resident perceptions. Thus, most of the presentation of the results and data are structured to present the contrasting or similar results across cities, facility types, designs, and cycling and driving cultures. The evaluation sought to answer the following questions:

1. Do the facilities attract more cyclists?
2. How well do the design features of the facilities work? In particular, do both the users of the protected bicycle facility and adjacent travel lanes understand the design intents of the facility, especially unique or experimental treatments at intersections?
3. Do the protected lanes improve perceived and actual safety?
4. What are the perceptions of nearby residents?
5. How attractive are the protected lanes to users who are least comfortable on higher stress bicycling routes?
6. Is the installation of the lanes associated with measureable increases in economic activity?

This research provides a unique look at the effectiveness of protected bike lanes intersection design, the understanding and perception of users, and perceptions of nearby residents across a variety of contexts.

Safety is examined through a video review conflict analysis (focused at intersections) and from user perceptions based on survey findings. Adequate crash data to conduct a crash analysis was not yet available due to the short period of time between construction and evaluation.

Economic activity is examined through a set of questions asked of bicyclists and nearby residents. A thorough analysis of tax data and development patterns will require a longer timeframe to play out, and thus, is not included in this report.

1.2 Organization of Report

This report attempts to provide a comprehensive overview of the research approach, process and findings of this study. The chapters of the report are as follows:

- Chapter 2 (page 6) provides an overview of prior research around the implementation and impact of protected bike lanes, with a focus on North America. The focus is on peer-reviewed research.
- Chapter 3 (page 8) provides descriptions of each facility included in this report along with the context of the protected bike lanes in the city's bicycle system. Also included are maps, pictures and cross sections of each facility. At the end of Section 3, two reference tables provide a summary of the facility routes pre- (Table 3-2) and post- (Table 3-3) construction.
- Chapter 4 (page 34) describes the methodology employed, including the selection of the study locations, development of survey and video review tools, and video and survey data collection.
- Chapter 5 (page 51) summarizes the information about the study's survey respondents, including detailed demographic information along with breakdowns of respondents' travel behaviors.
- Chapters 6-11 provide the findings from the research, with each chapter focusing on one of the research questions, in the order listed above. Findings can be found in the following chapters:
    - Findings: Ridership Changes (page 62)
    - Findings: Design Evaluation (page 73)
    - Findings: Safety (page 102)
    - Findings: Resident Perceptions (page 102)
    - Findings: Appeal to Different Groups (page 127)
    - Findings: Economic Effects (page 135)
- Chapter 12 (page 137) summarizes key findings and lessons for future evaluation of bicycle facilities.

The report's appendices (available online) provide the detail about the survey instruments, and responses for each survey question by city. The appendix also includes additional analysis of the origin-destinations of intercepted cyclists that is not described in the report.

1.3 Terminology Summary and List of Abbreviations

This report includes a number of terms and descriptions that are in need of clear definition. Table 1-1 defines the terms used in this report. Table 1-2 provides common abbreviations for facilities in figure captions and tables.

Table 1-1. Definitions of Common Terminology in the Report

Term	Definition
Bicycle signals	Traffic signals intended to control bicycle movements. In the context of this study, the signals used the bicycle symbol in the R-Y-G lens to communicate this message. 
Bike box	 A space reserved for bicycles to stop ahead of the stop bar for motor vehicles at the intersection approach.

Term	Definition
(Standard) Bike Lane	 A standard bike lane usually consists of a four to six foot lane, separated from traffic lanes by a six- to eight-inch white line. They may be either curb-tight (left) or adjacent to a parking strip (right). 
Buffer	Extra space separating the bike lane and the standard moving traffic lanes. A buffer may have flexposts or other vertical protection.
Chevrons	A double v-shaped pavement marking often used for lane guidance. Part of the shared use marking (MUTCD Fig 9C-9). 
Construction/Installation	In this report, the "construction" or "installation" of a protected bike lane refers to the time when the street was altered from its pre-existing layout to the updated "protected" layout.
Flex parking	A lane or portion of a lane designated for parking at certain times and as a moving traffic lane at other times (usually used for peak hour capacity).
Flexpost	 A plastic post attached to the street surface. Flexposts are flexible and are generally designed to withstand being driven over while imposing minimal damage to vehicles. Also known as a safe hit post, soft hit post, delineator post, etc.
Green skip coloring	A green pavement marking that consists of staggered wide green stripes that mark a right-turn lane as shared space (used in San Francisco). 
Mixing zone	A shared turn lane and bike lane at an intersection where bicyclists and turning motor vehicles are both allowed.
On-street facility	A facility that is within the curb-to-curb area of the streetscape (e.g., as opposed to the sidewalk, etc.).
Parking buffer	A buffer that consists of parking strip spaces (and an additional 2-3 space for opening doors and passenger entrance/exit).
Protected bike lane	Protected bike lanes are bicycle exclusive lanes with protected separation between the bike lane and standard traffic lanes where moving motor vehicles may be operating. Protection may be in the form of buffered space with flexposts, a curb, a parking strip, planters, or other vertical separation. They may be either one- or two-way. They are also known as cycle tracks.
Shared-use path	A path designated for non-motorized traffic, including bicycles, pedestrians and other non-motorized vehicles.
Sharrow	 Also called a Shared Lane Marking (MUTCD Fig 9C-9) consisting of a double chevron and bicycle symbol indicating that a lane is marked for bicycle shared use. A derivation of the sharrow with a green background (right) used in San Francisco. 
Through bike lane	A marked bike lane that suggests where bicyclists should ride that is used in the turning zone designs. These bike lanes makings are dashed rather than solid meaning motor vehicles may use these lanes when no bicycles are present. Abbreviated in places as TBL.

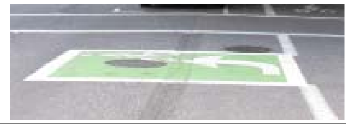
Term	Definition
Turning zone	Intersection designs where the protected lane ends and transitions to a through bike lane adjacent to a motor vehicle turning lane. Similar to a combined turn lane.
Two-stage turn queue box	A marked space for bicyclists to wait before making the second stage of a two-stage turn. 

Table 1-2. Abbreviations or Alternatives Used in the Report

Primary Use in Report	May also be referred to as:
Austin, TX	Austin
Avenue	Ave
Barton Springs Road	Barton Springs; BS Road
Bluebonnet Lane	Bluebonnet; BB Lane
Boulevard	Blvd
Chicago, IL	Chicago; Chi
Construction	Installation
Fell Street	Fell
Green Lanes Project	GLP
L Street	L St
Motor vehicle	MV
N Milwaukee Avenue	Milwaukee Avenue; Milwaukee; Milw Ave
n	Number in sample
N/S Dearborn Street	Dearborn Street; Dearborn
National Association of City Transportation Officials	NACTO
NE Multnomah Street	Multnomah Street; Mult St
North/South/East/West	N/S/E/W, as well of compound directions (e.g. NE, SW)
Northbound/ Southbound/ Eastbound/ Westbound	NB/SB/EB/WB
Oak Street	Oak
Portland, OR	Portland; PDX
Protected Bike Lane	Protected lane; Cycle track; Separated bike lane; Facility
Rio Grande Street	Rio Grande; RG Street
San Francisco, CA	San Francisco; SF
Through Bike Lane	TBL
Street	St
Washington, D.C.	DC

2 FINDINGS OF PRIOR RESEARCH

Until recently there was limited research on protected bike lanes in the North American context. Researchers have been working to make up for this shortfall, and recent findings suggest that protected bike lanes can both improve bicyclists' level of comfort and safety, and potentially increase the number of people cycling.

Several studies have found that, when asked, people prefer separated facilities over a striped bike lane or sharing lanes with motor vehicles *(Shafizadeh and Niemeyer, 1997; Rose and Marfurt, 2007; Emond et al, 2009; Winters and Teschke, 2010)*. Winters and Teschke (*2010*) found in a random sample of people in Vancouver, Canada, that the top four preferred facility types were separated facilities, with cycle tracks following off-street paths but above all other on-street facilities. Revealed preference data also supports the notion that people prefer protected bike lanes; one recent study of six cycle tracks in Montreal, Canada, found 2.5 times as many bicyclists on streets with cycle tracks compared to reference streets (*Lusk et al., 2011*).

Some research reveals that facility preference may vary among different groups of bicyclists. Some studies have found that more experienced cyclists prefer striped lanes over separate multiuse paths *(Tilahun et al, 2007; Stinson and Bhat, 2003; Hunt and Abraham, 2007; Akar and Clifton, 2009*). These differences may due to factors other than comfort, as paths often require greater deviations from the shortest route or involve mixing with pedestrians. On the other hand, research has found that women and less-experienced cyclists prefer more separated facilities and avoiding high traffic volumes and speeds *(Winters and Teschke, 2010; Jackson and Ruehr, 1998; Garrard et al, 2008; Krizek et al, 2005).*

Recent research shows that perceived safety plays an important role in a person's decision about whether or not to ride a bicycle, and also plays an important role in community support for new bicycling facilities (*Sanders, 2013*). Studies in Portland and Washington, D.C. found that bicyclists report feeling safer on separated bike facilities (*Monsere et al., 2012; Goodno et al., 2013*).

In terms of observed safety, preliminary evidence suggests that protected bike lanes can reduce the risk of crashes or injuries for cyclists. Lusk et al. *(2011)* analyzed 10 years of emergency medical response records and compared them to bicycle counts to calculate a relative risk of injury on six cycle tracks and eight control streets in Montreal. Their findings indicate that the cycle tracks resulted in a 28% lower risk of injury. A follow-up study of 19 cycle tracks in the United States found that that crash rate for bicyclists on cycle tracks was lower than on general roadways (*Lusk et al., 2013*). Another study examined records of adults treated at hospital emergency departments for injuries while bicycling, and compared injury sites to control sites in Vancouver and Toronto, Canada using a case-crossover design (*Harris et al., 2013*). They found that separated facilities for bicyclists were associated with lower injury risk. A recent literature review on the safety of urban cycle tracks found that cycle tracks can reduce collisions and injuries when effective intersection treatments are employed, though only one of the reviewed papers covered was from North America (*Thomas and DeMartis, 2013*).

An acknowledged challenge with protected bike lanes is that they generally come back into conflict with turning and cross traffic at intersections. A study in a country with considerable experience with protected bike lanes (Denmark) analyzed bicycle crash risk using traffic volumes and one to five years of before-and-after crash counts on 20 km of cycle tracks and 110 km of comparison routes *(Jensen 2008)*. The study found that crashes and injuries along cycle tracks increased at intersections but decreased along links, with an overall increase of 10%, indicating the need for careful design at intersections. Jensen also noted that cycle traffic increased 20%, and that the costs of injuries needed to be weighed against the benefits of increased cycling. There is a small body of research suggesting that riding on sidewalks is more dangerous than riding on the street (*Wachtel and Lewiston, 1994)*, which some have interpreted as supporting the idea that its safer to integrate bicycles into traffic than to separate them out. However, Lusk et al. *(2011)* argue that Wachtel and Lewiston's risk figure comes from analyzing intersection interactions only, and that when accounting for non-intersection crashes the risk is equivalent between sidewalk riding and roadway riding. Moreover, sidewalks and protected bike lanes have entirely different design attributes. Protected bike lanes are designed specifically for bicycles and contain bike safety measures at intersections.

Many benefits of increased cycling are widely accepted, including contributions to improved health outcomes, the potential to reduce motor vehicle demand and decreased air pollution. However, as more American cities explore investments in protected cycle facilities, which usually represent a greater financial investment than traditional bike lanes, there is increased interest in understanding the economic impacts of such investments. Several studies have examined the benefits of recreational bicycling and bicycle tourism with a focus on expenditures directly related to bicycle equipment or to travel expenses such as food and lodging, with each finding valuable contributions to local economies (*Wen and Rissel, 2008; Saelensminde, 2004; Meletiou et al, 2005; Busbee, 2005; Grabow et al, 2010; CRESP, 2000).* Bicycle manufacturing, retailing and service sectors have also been found to provide valuable economic contributions in Wisconsin (*Bicycle Federation of Wisconsin, 2005*) and Portland, OR (*Alta Planning + Design, 2008*). A New York City report found that retail businesses in the vicinity of protected bike lanes saw a 49% increase in sales, compared to a 3% increase city wide (*NYC Department of Transportation, 2012)*. Other studies have shown that customers arriving by bicycle to shops and restaurants provide increased number of overall customers, sales and, by certain measures, business equal to or better than customers arriving by motor vehicle (*Clifton et al, 2013; Drennen, 2003; Meisel, 2010*).

3 DESCRIPTION OF STUDY FACILITIES

The five cities and eight protected bike lanes included in this evaluation cover a range of protected bike lane designs (Table 3-1) and contexts (Figure 3-3). This chapter provides a detailed overview of each of the facilities. A pair of detailed tables at the end of this chapter provides an easy reference of the characteristics of the route before the construction of the protected bike lanes (Table 3-2) and the facility as constructed (Table 3-3). Specific intersection designs (which vary substantially and are a focus of the design evaluation are described in detail in the Chapter 7 (Design Evaluation).

Table 3-1. Study Cities and Facilities

City	Facility Studied	Type of Protected Facility
Washington, D.C.	L Street	One-way protected lane on a one-way street
Austin, TX	Bluebonnet Lane	Two-way protected lane on a two-way street
	Barton Springs Road	One-way protected lane on the south side of the road (other direction is shared use path)
	Rio Grande Street	Two-way protected lane on one-way street
San Francisco, CA	Oak /Fell Streets	Couplet of one-way protected lanes on one-way streets
Chicago, IL	N/S Dearborn Street	Two-way protected lane on one-way street
	N Milwaukee Avenue	One-way protected lanes on either side of a two-way street
Portland, OR	NE Multnomah Street	One-way protected lanes on either side of a two-way street

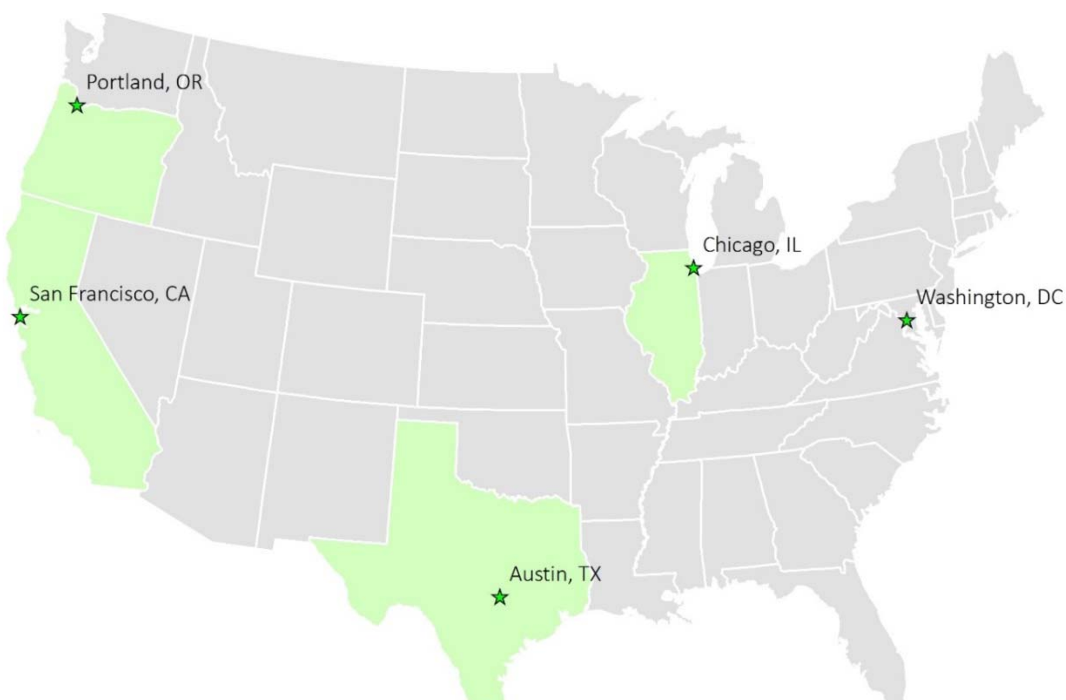
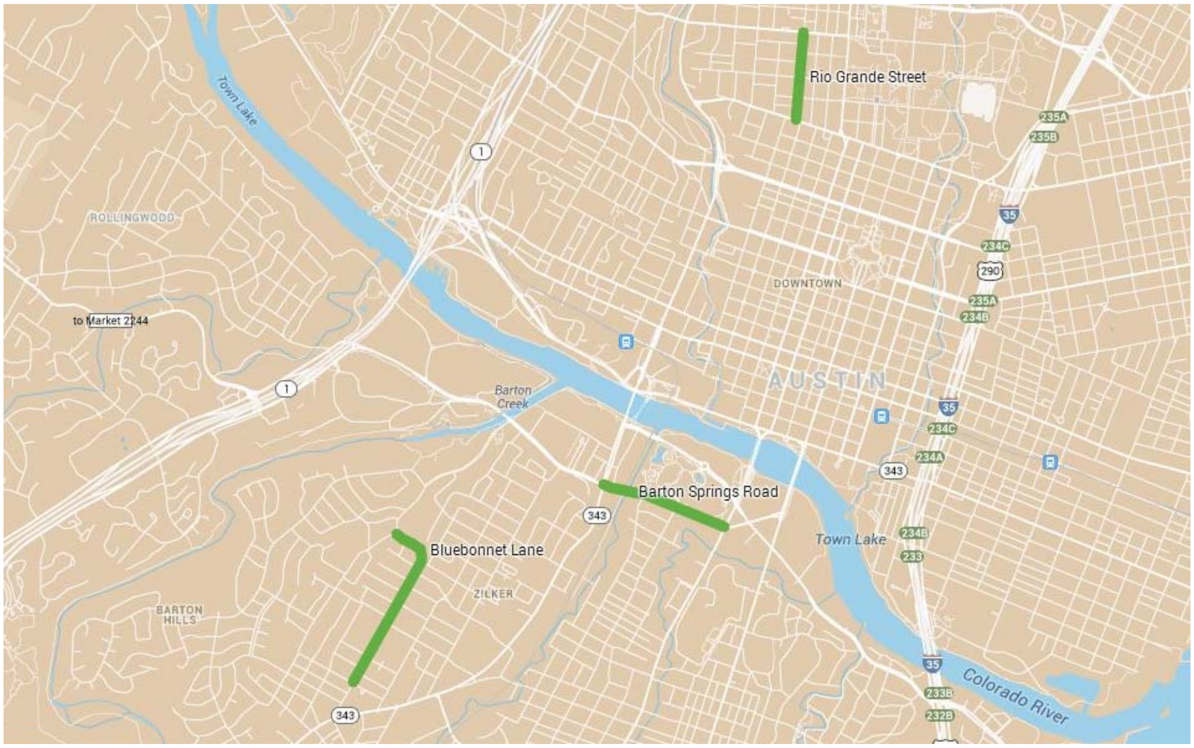


Figure 3-3. Study Cities

3.1 Austin, TX

Austin constructed its first protected cycling facility, the Lance Armstrong Bikeway, in 2009. By early 2013, Austin had installed four more, with plans for an additional five facilities in 2013. The city installed protected bike lanes on Barton Springs Road, Bluebonnet Lane, and Rio Grande Street as its showcase projects for the Green Lane Project. Their locations are shown in the overview map in Figure 3-4. All three are included in this research.



Source: Google Maps

Figure 3-4. Overview Map of Austin Study Facilities

3.1.1 Barton Springs Road

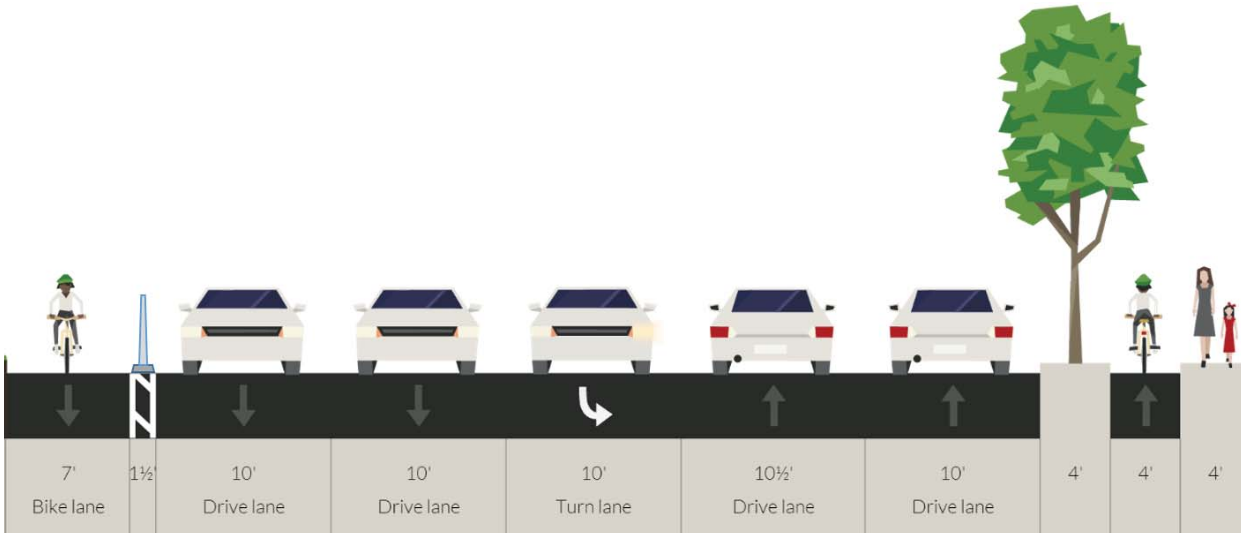
Barton Springs Road is a five-lane road with commercial uses on the south side and a park and events center on the north side. The Barton Springs Road protected bike lane was constructed in late spring 2013 and is a one-way east-bound protected bike lane on the south side of the road (Figure 3-5 and Figure 3-6). There is a west-bound, off-street path on the north side of the street (Figure 3-7).

The protected bike lane runs about one-half mile from S 1st Street to Lamar Boulevard (Figure 3-8). Space for the south-side protected lane was created by narrowing the motor vehicle lanes (Figure 3-6). Flexible plastic posts (flexposts) provide a continuous buffer on the south-side protected lane. There are four signalized intersections along the route. There are also two unsignalized intersections and several driveways along the route, where the bike lane is marked with chevrons.

(Photos: City of Austin)

Figure 3-5. Barton Springs Road Protected Bike Lane, Austin, TX

Figure 3-6. Barton Springs Road, Austin, TX, Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-7. Sample Cross section of Barton Springs Protected Bike Lanes

Source: Google Maps

Figure 3-8. Vicinity Map of Barton Springs Facility Extents

3.1.2 Bluebonnet Lane

The Bluebonnet Lane protected bike lane in Austin was constructed in August 2012 and consists of a two-way lane on a two-way street (Figure 3-9 and Figure 3-10). It runs approximately 0.7 miles from Lamar Boulevard to Robert E Lee Road (Figure 3-12). Along with the shared-use path and bike lanes on Robert E. Lee Road, it provides an alternative bicycle route to the busy Lamar Boulevard. Bluebonnet Lane is a primarily residential street and includes access to Zilker Elementary School. On-street parking was removed from the west side of the street in order to provide room for the protected lanes (Figure 3-9). Flexible plastic posts provide a continuous buffer for the duration of the facility.

There are no signalized intersections along the facility. The southern terminus of the protected lanes is an all-way stop intersection (Rabb Glen Street), where northbound bicyclists are provided their own turn lane to access the protected lanes. The northern end connects to a recently constructed shared-use path on Robert E. Lee Road. In between the ends, there are 15 unsignalized intersections and several residential driveways. Chevrons delineate cyclists' paths through the unsignalized intersections. Green paint is also used at the Zilker Elementary School driveway.

Figure 3-9. Bluebonnet Lane Protected Bike Lanes, Austin, TX

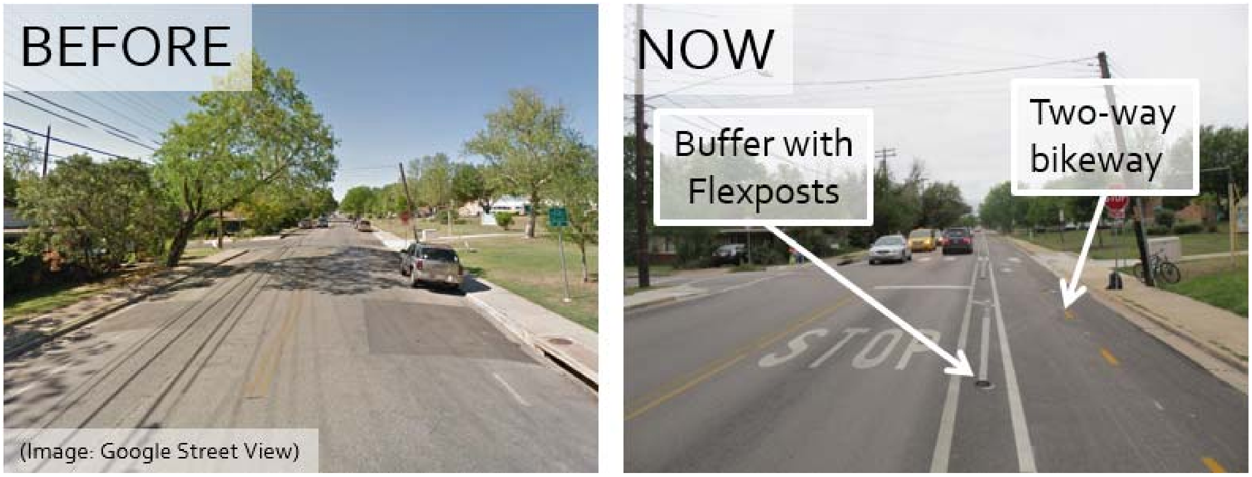
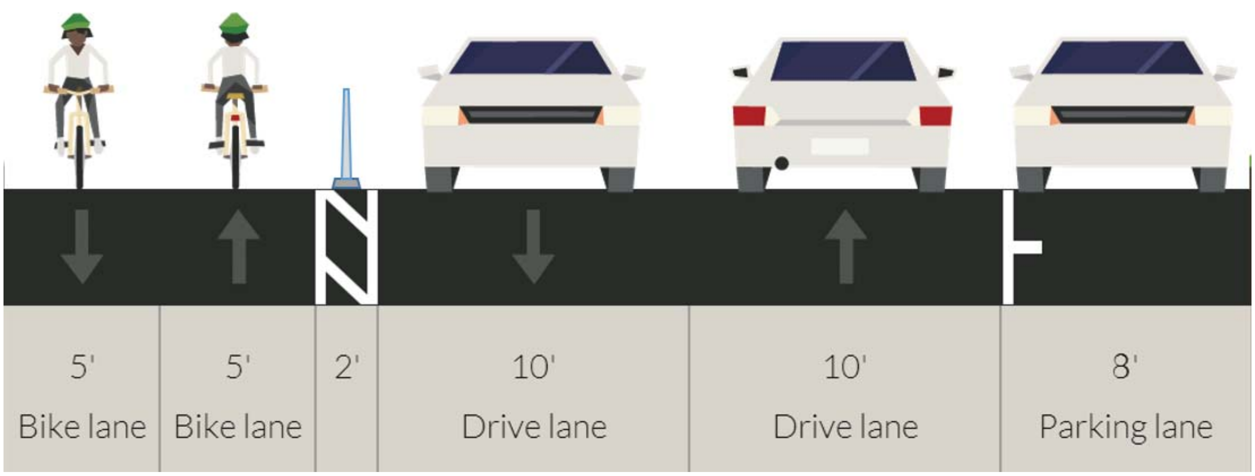
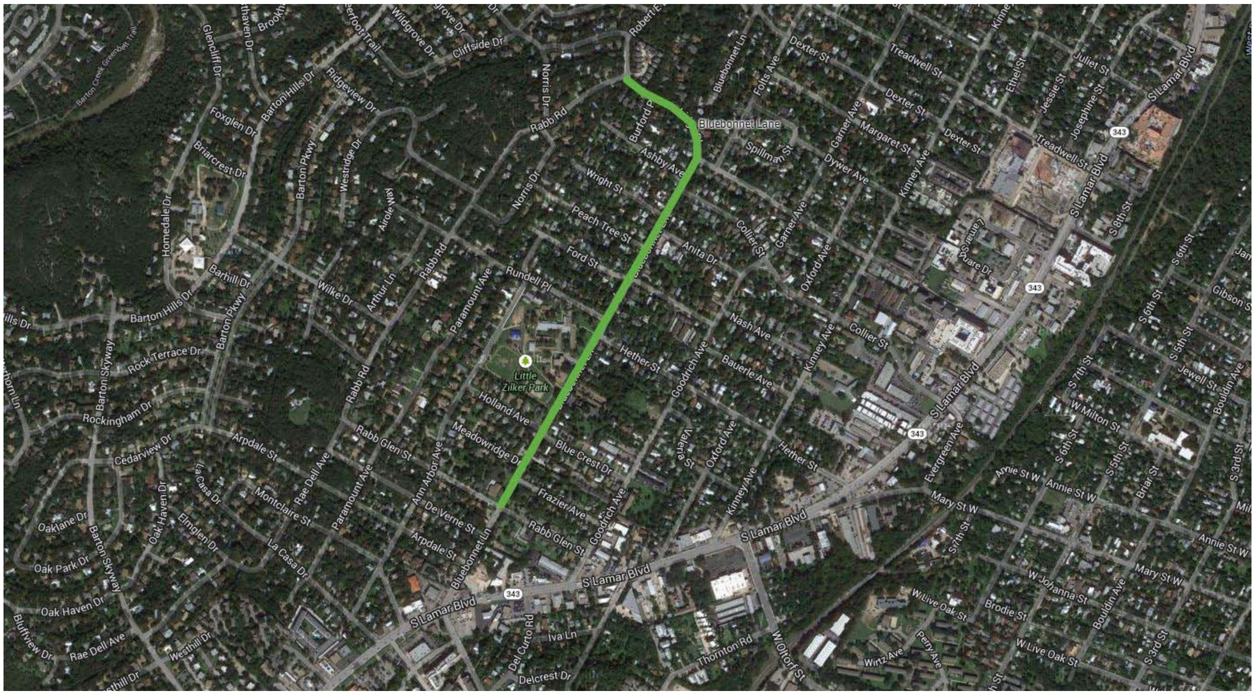


Figure 3-10. Bluebonnet Lane, Austin, TX, Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-9. Sample Cross section of Bluebonnet Protected Bike Lanes



Source: Google Maps

Figure 3-12. Vicinity Map of Bluebonnet Lane Facility Extents

3.1.3 Rio Grande Street

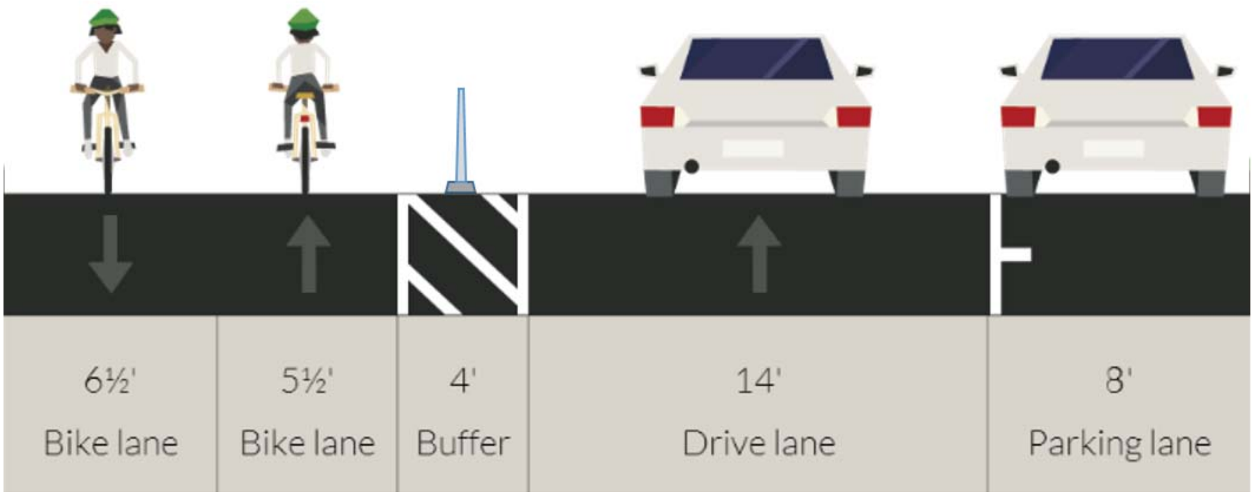
The Rio Grande Street protected bike lane was constructed in April 2012 and consists of a two-way protected facility on the left side of a one-way street (Figure 3-11). It runs nearly one-half mile from Martin Luther King Jr. Boulevard to 24th Street (Figure 3-14). The facility is three blocks west of the University of Texas-Austin campus on a street that is lined with a mix of residential, retail and office uses. It is planned for further expansion, but the expansion was not completed in time for this study.

A motor vehicle lane or limited on-street parking were removed from the street in places to provide room for the protected lanes (Figure 3-12). Flexible plastic posts at 20-foot intervals provide the buffer near intersections, with painted lines being the continuous buffer between these conflict areas (Figure 3-13); the city has plans to upgrade the buffer to include concrete curbed barriers. The only signalized intersections along the route are at each end. The two legs of Rio Grande Street are offset at the Martin Luther King Jr. Boulevard intersection. Northbound bicycle traffic is provided a lane marked through the intersection to the cycle track, while southbound bicycle traffic is controlled by a bicycle signal (there is no southbound motor vehicle traffic due to Rio Grande Street being one-way north of MLK Jr. Blvd.). At the time of the evaluation, the protected lanes ended at the signalized 24th Street intersection, where northbound cyclists are directed to share the road with motor vehicle traffic via temporary sharrows. There are five unsignalized intersections along the route, along with a handful of driveways and alleys. The intersection crossings lanes are marked with sharrows at these locations. The sharrows are augmented with green paint in select locations (both types of treatments can be seen in Figure 3-11).

Austin:
Rio Grande Street

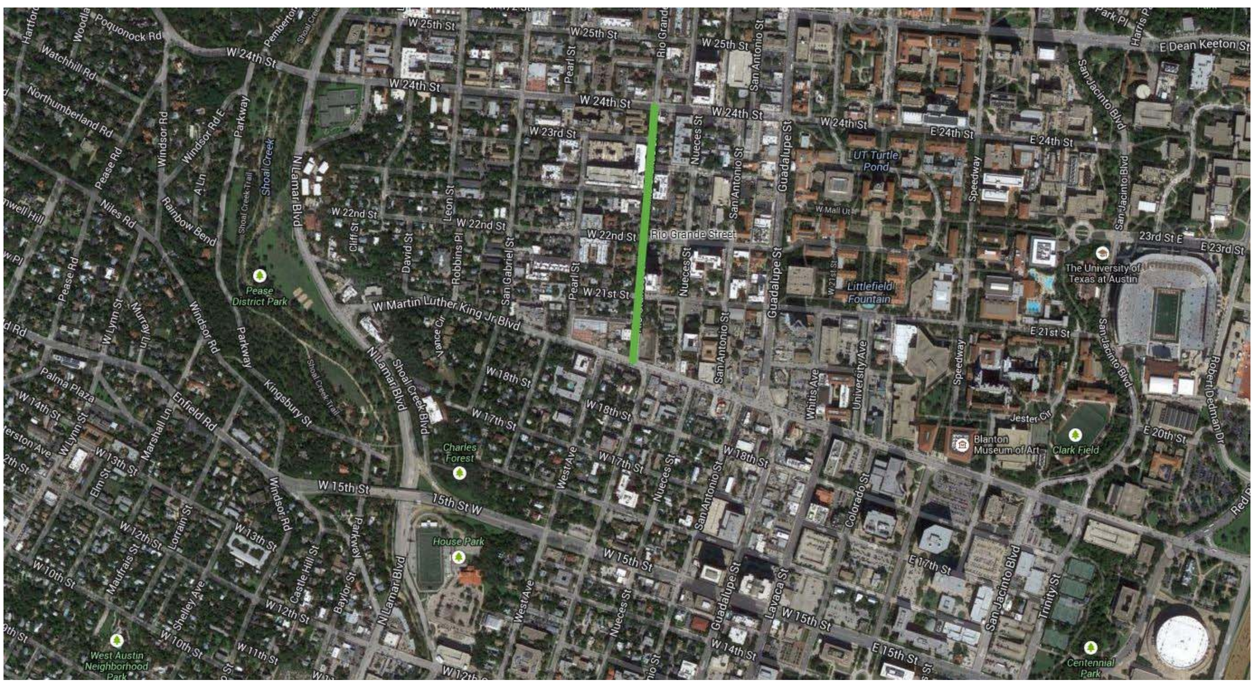
Figure 3-11. Rio Grande Street Protected Bike Lanes, Austin, TX

Figure 3-12. Rio Grande Street, Austin, TX, Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-13. Sample Cross section of Rio Grande Protected Bike Lane

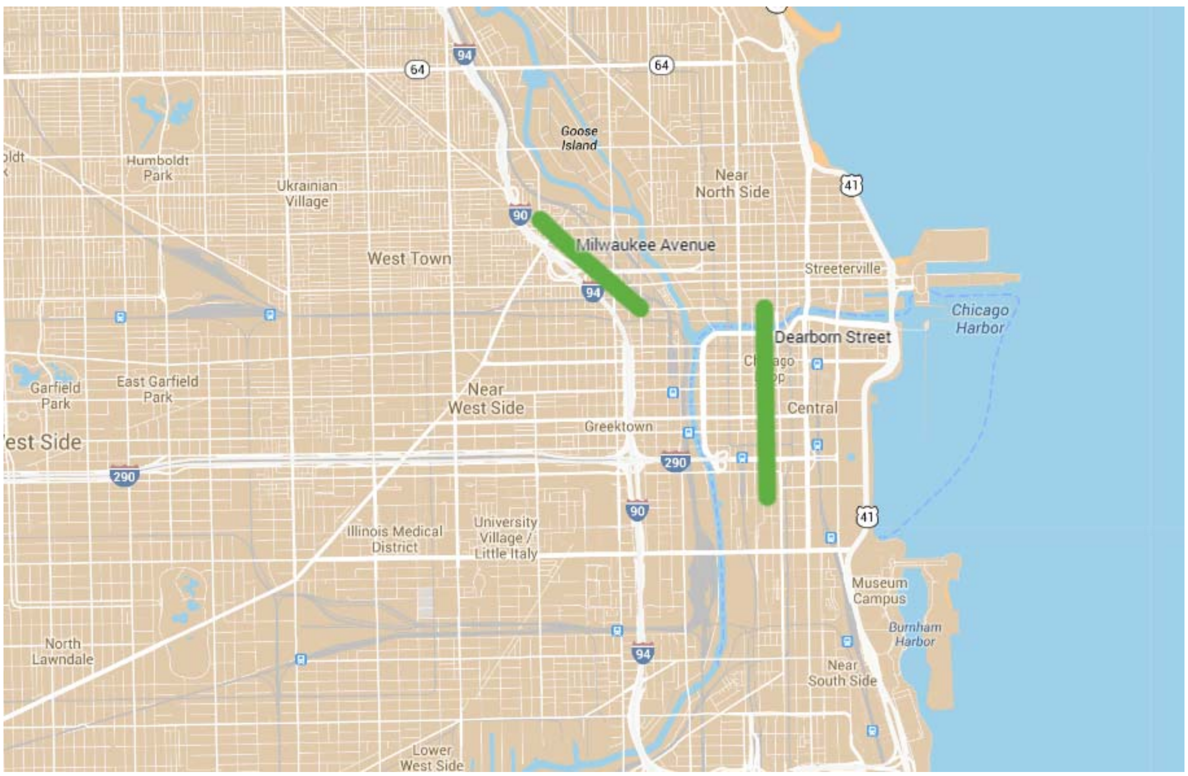


Source: Google Maps

Figure 3-14. Vicinity Map of Rio Grande Facility Extents

3.2 Chicago, IL

Chicago has launched a major effort to build a network of protected bike lanes, with the goal of completing 100 miles of protected bike lanes by 2015, starting with the half-mile Kinzie Street protected bike lane in July 2011. Between 2011 and 2013, Chicago installed 49 miles of protected bike lanes including Dearborn Street (2012/2013), Elston Avenue (2012), and Milwaukee Avenue (2013). Dearborn and Milwaukee are included in this research and their location is shown in the overview map in Figure 3-15.



Source: Google Maps

Figure 3-15. Overview Map of Chicago Study Facilities

3.2.1 Dearborn Street

The Dearborn Street protected bike lanes consist of a two-way cycle track on a one-way northbound street that runs through Chicago's downtown 'Loop,' from West Kinzie Street to West Polk Street (Figure 3-16). To install the protected bikeway, this section of Dearborn Street decreased from three motor vehicle lanes to two lanes (Figure 3-17). The bike lanes are separated by parking, flexposts, and a three-foot buffer zone; with bicycle signals at each intersection (eastbound cross streets only have bicycle signals for southbound bike traffic). The protected lanes are on the west (left) side of the roadway and do not interfere with bus transit making stops on the east side of the road. Northbound motor vehicles have a left-turn bay and signalized left turn with protected phasing across the bike lanes at westbound or two-way cross streets. Adjacent to the left turn lanes where on-street parking is restricted, bicyclists are protected from motor vehicles by a one-foot buffer and bollards spaced every ten feet (Figure 3-16 top). The facility has a 4-5' curbside southbound lane and a 4' northbound lane, and bicyclist detection at the Polk intersection (Figure

3-18). Bicyclists turning eastbound across Dearborn Street are provided two-stage turn queue boxes at five locations. Along the 12-block, 1.2-mile facility, there are 11 cross streets in addition to Polk and Kinzie, and approximately 12 additional motor vehicle crossing locations (e.g., parking entrances, alleys, etc.) (Figure 3-19). The route was constructed in December 2012 and finalized in May 2013.

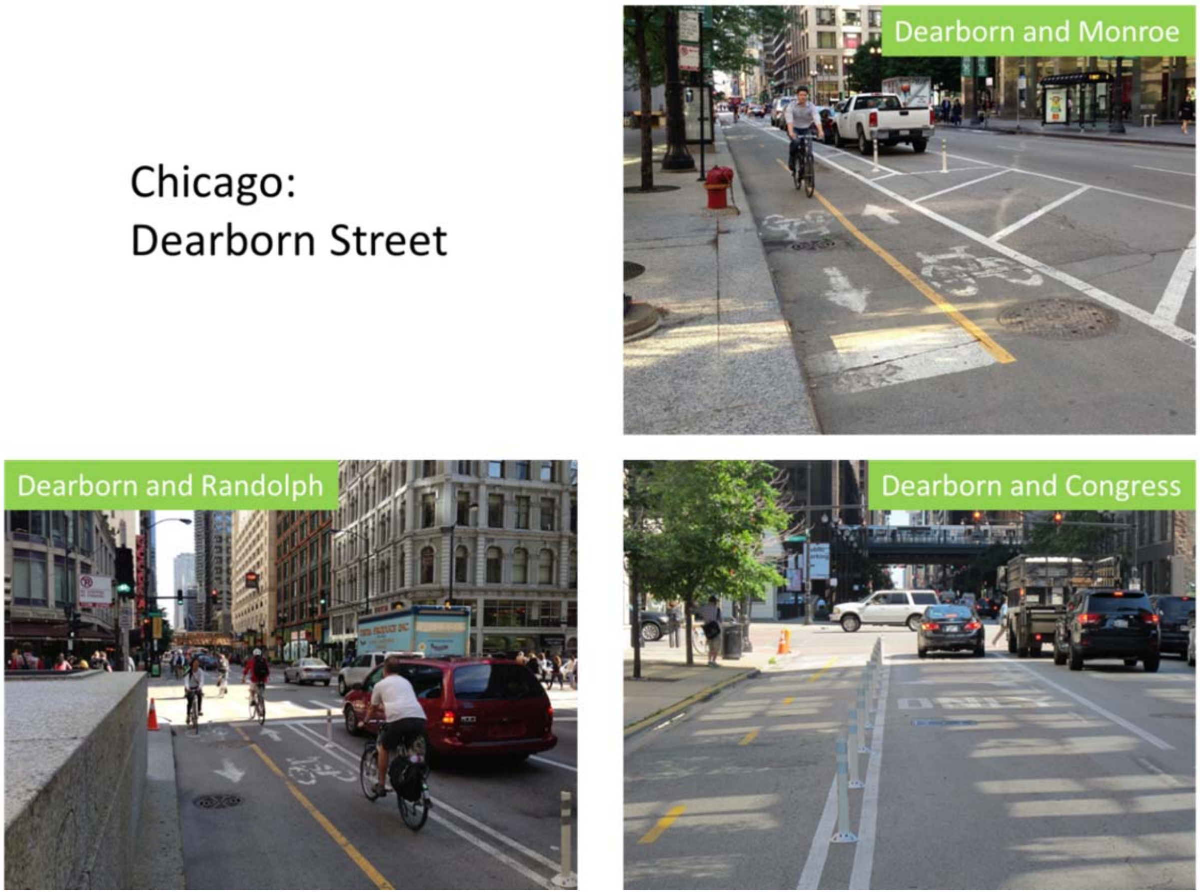
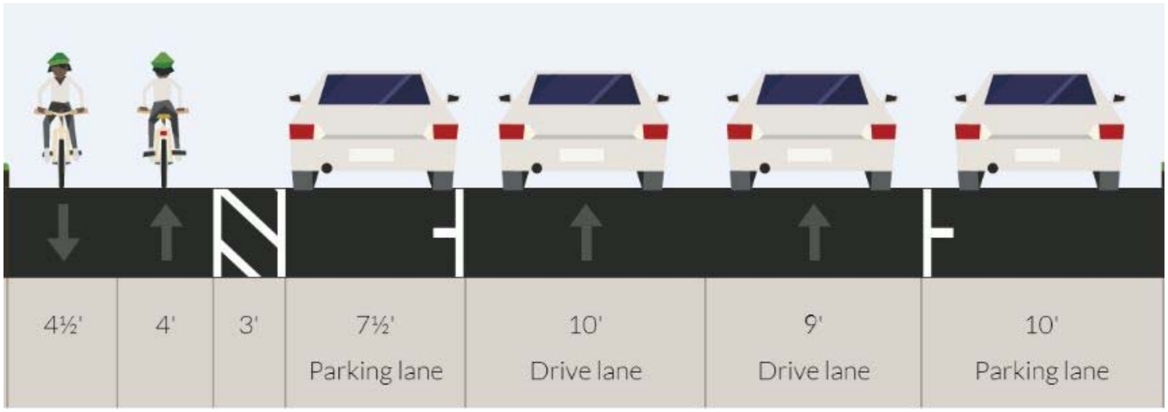


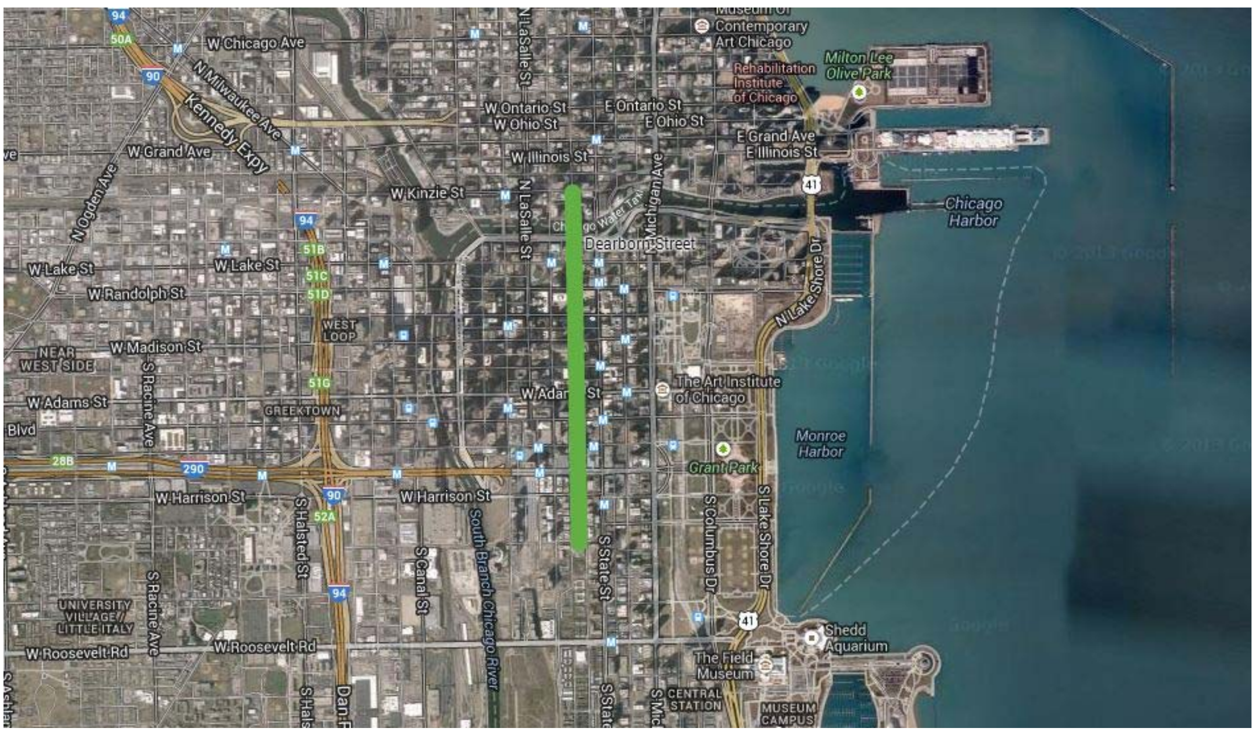
Figure 3-16. Dearborn Street Protected Bike Lanes, Chicago, IL

Figure 3-17. Dearborn Street, Chicago, IL, Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-18. Sample Cross section of Dearborn Street Protected Bike Lanes



Source: Google Maps

Figure 3-19. Vicinity Map of Dearborn Street Facility Extents

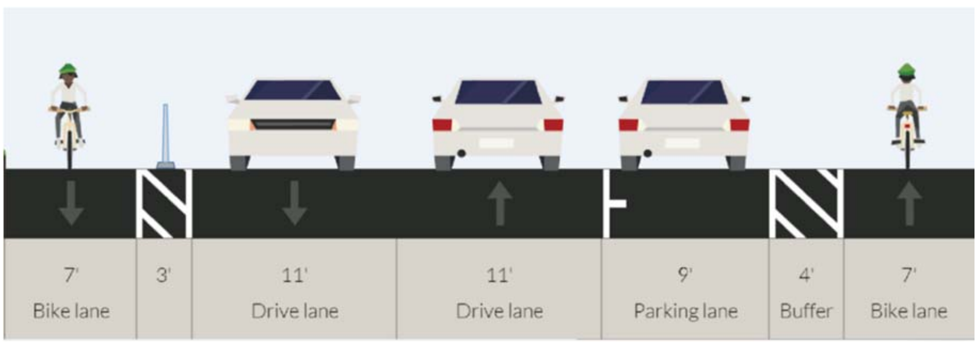
3.2.2 Milwaukee Avenue

The North Milwaukee Avenue protected bike lanes in Chicago were constructed in summer 2013 connecting protected bike lanes on West Kinzie Street and North Elston Avenue (Figure 3-20 and Figure 3-21). The facility is composed of a pair of protected bike lanes on either side of the street buffered by a mix of a two- to three-foot painted buffers with flexposts and parking protected areas (Figure 3-22). The route is 0.8 miles along a major radial route connecting central Chicago with neighborhoods to the northwest (Figure 3-23). Milwaukee is a diagonal street and contains a number of complex intersections of more than four legs and non-standard angles. The route incorporates several different treatments for bicycles and right-turning traffic (including turning zones and designating yield/crossing areas), as well as mixing zones for bicycles and buses at transit stops. In addition to seven signalized intersections, there are seven unsignalized intersections and approximately 15 other alleys or driveways.

Because the roadway was too narrow for protected bike lanes in each direction while still maintaining on-street parking, significant parking removal was required on blocks with protected lanes. Throughout the corridor, 57 parking spots, 10 loading/standing zone spots, and 2 taxi stand spots were removed. Fourteen parking spots were added to a side street along the corridor to offset some of the loss. Even with these efforts, there are portions of the route that are separated by only a striped two- to three-foot buffer.

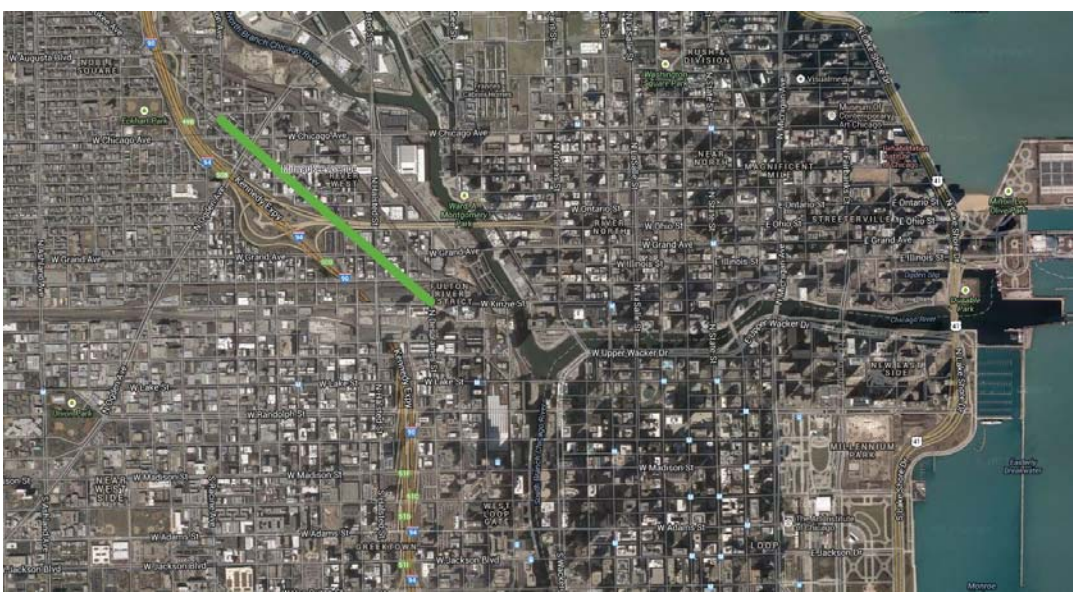
Figure 3-20. Milwaukee Ave. Protected Bike Lanes, Chicago, IL

Figure 3-21. Milwaukee Ave. Chicago, IL, Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-22. Sample Cross section of Milwaukee Protected Bike Lanes

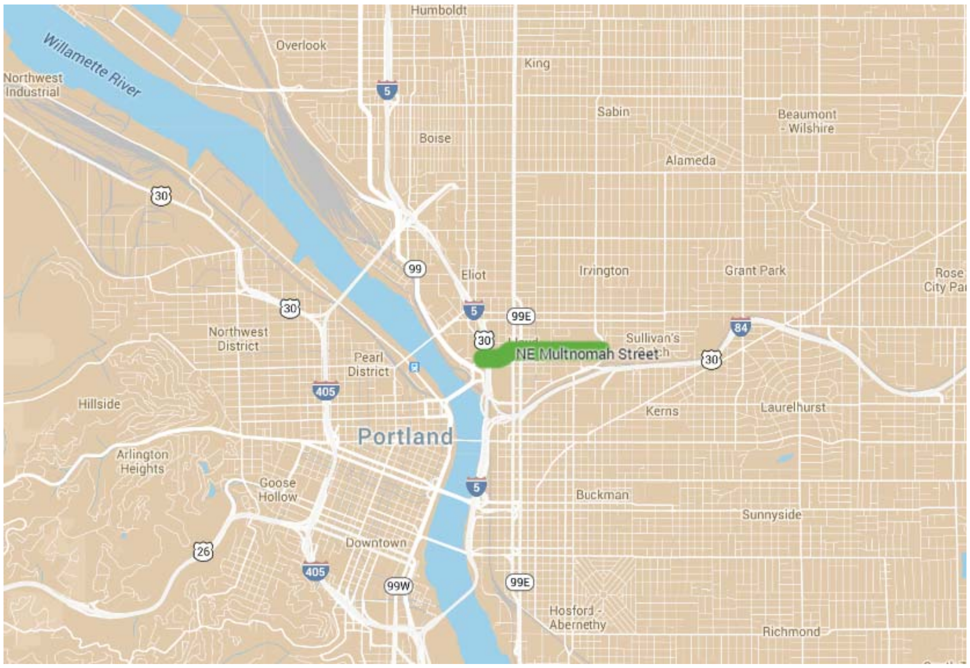


Source: Google Maps

Figure 3-23. Vicinity Map of Milwaukee Facility Extents

3.3 Portland, OR

Portland introduced its first protected on-street lane on Southwest Broadway in 2009, utilizing a design that includes a buffer of parked cars and a buffer zone for passengers exiting the parked vehicles. The city has since installed additional protected bike lanes on NE Cully Boulevard and for short segments of NE 33rd Avenue. In 2013 Portland added protected bike lanes to NE Multnomah Street. The location of the facility evaluated in this research in shown in Figure 3-24.



Source: Google Maps

Figure 3-24. Overview Map of Portland Study Facilities

3.3.1 NE Multnomah Street

The NE Multnomah Street protected bike lanes run between NE Wheeler Avenue on the west and NE 16th Avenue on the east. The street was originally a five-lane street with two travel lanes in each direction, a two-way left-turn lane, standard bike lanes, and no on-street parking. The street was "dieted" down to one travel lane in each direction, a two-way left-turn lane, and protected bike lanes (Figure 3-26). There is now a one-way bike lane on each side of the roadway, protected from motor vehicle traffic by parking, painted buffers, flexible bollards, and/or planters, depending on the road segment (Figure 3-25).

There are 10 signalized intersections and three unsignalized intersections along the route. In addition, there are driveways to major parking lots/structures that serve the Lloyd Center Mall and movie theaters (Figure 3-28). There are several bus transit stops on the corridor (a typical design is shown at NE 11th in Figure 3-25). Because the new design includes on-street parking as a buffer, the project resulted in 20 additional parking spots. The bike-lane width varies from four to seven feet, and the buffers vary from two to 11 feet, depending on roadway segment and type of buffer (Figure 3-27). The painted buffer utilizes a pale yellow color ("beeswax") as additional demarcation. Construction was completed in early 2013.

Figure 3-25. NE Multnomah St. Protected Bike Lanes, Portland, OR

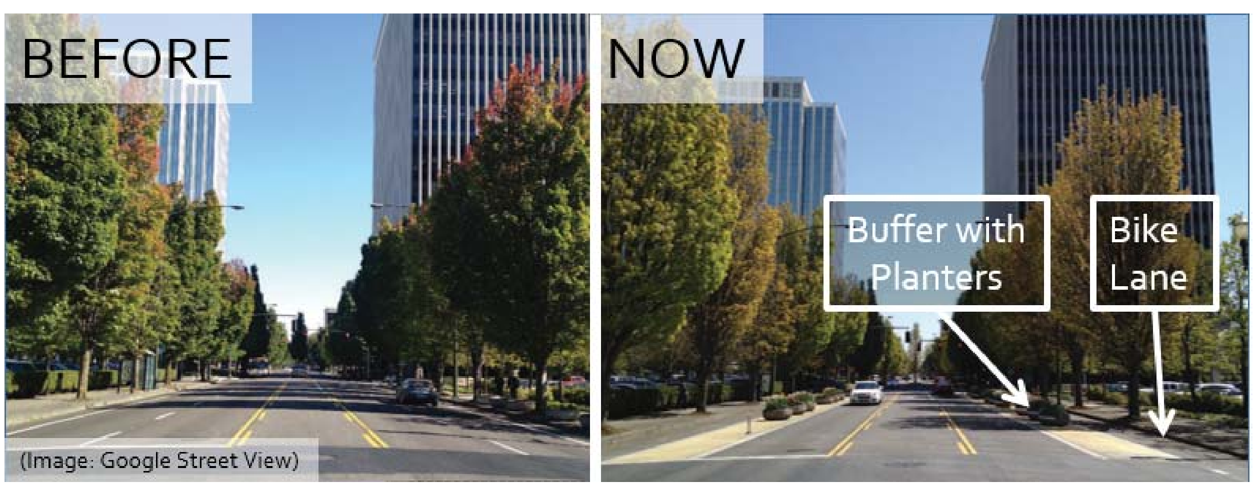
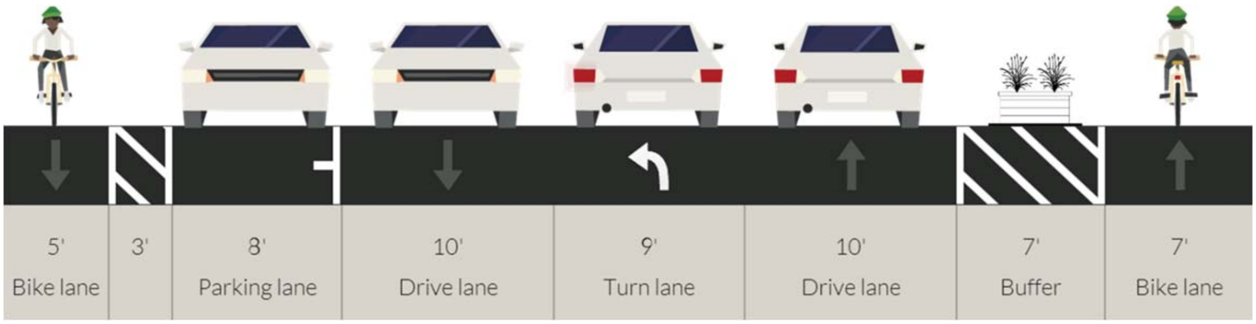


Figure 3-26. NE Multnomah St., Portland, OR, Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

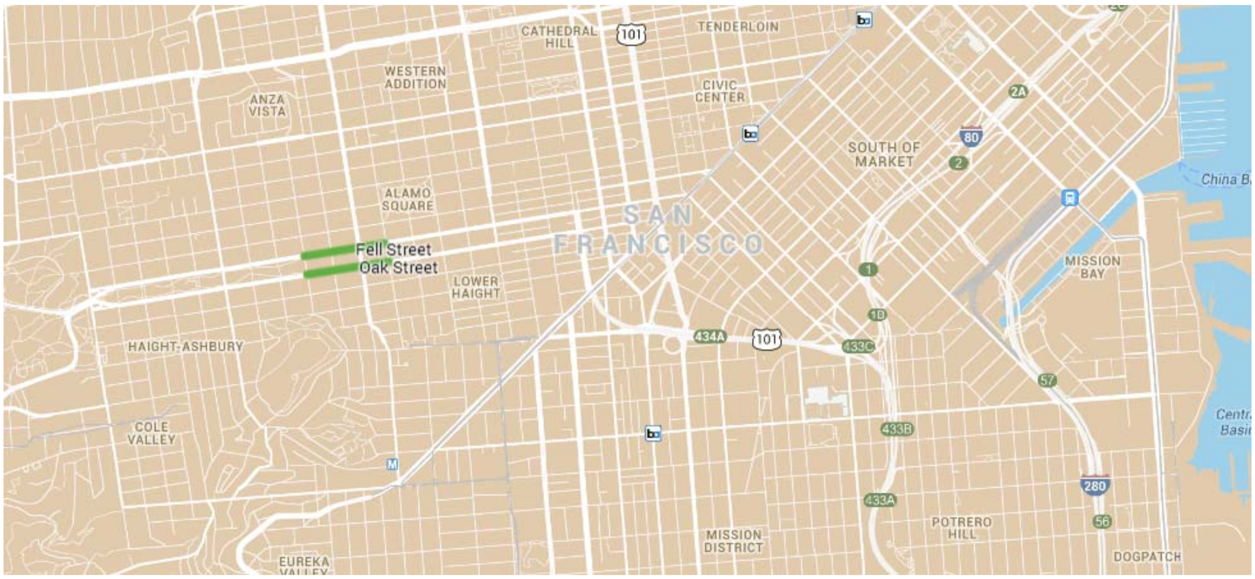
Figure 3-27. Sample Cross section of NE Multnomah Protected Bike Lanes

Source: Google Maps

Figure 3-28. Vicinity Map of NE Multnomah Facility Extents

3.4 San Francisco, CA

After a three-year injunction against new bicycle facilities was lifted in August 2010, San Francisco initiated the installation of numerous new bicycle facilities, including a number of protected bike lanes, including projects on Market Street, Laguna Honda Boulevard, Division Street, Cesar Chavez Street, and JFK Drive through Golden Gate Park. The Oak and Fell Street project included in this research created a couplet of protected lanes through a busy section of San Francisco that act as a critical link between downtown and the western neighborhoods. The location of the facilities is shown in the overview map in Figure 3-29.



Source: Google Maps

Figure 3-29. Overview Map of San Francisco Study Facilities

3.4.1 Oak and Fell Street

The Oak and Fell Street protected bike lanes run three blocks each between Scott and Baker Streets, and are an extension of the “Wiggle” bike route that is the flattest way to get between some of San Francisco’s notorious hills. They also provide most direct connection from Market Street to the Panhandle path, Golden Gate Park, and neighborhoods to the west of downtown (Figure 3-30). The protected lanes are on the left side of Fell Street and on the right side of Oak Street. To accommodate wider bikeways, corner sidewalk extensions, and storm water management features within the existing right-of-way, the San Francisco Municipal Transportation Agency (SFMTA) reallocated curbside space previously used for automobile parking along these blocks (Figure 3-31). The bicycle lanes are 7’3” wide, buffered from the 9’6” motor vehicle lanes by a 5’ painted buffer with flexposts (Figure 3-32 and Figure 3-33). Much of the bike route is adjacent to homes with driveways, where there are no flexposts but just a painted buffer. A raised curb will be added to the buffers along other portions of these blocks.

There are eight signalized intersections along the route. Special treatments at these intersections include marked mixing zones and signal timing improved for bicyclists and pedestrians. There are several building/parking structure entrances/exits along the route, along with many driveways (Figure 3-34).

Figure 3-30. Fell and Oak Street Protected Bike Lanes, San Francisco, CA

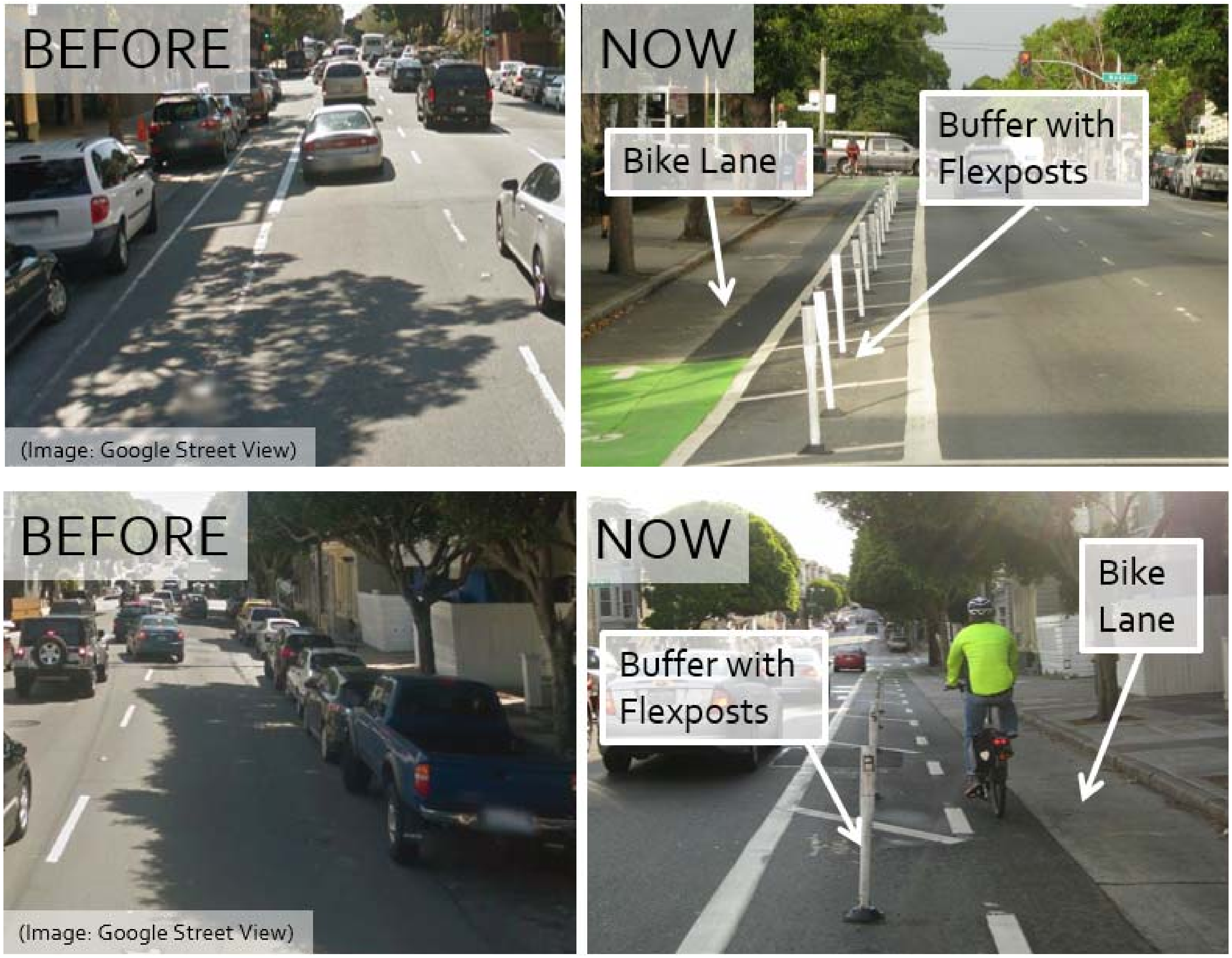
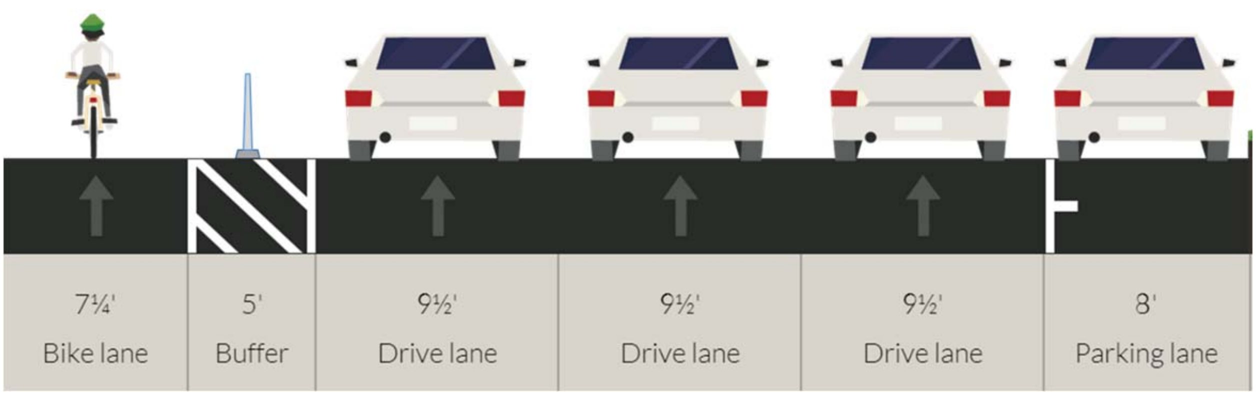
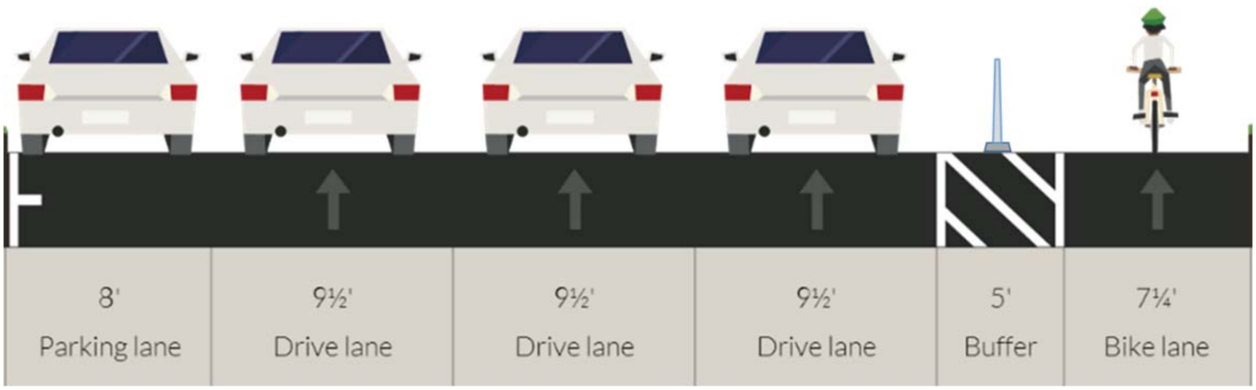


Figure 3-31. Fell Street (top) and Oak Street (bottom), San Francisco, CA, Before and After Installation of Protected Bike Lane



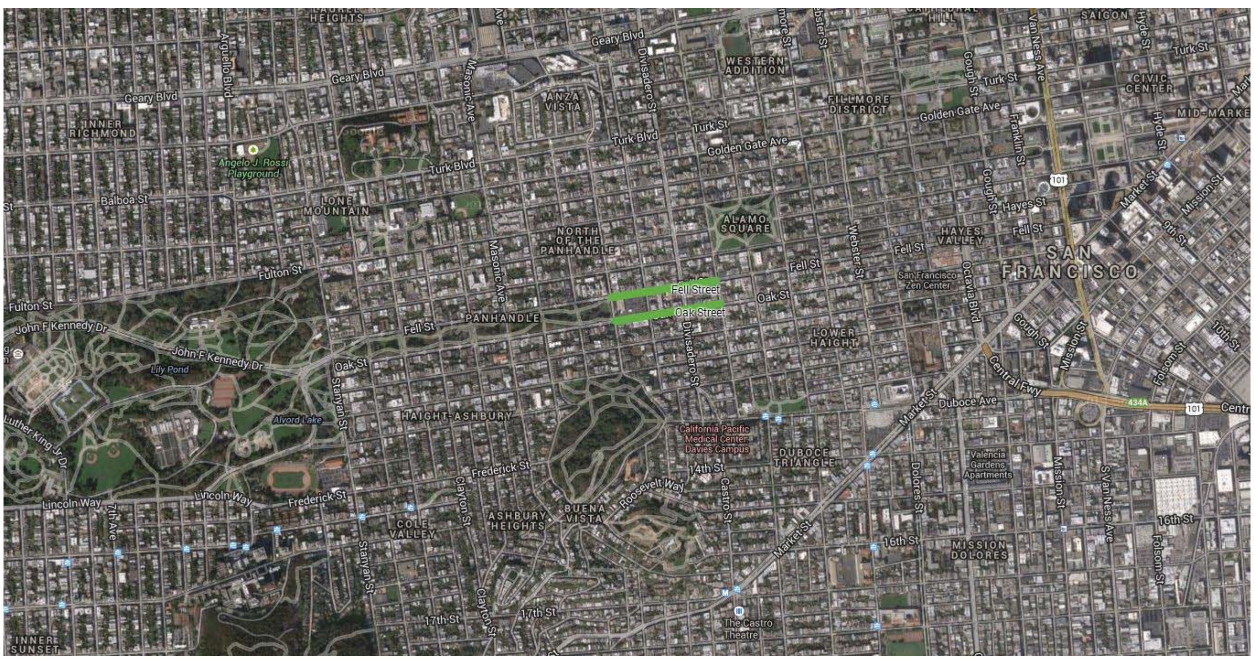
Graphics Source: Streetmix.com

Figure 3-32. Sample Cross section of Fell Street Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-33. Sample Cross section of Oak Street Protected Bike Lane

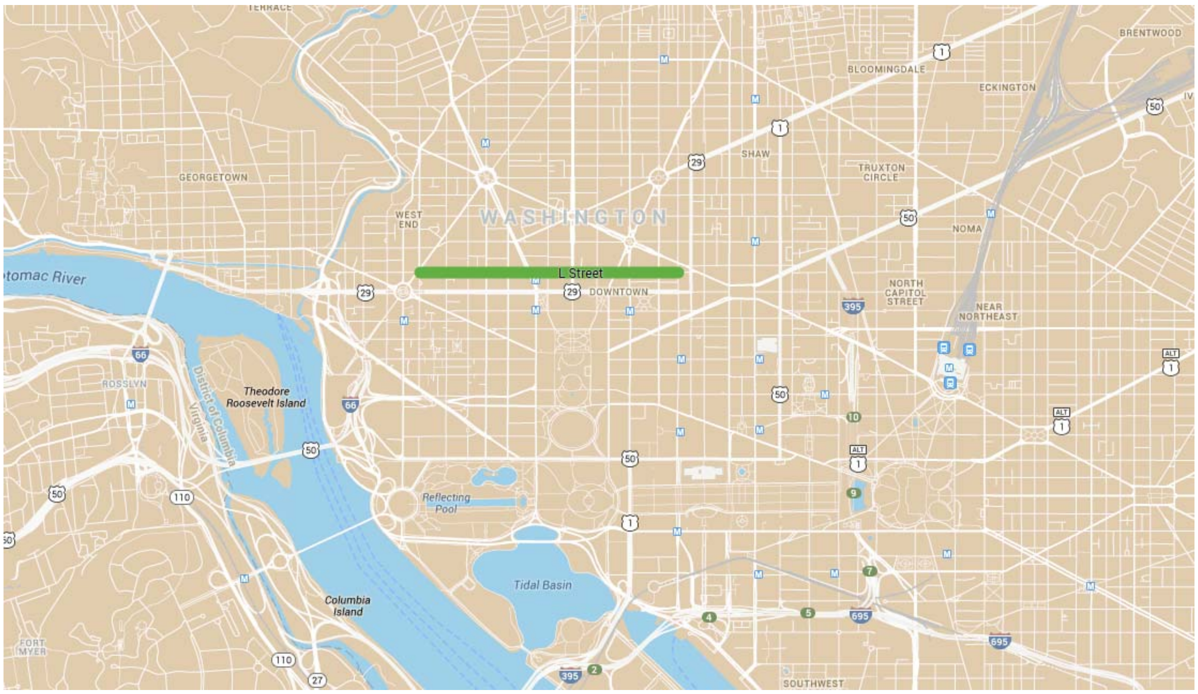


Source: Google Maps

Figure 3-34. Vicinity Map of Oak/Fell Facility Extents

3.5 Washington, D.C.

Washington, D.C., built a protected bike lane buffered with parking on 15th Street NW in 2009, and expanded it to a two-way (north/south) facility in 2010. Also in 2010, buffered center bike lanes were added to Pennsylvania Avenue NW between the Capitol and the White House and Capital Bikeshare opened for business, marking a major commitment to bicycle infrastructure. Protected lanes on L Street NW (eastbound) and M Street NW (planned, westbound) add a significant east/west route to the protected bikeway network in downtown DC. The L Street facility is included in this research and its location is shown in Figure 3-35.



Source: Google Maps

Figure 3-35 Overview Map of Washington, D.C., Facilities

The L Street protected bike lane runs from New Hampshire Avenue to 12th Street, and was constructed in October 2012. It is a one-way left-side protected bike lane on a one-way eastbound street (decreased from 4 MV lanes to 3 MV lanes in places) in downtown Washington D.C., separated by a 3’ striped buffer zone with plastic flexposts (Figure 3-37 and Figure 3-38). Bicycles move with standard traffic signals along the 1.12-mile route (Figure 3-39). The typical intersection design includes a 13’ wide turning zone for bicycles and left-turning traffic at northbound cross streets (including a 4’ through bike lane) and a street-wide bike box designed to move cyclists across the streets at southbound cross streets (both mixing lane and bike box are at two-way cross streets). Along the route there are 15 signalized cross streets and approximately 14 additional motor vehicle crossing locations (e.g., parking entrances, alleys, etc.). Some intersections along the route give pedestrians a three-second head start (known as a leading pedestrian interval or LPI) before initiating the green signal phase for vehicle traffic. Legislation is pending in 2014 to allow bicyclists to move on the LPI, though at the time of the report bicyclists were legally bound by the motor vehicle signal. The L Street route is the eastbound portion of a planned east-west protected bike lane couplet (along with M Street).

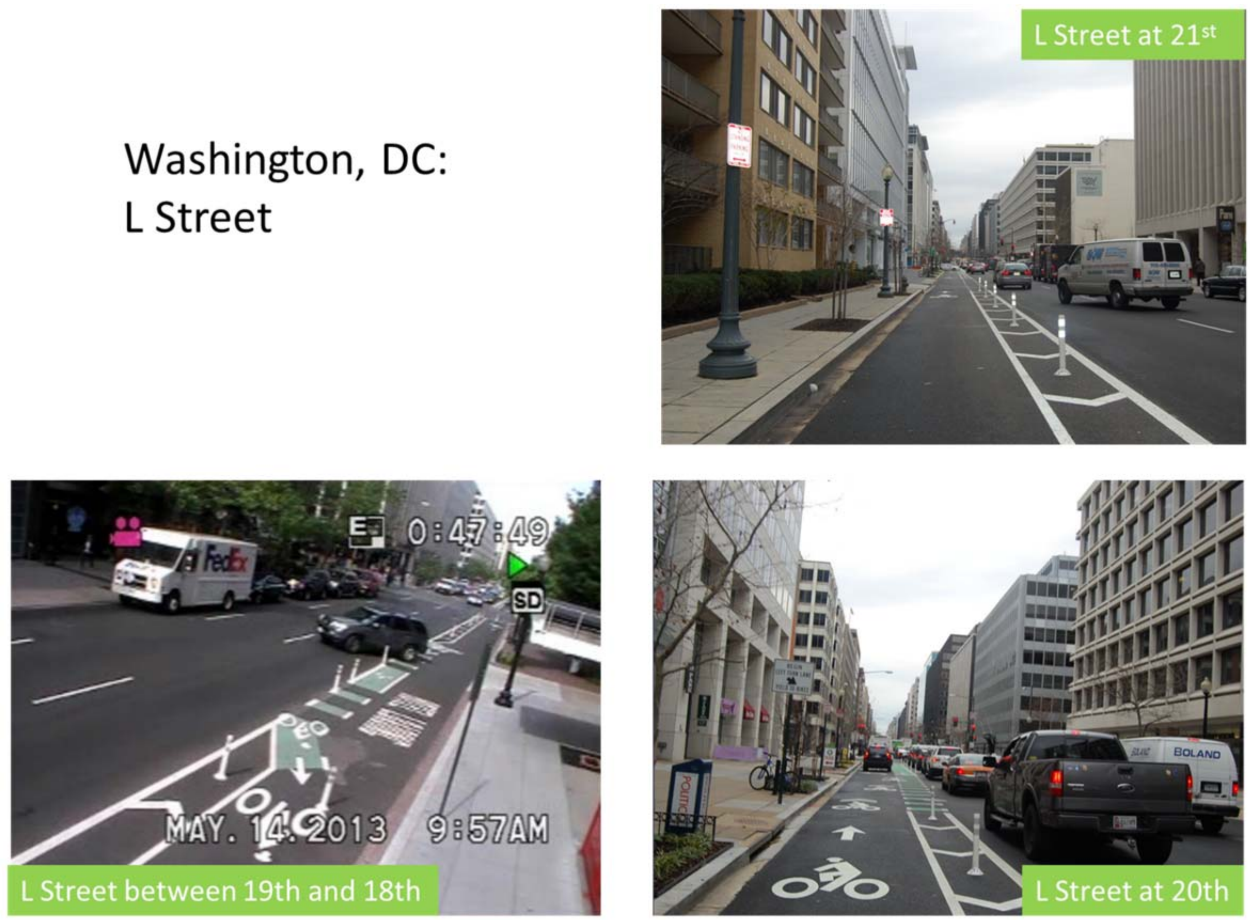
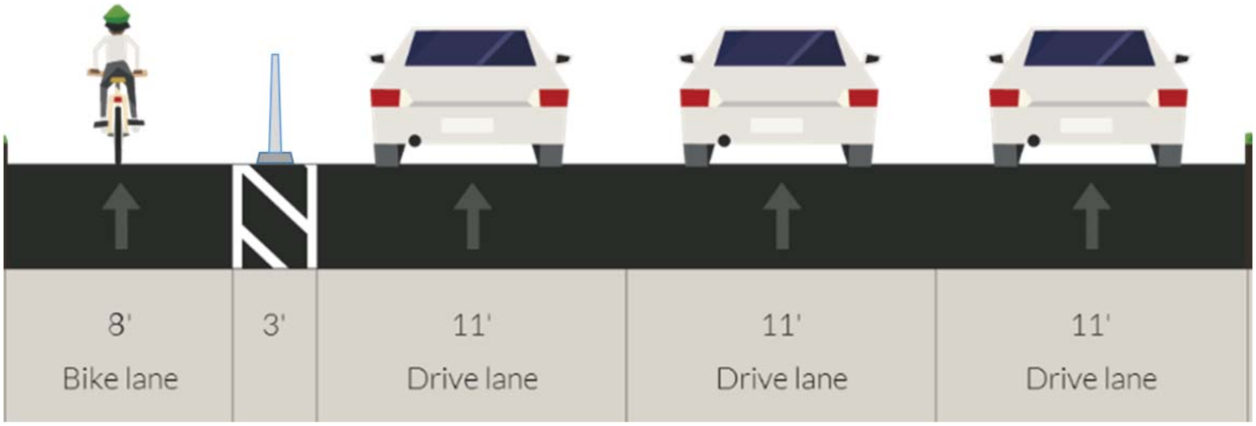


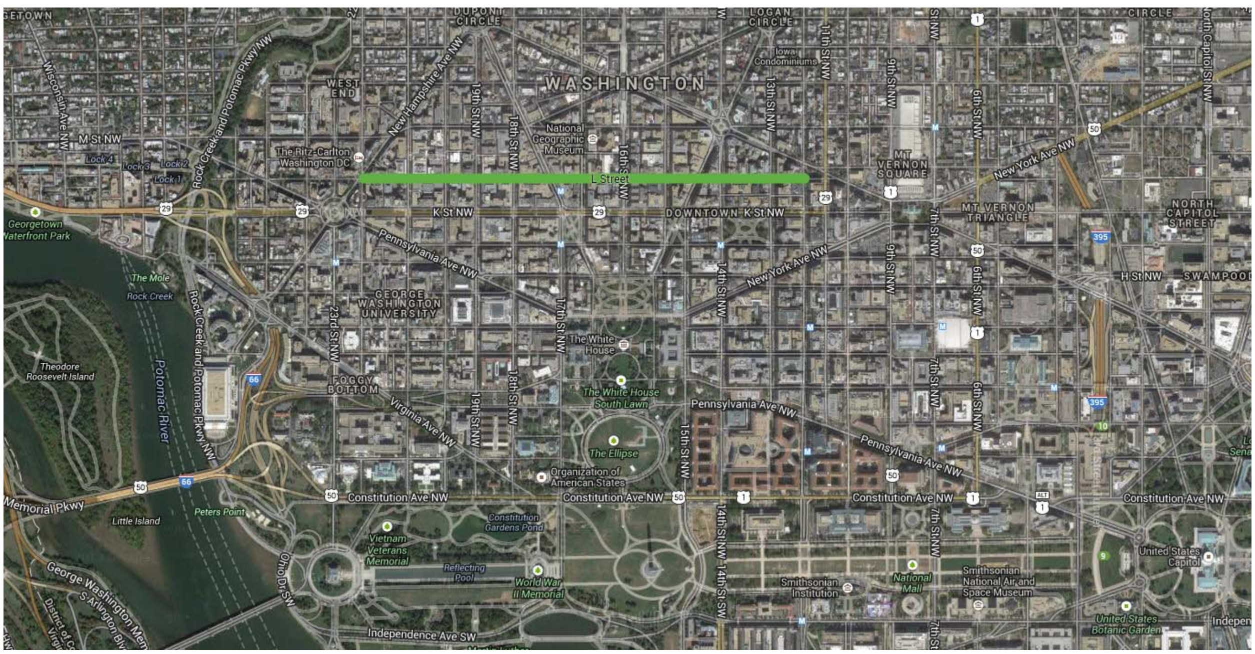
Figure 3-36. L Street Protected Bike Lane, Washington, D.C.

Figure 3-37. L Street, Washington, D.C., Before and After Installation of Protected Bike Lane



Graphics Source: Streetmix.com

Figure 3-38. Sample cross section of L Street Protected Bike Lane



Source: Google Maps

Figure 3-39. Vicinity Map of L Street Facility Extents

3.6 Summary of Facility Data

Table 3-2 provides a summary of the pre-installation characteristics of the study facilities. Table 3-3 provides a summary of the post-installation characteristics of each facility.

Table 3-2. Pre-Installation Characteristics of Study Routes

Data Element	Austin			Chicago		Portland	San Francisco		Washington DC
	Barton Springs Road	Bluebonnet Lane	Rio Grande St	N/S Dearborn St	N Milwaukee Ave	NE Multnomah St	Fell St	Oak St	L Street NW
From	S 1st St	Rabb Glen St	W MLK Jr Blvd	W Polk	W Kinzie	NE 1st St	Scott St	Baker St	Penn. Ave
To	S Lamar Blvd	Rabb Rd	W 24th St	W Kinzie	N Elston	NE 13th St	Baker St	Scott St	Mass. Ave
Standard Traffic Lanes	2 eb, 1 center turn lane, 2 wb	1 nb, 1 sb	2 nb	3-4 nb	1 nb, 1 sb	2 eb, 1 center turn lane, 2 wb	3 wb	3 eb	3 eb
Standard / Striped Bike Lanes	None	1 nb, 1 sb	1 nb	None	1 nb, 1 sb	1 eb, 1 wb	1 wb	None	None
Parking Allowed	No	Both sides	Left Side	Left side	Both sides	No	Both sides	Both sides	Right side, Left side (flex)
Length (miles)	0.5	0.7	0.4	1.2	0.8	0.8	0.3	0.3	1.12
# Signalized Intersections	4	0	2	12 to 13	7	10	4	4	15
# Unsignalized Intersections	2	15	5	0	5	3	0	0	0
ADT	23-28,000	3,500	5,000	8-16,000	12,000	10,000	28,000	30,000	12-14,000
Transit stops on route	Yes	No	No	Yes	Yes	Yes	No	No	No
Speed Limit	35	30	30	30	30	25	30	30	25
85% Speed (MPH)	34-36	30-32	21	n/a	36	28	n/a	30.5	n/a

Table 3-3. Post-Installation Roadway Characteristics

Data Element	Austin			Chicago		Portland	San Francisco		Washington DC
	Barton Springs Road	Bluebonnet Lane	Rio Grande St	N/S Dearborn	N Milwaukee Ave	NE Multnomah	Fell	Oak	L Street NW
Protected Lane Description	One-way EB protected lane on south side (+WB shared path on north side)	Two-way protected lanes on two-way street	Two-way protected lanes on one-way street	Two-way protected lanes on one-way street	Pair of one-way protected lanes on either side of two-way street	Pair of one-way protected lanes on either side of two-way street	One-way protected lane on one-way street	One-way protected lane on one-way street	One-way protected lane on one-way street
Construction Timeframe	Spring 2013	August 2012	April 2012	Nov./ Dec. 2012 and May 2013	April/May 2013	Fall 2012/ Winter 2013	Spring /summer 2013	Spring /summer 2013	October 2012
BL Placement (in relation to traffic)	Right	Right	Left	Left	Right	Right	Left	Right	Left
Bike Lane Width (representative)	5'-7'	5' + 5'	6.5' + 5.5'	5' + 4'	7'	4'-7'	7'3"	7'3"	8'
Buffer Type	Flexposts	Flexposts	Flexposts	Flexposts; MV parking	Paint; Flexposts; MV Parking	Concrete Planters; MV Parking	Flexposts	Flexposts	Flexposts
Typical Buffer Width	1.5'	2'	4'	3'; 8' parking strip	2-4'; 9' parking strip	2'-8'	5'	5'	3'
# Bicycle Signals	1	0	1	12 to 13	1	0	0	0	0
Loss of MV Travel Lane	No	No	In places	One lane	Loss of dedicated turn or bus lane in places	One lane in each direction	No	No	In places
Net Loss of Parking	No	~150	No	21	69	+27 gained	28	27	151
Typical MV Lane Width	10'-10.5'	10'	14'	9'-10'	10'-11'	10'	9'6"	9'6"	11'
# Mixing or Turning zones	0	0	0	0	0	11 (6 bus/bike; 3 bus/mv/bike; 2 mv/bike)	3	3	11
ADT	n/a	n/a	n/a	n/a	n/a	7,600	n/a	n/a	n/a
85% speed	n/a	n/a	n/a	n/a	n/a	25-27	n/a	25	n/a

4 METHODOLOGY

Cities and candidate facilities were identified based on inclusion in the Green Lanes Project cohort. The potential facilities to be included in this research were then narrowed to those constructed between approximately summer 2012 and early summer 2013. Due to delays in construction, no facilities in Memphis, TN, one of the original GLP cities, were included in this study. After site visits, one to two facilities in each city were selected for evaluation. In general, evaluations employed the collection and review of video at two to three locations for each facility for user compliance and safety measures, and surveys of cyclists (intercept) and residents (mail-out) for feedback on experiences and perceptions. Exceptions to this approach were that video data was not collected in Austin, the resident survey was not administered for Rio Grande Street, and the bicyclist survey was not administered for Bluebonnet Lane.

In addition, available count and other facility data provided by each city were reviewed to assist in the safety and count analyses. An overview of the project elements and timeline is shown in Figure 4-1. The timing and scope of the study did not allow us to collect original before data or data for comparison or control locations.

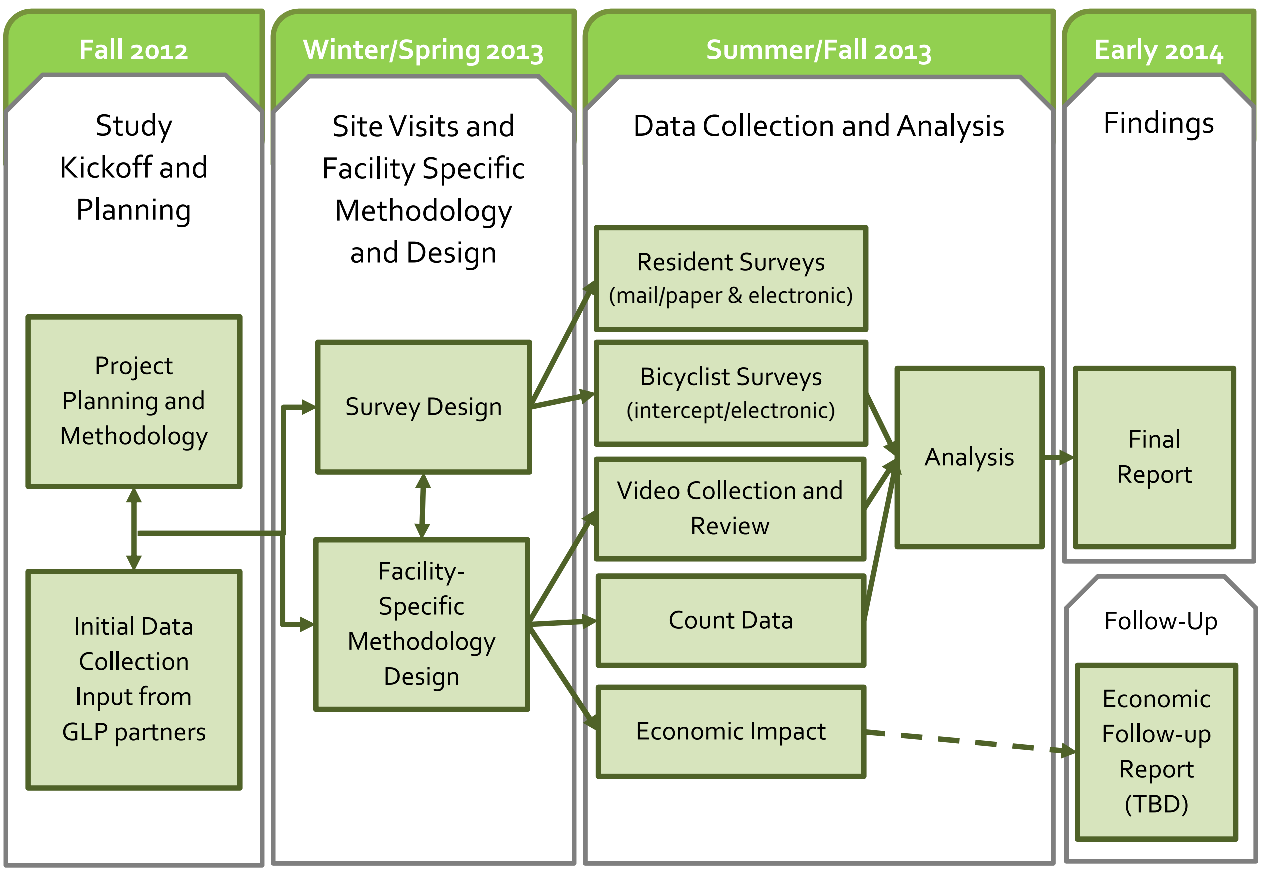


Figure 4-1. Diagram of Study Elements

The study started in late 2012 with a goal of developing the study methodology, survey instruments and video review tools in winter and spring 2013, with data collection occurring over summer 2013. As shown in Table 4-1, data collection extended into fall 2013. In addition, because the impacts of the facilities on the local economy likely take longer to actualize, the majority of the research for that objective will be completed later.

Table 4-1. Timeline of Project Data Collection Efforts

City	Route	Site Visit*	Resident Survey	Bicyclist Intercept Survey	Video Data Collection Dates
Washington, D.C.	L Street	January	May - June	June	May 14/15/16
Austin, TX	Bluebonnet Lane	April	July - August	-	-
	Barton Springs Road	April	July - August	June (+ October)	-
	Rio Grande Street	April	-	June (+ October)	-
San Francisco, CA	Oak Street	May	September - October	August	September 25/26/28[1]
	Fell Street	May	September - October	August	September 25/26/28[1]
Chicago, IL	N/S Dearborn Street	May	September - October	September	October 2/3/4[1]
	N Milwaukee Avenue	May	September - October	September	September 25/26[1]
Portland, OR	NE Multnomah Street	July	October - November	October	October 8/9

*All dates 2013
[1]Other dates were also collected at certain locations due to equipment failure or another issue on one of the original planned dates

4.1 Video Collection and Review

Through site visits to each facility and in coordination with the city staff at each location, intersections and other locations to collect video and analyze user behavior and operations were identified. Due to construction activity at a building on Rio Grande and routes with relatively low traffic volumes at intersections, video was not collected for the Austin locations. For all other facilities, the study team worked with a contractor to mount a pair of cameras for a two to three day period at three different intersections or other locations on each facility (Figure 4-2). The camera views allowed for collection of vehicle positioning, bicyclist positioning, traffic signal indications, and other features. The following section describes the objectives of the video review, the selected locations, and the data reduction process.

Figure 4-2. Example Video Screenshots (2 views) from San Francisco at Oak and Broderick

4.1.1 Video Review Objectives

The purpose of the video review was to analyze the actual behavior of bicyclists and motor vehicle drivers in order to determine how well each user type understands the design intent of the facility and how potential conflicts arise. In contrast, the surveys collect data on *stated* behavior and perceptions. In instances where the two analyses overlap, the video review and survey results can be contrasted to compare how individuals behave to how they say they do, or should, act. Finally, the video data were also used to supplement the bicyclist counts provided by the cities for the after-construction period.

4.1.2 Location Selection

Video was recorded at 12 locations along six study roadways in four cities in the spring and fall of 2013. Camera locations and mounting positions at each study site were selected that would best capture potential turning conflicts with motorists and pedestrians and allow us to identify which mixing zone treatments or other crossing treatments were most effective. The selected locations and a brief description of each are provided in Table 4-2.

Cameras were mounted for at least 48 hours with the goal of capturing two midweek days between the hours of 7 a.m. and 7 p.m. Because the Oak Street and Fell Street facilities are popular weekend routes for accessing Golden Gate Park, video was collected on a Saturday at those locations. Generally the collection days were consecutive, though in a few cases equipment failure necessitated redeployment (Dearborn at Randolph and Oak at Broderick).

Table 4-2. Summary of Video Data Collection

	Facility	Cross Street	Type	Description	Video Date	Video Day
Chicago	N/S Dearborn Street	Congress Parkway	Intersection	Two-way facility, MV left-turn signalized	10/2/2013	Wednesday
					10/3/2013	Thursday
					10/4/2013	Friday
		Madison Street	Intersection	Two-way facility, MV left-turn signalized	10/2/2013	Wednesday
					10/3/2013	Thursday
					10/4/2013	Friday
		Randolph Street	Intersection	Two-way facility, MV left-turn signalized	10/2/2013	Wednesday
					10/4/2013	Friday
					10/22/2013	Tuesday
	N Milwaukee Avenue	Elston Avenue	Intersection	Bicycle signal, right-turn over facility	9/25/2013	Wednesday
					9/26/2013	Thursday
Portland	NE Multnomah Street	9th Street	Intersection	Mixing zone w/ right-turning MVs	10/8/2013	Tuesday
					10/9/2013	Wednesday
		11th Street	Transit	Right-turn over facility, skip crossing markings	10/8/2013	Tuesday
					10/9/2013	Wednesday
San Francisco	Fell Street	Baker Street	Intersection	Mixing Zone with Green Skip Coloring (Left turns)	9/25/2013	Wednesday
					9/26/2013	Thursday
					9/28/2013	Saturday
	Oak Street	Broderick Street	Intersection	Mixing Zone with Sharrow Marking (Right Turns)	9/25/2013	Wednesday
					9/26/2013	Thursday
					11/9/2013	Saturday
		Divisadero Street	Intersection	Turning Zone with Unrestricted Entry and TBL	9/25/2013	Wednesday
					9/26/2013	Thursday
					9/28/2013	Saturday
Washington, D.C.	L Street NW	Btwn 19th St and 18th St	Hotel Zone	Loading zone with MV entrance and exit	5/15/2013	Wednesday
					5/16/2013	Thursday
		15th Street	Intersection	Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)	5/14/2013	Tuesday
					5/15/2013	Wednesday
		Connecticut Avenue	Intersection	Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)	5/14/2013	Tuesday
					5/15/2013	Wednesday

4.1.3 Video Data Reduction

Study team members manually viewed the video footage and coded information on bicyclists and turning motorists. The following section describes how data regarding bicyclists and motor vehicle drivers was reduced, including the types of data collected, for which locations it was collected and the types of quality control checks employed.

4.1.3.1 Bicyclist Behaviors and Paths

Different actions and descriptions were coded for each bicyclist traveling in the study facility or in the adjacent roadway. The types of data collected vary from one location to the next, though many elements were collected for all or multiple locations to allow for comparison across facilities and designs. Most of these elements are at intersections. See Chapter 7 for plan views of the intersections to better understand the variables. The following is a description of the types of data collected regarding bicyclists and at which locations they were collected:

Through Bike Lane Use: Whether the bicyclist rode in the through bike lane (TBL) in the mixing or loading zone and whether a motor vehicle was present at the time the cyclist rode through the zone. This variable was also used to note if the cyclist was not in the study facility, forced out of the study facility by a motor vehicle, or traveling the wrong way in the study facility. As noted below, at four locations these data were collected not for an TBL but for another treatment (e.g., sharrow or painted buffer). These data were collected at the following locations:

- All locations on L Street
- Oak Street/Divisadero Street
- Oak Street/Broderick Street – sharrow use
- NE Multnomah Street/9th Street –buffer space use

Stopping Location: If a bicyclist did stop, where he or she stopped in relation to a bike box (if present), crosswalk, intersection, or other feature. These data were collected at the following locations:

- All intersections

Signal Compliance: If a bicyclist was required to stop for a signal, whether he or she stopped and remained stopped until the signal turned green or made a legal turn on red. These data were collected at the following locations:

- All intersections

Turning Movement: The direction the bicyclist traveled through the intersection. If the bicyclist turned across motor vehicle lanes (e.g., a left turn from a right-side facility), reviewers noted how they made the turn (i.e., merged into motor vehicle lanes, used the crosswalk, other). These data were collected at the following locations:

- All intersections

Number of Bikes at Intersection: The number of bikes already present at the intersection when the subject bicyclist arrives. This is typically only recorded for stopping bicyclists to determine if the presence of other bicyclists changes signal compliance behavior. These data were collected at the following locations:

- All intersections

Avoidance Maneuvers/Conflicts: During the review of the video data, all potential conflicts were flagged by the research assistants, who were instructed to liberally define these events as any motor vehicle–bicycle interaction that did not appear typical. To ensure repeatability in defining conflicts, each flagged event was reviewed by the lead researchers on the study team. Drawing on work in earlier studies, the conflicts were identified and categorized based on observed precautionary braking, precautionary change of direction, emergency braking, emergency change of direction, and/or full stop by either the motorist or cyclist (*Dill et all, 2011; Allen et al., 2005; Atkins, 2005; Hunter, 2000)*.

Each vehicle-bicycle interaction was rated as <u>major</u> (near collision with emergency braking and/or change of direction); <u>substantial</u> (emergency braking and/or change of direction); <u>minor</u> (precautionary braking and/or change of direction); or <u>precautionary</u> (a low-risk interaction where a minor change in direction or speed was needed to avoid a conflict); or <u>no conflict</u>. The severity of conflicts was measured by actions of either the motorist or the cyclist. A conflict was defined as series of events that could lead to a collision. These data were collected at the following locations:

- All intersections

Cyclist Location: The location of the cyclist, if there is no mixing zone, in relation to the roadway (i.e., in study facility, in motor vehicle lane, on sidewalk, wrong-way cyclist, or other). These data were collected at the following locations:

- All Dearborn Street intersections – Also includes information on whether the bicyclist was in the correct or incorrect lane on the two-way facility
- Milwaukee Avenue/Elston Avenue
- All NE Multnomah Street intersections

Direction: Direction of the bicyclist's travel in a two-way facility. These data were collected at the following locations:

- All Dearborn Street intersections

Bus Interaction: Action taken by the bicyclist if a bus is present at the transit stop (i.e., rides around bus in motor vehicle lane, rides around bus on sidewalk, or waits behind bus). These data were collected at the following location:

- NE Multnomah Street/11th Street Transit Stop

4.1.3.2 Motor Vehicle Driver Behaviors and Paths

Data were also collected on the actions of drivers of motor vehicles that either merge into the mixing zone, if applicable, or turn across the study facility. As with bicyclists, some of the data collected are location specific and others were collected for multiple locations. The following is a description of the types of data collected regarding motor vehicle driver actions and at which locations they were collected:

Vehicle Type: Type of vehicle observed (i.e., personal vehicle, taxi, delivery van/truck, motorcycle/scooter, large truck, or other). These data were collected at the following locations:

- All locations

Turning or Mixing Zone/Turn-Lane Entrance: Where the driver entered the mixing zone or turn lane (i.e., in the merge zone, before the merge zone/drove in study facility, other point of access [e.g., garage], after the merge zone/across the buffer). If the driver did not enter the mixing zone or turn lane, it was noted if the driver turned from the wrong lane or turned while straddling the through lane and the mixing zone lane/buffer. These data were collected at the following locations:

- Both L Street intersections – turning zones
- All Fell Street and Oak Street intersections – turning and mixing zones
- NE Multnomah Street/9th Street – mixing zone

Merging Vehicle/Bike Interaction: Describes how the merging motor vehicle driver interacted with any bicyclists traveling in the study facility (i.e., whether a bike was present, who proceeded first, whether either user slowed or yielded for the other user, and whether there was a conflict). These data were collected at the following locations:

- All L Street locations
- All Fell Street and Oak Street intersections
- NE Multnomah Street/9th Street
- NE Multnomah Street/11th Street – recorded for the entrance and the exit of the transit stop only

Through Bike Lane Encroachment: Indicates if the motor vehicle stopped in the TBL or turned while still driving through the TBL. Temporary infringements that were part of the merging process were not counted. Reviewers were instructed to only use the code if the infringement was clearly visible on the video. At two locations, as noted below, a standard bike lane, instead of a TBL, is present. These data were collected at the following locations:

- All L Street locations
- Oak Street/Divisadero Street

Stopping Location: If a motor vehicle stopped, where it did so in relation to (i.e., behind, in or beyond) a bike box, crosswalk, intersection, or other feature. These data were collected at the following locations:

- Both Oak Street intersections

Turning Location: Identifies where a motor vehicle turned from (i.e., motor vehicle lane, bike lane, buffer between bike lane and motor vehicle lane, from wrong motor vehicle lane, other) at intersections without mixing zones. These data were collected at the following locations:

- All Dearborn Street locations
- Milwaukee Avenue/Elston Avenue
- NE Multnomah Street/9th Street

Turning Vehicle/Bike Interaction: Describes how the turning motor vehicle driver interacted with any bicyclists traveling in the study facility (i.e., whether a bike was present, who proceeded first, whether either user slowed or yielded for the other user, and whether there was a conflict). These data are for locations where motor vehicles do not merge across the bike lane. These data were collected at the following locations:

- All Dearborn Street locations
- Milwaukee Avenue/Elston Avenue
- NE Multnomah Street/9th Street

Signal Compliance: The signal phase that a motor vehicle turned on (i.e., green/yellow or red) or whether the vehicle entered the intersection on red (before completing their passage through on green). This is only collected at locations where protected left-turn phasing was recently added to separate bicycles and turning motor vehicles. These data were collected at the following locations:

- All Dearborn Street intersections

4.1.3.3 Video Data Reduction Process

Project team members reduced the data from the video for morning (7-9 a.m.), midday (11 a.m. – 1 p.m.), and evening (4-6 p.m.) peak periods for two or three weekdays at each location. In San Francisco, data was also collected for the Saturday midday (12-2 p.m.) period to evaluate the anticipated high proportion of recreational riders traveling to and from Golden Gate Park. This effort produced data from a total of 168 hours of video analyzed in this report.

The video was reviewed and reduced by six individuals: three undergraduate students and three graduate students. One of the graduate students was involved throughout the project and was also responsible for quality-control checks. The other five reviewers were brought in to specifically help with data collection and reduction efforts. Each reviewer watched 8 to 23 two-hour time periods. In order to avoid a specific reviewer's tendencies from biasing an entire location, reviews were assigned such that no individual watched more than one day's worth of video for a location (e.g., Reviewer A reduced the video for Connecticut Avenue at L Street on May 14th, while Reviewer B reduced the video for the same intersection on May 15th). Reviews were also assigned to spread the individuals across the study facilities as evenly as possible (e.g., five reviewers reduced video of the Fell and Oak streets couplet).

The project team prepared data collection spreadsheets for each video location. Each spreadsheet contained separate worksheets for motor vehicle data, bicyclist data, and general comments about the intersection. The two mode-specific data collection sheets were set up with headers containing a legend for how different actions should be coded. For items that were collected across multiple locations, the codes were set up to be consistent. Reviewers were provided with these spreadsheets, along with written instructions for each facility. The written instructions contained general guidance, specific directions for unique or potentially challenging situations, and tips on what camera locations provided the best view. Reviewers were also provided with in-person instructions before starting their first videos on their own.

4.1.3.4 Quality Control

A project team member performed spot checks on video for every day at each location (except for video he reduced himself). The aim of these spot checks was to ensure that reviewers were not missing observations, were correctly interpreting the project team's instructions, and that judgments were generally consistent (e.g., what counts as being stopped in a bike box vs. behind a bike box). These checks varied in terms of their length, but generally included at least 15 minutes of video and 25 observations each of bicyclists and motor vehicles. Most of these spot checks revealed only minor corrections, though some did uncover consistent interpretation issues that needed to be addressed. In certain cases, video needed to be reduced again to recode a certain variable. When this was necessary, either the original video reviewer or the spot check reviewer performed the correction.

A second round of quality control was performed after the reviews were completed. Data for each intersection were compared on a day-to-day basis to identify any potentially significant biases imparted by a reviewer. While some variation was to be expected due to daily variations in traffic and minor differences in viewer interpretation, significant fluctuations from one day to the next may indicate a more serious bias problem. Project team members identified 21 instances, out of a possible 137 variables, where further investigation of the difference might be warranted. Of the 21 identified instances, 15 were reviewed and recoded, while the other six were determined to not likely materially impact the results of the study. The types of changes made as a part of this process included:

- Reviewing the use of the Precautionary Avoidance Maneuver codes for potential overuse (nine instances)

- Reviewing the use of motor vehicle turning and merging location codes (three instances)
- Reviewing the use of cyclist location and stopping codes (two instances)
- Removing the inclusion of bicyclists turning onto the study facility from a side street (one instance)

As noted in the above list, the most common issue was the overuse of <u>precautionary</u> conflict codes. This is to be expected, as identifying and classifying avoidance maneuvers is likely the most subjective task reviewers were asked to perform. That there were only a few instances needing further review for any of the other codes indicates that the reviewers were likely relatively consistent in their judgment of them or that any issues were corrected during the spot check phase of reviews.

Finally, due to the subjective nature, as well as the potential information to be gleaned from them, all instances that were coded as having a <u>precautionary</u> conflict were reviewed by three project team members. Because this procedure was used, the original reviewers were asked to err on the side of inclusion when it came to these instances. A total of 74 instances were reviewed, with the three-person committee voting on each instance as to whether it constituted a <u>minor</u> (precautionary braking and/or change of direction), or <u>precautionary</u> (a low-risk interaction where a minor change in direction or speed was needed to avoid a conflict), or <u>no conflict</u>. The instances were then recoded on what a majority of the committee recommended it be rated. This process resulted in 13 instances remaining as having a minor conflict avoidance maneuver, 37 being downgraded to precautionary maneuvers, 13 being downgraded to not having an avoidance maneuver, and 11 as not being relevant to the design of the protected bike lane (i.e., took place away from the facility in a motor vehicle lane or on the sidewalk).

4.1.4 Results

Table 4-3 contains the number of observations at each location by time period. In the sample of locations, the largest number of bicyclists was observed on the Chicago facilities, N/S Dearborn Street and N Milwaukee Avenue. These locations also generally had the highest number of motor vehicles merging into mixing zones or turning across the facility.

Table 4-3. Number of Observations at Each Location

Facility		Cross Street	Time Period[1]	Bicyclists	Turning/Merging Motor Vehicles
Chicago	N/S Dearborn Street	Congress Parkway	7-9 a.m.[2]	474	575
			11 a.m. – 1 p.m.[2]	208	545
			4-6 p.m.[2]	496	468
		Madison Street	7-9 a.m.[2]	971	1,340
			11 a.m. – 1 p.m.[2]	453	1,242
			4-6 p.m.[2]	1,283	1,310
		Randolph Street	7-9 a.m.[2]	943	1,053
			11 a.m. – 1 p.m.[2]	423	1,446
			4-6 p.m.[2]	1,278	1,118
	N Milwaukee Avenue	Elston Avenue	7-9 a.m.	74	922
			11 a.m. – 1 p.m.	162	792
			4-6 p.m.	1,679	1,228
Portland	NE Multnomah Street	9th Street	7-9 a.m.	125	376
			11 a.m. – 1 p.m.	59	530
			4-6 p.m.	79	618
		11th Street (Transit Stop)	7-9 a.m.	12	9
			11 a.m. – 1 p.m.	21	9
			4-6 p.m.	148	25
San Francisco	Fell Street	Baker Street	7-9 a.m.	363	109
			11 a.m. – 1 p.m.	281	158
			4-6 p.m.	903	190
			12-2 p.m.[3]	400	44
	Oak Street	Broderick Street	7-9 a.m.	751	95
			11 a.m. – 1 p.m.	208	77
			4-6 p.m.	331	99
			12-2 p.m.[3]	211	52
		Divisadero Street	7-9 a.m.	804	504
			11 a.m. – 1 p.m.	234	510
			4-6 p.m.	383	617
			12-2 p.m.[3]	292	269
Washington, D.C.	L Street NW	Btwn 19th St and 18th St	7-9 a.m.	225	15
			11 a.m. – 1 p.m.	142	28
			4-6 p.m.	376	23
		15th Street	7-9 a.m.	149	708
			11 a.m. – 1 p.m.	173	581
			4-6 p.m.	441	691
		Connecticut Avenue	7-9 a.m.	198	438
			11 a.m. – 1 p.m.	178	412
			4-6 p.m.	462	498

[1]All time periods includes two weekdays, unless otherwise noted, [2]Includes three weekdays, [3]Includes only one Saturday

4.2 User Surveys

Two types of surveys were conducted in each city: 1) intercept surveys of bicyclists riding on the facilities and 2) surveys of residents living nearby the facility. The survey method was reviewed and approved by PSU's Human Subjects Research Review Committee (HSRRC). One base survey was developed for the bicyclist survey and one for the resident survey. Certain questions are consistent between these two surveys, including a number of questions about general perceptions of bicycling and comfort on various facilities, along with a set of demographic questions. Each of these base surveys was then adapted by adding more detailed facility-specific questions and removing certain questions that may be irrelevant given the specific context.

This section describes these project surveys, their objectives and their respective design processes.

4.2.1 Survey Objectives

The primary objective of both the resident and bicyclist surveys was to gain a better understanding of the following for all users of the transportation system (i.e., bicyclists, drivers, and pedestrians):

- Behavior in and around the protected bike lanes;
- The level of comprehension of the protected bike lanes' design features;
- Perceptions of the protected bike lanes' impact and effectiveness;
- How effective the protected bike lanes are at accomplishing their purposes, especially in regards to safety and comfort; and
- The level and type of use of the protected lanes.

The two surveys differ in their intended audience and level of detail. The resident survey is intended to gather information from individuals living near the cycle track, including those that bike, drive, or walk on the street that it was built on. This was the only way this research gathered systematic data from individuals who drive or walk on the street. It may be possible that drivers and pedestrians who are residents have different opinions and behavior than other drivers or pedestrians. The bicyclist survey was administered to bicyclists only and attempts to collect more detailed data about their experiences riding in the protected lanes.

In a few circumstances, either the resident or the bicyclist survey was not completed due to a failure to generate enough responses for analysis. In particular:

- A bicyclist intercept survey on Bluebonnet Lane in Austin resulted in only two completed responses after only about nine postcards were distributed. This reflected the low use of the facility during the survey period (during the summer, outside of the school year).
- We did not conduct a resident mail-out survey for Rio Grande because the nearby population, dominated by student housing at the University of Texas, had already entered summer break at the time of data collection. An email survey was distributed through the local neighborhood association, but yielded only five completed responses.

4.2.2 Survey Design and Refinement

The first step in the design of the surveys was the development of a generic template for each survey type (i.e., resident or bicyclist) with common questions across facilities. With the exception of when a question was not relevant to a particular facility, these questions were asked in each survey (e.g., a question about signalized intersections was not asked if there were no signalized intersections along the facility). Having the generic templates provided not only for easier assembly of each facility-specific survey, it also ensured that all of the questions in the template were being asked with the same wording for each survey and that similar information was being gathered for each facility. This uniformity allowed the project team to aggregate data and to compare results across cities.

The initial templates for each survey were designed by the research team drawing from its past surveys of bicycle facilities in Portland and Washington, D.C. An effort was made to present questions neutrally, allowing respondents to provide meaningful positive or negative answers regarding the facility's impact and effectiveness.

After the internal development of the survey templates, there were several rounds of reviews and refinement. Templates were reviewed by the other team members and staff from the study cities. Feedback from this review was incorporated into the initial survey template. Pilot surveys were tested using a Portland State University survey methods class for the resident survey and transportation students at PSU for the bicyclist survey. The feedback from the pilot survey tests yielded further improvements to the questions and formatting.

After revising the survey templates from the piloting efforts, surveys specific to each study facility were developed. These surveys began with the templates and were modified in the following manner:

- Facility and location-specific language replaced generic placeholders (e.g., "facility" became "Bluebonnet Lane cycle track");
- Non-relevant questions to the specific study facility were removed (e.g., economic-related questions were not needed if there were no businesses along the corridor); and
- Specific questions that addressed unique design features of the study facility were added (e.g., questions related to the operation of a specific mixing zone or the functionality of a two-way cycle track).

Once the project team was satisfied with the design of the facility-specific survey, it was sent to the appropriate city's staff members for their review. Their feedback was then incorporated into the final survey.

4.2.3 Survey Instruments

The following section describes the overall make-up of the resident and bicyclist surveys and the process by which they were designed.

4.2.3.1 Resident Survey Structure

The resident surveys contained around 50 questions covering a range of topics. Figure 4-3 shows the overall structure of the resident survey.

The first section of the survey is about the respondent's travel habits and opinions, which helps to understand their attitudes about bicycling and other travel modes and their level of (theoretical) comfort under different bicycling scenarios.

The next section asked all respondents (regardless of how they use the street) about their opinion of the impact the facility has had on their neighborhood, the safety of the street, and the effectiveness of its design in accomplishing its objectives (e.g., clear and adequate separation of bicyclists from motor vehicles).

Following this overall section, respondents were asked questions related to their experiences driving, bicycling, or walking on the street since the cycle track was built. Respondents were instructed to skip sections that are not relevant to them (e.g., if they have not bicycled on the cycle track since it was built, they were instructed to skip the bicycling section). The goal of these sections was to discern the impacts and benefits the protected lane has had on users of various modes of transportation (e.g., do drivers have a more difficult time finding parking on the street? Do bicyclists feel comfortable in the cycle track? Do pedestrians think the cycle track has improved or degraded the street's walking environment?). The questions for residents who had bicycled on the new lane were a subset of the questions from the bicyclist survey.

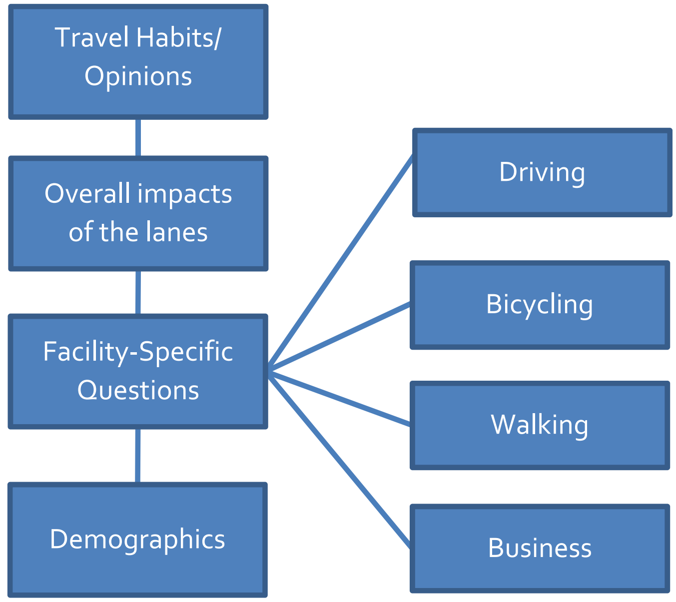


Figure 4-3. Resident Survey Structure

In an effort to identify possible economic impacts of the new cycle track, the survey contained questions regarding consumer habits in the study area. This block of questions was designed to evaluate whether the facility had any impact on decisions about spending money at businesses in the area of the new facility.

The survey concluded with demographic questions that were standardized across all surveys.

4.2.3.2 Bicyclist Survey Structure

The bicyclist survey was different from the resident survey in its overall intent in that it was targeted at a more specific population (i.e., people who have bicycled on the cycle track). It included more detailed questions about the bicycling experience on the new lane and about the respondent's stated level of comfort bicycling under different scenarios. In this regard, it complemented the resident survey's broad reach to many user types and more general questions.

Several questions were based on or identical to those from the resident survey, and the overall structure of this survey is similar to that of the resident survey. The bicyclist survey began with general questions about travel habits and opinions and questions about the trip they were making when they were intercepted for the survey. The next section included specific questions about their experience while bicycling in the new facility. These questions were more detailed than those in the bicyclist portion of the resident survey. In addition to the topics covered in the resident survey, respondents to the bicyclist survey were asked about obstacles they encounter in the cycle track and potentially dangerous situations they have encountered. They were asked the same set of demographic questions.

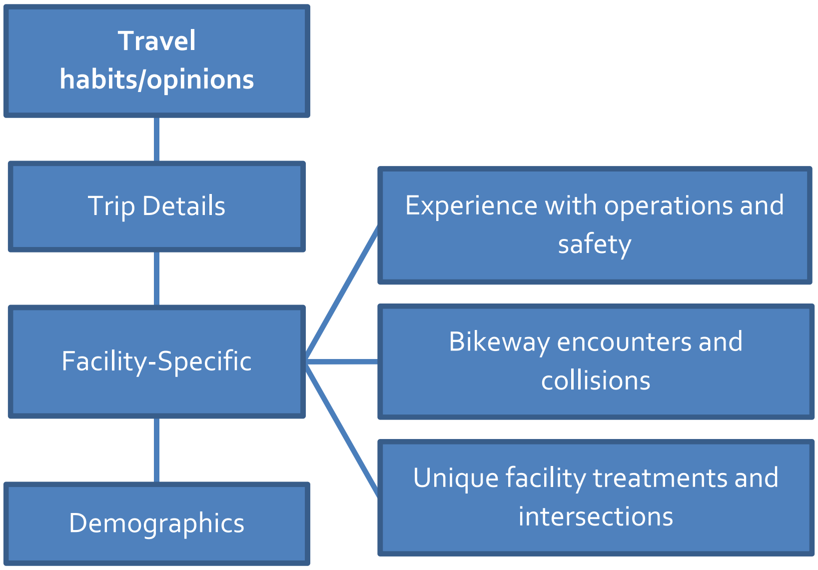


Figure 4-4. Bicyclist Survey Structure

4.2.4 Survey Administration

Figure 4-5 shows the distribution and response methods for the resident and bicyclist surveys, which are described in greater detail in the following subsections.

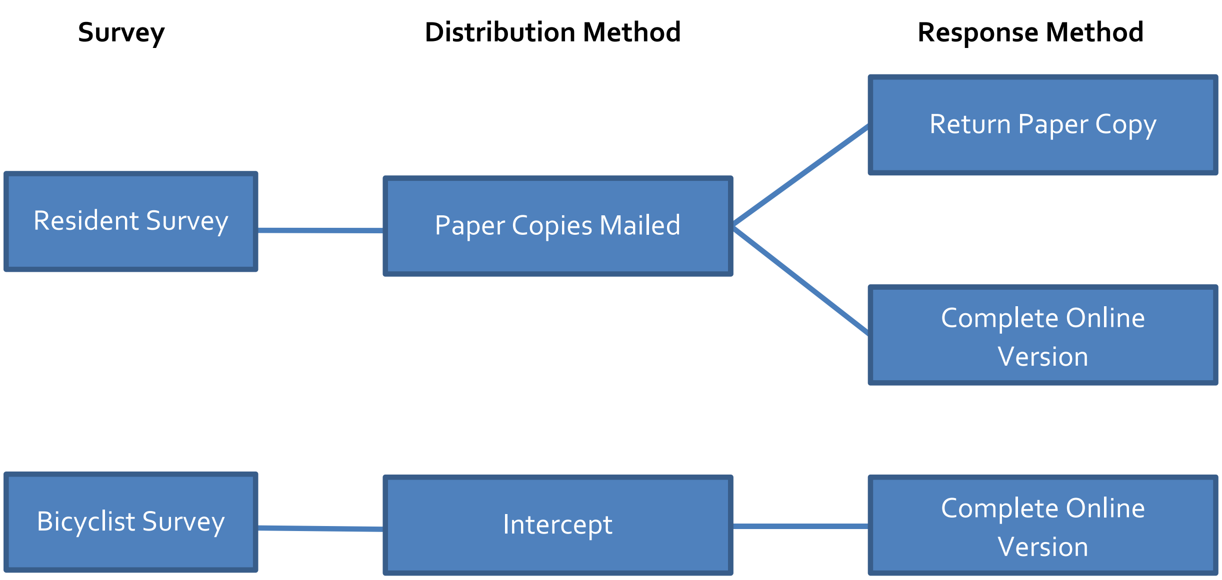


Figure 4-5. Survey Administration Methods

4.2.4.1 Resident Survey

Paper copies of the resident survey were mailed to up to 2,000 resident addresses within a specific boundary (up to a quarter mile) of each study facility. The size of the boundary around each facility differed based on the density of the surrounding area and the resulting distance needed to achieve an ample sample size. Resident addresses are taken from the Reference USA database accessed through a PSU subscription service.

The paper surveys were printed in booklet form and ranged in size from 8-12 pages. In addition to the survey, each envelope included an invitation letter introducing the project, and a postage-paid return envelope. The packet also contained a slip of paper on which the respondent could record his or her contact information (the surveys themselves are anonymous) to be entered into a drawing for one of three $100 Amazon.com gift cards. Each survey had a unique number to track whether a household had responded. The survey responses were never linked to the names of the individuals in the household.

Survey recipients were given two options for completing the survey. They could fill out the paper copy of the survey and return it in the postage-paid envelope. Alternatively, they were given the option of completing an online version of the questionnaire. The introduction letter and first page of the paper survey contained an address for the online survey and a code that the respondent had to enter to access the survey. The code for the online survey was the same as the one assigned to the paper survey so that the project team can remove any duplicate survey entries. If completing the online version, the respondent could enter the incentive drawing electronically.

A reminder postcard was sent a few days after the first survey. A second copy of the survey was sent to households that had not responded to the original survey by the requested completed date (typically about two weeks from when it was mailed).

4.2.4.2 Bicyclist Survey – Intercepted Bicyclists

The bicyclist survey was designed as an intercept survey with riders receiving a postcard directing them to a web address to complete the survey electronically. Project team members, volunteers or city staff intercepted bicyclists along the study facility and handed them a postcard encouraging them to take an online survey. The postcard included a web address and unique code needed to access the survey. The logistics of the intercept method were slightly different for each facility. Locations for survey distribution along each facility were typically at locations where bicyclists were already required to stop (i.e., stop-controlled or signalized intersections) so that the postcard distributors would not distract the bicyclists and potentially endanger their safety. While volunteers were able to provide some basic information to the bicyclists if they asked and encouraged them to complete the survey, they were asked not to encourage riders to respond in any certain way. The survey intercept times and days were determined based on ridership patterns along the route. Typically, the AM and PM commuter peak periods were surveyed, along with a possible midday or weekend period. To reduce the likelihood that an individual received more than one survey postcard, each time period was generally only surveyed once.

Similar to the resident survey, respondents to the bicyclist survey were provided the option to enter a drawing for one of three $100 Amazon.com gift cards.

4.2.4.3 Bicyclist Survey – Open Survey

In addition to the bicyclist intercept surveys, the research team distributed the survey to the Internet through local advocacy groups in each city. In the intercept surveys each respondent was observed on the facility and given a card with a unique number. In the open surveys, the distribution could not be easily controlled. For this reason, these data are not included in the results presented in this report.

4.3 Bicycle Count Data

The analysis of change in ridership based on bicycle count data is draws from counts conducted by each participating city's staff or volunteers and counts taken from the study team's video review. All pre-installation counts were conducted by the cities independently of this study. Post-installation count data is derived from a combination of city counts and bicyclist tallies collected during the study's video review process. All of the counts used in the analysis are from specific time frames – usually 2-4 hours during AM or PM peak travel periods. Because count collection methods, duration, timing, frequency and regularity varied from location to location, and specific count locations occasionally varied on a specific facility, the best comparable counts for each specific facility were used given the available data.

Evaluating the effects of a facility on ridership using count data has some limitations. In particular, it is difficult to determine whether any changes in traffic volumes are due to net increases (or decreases) in ridership or people changing their routes from other streets. Although not included in this report, analyzing ridership on parallel routes would be one way to address this limitation. Other factors influence counts, such as season, weather and events, which can also limit before-and-after comparisons. Long data collection time periods (e.g., months or a year) can minimize this issue. The timing of this study precluded the collection of thorough count data before construction. Instead, secondary data was relied upon for this analysis.

4.3.1 City Bicyclist Counts

Table 4-4 shows the types of count data provided by partner cities at each location for the pre- and post-installation periods.

Table 4-4. Count Data Provided by Participating Cities

City	Street (s)	Count Type	Before Counts	After Counts
Austin	Barton Springs Road	Tube counter	Midweek 24-hour collection	Midweek 24-hour collection
	Bluebonnet Lane	Tube counter	Midweek 24-hour collection	Midweek 24-hour collection
	Rio Grande St	Tube counter	Midweek 24-hour collection	Midweek 24-hour collection
Chicago	N/S Dearborn St	Manual Count	Midweek 12-hour collection (7am-7pm)	Midweek PM peak 430-630pm
	N Milwaukee Ave	Manual Count	Midweek 12-hour collection (7am-7pm)	Midweek 7-9am and 4-6pm
Portland	NE Multnomah St	Manual Count	Midweek 4-6pm	Midweek 4-6pm
San Francisco	Fell St	Automated eco-vision counter	May 2012 to May 2013.	n/a – Counter positioned at old BL location.
		Pyro Sensor	n/a	May 2013
		Tube Count	n/a	May 2013
		Manual Count	Midweek 7-9am and 430-630pm	n/a
	Oak St	Manual Count	Midweek 7-9am and 430-630pm	n/a
Washington D.C.	L Street	Manual Count	Midweek 6-10am and 3-7pm	Midweek 6-10am and 3-7pm

The best possible count comparison or comparisons were sought out for each facility, taking into account the count time of day, duration, day of week, and time of year. In cases where count timing for pre- and post-installation periods were not consistent, the shorter count duration was used to conduct the comparison; for example, if a 24-hour pre-installation count and a 4-6 p.m. post-installation count were available, the 4-6 p.m. count was extracted from the 24-hour pre- count and used as the pre- comparison.

In addition to being subject to the availability of existing count data, this analysis also did not explicitly adjust for particular circumstances, especially the weather conditions, of the count days. For example, September 2013 counts conducted on Milwaukee Avenue in Chicago happened to occur on an unusually hot day, with temperatures reaching 95 degrees and potentially depressing ridership numbers. In another case, the best available pre-installation count for one location on Bluebonnet Lane in Austin took place after the school year at a location adjacent to an elementary school, potentially causing the pre- counts to be low at that location.

4.3.2 Bicyclist Counts from Video Review

Bicyclists counts were taken from tallies made during the study video review. For each day of video review, tallies were taken for the 7-9 a.m., 11 a.m.-1 p.m. and 4-6 p.m. hours (with the exception of Saturday time periods on Oak and Fell Streets, for which only the 12-2 p.m. period was tallied). See Table 4-2 for the days tallied. A similar process of identifying and extracting the best matched comparison periods was conducted for comparing the study video review bicyclist tallies.

5 SURVEY RESPONDENTS

5.1 Survey Response Rates

Response rates for each survey are shown in Table 5-1. A total of 10,221 surveys were mailed to residents living near the new facilities; 475 of those were returned as undeliverable and 2,283 were returned with responses. Surveys were considered completed as long as any portion of the survey was completed. Response rates ranged from a low of 13% near the L Street facility in Washington D.C., to a high of 34% near NE Multnomah Street in Portland. The overall response rate for residents was 23%. Just over a third of all respondents (34%) opted to complete the web survey, demonstrating the value of having that option.

Response rates for the bicyclist intercept survey were calculated by dividing the number of responses by the number of postcards distributed; the number of people who declined to take a postcard was not recorded. Postcards were numbered but volunteers did not always diligently log starting and stopping numbers. The response rate ranged from 21% along Dearborn Street in Chicago to 56% along NE Multnomah Street in Portland, with an overall response rate of 33%. Note that the surveys on Barton Springs and Rio Grande in Austin yielded the fewest completed surveys.

Table 5-1. Survey Distribution and Response Rates

City	Route	Resident Survey					Bicyclist Survey		
		Mailed (not delivered)	Paper Responses	Web Responses	Total Responses	Response Rate	Distrib-uted*	Returned	Response Rate
Washington, D.C.	L Street	2,000 (168)	148	88	236	13%	763	300	39%
Austin, TX	Bluebonnet	1,661 (71)	304	135	439	28%	-	-	-
	Barton Springs	343 (10)	55	36	91	27%	73	18	25%
	Rio Grande	-			-	-	98	43	44%
San Francisco, CA	Oak /Fell	1,967 (32)	318	199	517	27%	900	278	31%
Chicago, IL	N/S Dearborn	1,200 (81)	121	76	197	18%	600	124	21%
	N Milwaukee	1,500 (30)	185	126	311	21%	775	236	30%
Portland, OR	NE Multnomah	1,550 (83)	368	124	492	34%	200	112	56%
Overall		**9,746**	**1,499**	**784**	**2,283**	**23%**	**3,409**	**1,111**	**33%**

Note: Response rate for resident survey calculated based upon number of mailed surveys not returned as undeliverable, "mailed" minus "not delivered."
*Estimated for San Francisco, Chicago, and Portland due to volunteer logging.

5.2 Overview of Survey Respondents

5.2.1 Resident Survey Respondents

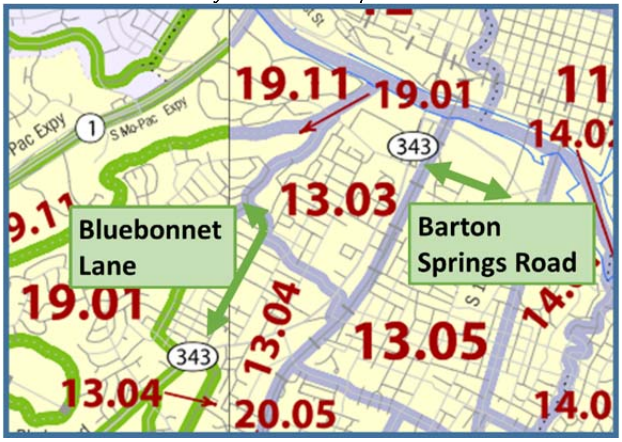
Of the 2,283 resident responses received, 2,225 provided some or all of the requested demographic information (which was the last section of the survey). Information about the basic characteristics of resident survey respondents, along with percentages from roughly comparable Census tracts, is shown in Table 5-2. The Census tracts used for comparison are not perfect matches, as only a sample of residents living within 0.1 to 0.25 miles of the new facility were invited to participate. The Census tracts generally cover a larger area (see Figure 5-1); however, the comparison provides a sense of the representativeness of the sample.

Comparing the overall sample across the cities, resident survey respondents were considerably older, more likely to be homeowners, and more likely to have at least a four-year college degree. The survey sample contained a slightly higher percentage of respondents identifying as white than comparison tracts (81% compared to 76%), and slightly fewer identifying as black, Hispanic/Latino, or Asian (5-6% compared 8-9%). Respondents were also more likely to have children in the household and work from home. Although the combined group of respondents was only slightly more likely to be earning $100,000 or more, this group was in fact overrepresented in most individual localities.

Table 5-2. Resident Survey Respondents with Census Comparison

	Demographic Variable	Austin Barton Springs + Bluebonnet		Chicago Dearborn		Chicago Milwaukee		Portland Multnomah		San Francisco Oak + Fell		D.C. L Street		Total	
		Survey	Census	Survey	Census	Survey	Census	Survey	Census	Survey	Census	Survey	Census	Survey	Census
Household	Homeowners	79%	51%	72%	38%	63%	49%	39%	27%	39%	22%	50%	24%	55%	34%
	3+ years at address	81%		74%		75%		56%		81%		68%		73%	
	2+ Adults in HH	70%		58%		67%		54%		69%		58%		64%	
	Children in HH	24%	15%	9%	4%	17%	11%	10%	10%	15%	12%	7%	3%	15%	10%
Travel	Driver's License	98%		96%		98%		92%		95%		95%		96%	
	Transit Pass	10%		87%		82%		27%		61%		86%		50%	
	Bike Share Membership	n/a		6%		6%		n/a		1%		14%		5%	
	Car Share Membership	14%		26%		8%		12%		27%		25%		18%	
	Own/Lease a car	96%		56%		89%		84%		78%		62%		81%	
	Own working bicycle	77%		62%		69%		59%		71%		50%		67%	
Demographic	Female	52%	50%	55%	41%	52%	48%	59%	53%	50%	46%	50%	53%	53%	48%
	<35 years of age	15%	45%	25%	58%	39%	56%	23%	38%	27%	49%	44%	58%	26%	51%
	35 to 54 years	43%	35%	41%	30%	42%	34%	32%	26%	46%	36%	30%	28%	40%	33%
	55 + years	42%	20%	34%	12%	19%	9%	45%	36%	27%	15%	26%	15%	34%	16%
	White	88%	92%	78%	65%	75%	75%	88%	83%	77%	73%	72%	70%	81%	76%
	Black	0%	1%	5%	13%	7%	12%	4%	5%	7%	7%	7%	11%	5%	8%
	Hispanic or Latino/a	6%	13%	4%	7%	6%	8%	2%	3%	7%	10%	7%	14%	5%	9%
	Asian	2%	2%	6%	16%	8%	9%	5%	5%	8%	11%	9%	11%	6%	9%
	Other or no response	3%	5%	7%	7%	4%	4%	1%	7%	1%	9%	4%	7%	3%	7%
Education/ Employment	Work Outside Home	61%	77%	76%	68%	78%	84%	57%	58%	69%	75%	72%	75%	66%	75%
	Work From Home	20%	9%	15%	3%	16%	6%	9%	2%	18%	6%	10%	1%	15%	5%
	In School	1%		5%		3%		4%		3%		5%		3%	
	Not Employed	17%	14%	6%	29%	8%	10%	35%	40%	16%	20%	10%	24%	18%	20%
	Income <$50k	22%	38%	10%	28%	13%	20%	38%	57%	20%	29%	12%	41%	22%	21%
	$50k to $100k	37%	35%	40%	36%	31%	29%	42%	23%	34%	27%	39%	24%	37%	40%
	>$100k	41%	27%	50%	36%	56%	51%	19%	20%	46%	43%	48%	34%	41%	39%
	Four year college +	83%	61%	90%	64%	85%	77%	79%	59%	82%	69%	90%	76%	83%	69%
	n	516		195		296		481		508		229		2,225	
Comparison Tracts - ACS 2008-2012 5 year data		Travis Co.: 13.03; 13.04		Cook Co.: 8391		Cook Co.: 2801; 2435; 8423		Mult. Co.: 23.03; 24.02		SF Co.: 164; 165; 166; 167		DC: 101; 107			

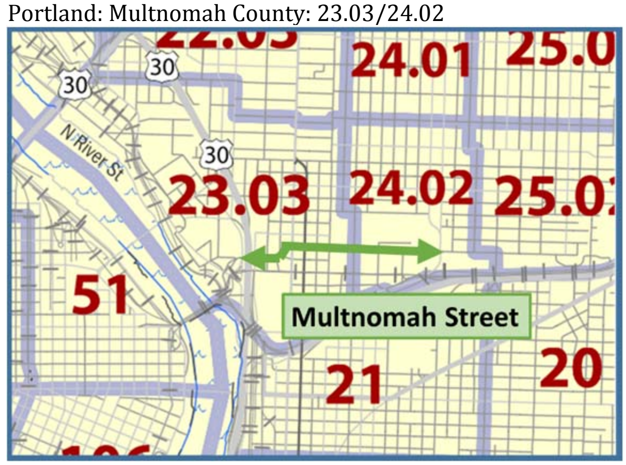
Austin: Travis County Tracts 13.03/13.04



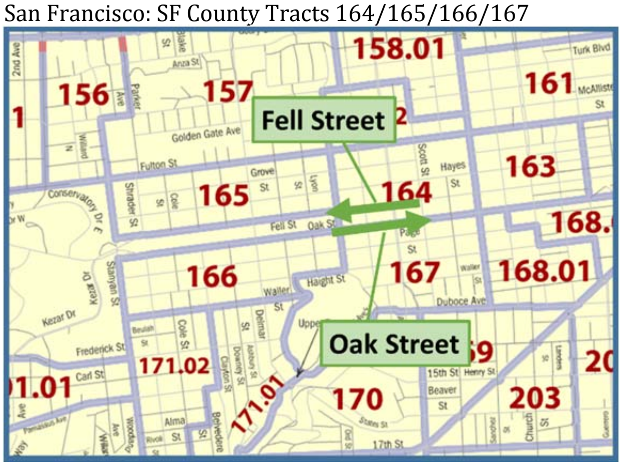
Chicago/Dearborn: Cook County Tract 8391

Chicago/Milwaukee: Cook County Tracts 2801/2435/8423

Portland: Multnomah County: 23.03/24.02



San Francisco: SF County Tracts 164/165/166/167



D.C.: Tracts 101/107

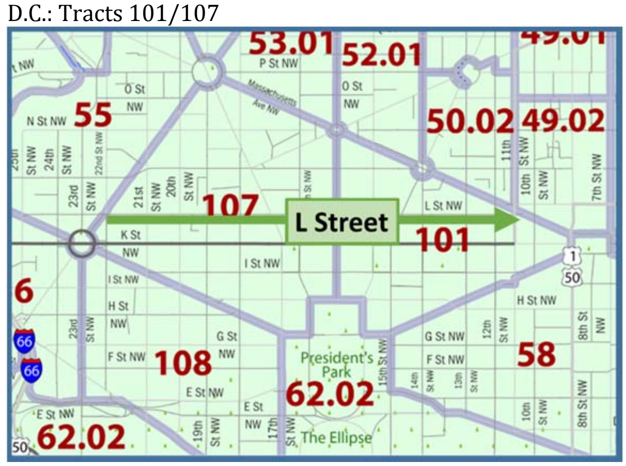


Figure 5-1. Illustration of Census Tracts used for Resident Demographic Comparison

Resident respondents were asked to indicate how frequently they used a motor vehicle, walked, bicycled or used public transportation for their commute trip, and were broken down based on their primary stated mode of commute. For each mode, respondents could select "most trips," "some trips" or "no trips." Those that selected "most trips" for only one mode were placed into that category. If they selected "most trips" for more than one mode they were placed in the "mix" category. If they did not select "most trips" for any mode, a similar categorization process was done based on whether they selected "some trips" for any mode. Those that responded "no trips" to each mode were placed into a "non-commuter" category (which may include those that work from home, are retired, or are otherwise not employed). The breakdown of the assigned "primary mode" along with comparison commute modes from the selected Census tracts can be seen in Table 5-3.

Table 5-3. Imputed Primary Mode, with Census Comparison

City	Source	Car/ Truck	Foot	Transit	"Other"	Bicycle	Mix	Non-commuter	Not in Labor Force	n
Austin	Survey	71%	2%	2%	1%	5%	7%	11%	-	527
	Census	*58%*	*1%*	*2%*	*7%*			*17%*	*16%*	
Chicago Dearborn	Survey	18%	37%	21%	1%	4%	17%	3%	-	197
	Census	*12%*	*40%*	*10%*	*3%*			*7%*	*28%*	
Chicago Milwaukee	Survey	42%	11%	19%	0%	4%	21%	3%	-	311
	Census	*29%*	*22%*	*20%*	*6%*			*13%*	*10%*	
Portland	Survey	38%	9%	12%	1%	7%	13%	21%	-	490
	Census	*31%*	*9%*	*10%*	*7%*			*10%*	*34%*	
San Francisco	Survey	31%	10%	20%	1%	13%	19%	8%	-	517
	Census	*22%*	*8%*	*30%*	*9%*			*12%*	*19%*	
Washington, D.C.	Survey	16%	43%	12%	0%	5%	16%	9%	-	235
	Census	*16%*	*34%*	*22%*	*2%*			*5%*	*21%*	
Total	Survey	40%	14%	13%	1%	7%	15%	10%	-	2,277
	Census	*27%*	*15%*	*20%*	*7%*			*12%*	*19%*	

To take into account respondents' views toward bicycling, residents were broke them down into bicyclist types using an established methodology for grouping people into a "cyclist typology" (*Geller, 2009; Dill and McNeil, 2012*). People were grouped into four categories: *Strong and Fearless*, *Enthused and Confident*, *Interested but Concerned*, and *No How No Way* (Table 5-4). Several of the findings sections that follow use these categories to examine attitudes of residents toward the protected lanes. The grouping was largely based upon their stated level of comfort bicycling in different environments, consistent with the method developed in Dill and McNeil (*2012*). However, the method was not identical, so comparisons with the distribution of bicyclists from that study are made cautiously. One notable difference is the large share of respondents in the *Enthused and Confident* category. This may be due to differences in survey methods. For example, Dill and McNeil used a random phone survey which may be subject to less response bias; more confident bicyclists may have been more likely to respond to this mail survey. In addition, the demographics of the neighborhoods studied here may result in more confident bicyclists, compared to a random survey across a city or region.

Table 5-4. Resident Respondents Categorized into Four Types of Cyclists

Type of Cyclist	Austin	Chicago	Portland	San Francisco	Washington, D.C.	All
Strong and Fearless	3%	5%	4%	7%	6%	5%
Enthused and Confident	22%	25%	32%	31%	26%	27%
Interested But Concerned	56%	40%	36%	40%	40%	43%
No Way No How	18%	30%	27%	22%	28%	25%
Total	489	456	411	469	211	2,036

5.2.2 Bicyclist Survey Respondents

Bicyclist survey respondents (Table 5-5) tended to be a relatively multimodal group, with at least two-thirds of respondents on each facility owning a car (73% overall average) and most having a transit pass (72% overall average). Over a quarter (28%) has a car-share membership. About a fifth of respondents in cities with bike-share systems were members at the time of the survey (19%). On average, respondents owned more bicycles (2.9 per household) than cars (1.2 per household).

In comparison to the resident respondents, the intercepted bicyclist respondents were more likely to be white (89% compared to 81%); male (68% vs 47%); work outside the home (90% vs. 66%); and make over $100,000 per year (48% vs. 41%). The bicyclist respondents were about as likely as resident respondents to possess a four-year degree (82%). An overview of bicyclist survey respondents is provided in Table 5-5.

Table 5-5. Bicyclist Intercept Survey Respondents

Demographic Variable		Austin		Chicago		Portland	S.F.	D.C.	
		Barton Springs	Rio Grande	Dearborn	Milwaukee	Multnomah	Oak & Fell	L Street	Total
HH	2 + Adults	65%	62%	79%	78%	77%	82%	78%	78%
	Children in HH	35%	10%	22%	18%	34%	24%	30%	25%
Travel	Own/Lease a car	76%	74%	68%	68%	86%	69%	73%	73%
	Driver's License	82%	90%	97%	97%	95%	98%	98%	97%
	Transit Pass	24%	33%	94%	90%	30%	57%	87%	72%
	Bike Share Member	n/a	n/a	35%	17%	n/a	6%	35%	19%[1]
	Car Share Member	12%	14%	23%	20%	31%	29%	35%	28%
Demographic	Female	24%	24%	36%	36%	44%	28%	28%	32%
	<35 years of age	41%	71%	58%	69%	37%	55%	51%	56%
	35 to 54 years	53%	21%	34%	29%	44%	40%	41%	37%
	55 + years	6%	5%	6%	1%	17%	4%	8%	6%
	White	71%	81%	88%	91%	92%	85%	91%	89%
	Black	0%	0%	3%	0%	0%	1%	3%	1%
	Hispanic or Latino/a	6%	10%	3%	4%	7%	4%	4%	5%
	Asian	12%	10%	10%	4%	2%	11%	4%	7%
	Other	12%	7%	3%	3%	5%	5%	4%	4%
Education/ Employment	Work Outside Home	76%	74%	91%	98%	89%	94%	93%	93%
	Work From Home	18%	10%	7%	1%	8%	8%	7%	7%
	In School	12%	43%	9%	6%	7%	7%	5%	8%
	Not Employed	0%	0%	2%	1%	6%	2%	3%	2%
	Income <$50k	35%	57%	23%	21%	21%	17%	11%	19%
	Income >$100k	47%	29%	42%	43%	29%	47%	67%	48%
	Four-year college degree or more	76%	55%	92%	90%	90%	90%	93%	89%
n		17	42	117	208	108	248	282	1,022

[1]Only includes cities with bike share

Intercepted bicyclists were also categorized into a cyclist typology using the same process described for the residents above, as shown in Table 5-6. In the case of the bicyclists, there were obviously no respondents in the *No Way No How* category. As a result, the percentage of respondents falling into each of the other type categories was somewhat higher for the intercepted bicyclists than for the residents. Over half of the intercepted bicyclists fell into the *Interested But Concerned* category.

Table 5-6. Bicyclist Respondents Categorized into Four Types of Cyclists

Type of Cyclist	Austin		Chicago		Portland	S.F.	D.C.	Total
	Barton Springs	Rio Grande	Dearborn	Milwaukee	Multnomah	Oak & Fell	L Street	
Strong and Fearless	0%	7%	5%	10%	3%	3%	16%	8%
Enthused and Confident	41%	33%	39%	36%	37%	40%	41%	39%
Interested But Concerned	59%	60%	56%	55%	60%	56%	44%	53%
No Way No How	-	-	-	-	-	-	-	-
Total	17	42	117	208	108	247	281	1,020

5.2.2.1 *Where are bicyclists going to and from?*

The bicyclist survey asked for the addresses of where the respondent was traveling from (origin) and to (destination) when they were intercepted to complete the survey. These addresses were geocoded for analysis to estimate how far out of their way cyclists may be going to use the new protected lane. In the absence of detailed route information, ESRI's Network Analyst tool was used to generate theoretical bicyclist travel routes, assuming that cyclists tend to minimize out-of-direction travel. Two sets of trip routes were run for each set of origin and destination points:

- Shortest Network Distance (Shortest Path) - A route solution that found the shortest network distance between each trip origin and destination. This simple method considered only distance and did not assign any benefit to travel on local streets or punishment for travel on high-speed arterials.
- Shortest Network Distance with Cycle Track (Assumed Path) - A route solution that required a cyclist to travel on the cycle track for at least one block. In this analysis each block of the cycle track was treated as a destination, and a route was found between each trip origin and the closest destination on the cycle track. A second route solution found the distance between the cycle track midpoint and the ultimate trip destination. Trip legs were aggregated, summed, and then analyzed against the shortest network distance.

In some cases trips were excluded from the analysis. This occurred when an interview respondent reported identical origin and destination points, or multiple origin and destination points. Trips over seven miles were also excluded to minimize the likelihood of including trips that were not exclusively taken by bicycle (e.g., to exclude combined bike and transit trips). Trip-end maps are shown in Figure 5-2 to Figure 5-5.

Figure 5-2. Austin Bicyclist Surveys - Geocoded Trip Ends

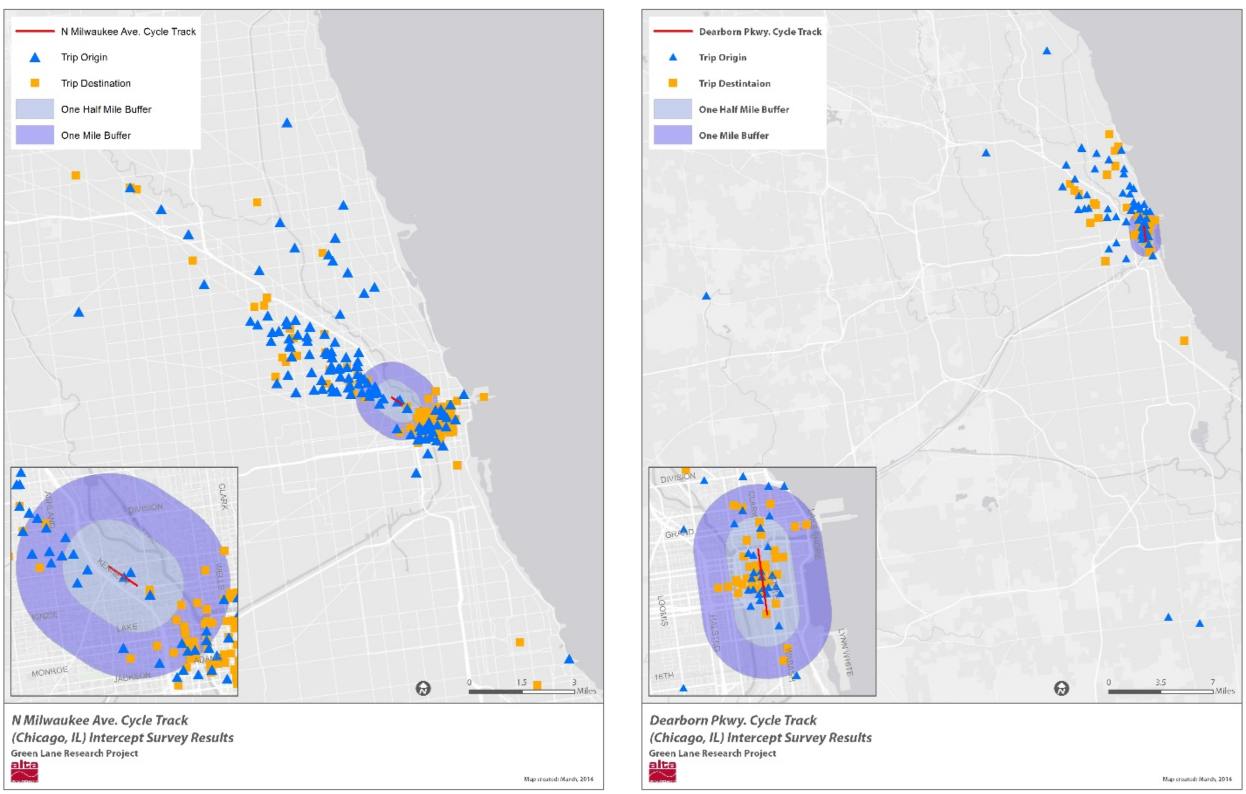


Figure 5-3. Chicago Bicyclist Surveys – Geocoded Trip Ends

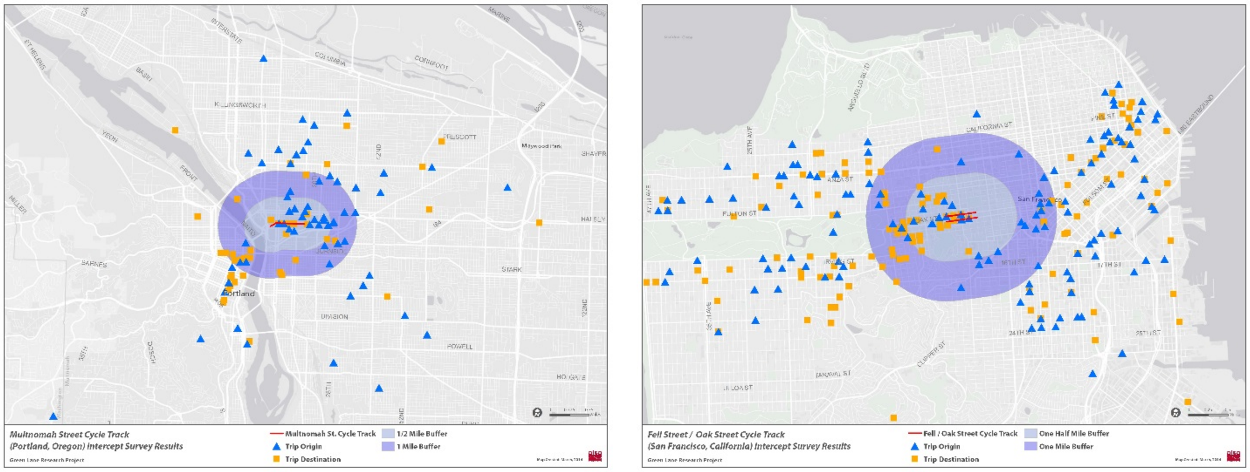


Figure 5-4. Portland and San Francisco Bicyclist Surveys – Geocoded Trip Ends

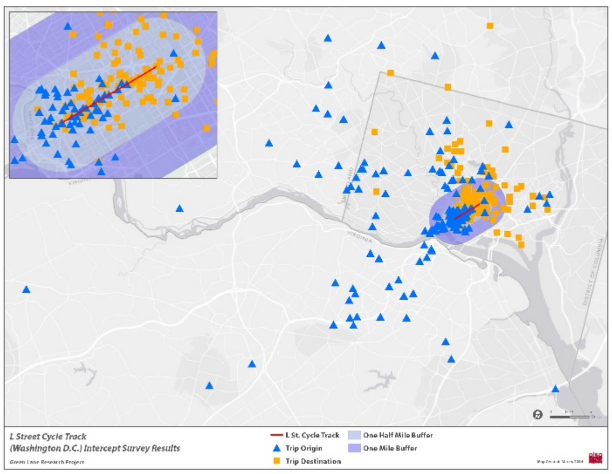


Figure 5-5. Washington D.C. Bicyclist Survey – Geocoded Trip Ends

5.2.2.2 Proximity to Protected Bike Lanes

Table 5-7 identifies the distance of the trip origin and destination (whichever is closest) from the protected lane. There appears to be a split between the facilities studied as to whether users had an origin or destination near the facility. For example, more than 80% of survey respondents reported either a trip origin or destination within a quarter mile of the L Street lane. Users of the Barton Springs facility in Austin and Dearborn in Chicago also tended to have an origin or destination relatively nearby. On Milwaukee Avenue in Chicago, by contrast, the closest trip origin or destination tended to be between 1-2 miles from the protected bike lane (75% of trips). Users of the Oak/Fell facility in San Francisco also tended not to have an origin or destination nearby. The differences across locations are likely indicative of the context of the given facility. For example, while L Street is located in downtown Washington, D.C., near many likely work (and other) destinations, the Milwaukee Avenue and Oak and Fell Street lanes serve as connectors between their city's downtown and more distant neighborhoods.

Table 5-7. Percent of Intercepted Bicyclists by Distance of Origin or Destination to Protected Bike Lane (Miles)

Location	Distance (miles) between closest origin or destination to protected lane								Total
	0.00 - 0.25	0.25 - 0.50	0.50 - 0.75	0.75 – 1.00	1.00 – 1.50	1.50 – 2.00	2.00 – 2.50	> 2.50	
Barton Springs, Austin	20%	30%	0%	0%	10%	30%	10%	0%	100%
Rio Grande, Austin	30%	17%	26%	17%	4%	0%	0%	4%	100%
Dearborn, Chicago	30%	25%	25%	12%	7%	2%	0%	0%	100%
Milwaukee, Chicago	4%	1%	4%	8%	39%	37%	8%	0%	100%
NE Multnomah , Portland	13%	38%	13%	7%	18%	8%	3%	0%	100%
Oak & Fell, San Francisco	10%	4%	10%	11%	14%	21%	18%	12%	100%
L Street, Wash. D.C.	80%	15%	2%	3%	0%	0%	0%	0%	100%

6 FINDINGS: RIDERSHIP CHANGES

This chapter summarizes the research findings related to the question of whether the facilities attract more cyclists. The question of increased levels of bicycling is answered here using three types of data: pre- and post-construction counts, intercept surveys of bicyclists, and resident surveys.

Overall count data show a substantial increase in ridership across all facilities within the first year of installation. Table 6-1 shows bicyclist count changes between the pre- and post-construction phases, averaging both the city count data and our video count data for the post-construction phase, as explained in Section 4.3.

The magnitude of change varies considerably between facilities. The count data reveal a positive trend, however, no clear pattern with respect to the existence of a striped bike lane in the pre-construction period versus no pre-existing bike lane (Figure 6-1). Results from the intercept survey suggest that fewer bicyclists on the routes with striped lanes prior to construction would have taken another route or mode previously, and that higher shares were already cycling on those streets before construction. The two one-way streets with two-way facilities (Rio Grande and Dearborn, shown in blue in the figure) saw the largest increase (as expected since bicycles can now travel in two directions).

Table 6-1. Overview of Change in Ridership

City	Facility	Pre-Existing Bike Facility	Increase (City Counts*)	Increase (Video Analysis**)	Average Count Increase	Citywide Increase 2010 - 2012***	Survey: share of cyclists who ride "more frequently
Austin	Barton Springs	No	58%	n/a	58%	39%	39%
	Bluebonnet	Bike Lane	46%	n/a	46%		n/a
	Rio Grande	Bike Lane	126%	n/a	126%		79%
Chicago	Dearborn	No	126%	215%	171%	21%	86%
	Milwaukee	Bike Lane	4%	38%	21%		31%
Portland	NE Multnomah	Bike Lane	39%	97%	68%	10%	51%
San Francisco	Oak	No	n/a	n/a	n/a	10%	44%
	Fell	Bike Lane	50%	42%	46%		28%
Washington, D.C.	L Street	No	67%	63%	65%	31%	66%
				Overall:	75%		

*City Counts considers pre- and post-installation counts conducted by the City
**Video Analysis also uses pre-installation counts conducted by the City, and compares them with post-installation counts from the study team's video review.
***Change in number of workers commuting by bicycle, based on American Community Survey 2010 and 2012 1-year estimates. Note that the margins of error for the ACS data are not considered.

The range in changes in bicyclist volumes may be due as much to the context in each city's network as the specific design of each facility. For example, Oak and Fell Streets in San Francisco were well-known bicycle routes prior to the new lanes because of the lack of good alternatives; they function as a key link between outer neighborhoods (including a path through Golden Gate Park) and other bicycle infrastructure leading to downtown. Streets with relatively high ridership before the installation of the protected lanes are likely to see smaller *percentage* increases in riders, particularly in this short timeframe (usually less than one year). Milwaukee in Chicago was the street with the highest ridership prior to construction, with 2-10 times as many bicycles compared with the other streets. The estimated 21% increase in riders on that facility represents a large *number*, larger than the total riders for some lanes.

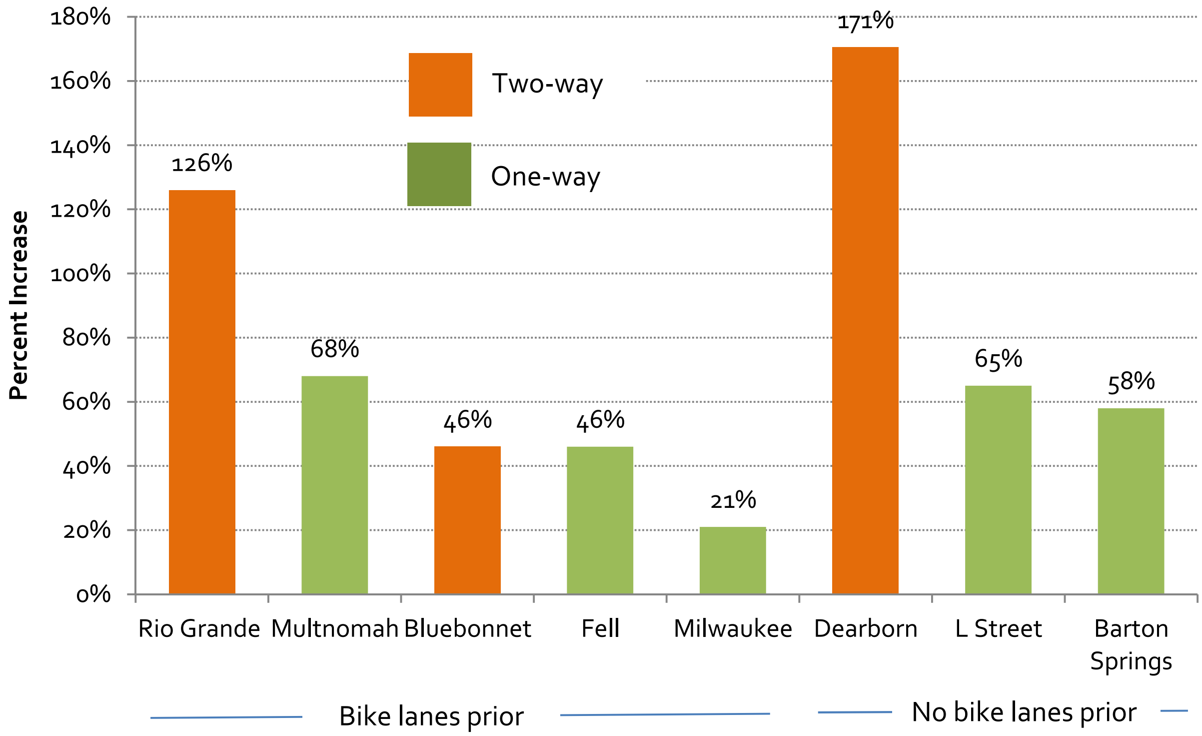


Figure 6-1. Changes in Volume of Bicycles after Protected Bike Lane Installation

Some of the ridership increases at each facility likely came from new riders (i.e., riders who, absent the protected bike lane, would have travelled via a different mode or would not have taken the trip). The increases also likely came from riders diverted from other nearby streets (i.e., riders who were attracted to the route because of the facility, but would have chosen to ride a bicycle for that trip regardless). Our intercept survey of bicyclists found that 10% would have made the trip by another mode and 1% would not have made the trip, indicating that there are some new riders attracted to the facilities. The remainder would have bicycled on a different route (24%) or the same route (65%). More details on the survey findings are in Section 6.3.

As explained in the methodology in Section 4.3, comparable count data on nearby alternatives was not available. Instead, the changes in ridership from the available count data are compared to changes in bicycle commuting using data from the 2010-2012 American Community Survey (ACS), which serves as a measure of overall bicycling in the city. In most cases, the increase in the number of bicycles on the street is higher than the increase in the number of commuters cycling citywide. However, our calculations based on the percentage change in the ACS counts does not take into account the margins of error associated with the ACS data.

The following two sections (6.1 and 6.2) provide more details of the count data comparisons.

6.1 Bicycle Counts Conducted By Cities

Each city conducted both before and after counts of bicyclists along the facility routes. Count data were from either automatic counters or two- to four-hour manual counts during peak AM or PM hours. Table 6-2 provides a summary of count days/times utilized to assess approximate post-construction ridership, along with notes on the pre-installation comparison period.

Bicyclist count data provided by each city show an increase in ridership across all facilities, and with most facilities showing increases of 50% or more on counts from one to two years prior at similar points in time. On average, counts at two-way protected facilities increased the most (Bluebonnet Lane and Rio Grande Street in Austin, and Dearborn Street in Chicago), with an average increase of 150%. Dearborn Street and Rio Grande Street, which saw the largest increases, went from being one-way streets to providing two-way travel for bicyclists, while Bluebonnet Lane was a two-way street with a part-time bike/parking lane. Routes with new one-way protected lanes (Barton Springs Road in Austin, Milwaukee Avenue in Chicago, NE Multnomah Street in Portland, Fell Street in San Francisco and L Street in D.C.) saw an average increase of 47%.

Count days had an impact on certain facilities. For example, one of the counts on Bluebonnet Lane did not have a comparable count time during the school year, and thus is compared to a period after the school year ended in 2012 – this likely accounts for part of the large increase. In the other direction, on Milwaukee Avenue in Chicago, the after count from September 2013 was taken on a very hot day (95 degrees during the PM commute) that was much warmer than the comparison day in September 2012, and may have accounted for the decrease in ridership seen during that count.

Table 6-2. Summary of Bicyclist Count Change Calculated from City Count Data

City	Facility	Location	Date (2013)	Day of Week	Count Time	# Hours	Bicycle Count	% Increase (similar period)	Notes on comparison period
Austin	Barton Springs	@ ~ Bouldin	5/6	Mon.	12am-12am	24	222	213%	May 2012 (Thurs)
			11/19-20	Tues/Weds	11am-11am	24	246	9%	Nov 2011 (Tues-Wed)
			Increase across two Barton Springs days:					58%	
	Bluebonnet	@ ~ Peach Tree	5/12	Weds	12am-12am	24	134	15%	May 2012 (Weds &Thurs)
		@ ~ Holland	5/12	Weds	12am-12am	24	106	123%	June 2012 (Thurs/Fri & Mon) -After school year.
		Increase across two Bluebonnet locations:						46%	
	Rio Grand	@ West 22 ½	11/18-19	Mon/Tues	11am-11am	24	746	126%	Oct. 2011 (Mon/Tues)
					Increase:			126%	
Chicago	Dearborn	@ Harrison	7/16	Tues.	430-630pm	2	166	538%	August 2012 (Wed)
		@ Washington	7/16	Tues.	430-630pm	2	467	151%	August 2012 (Wed)
		@ Kinzie	7/16	Tues.	430-630pm	2	523	75%	August 2012 (Wed)
		Increase across three Dearborn locations:						126%	
	Milwaukee	@ Elston	7/10	Weds	7am-9am	2	1153	-1%	July 2012 (Wed)
			8/14	Weds	7am-9am	2	1199	8%	August 2012 (Wed)
			9/10	Weds	7am-9am	2	1128	-1%	Sept 2012 (Wed). After period was 80 degrees.
			7/10	Weds	4pm-6pm	2	1078	2%	July 2012 (Wed)
			8/14	Weds	4pm-6pm	2	1077	26%	August 2012 (Wed)
			9/10	Weds	4pm-6pm	2	804	-11%	Sept 2012 (Wed). After period was 95 degrees.
			Increase across all Milwaukee days:					4%	
Portland	Mult.	@ 7th	7/25	Thurs	4pm-6pm	2	134	33%	Sept. 2012 (Tues & Weds)
		@ Wheeler	7/30	Tues	4-6pm	2	99	48%	July & Aug. 2012 (Thurs)
		Increase across two NE Multnomah locations:						39%	
SF	Fell	West of Scott			430-630pm	2	684	50%	Sept. 2011
					Increase:			50%	
DC	L Street	@ Connecticut	5/9	Thurs.	6am-10am	4	196	37%	June 2010, 2011, 2012 (Ave. of 3 midweek days)
			5/9	Thurs.	3pm-7pm	4	364	89%	June 2010, 2011, 2012 (Ave. of 3 midweek days)
			Increase across L Street time periods:					67%	

6.2 Bicycle Counts Conducted During Study Video Review

Counts conducted as part of the video analysis for this project suggest similar increases in ridership. Reviewed video segments with comparable pre-construction counts available (pre-construction counts were provided by the participating cities) are listed in Table 6-3, along with the average increase between the pre-construction period and the reviewed hours.

Table 6-3. Summary of PSU Video Review Count Data (when comparable "pre" data is available)

City	Facility	Location	Date	Time	# Bicyclists
Chicago	Dearborn Street	@ Congress Pkwy (Video Count)	10/2/2013	4-6 p.m.	199
			10/3/2013	4-6 p.m.	73
			10/4/2013	4-6 p.m.	176
		Compare to: @ Harrison Street	8/28/2012	430-630 p.m.	26
		Post-Construction Count Increase:			474%
		@ Madison Street	10/2/2013	4-6 p.m.	551
			10/3/2013	4-6 p.m.	315
			10/4/2013	4-6 p.m.	417
		Compare to: @ Washington Street	8/28/2012	430-630 p.m.	186
		Post-Construction Count Increase:			130%
		@ Randolph Street	10/2/2013	4-6 p.m.	586
			10/4/2013	4-6 p.m.	423
			10/22/2013	4-6 p.m.	269
		Compare to: @ Washington Street	8/28/2012	430-630 p.m.	186
		Post-Construction Count Increase:			129%
	Milwaukee Avenue	@ Elston Avenue	9/25/2013	4-6 p.m.	859
			9/26/2013	4-6 p.m.	946
		Compare to: @ Elston Avenue	9/12/2012	4-6 p.m.	744
			10/10/2012	4-6 p.m.	566
		Post-Construction Count Increase:			38%
D.C.	L Street	@ Connecticut Avenue	5/14/2013	7-9 a.m.	90
			5/15/2013	7-9 a.m.	108
			6/20/2012	7-9 a.m.	103
		Post-Construction Count Increase:			-4%
		@ Connecticut Avenue	5/14/2013	4-6 p.m.	234
			5/15/2013	4-6 p.m.	228
			6/20/2012	4-6 p.m.	100
		Post-Construction Count Increase:			131%
Portland	NE Multnomah Street	@ 7th Street (WB)	10/8/2013	4-6 p.m.	25
			10/9/2013	4-6 p.m.	38
			10/11/2011	4-6 p.m.	16
		Post-Construction Count Increase:			97%
San Francisco	Fell Street	@ Baker Street	9/25/2013	7-9 a.m.	185
			9/26/2013	7-9 a.m.	178
		Compare to: @ Divisadero	9/26/2012	7-9 a.m.	116
			9/27/2012	7-9 a.m.	134
		Post-Construction Count Increase:			45%

City	Facility	Location	Date	Time	# Bicyclists
		@ Baker Street	9/25/2013	11 a.m. - 1 p.m.	127
			9/26/2013	11 a.m. - 1 p.m.	154
		Compare to: @ Divisadero	9/26/2012	11 a.m. - 1 p.m.	118
			9/27/2012	11 a.m. - 1 p.m.	131
		Post-Construction Count Increase:			13%
		@ Baker Street	9/25/2013	4-6 p.m.	444
			9/26/2013	4-6 p.m.	459
		Compare to: @ Divisadero	9/26/2012	4-6 p.m.	297
			9/27/2012	4-6 p.m.	295
		Post-Construction Count Increase:			53%
		@ Baker Street (Sat.)	9/28/2013	12-2 p.m.	400
		Compare to: @ Divisadero (Sat.)	9/29/2012	12-2 p.m.	316
		Post-Construction Count Increase:			27%
		@ Broderick Street	9/25/2013	7-9 a.m.	405
			9/26/2013	7-9 a.m.	346
		Compare to: @ Oak bt Broderick & Divisadero	6/5/2012	7-9 a.m.	298
	Oak Street	Post-Construction Count Increase:			26%
		@ Divisadero Street	9/25/2013	7-9 a.m.	422
			9/26/2013	7-9 a.m.	382
		Compare to: @ Oak bt Broderick & Divisadero	6/5/2012	7-9 a.m.	298
		Post-Construction Count Increase:			35%

6.3 Findings from Intercept Surveys of Bicyclists

The intercept survey of bicyclists can help explain whether any changes in the number of cyclists on the facilities are due to new riders, riders shifting routes, and/or riders riding more often. Asked how they would have made the intercepted trip prior to the construction of the new facility, 10% of respondents indicated they would have taken a mode other than a bicycle (Table 6-4). Dearborn Street had the highest rate of those who would have taken their trip by another mode at 20%, while other facilities ranged from about 6% to 10%. Nearly one-quarter (24%) stated they would have bicycled but on a different route.

Table 6-4. Bicyclist Mode/Route Without the New Facility

City	Route	Consider the trip you were making when you were handed the postcard. Before the [facility] was built, how would you have made this trip?				
		By bicycle, using this same route	By bicycle, using another route	By Other Mode	Would not have taken trip	Total
Austin	Barton Springs	65%	29%	6%	0%	17
	Rio Grande	55%	38%	7%	0%	42
Chicago	Dearborn	17%	60%	21%	2%	123
	Milwaukee	83%	6%	10%	1%	231
Portland	NE Multnomah	56%	34%	10%	0%	109
San Francisco	Oak Street	75%	18%	6%	1%	247
	Fell Street	80%	11%	7%	1%	247
Washington, D.C.	L Street	56%	32%	10%	2%	300
Total*		65%	24%	10%	1%	1316

*Oak and Fell respondents are counted twice in the total numbers – once for their responses regarding Oak and once for Fell.

Nearly half (49%) of bicyclists indicated that they were travelling on this route more frequently than they were prior to the facilities' construction (Table 6-5). This ranged between a low of 28% for Fell Street in San Francisco and 31% for Milwaukee Avenue in Chicago (where over two-thirds of bicyclists stated they were travelling on the route at about the same frequency as before) to a high of 86% for Dearborn Street, where the street appears to be much more attractive for bicycling than before.

Table 6-5. Bicyclist Survey – Change in Stated Frequency of Riding

City	Route	Since the [FACILITY] was built, do you travel on this route:				
		Less frequently	More frequently	About the same	This is my first time on this route	n
Austin	Barton Springs	0%	39%	56%	6%	18
	Rio Grande	0%	79%	12%	10%	42
Chicago	Dearborn	1%	86%	7%	6%	123
	Milwaukee	1%	31%	67%	1%	231
Portland	NE Multnomah	4%	51%	43%	2%	109
San Francisco	Oak Street	0%	44%	54%	2%	247
	Fell Street	0%	28%	72%	0%	247
Washington, D.C.	L Street	1%	66%	30%	3%	300
Total*		1%	49%	48%	2%	1,317

*Oak and Fell respondents are counted twice in the total numbers – once for their responses regarding Oak and once for Fell.

We also asked how the intercepted bicyclists' overall amount of cycling had changed because of the new facility. Not surprisingly, no one indicated that their frequency of overall bicycling decreased (Table 6-6). However, nearly a quarter of respondents stated that their overall frequency of bicycling increased. On Dearborn Street, over half of respondents indicated that their bicycling had increased because of the new protected bike lanes, while Barton Springs, Rio Grande, Milwaukee and L Street all had around a third of respondents state the same.

Table 6-6. Change in Overall Levels of Bicycling by Intercepted Bicyclists

Because of the protected bike lane, how often I ride a bicycle overall has . . .		Decreased	Increased	n
Austin	Barton Springs	0%	33%	18
	Rio Grande	0%	40%	40
Chicago	Dearborn	0%	53%	120
	Milwaukee	0%	32%	225
Portland	NE Multnomah	0%	21%	106
San Francisco	Oak Street	0%	19%	238
	Fell Street	0%	23%	240
Washington, D.C.	L Street	0%	30%	292
Total		0%	24%	1,279

6.3.1 How far out of the way will bicyclists go to ride on the protected facilities?

Using the analysis of the stated trip origin and destination of intercepted bicyclists, the study team examined how far out of their way the cyclists might be going to use the new protected lane. Table 6-7 shows the estimated total trip length of the trips bicyclists were taking when they were intercepted and asked to take our survey, assuming they took the shortest possible path between the protected lane and their origin and destination. There were very few trips less than one mile. The exception was Rio Grande, in Austin, where about 27% of the trips were one mile or less. The D.C. and Portland lanes had the next shortest trips, with about half being one to three miles. Trips tended to be longer on Oak/Fell in San Francisco and Milwaukee Avenue in Chicago, where nearly half of trips were between three and five miles. A majority of the trips (60%) on the Barton Springs cycle track were four miles or more.

For comparison, Table 6-8 shows the estimated trip distance if they had taken the shortest possible path (whether or not it included the street with the new protected lane), and Table 6-9 illustrates the percentage difference between the shortest and assumed path. Out-of-direction travel was minimal for a large percentage of users on the Barton Springs and Milwaukee lanes, which serve as the primary direct connections between downtown and surrounding neighborhoods in their respective cities. Most trips on the Rio Grande, Dearborn, Portland, and San Francisco protected bike lanes required up to 5% of out-of-direction travel. D.C. had the highest percentage of users with out-of-direction travel greater than 5% (42% of users), followed by San Francisco (30%), Dearborn (26%), and Portland (21%). The table also shows the share of bicyclists who agreed that they would go out of their way to use the protected lane. There does not appear to be a strong correlation between agreement with that statement and the estimated level of out-of-direction travel.

Table 6-7. Trip Distance (Assumed Path via the Protected Lane)

Facility, City	Percent of trips longer than:						
	6 mi.	5 mi.	4 mi.	3 mi.	2 mi.	1 mi.	.5 mi.
Barton Springs, Austin	0%	10%	60%	70%	90%	100%	100%
Rio Grande, Austin	4%	8%	21%	25%	34%	73%	90%
Dearborn, Chicago	14%	30%	42%	58%	74%	93%	98%
Milwaukee, Chicago	8%	22%	46%	76%	95%	98%	99%
NE Multnomah, Portland	2%	10%	26%	44%	83%	94%	97%
Oak & Fell, San Francisco	11%	28%	52%	76%	90%	98%	99%
L Street, Wash. D.C.	6%	15%	22%	36%	58%	88%	97%

Table 6-8. Cumulative Trip Distances (Shortest Path)

Facility, City	Percent of trips longer than:						
	6 mi.	5 mi.	4 mi.	3 mi.	2 mi.	1 mi.	.5 mi.
Barton Springs, Austin	0%	10%	60%	70%	90%	100%	100%
Rio Grande, Austin	4%	8%	17%	26%	35%	70%	92%
Dearborn, Chicago	14%	26%	40%	56%	72%	93%	98%
Milwaukee, Chicago	7%	23%	47%	77%	96%	99%	100%
NE Multnomah, Portland	2%	5%	25%	45%	83%	96%	99%
Oak & Fell, San Francisco	7%	23%	43%	73%	89%	99%	100%
L Street, Wash. D.C.	5%	12%	19%	32%	55%	86%	96%

Table 6-9. Deviation from Shortest Path to Ride on Protected Facility

Location	Cumulative Estimated Deviation from Shortest Path					"I would go out of my way to ride on [this street] compared to other streets"	
	>30%	>20%	>10%	>5%	>1%	Agree Somewhat	Agree Strongly
Barton Springs, Austin	0%	0%	0%	10%	30%	38%	44%
Rio Grande, Austin	0%	0%	0%	13%	52%	48%	40%
Dearborn, Chicago	4%	4%	16%	26%	62%	33%	59%
Milwaukee, Chicago	2%	3%	3%	6%	15%	53%	33%
NE Multnomah, Portland	2%	2%	4%	21%	50%	48%	31%
Oak & Fell, San Francisco	4%	10%	22%	30%	72%	49%	33%
L Street, Wash. D.C.	1%	6%	23%	42%	82%	44%	43%

6.4 Findings from Resident Surveys

All residents were asked about their general travel behavior and changes in the past two years. Table 6-10 presents responses to changes in the number of bicycle trips grouped by respondent bicyclist type. Not surprisingly, almost none of those in the "No Way No How" group were bicycling more than two years ago. However, between 30% and 37% of residents typed into the other groups indicated that they are riding a bicycle more often now. Overall, those who indicated they are riding more now outnumber those who are riding less by two and half times.

Table 6-10. Compared to two years ago, are you taking more or fewer trips by bicycling?

Participant Group:	Strong and Fearless	Enthused and Confident	Interested but Concerned	No Way No How	Total
More Trips	30%	37%	31%	1%	26%
No Change	60%	51%	57%	91%	63%
Fewer Trips	10%	12%	12%	8%	11%
n	91	491	841	393	1,816

Residents were also asked to indicate whether the number of people riding bicycles on the street had increased or decreased due to the bike lanes (regardless of whether the respondents themselves are riding a bicycle). As seen in Table 6-11, well over half of each participant group (and 66% of all respondents) indicated that the number of people they see bicycling had increased somewhat or increased a lot. Only 1% indicated that the number of bicyclists had decreased.

Table 6-11. Perception of Number of Bicyclists (all respondents)

Because of the [facility],		Strong and Fearless	Enthused and Confident	Interested but Concerned	No Way No How	Total
the number of people I see riding bikes on the street has . . .	Decreased	2%	0%	1%	2%	1%
	Increased	74%	70%	67%	57%	66%
	n	98	522	815	487	1,922

Residents who had bicycled on the facility were asked about the facility's influence on where and how often they ride a bicycle, as shown in Table 6-12. Note that a few respondents (30) who were categorized into the *No Way No How* group based on statements about current and intended bicycling behavior nonetheless indicated that they had ridden on the facility since it was built, and are included in this table. Nearly three-quarters stated they are now more likely to choose the street with the protected bike lane as opposed to other streets. Among this group of people that have ridden a bicycle on the protected bike lane, over 40% indicated that they are now riding a bicycle more often because of the new facility.

Table 6-12. Residents Who Bicycle on Facility: Influence on Where and How Often to Bicycle

Question	Response	Strong and Fearless	Enthused and Confident	Interested but Concerned	No Way No How	Total
Because of the [facility], the likelihood that I will choose to bicycle on this street as opposed to other streets has . . .	Decreased	5%	2%	4%	34%	5%
	Increased	43%	78%	78%	23%	73%
	n	58	287	383	35	763
Because of the [facility], how often I ride a bicycle overall has . . .	Decreased	5%	1%	5%	23%	4%
	Increased	20%	45%	43%	7%	41%
	n	55	283	379	30	747

7 FINDINGS: DESIGN EVALUATION

This chapter seeks to answer the research question about how well the design features of the facilities work. To do so, comprehension and compliance perceptions from the survey responses and paired them with observations from the video were summarized. The focus of the analysis is on intersection designs, which is a critical component of making the protected lane concept function. The chapter first reviews the designs of mixing zones, and then examines the performance of the bicycle-specific signals. The final section reviews some elements of design that were only evaluated at one or two locations (loading zones, transit stops, minor driveways, understanding of green pavement markings, and width related to two-way sections).

7.1 Intersections

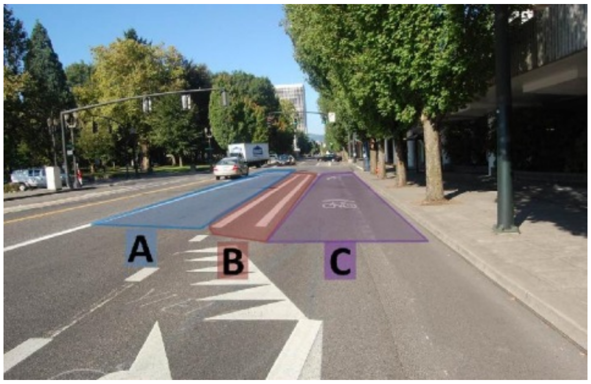
Each of the facilities evaluated presented different designs for bicycles to mix with turning motor vehicle traffic. The designs accomplish this primarily through striping, the use of green pavement markings, shared lane-use markings (sharrows), and the use of flexpost or safe hit delineators. As shown in Figure 7-1, the contexts evaluated include both left- and right-turn designs. Driver behaviors are likely to be different merging/turning left or right but the sample of designs is too small to make many observations about this difference.

Table 7-1 summarizes the through bicycle volumes, the turning vehicle volumes, and the design dimensions for each intersections. The table also includes the average hourly volumes from the 2-day period in the video data collection. Figure 7-2 present the plan view schematics for each of the intersections studied. The design dimensions and most details are shown (note signage is not shown and was not evaluated). The expected driver and cyclists behaviors at these intersections are presented in section 7.1.1.

In general, there are three different design approaches that were evaluated. First, some designs require the bicycles and turning vehicles to "mix" in the same space. These designs are called "mixing zones". The second approach moves the through bicycle from the protected lane near the curb to the left or right of the turning traffic into a narrow through bike lane. These are called "turning zones". There is a defined turn/merge gap for this maneuver. These through bike lanes are marked with dotted lines recognizing that larger vehicles will probably encroach on the bike lane due to the narrow widths of the turning lanes. The third design involves signalization of the bicycle movement (discussed in the subsequent section).

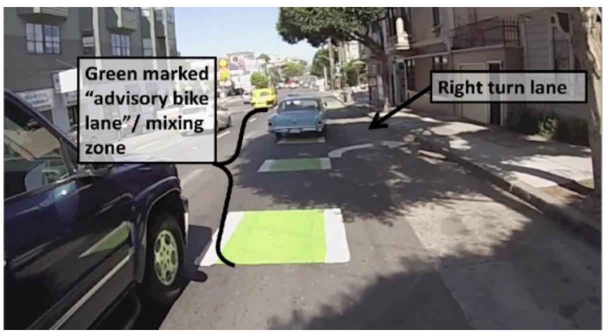
The turning vehicle volumes are more consistent over the three time periods shown in the table. The largest volume of turning vehicles is in Washington DC at L Street and 15th (177 in average period), though NE Multnomah/9th and Oak/Divisadero are also high (155 and 154, respectively). The bicycle volumes vary much more between the time periods and locations. The largest number of bicycles are using the San Francisco intersections with the lowest counts in Portland at NE Multnomah / 9th.

In the following subsections, the self-reported and observed behaviors of people on bicycles and people driving are presented.



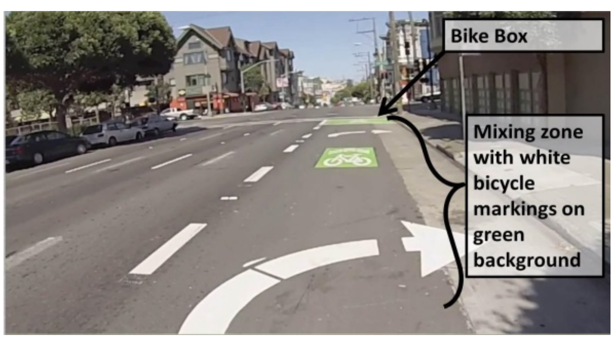
Mixing Zone with Yield Entry Markings
Photo from survey (shown): NE Multnomah and NE 9th Ave
Video Location(s): NE Multnomah and NE 9th Ave

Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)
Photo from survey (shown): L Street
Video Location(s): L Street/ 15th Street, L Street/ Connecticut



Turning Zone with Unrestricted Entry and Through Bike Lane (TBL)
Photo from survey (shown): Oak St. and Divisadero St.
Video Location(s): Oak St. and Divisadero St.

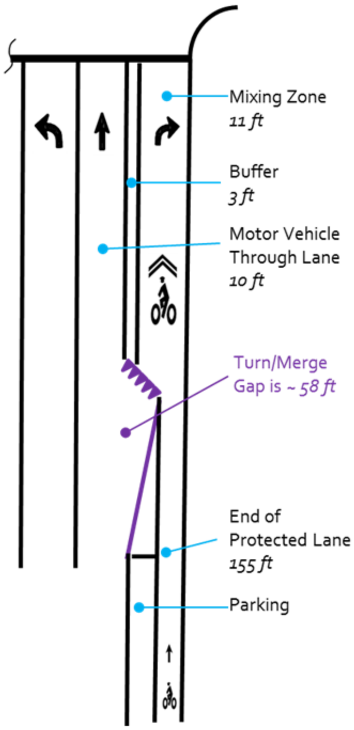
Turning Zone with Unrestricted Entry and Through Bike Lane (TBL)
Photo from survey (shown): Fell St. and Divisadero St.
Video Location(s): No video



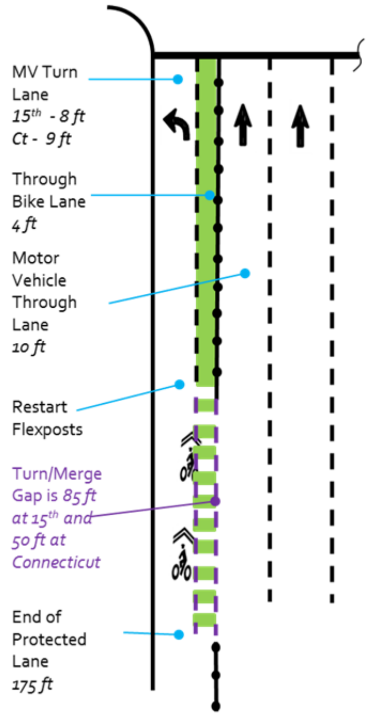
Mixing Zone with Sharrow
Photo from survey (shown): Oak St. and Broderick St.
Video Location(s): Oak St. and Broderick St

Mixing Zone with Green Coloring
Photo from survey (shown): Fell St. and Broderick St.
Video Location(s): Fell St. and Baker St.

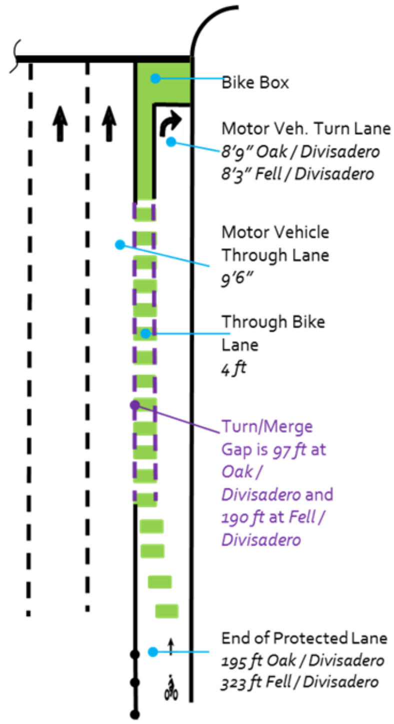
Figure 7-1. Intersection Designs Evaluated



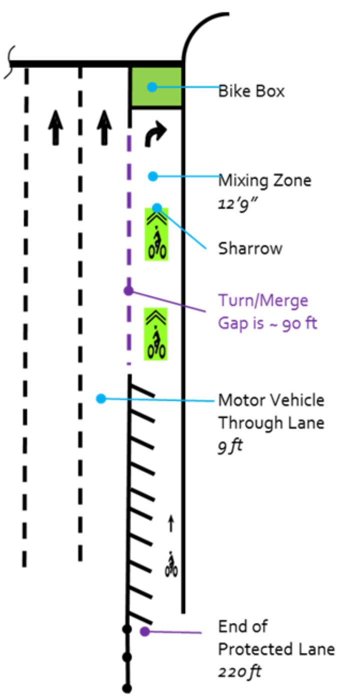
Mixing Zone with Yield Entry Markings
NE Multnomah and NE 9th Ave



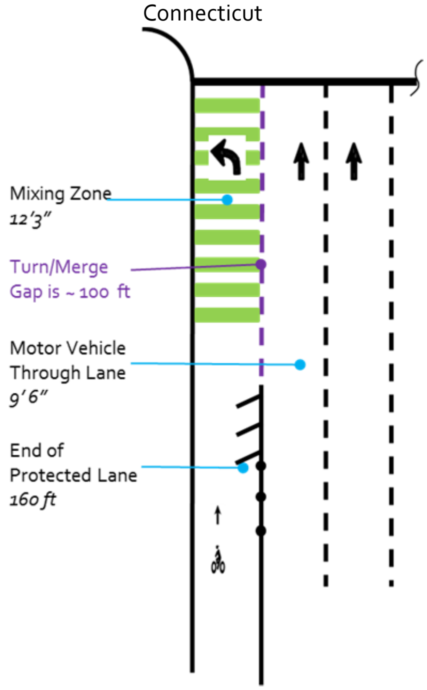
Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)
L Street/ 15th Street, L Street/ Connecticut



Turning Zone with Unrestricted Entry and Through Bike Lane (TBL)
Fell St. and Divisadero St
Oak St. and Divisadero St



Mixing Zone with Sharrow
Oak St. and Broderick St



Mixing Zone with Green Coloring
Fell St. and Baker St

For each figure:

Dimension is width for mixing zone, motor vehicle turn lane, motor vehicle through lane, through bicycle lane.

End of protected lane is measured from the stop bar.

Turn merge gap is length.

Figure 7-2 Plan Schematics for Intersections (Not to Scale and Not all Design Elements Shown)

Table 7-1 Summary of Design Dimensions and Exposures

Design Type	Intersection	Direction of Turning Traffic	Through Bikes (Avg. Hour Count)			Turning Vehicles Per Hour (Avg. Hour Count)			Width of Vehicle Turning Lane (ft)	Width of Through Bike Lane or Buffer (ft)	Turn Merge Gap (ft)
			AM	MID	PM	AM	MID	PM			
Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)	L Street / 15th	Left	37	43	110	177	146	173	8	4	85
Turning Zone with Post Restricted Entry and TBL	L Street / Connecticut	Left	50	45	116	110	103	125	9	4	50
Turning Zone with Unrestricted Entry and TBL	Oak / Divisadero	Right	201	59	96	126	128	154	8'9"	4	97
Turning Zone with Unrestricted Entry and TBL	Fell / Divisadero	Left	No Video						8'3"	4	323
Mixing Zone with Yield Entry Markings	NE Multnomah / 9th	Right	31	15	20	94	133	155	11'	3	85
Mixing Zone with Sharrow Marking	Oak / Broderick	Right	188	52	83	24	19	25	12'9"	-	90
Mixing Zone with Green Skip Coloring	Fell / Baker	Left	91	70	226	27	40	48	12'3"	-	100

Note: Peak bicycle volume and corresponding vehicle volume highlighted.

7.1.1 Definition of Expected User Behaviors

In order to evaluate the designs, the expected behaviors need to be defined. While the expected behaviors are labeled "correct" in our analysis other observed behaviors are sometimes acceptable. To the degree to which the incorrect behavior is critical issue depends on the situation. In Figure 7-2, the appropriate turn/merge gap is identified with purple color (light gray in black and white print).

Table 7-2 Expected User Behaviors

Design Type	Through Bicycle Behavior	Driver Turning Behavior
Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)	From the protected lane, follow sharrows through the turn/merge gap to the through bicycle lane, positioning themselves completely in TBL	From the through vehicle lane, cross the through bicycle lane at the turn/merge gap and position vehicle for turn entirely in motor vehicle turn lane
Turning Zone with Unrestricted Entry and TBL	From the protected lane, follow the TBL marking through the turn/merge gap to the through bicycle lane positioning themselves completely in TBL	
Mixing Zone with Yield Entry Markings	From the protected lane, enter the mixing zone (riding over sharrows if present), positioning themselves completely in mixing zone	From the through vehicle lane, enter the mixing zone at the turn/merge gap and position vehicle for turn entirely in mixing zone
Mixing Zone with Sharrow Marking		
Mixing Zone with Green Skip Coloring		

7.1.2 Bicyclist Understanding

This section summarizes survey and video findings related to the cyclists' understanding of using the mixing zone.

7.1.2.1 Findings from Survey

Table 7-3 summarizes the responses to two questions from the intercept surveys that gauged cyclists' understanding of the designs. The first question asked about respondents' level of agreement with the statement, "I understand where I am supposed to ride when approaching the intersection." The self-reported understanding of each design was very high and consistent. Over 91% of respondents agreed with the statement for each design. Some difference does exist between the percent of "strongly agree" responses. The strongest agreement was for the *Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)* design in Washington, D.C. (85% strongly agree). The similar design in San Francisco but without the restricted entry at the Fell/Divisadero intersection had the second-highest level of strong agreement (81%). The same design but with right-turning traffic at Oak/ Divisadero has lower strong agreement (75%), but the same total agreement (98%). The two other designs in San Francisco (*Mixing Zone with Green Skip Coloring* and *Mixing Zone with Sharrow Marking*) had similar agreement levels (74% and 71%, respectively). Finally, the *Mixing Zone with Yield Entry Markings* used in Portland had the lowest strong agreement with this statement (91% total— 63% strongly agree, 28% somewhat agree), though still very high.

For the three designs using Through Bike Lanes (TBLs) that suggest cyclists to follow a path through the intersections, intercepted cyclists were asked their agreement with the statement, "I usually follow the bicycle lane marking and move over to the right/left (into the green marked bike lane) when approaching the intersection." The responses are summarized in Table 7-3. Cyclists had high and consistent level of overall agreement with this statement. For the D.C. design with flexposts and sharrows indicating the desired path, the total agreement was 96% of responses (82% strongly agree, 14% somewhat agree). In San Francisco, the overall agreement was nearly identical and similar to D.C. (95% and 96% overall agreement). However, there was a lower percentage of strong agreement in San Francisco (69% strong agreement).

Table 7-3. Positioning Related Questions from the Cyclist Intercept Survey

Question	Intersection	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
I understand where I am supposed to ride when approaching the intersection.	Turning Zone with Post Restricted Entry and Through Bike Lane (TBL): L Street	1%	2%	12%	85%	283
	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	0%	2%	23%	75%	236
	Turning Zone with Unrestricted Entry and TBL: Fell/Divisadero	0%	2%	17%	81%	242
	Mixing Zone with Yield Entry Markings: NE Multnomah / 9th	5%	5%	28%	63%	170
	Mixing Zone with Sharrow: Oak/Broderick	0%	2%	26%	71%	231
	Mixing Zone with Green Skip Coloring: Fell/Broderick	0%	3%	22%	74%	239
I usually follow the bicycle lane marking and move over to the right/left (into the green marked bike lane) when approaching the intersection.	Turning Zone with Restricted Entry and TBL: L Street	1%	3%	14%	82%	283
	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	1%	4%	26%	69%	234
	Turning Zone with Unrestricted Entry and TBL: Fell/Divisadero	0%	4%	27%	69%	241

Communicating when a street space is shared for two purposes— right-turning vehicles and through bicycles— is a design challenge. Therefore, in the cyclist survey in Portland and the resident survey (that includes users of all modes) in San Francisco, questions were asked about the proper lane position for a bicyclist continuing through the intersection by selecting a region of a photograph of the intersection. A sample of the image of the survey question for Portland can be seen in Figure 7-1. This type of question was not asked in the D.C. survey. Table 7-4 summarizes the self-reported understanding of correct lane positioning for bicycles going through the intersection and turning right. In the table, the correct response is bolded and in green text and the cell is shaded since this varies for each design.

When asked to identify the correct lane for through bicyclists, the *Turning Zone with Unrestricted Entry and TBL* designs in San Francisco elicited the highest understanding. A total of 93-94% of respondents identified the correct lane for the through cyclists. For the *Mixing Zone with Sharrow*, 79% correctly identified the mixing zone as the proper location for bicyclists continuing straight. Approximately 20% of respondents incorrectly identified the motor-vehicle through lane as the space for through bicycles. As seen in the photo in Figure 7-1, the sharrow and right-turn- only pavement marking are both visible. (Note that right-turning volume is low at this intersection, which is partially why this design was chosen). The responses were similar for the *Mixing Zone with Green Skip Coloring*; 73% correctly identified the mixing zone and 25% of respondents incorrectly identified the motor-vehicle through lane as the correct location. Again, the right-turn- only pavement marking might be communicating this is right-turn-only lane for all vehicles. In Portland, nearly 55% of respondents incorrectly identified the buffer space in the *Mixing Zone with Yield Entry Markings* as the proper location for through cyclists. A possible interpretation of the low comprehension is that, in this case, the buffer markings resemble a bicycle lane. In the NACTO design guidance, the buffer space is hatched which might help direct cyclists to the mixing zones. If the shared turn lane is blocked by vehicle, the video shows that a cyclists will move to the left to get by both faster and easier. Also, the *Mixing Zone with Yield Entry Markings* in the only design that does not include green markings of any sort.

When asked to identify the correct lane for right-turning bicyclists, the designs essentially flipped in the correct comprehension. Over 96% of the respondents correctly identified the mixing zone lane for the *Mixing Zone with Yield Entry Markings,* the *Mixing Zone with Sharrow,* and the *Mixing Zone with Green Skip Coloring* designs as the correct lane for turning bicycles. Interestingly, for the two *Turning Zone with Unrestricted Entry and TBL* designs, about 25% of respondents thought a turning bicyclist should be in the TBL to make a left or right turn. A possible interpretation is the respondents believe when road space is marked with green, bicycles should be travelling within it.

Table 7-4. Comprehension of Mixing Zone Markings Self-Reported in Surveys, Bicycle Movements

Movement and Options		Turning Zone with Unrestricted Entry and TBL: Fell/Divisadero	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	Mixing Zone with Yield Entry Markings: NE Multnomah/ 9th	Mixing Zone with Sharrow: Oak/Broderick	Mixing Zone with Green Skip Coloring: Fell/Baker
A bicyclist continuing straight should be in:	Mixing Zone/MV Turn Lane	4%	5%	**51%**	**79%**	**73%**
	Through Bike Lane or *Buffer	**94%**	**93%**	*55%	n/a	n/a
	MV Through Lane	2%	2%	0%	20%	25%
	n	480	512	107	105	511
A bicyclist turning right/left should be in:	Mixing Zone/MV Turn Lane	**73%**	**74%**	**98%**	**97%**	**96%**
	Through Bike Lane or *Buffer	27%	24%	*4%	n/a	n/a
	MV Through Lane	0%	1%	0%	1%	2%
	n	507	511	106	515	511

Source: Resident survey in San Francisco, Cyclist survey in Portland
Note: Correct response in bold green type with grey shading. Respondents allowed to choose multiple response options, so column percentages may not add to 100%.
* means percentage refers to the buffer zone.

7.1.2.2 Findings from Video Review

In the video review, the paths and actions of cyclists through the intersection were observed and recorded. To attempt to control for the influence of motor vehicles on path choice, the video review noted whether a vehicle was present. Table 7-5 summarizes the results of the video review for the TBL in Washington, D.C., and San Francisco. Overall volumes were shown earlier in report and note the table excludes bicyclists not using the protected facility. The table shows that bicyclists use the

TBLs at L Street at Connecticut Avenue and Oak Street at Divisadero Street nearly as often when there are not cars as when there are — about 87% of the time with the exception of L Street at 15th Street. At L Street and 15th Street, bicyclists only use the TBL when cars aren't present two-thirds of the time; however, this is probably due to the number of bicyclists turning left onto the 15th Street protected bike lanes. Though not shown in the table, additional analysis found that the use of the TBL is 84% for through bicyclists, which is comparable to the other two locations. The video review also noted when cars forced bicyclists out of the TBL. This is relatively infrequent at the L Street intersections (about 4% of the observations when cars are present) because the design has restricted entry and shorter turning/merge space. At the Oak/Divisadero location, however, this occurs more frequently, about 13% of the time. This primarily occurs when motor vehicles merge late or straddle the TBL (which is shown in Table 7-10 to occur for 21% of turning motor vehicles).

Table 7-5. Observed Use of Through Bike Lanes in SF and D.C. Designs

Through Bicyclist Lane Use	Turning Zone with Post Restricted Entry and TBL: L Street/ 15th Street:		Turning Zone with Post Restricted Entry and TBL: L Street/ Connecticut		Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero:	
	No Cars Present	Cars Present	No Cars Present	Cars Present	No Cars Present	Cars Present
In TBL	68%	89%	87%	93%	83%	81%
Not in TBL	32%	8%	13%	3%	17%	6%
Forced out by MV	0%	3%	0%	4%	0%	13%
n	225	448	434	320	1237	404

Note: Excludes bicyclists observed not in protected lane or wrong way cyclists

Table 7-6 shows the observed through lane use for bicyclist for the *Mixing Zone with Yield Entry Markings* and the *Mixing Zone with Sharrow* designs. The schematics defining each space are in Figure 7-2. Over half of all bicyclists surveyed thought they should use the buffer space if continuing straight at NE Multnomah/9th. In the observed video, only about 15% of the observed cyclists used the buffer space when a car was not present. When a car was present, the buffer space was more than twice as likely to be used (37%). These percentages are significantly lower than what might have been expected given the responses to the survey in Table 7-6. The observed behavior possibly reveals a preference to be out of the vehicle turn lane and reveals a potential weakness of the mixing zone designs. At the Oak/Broderick intersection, there was a significant difference in the cyclists' path when cars were present or not, as shown in Table 7-6. When there were no cars present, about 76% of cyclists rode directly over the sharrows in the center of the lane. The video review did not log whether the cyclists went to right of left of the sharrow. This may be partially influenced by the sharrows being located in the asphalt, not the concrete, section of the lane, and cyclists seemed to want to avoid the rough concrete section. When vehicles were present, how often the cyclists' path took them over the sharrows declined to 30%.

Table 7-6. Observed Use of Mixing Zone in Portland and Sharrow Paths in San Francisco

Mixing Zone with Yield Entry Markings: NE Multnomah/9th			Mixing Zone with Sharrow: Oak/Broderick		
Through Bicyclist Lane Use	No Cars Present	Cars Present	Through Bicyclist Lane Use	No Cars Present	Cars Present
In Mixing Zone	85%	63%	Cyclist Rode Over Sharrow	76%	30%
Uses Buffer	15%	37%	Cyclist Did Not Ride Over Sharrow	24%	70%
n	163	87	n	115	1351

Note: Excludes Bicyclists Observed Not in Protected Lane or Wrong-Way Cyclists

7.1.3 Driver Understanding of Turning Location

This section summarizes survey and video findings related to motorists' understanding and bicyclists' perception of motorists using the mixing zone.

7.1.3.1 Findings from the Surveys

As described, the cyclist survey in Portland and the resident survey in San Francisco asked questions about the proper lane position for a driver turning right (or left) at the intersection by selecting a region of a photograph of the intersection. Table 7-7 summarizes the answers to questions for each of the designs. The mixing of the perspectives of cyclists and residents (who drive and cycle) is a result of limited space on the Portland resident survey. Most cyclists presumably drive (see demographics) but will have a different perspective than someone who only drives. When asked where motor vehicles should be when making a turn, the self-reported understanding of where motor vehicles should turn from is high for all the designs in San Francisco (92% at Oak/Divisadero; 95% at Oak/Broderick; 97% at Fell/Divisadero; and 95% at Fell/Baker). Interestingly, about 21% of respondents on the NE Multnomah/9th intersection (all bicyclists) thought that turning cars should be in the through lane to make their right turn rather than the mixing zone.

Table 7-7. Comprehension of Lane Position for Turning Motor Vehicles, Self-Reported in Survey

Question	Responses	Turning Zone with Unrestricted Entry and TBL: Fell/Divisadero	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	Mixing Zone with Yield Entry Markings: NE Multnomah/ 9th	Mixing Zone with Sharrow Mixing Zone: Oak/Broderick	Mixing Zone with Green Skip Coloring: Fell/Baker
A motorist turning right/left should be in:	MV Through Lane	1%	3%	21%	5%	3%
	Through Bike Lane or *Buffer	1%	4%	*2%	n/a	n/a
	Mixing Zone/MV Turn Lane	**97%**	**92%**	**79%**	**95%**	**95%**
	n	513	506	107	515	487

Notes:
Source: Resident survey in San Francisco and bicyclist survey in Portland.
Correct response for each design in bold green type with grey shading.
* means percentage refers to the buffer zone.

In addition, a specific question was asked about the meaning of the "shark teeth" yield marking to residents in the Portland survey, as shown in Table 7-8. The meaning of the symbol is not well understood by survey respondents, as only 41% agree that it indicates they should yield to bicyclists. This finding is not surprising as the symbols are not commonly found on most streets, due to the lack of locations with yield control.

Table 7-8. Comprehension of Yield Markings in the Mixing Zone with Yield Entry Markings

Question	Strongly Disagree	Somewhat Disagree	Somewh at Agree	Strongly Agree	I don't know	n
The markings in Picture A (shark teeth) indicate that motorists should yield to bicyclists when making a right turn (RS).	14%	25%	21%	20%	12%	453

Note: 7% had no opinion

Two questions were asked of cyclists about their perception of motorists' turning behaviors. Table 7-9 summarizes these perceptions. In the first question, bicyclists were asked about their agreement with the statement, "Motorists generally understand how to make left/right turns at these intersections." The highest level of agreement on whether motor vehicle drivers understand how to turn was at the *Mixing Zone with Sharrow* at the Oak/Broderick intersection (76% agree) and the *Mixing Zone with Green Skip Coloring* at Fell/Broderick (70% agree). The *Mixing Zone with Yield Entry Markings* NE Multnomah/9th had lower overall agreement (64%). The cyclist's perceptions were the lowest for the other designs in San Francisco with the TBL at the Divisadero intersections— the overall agreement with the statement is between 54% and 57%.

In the second question, bicyclists were asked their level of agreement with the statement, "I often see motorists making left/right turns from the wrong lane." Table 7-9 summarizes these results. Bicyclists report seeing motor vehicles turn from the wrong lane most often on *Turning Zone with Post Restricted Entry and Through Bike Lane (TBL)* at L Street (59% agree, though only 9% strongly agree). All other locations have overall levels of agreement less than 50%. The lowest is *Mixing Zone* *with Sharrow* at Oak/Broderick (38%), followed by *Mixing Zone with Green Skip Coloring* at Fell/Broderick and *Mixing Zone with Yield Entry Markings* at NE Multnomah/9th (41% each). Also, note that the strongly-agree percentage is remarkably similar across all locations, except the Oak/Broderick intersection.

Table 7-9. Perception of Motor Vehicle Behaviors, Self-Reported in Bicyclists Survey

Question	Intersection	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Motorists generally understand how to make left/right turns at these intersections (BS):	Turning Zone with Post Restricted Entry and TBL: L Street	10%	32%	49%	9%	269
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Oak/ Divisadero	11%	32%	44%	13%	230
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Fell/Divisadero	13%	33%	41%	13%	239
	Mixing Zone with Yield Entry Markings: NE Multnomah/9th	9%	28%	53%	11%	104
	Mixing Zone with Sharrow Marking: Oak/Broderick	4%	19%	60%	16%	224
	Mixing Zone with Green Skip Coloring: Fell/Broderick	6%	24%	52%	18%	236
I often see motorists making left/right turns from the wrong lane (i.e., the lanes to the right/left of the cycle track rather than the left/right turn lane) (BS):	Turning Zone with Post Restricted Entry and TBL: L Street	15%	26%	44%	15%	266
	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	17%	35%	36%	12%	220
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Fell/Divisadero	13%	39%	33%	14%	230
	Mixing Zone with Yield Entry Markings: NE Multnomah/9th	27%	32%	28%	13%	96
	Mixing Zone with Sharrow Marking Mixing Zone: Oak/Broderick	19%	42%	32%	6%	211
	Mixing Zone with Green Skip Coloring: Fell/Broderick	16%	43%	27%	14%	233

7.1.3.2 Findings from Video Review

In the video review, vehicles were coded based on where they entered the merge zone, and if they did not, if they merged early, merged across the buffer/ABL (a late decision to turn), or just turned from the wrong lane. Table 7-10 summarizes the result of the video review. The correct behavior, entered in the merge zone, is bolded in green and the cell is shaded. Of the designs evaluated, motorists are most likely to merge into the zone at the appropriate location at *Mixing Zone with Yield Entry Markings* at NE Multnomah/9th (93% of observed vehicles entered correctly) and the two D.C. intersections on L St. with the *Turning Zone with Post Restricted Entry and TBL* (88% and 86%). These intersections have strong guidance (i.e., posts and parked cars) that make it difficult or impossible for motor vehicles to enter the bike lane at any location other than the designated merge point. They are least likely at the San Francisco locations, especially the sharrow at Oak/Broderick (only 48%) and the full green skip marking at Fell/Baker (49%). Motorists are entering early at Oak/Broderick (20% fully into the facility early and another 11% just merging a bit early across the buffer). One issue at the Oak/Broderick intersection is there are not many posts before the merge zone due to driveways. Finally, at Baker/Fell, where the green skip markings cover the entire lane, nearly 20% of the observed motor vehicles are turning from the wrong lane and another 17% are turning while straddling the turn lane and the through lane; 15% also enter early.

Table 7-10. Observed Motor Vehicle Turning Location at Mixing Zone Intersections

Motor Vehicle Actions	Turning Zone with Post Restricted Entry and TBL: L Street/ 15th Street	Turning Zone with Post Restricted Entry and TBL: L Street/ Connecticut	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	Mixing Zone with Yield Entry Markings: NE Multnomah/ 9th	Mixing Zone with Sharrow: Oak/Broderick	Mixing Zone with Green Skip Coloring: Fell/Baker:
Entered in Merge Zone	**88%**	**86%**	**66%**	**93%**	**48%**	**49%**
Wrong Lane	2%	8%	6%	1%	7%	18%
Entered Early	7%	2%	7%	2%	20%	15%
Entered from Garage/Alley/etc.	2%	4%	0%	n/a	4%	0%
Merged Across Buffer/ABL	n/a	n/a	11%	n/a	11%	0%
Straddled Lanes/Buffer	n/a	n/a	10%	5%	9%	17%
Other	0%	1%	0%	0%	0%	1%
n	1978	1348	1900	1524	323	501

Notes: Correct response for each design in bold green type with grey shading.

7.1.4 Motor Vehicle and Bicycle Interactions in the Mixing or Merge Zones

This section summarizes survey and video findings related to the interactions using the mixing or merge zones. Note Figure 7-1 the surveys referred to the through bike lanes as "advisory bike lane" and the merging zones as "mixing zones". Analysis of conflicts is presented in Section 8.3.

7.1.4.1 Findings from Survey

Figure 7-10 shows the response distribution to the level of agreement with the statement, "Turning motorists generally yield to bicyclists when moving through the mixing zone and into the left/right-turn lane" that was asked of the intercepted cyclists. Overall, the bicyclists using the San Francisco designs (except at the Fell/Divisadero special situation with a gas station) have the highest overall agreement with motorist yielding, although the "strongly agree" percentages are pretty consistent across facilities. Overall agreement with the statement for L Street is the lowest (66%).

Cyclists in San Francisco were asked to state their level of agreement with the statement, "Cars rarely block my pathway through the mixing zone." Table 7-12 shows the response distribution. Bicyclists strongly disagreed (68% overall) that cars rarely block their pathway through the mixing zone at *Turning Zone with Unrestricted Entry and TBL* at Fell/Divisadero. This is most likely due to the queue of cars that frequently waits to get into the gas station. The other intersection with the same design (Fell/Divisadero) had lower disagreement (39%) reflecting some benefit of the through bike lane. Otherwise, the lowest perception of blockage is at *Mixing Zone with Green Skip Coloring* at Fell/Broderick, which is most likely due to lower turning volumes.

Table 7-11. Cyclist Self-Reported Perceptions of Motorist Yielding Behavior through Mixing Zone

Question	Intersection	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Turning motorists generally yield to bicyclists when moving through the mixing zone and into the left/right-turn lane.	Turning Zone with Post Restricted Entry TBL: L Street	9%	24%	49%	17%	275
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Oak/ Divisadero	5%	18%	58%	19%	230
	Turning Zone with Unrestricted Entry and TBL: Fell/Divisadero	10%	29%	47%	15%	238
	Mixing Zone with Yield Entry Markings: NE Multnomah / 9th	13%	18%	55%	14%	104
	Mixing Zone with Sharrow Marking: Oak/Broderick	3%	19%	63%	15%	220
	Mixing Zone with Green Skip Coloring: Fell/Broderick	4%	16%	58%	22%	237

Table 7-12. Cyclist Self-Reported Perceptions of Blocked Path

Question	Intersection	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Cars rarely block my pathway through the mixing zone.	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero	12%	31%	43%	14%	232
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Fell/Divisadero	33%	35%	24%	7%	241
	Mixing Zone with Sharrow Marking: Oak/Broderick	9%	30%	43%	17%	225
	Mixing Zone with Green Skip Coloring: Fell/Broderick	6%	24%	52%	18%	236

7.1.4.2 Findings from Video Review

In the video review, the observed position of the vehicle after it had completed its merge through the mixing zone and had started its turn was recorded. Vehicles were coded as either having wheels still in the TBL or not in the TBL at all. Note that it's not illegal or unexpected to have some drivers in the TBL given the dotted marking. Table 7-13 shows that motorists are most likely to stop in the TBL or turn while still driving in it at Oak/Divisadero, followed by L St/Connecticut. The relatively high percentage of encroachment is primarily due to the narrow turn lane widths. If the turn lanes were wider less encroachment would occur. At Oak/ Divisadero this can be attributed in part to the number of motorists that merge late or turn while straddling the TBL and the through lane, as well as the lane being narrower than the L Street lanes.

Table 7-13. Observed Vehicle Position at Intersections and Turning for TBL Designs

Question	Observed Behavior	Turning Zone with Post Restricted Entry and TBL: L Street/ 15th Street	Turning Zone with Post Restricted Entry and TBL: L Street/ Connecticut	Turning Zone with Unrestricted Entry and TBL: Oak/ Divisadero
Motor Vehicle (Through Bike Lane) Use	Not in TBL	70%	59%	34%
	Drove/Stopped in TBL	30%	41%	66%
	n *	47	104	125
Turn Lane Width		8 ft	9 ft	8′ 9″

Notes: *Observations excludes those who don't enter and those movements coded unable to determine

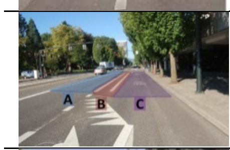
7.1.5 Summary of Evaluation Criteria

Table 7-14 summarizes a select number of metrics from the survey and the video review for each of the designs presented in this section. Note that the columns on percent agreeing they feel safe are presented and discussed in the following chapter, but are included here to make this summary more useful. Key findings from this summary table include the following:

- For all the mixing zone designs, nearly all (over 90%) of the bicyclists generally stated that they understood where they were supposed to ride.
- For the turning zones, the design using the through bike lane (TBL) works well for its intended purpose. The TBLs help position cyclists and reduce confusion compared to sharrows in mixing zones. The design in Washington D.C. (where vehicles have a limited entry into the turning lane) had high correct lane use by turning vehicles (87%) and by through bicyclists (91%). This suggests a clear benefit of the restricted entry approach and creating a semi-protected through bicycle lane.
- For the mixing zones, evaluation of the video found that in the *Mixing Zone with Yield Markings* design in Portland, OR (generally following the NACTO Design Guidance) nearly all (93%) of the turning vehicles used the lane as intended—the highest compliance of any design. However, only 63% of observed bicycles correctly used the mixing zone when a car was present (they chose to go around vehicle in the buffer space to left). This is not necessarily a critical issue and hatching this space would likely change this observed behavior. However, the observed behavior does suggest a preference of giving cyclists space with a TBL.
- When comparing the turning and mixing zone intersection designs, the video revealed that a low of 1% to a high of 18% of the turning vehicles at mixing zones actually turned from the wrong lane. The incorrect rate was highest at the *Mixing Zone with Green Coloring* at Fell and Baker in San Francisco, which has since removed and replaced with another design. The *Mixing Zone with Yield Markings* design in Portland and the *Turning Zone with Post-Restricted Entry and TBL* in Washington, D.C. had the fewest vehicles observed turning from the wrong lanes (2% and 1% respectively) indicating that clear marking of the vehicle entry point to the turning lane is beneficial.

- Based on observed behaviors, green pavement marking is effective at communicating the space that should be used by bicycles and that over use of green marking may result in some drivers avoiding the space.

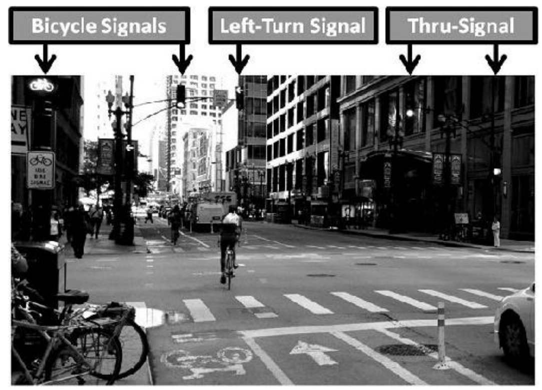
Table 7-14. Summary of Intersection Zone Design Evaluation

Intersection Design		Turning Vehicles (Avg Hour During Peak Bicycles)	Through Bicycles (Avg Hour, Peak)	Survey				Video		Survey	
				Percent Strongly Agreeing Bicyclists "Understand"	Correctly Identified Location			Correct Lane Use		Percent	
					Through	Turning Bicycle	Turning Motorist	Turning Motorist	Through Bicyclist	Strongly Agreeing Vehicles Yield	Agreeing They Feel Safe
	Turning Zone with Post Restricted Entry and Through Bike Lane (TBL): L Street & 15th	110	173	85%	-	-	-	87%	91%	17%	64%
	L Street & Connecticut Avenue	116	125								
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Oak/ Divisadero	126	201	75%	94%	73%	92%	66%	81%	19%	74%
	Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Fell/Divisadero	-	-	81%	93%	74%	97%	-	-	15%	72%
	Mixing Zone with Yield Entry Markings: NE Multnomah / 9th	94	31	63%	51%	98%	79%	93%	63%	14%	73%
	Mixing Zone with Sharrow Marking: Oak/Broderick	24	188	71%	79%	97%	95%	48%	30%	15%	79%
	Mixing Zone with Green Skip Coloring: Fell/Broderick or Fell/Baker	48	226	74%	73%	96%	95%	49%	-	22%	84%

7.2 Bicycle-Specific Signal Comprehension and Compliance

The project collected video at five locations where bicycle movements are controlled by a separate bicycle signal: three intersections on Dearborn in Chicago at Randolph, Madison, and Congress; Milwaukee at Elston in Chicago; and in San Francisco at Oak and Broderick. In addition, survey questions were asked of bicyclists on Rio Grande in Austin that used an intersection controlled by a bicycle signal at MLK. These locations are shown in Figure 7-3.

Leading Bike Interval with Bike Signal
Photo from survey (shown): Oak/Broderick
Video Location(s): Oak/Broderick



Fully Signalized Intersection
Photo from survey (shown): Dearborn and Madison
Video Location(s): Randolph, Madison, Congress

Offset Intersection with Long Crossing
Photo from survey (shown): Rio Grande: MLK (Bike Signal)
Video Location(s): No video

Bicycle Lane to Right of Right-turn Lane
Photo from survey (shown): Milwaukee and Elston, Chicago
Video Location(s): Milwaukee and Elston, Chicago

Figure 7-3. Intersections with Bicycle Signals

7.2.1 Comprehension of Bicycle-Specific Signals

This section summarizes survey findings related to the understanding of the bicycle signal designs.

7.2.1.1 Findings from Survey

In the surveys, a number of questions were asked about whether drivers and cyclists noticed and understood the bicycle signal concept. Table 7-15 summarizes these questions and the responses from the resident survey. Nearly all survey respondents (97%) responded “Yes” to the question, “Prior to taking this survey, had you noticed the bicycle signals on Dearborn Street?” Also, in a related question summarized in Table 7-16, none of the intercepted bicyclists answered, “I did not know it was there" when asked about the signal on Rio Grande at MLK in Austin (though the sample is very small, n=34).

In the Chicago resident survey, 78% of the 60 people who responded to these questions think that the bike symbol in the signal lens is a good way to communicate that the signal controls bicycle movements. There was some self-reported confusion about which signal is intended for the motor vehicle. In the survey, only 66% agreed that it clear to them at the Dearborn intersections which signal is for the vehicles. However, it is not clear if they are confusing the left-turn arrow and the through motor vehicle signal or the bicycle signal on the mast arm. Finally, one question was asked about preference for separate signals for bicycles. Table 7-15 summarizes the responses to the statement that, "I like that bicyclists and turning cars each have their own signal" from the Chicago resident survey on Dearborn. Overall, 74% of the 84 respondents agreed with this statement.

Table 7-15. Bicycle Signal Questions from Resident Survey (Dearborn - Chicago)

Question	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
At these intersections, it is always clear to me which signal I should use as a motorist.	12%	22%	29%	37%	147
Using the small bicycle in the bicycle signal lens is a good way to communicate the signal is only for bicycles.	8%	5%	35%	52%	60
I like that bicyclists and turning cars each have their own signal.	11%	15%	36%	38%	84

7.2.2 Compliance by Bicyclists

Compliance by bicyclists with traffic signals is influenced by many factors (in addition to design) such as the wait time, length and phasing of the intervals, cross street volumes, progression quality and cycling culture. Compliance observations are summarized here but the many of the possible confounding factors were not compiled or analyzed in this research.

7.2.2.1 Findings from Survey

A number of questions were asked regarding the perceptions of compliance of cyclists by motorists and self-reported compliance by cyclists. Table 7-16 summarizes these results. In Chicago, motorist perception of how often they encounter bicyclists in their path when attempting to make a left turn is high. A total of 45% said they "sometimes" encounter a bicyclist when making a left turn and another 16% said often. This implies that either the cyclist or motor vehicle driver is disregarding the red indication since all movements are separated in time. This perception is higher than actual observed behavior (discussed in next paragraph).

Table 7-16. Self-Reported Compliance and Observations from Surveys (Austin and Chicago)

Question	Intersection and Source	Responses	Percent
How often do you wait for the bicycle signal to turn green before crossing MLK?	Austin Bicyclist Surveys	I did not know it was there	0%
		Never	6%
		Some of the Time	24%
		Most of the Time	38%
		Always	32%
		n	34
When making a left turn off of Dearborn Street, how often do you encounter bicyclists in your path?	Dearborn, Resident Survey	Never	11%
		Rarely	27%
		Sometimes	45%
		Often	16%
		n	140

7.2.2.2 Findings from Video Review

Cyclist compliance with the bicycle signals was tabulated during the video review. Cyclists facing a red bicycle signal indication were categorized as waiting for the green/stopping and making a legal turn on red or proceeding illegally on red. Figure 7-4 shows the results of these observations for the locations with bicycle signals. On Dearborn, the cyclists through movement phase starts with the motor vehicle through movement; the bicycle green interval ends then the protected left-turn movement for vehicles lags (though movement continues) Observed compliance at the intersections of Randolph and Congress on Dearborn is highest (92-93%).

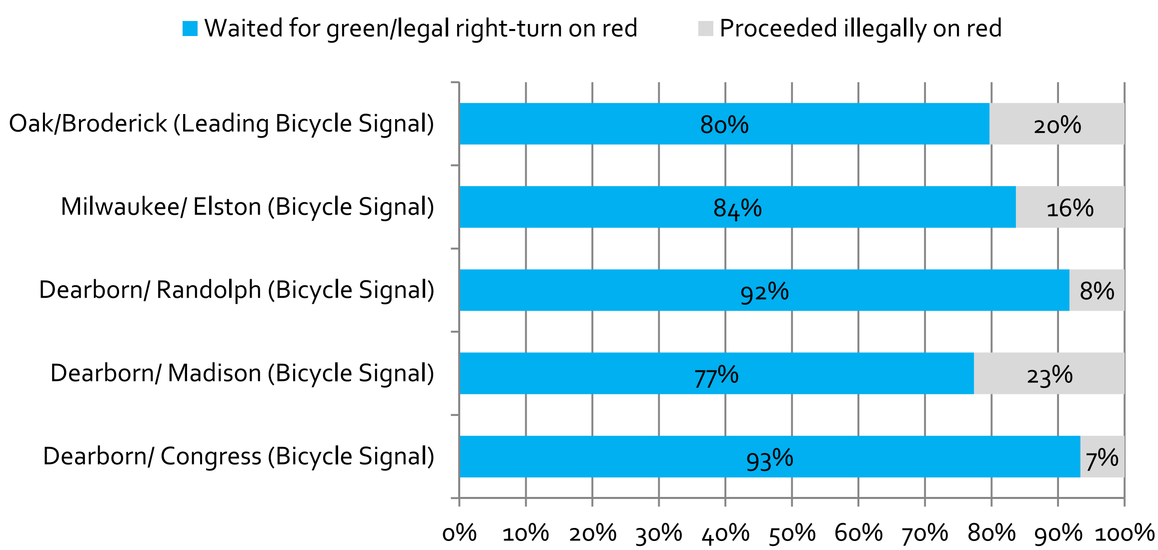


Figure 7-4. Observed Cyclist Compliance with Bicycle Traffic Signal

7.2.3 Compliance by Drivers

7.2.3.1 Findings from Survey

Bicyclists were also surveyed about their perspectives on how well motorists understand and comply with the signals on Dearborn, as shown in Table 7-17. There is a general perception that they know and understand to follow the left-turn arrows. Overall, only 25% somewhat or strongly agree that they often see motorists turning illegally when the bicycle signal is green.

Table 7-17. Perceptions of Motorist Compliance from Cyclist Survey (Chicago)

Question	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	n
Motorists know not to turn across the bike lanes at intersections when the bicycle signal is green (and the turn arrow for cars is red).	8%	26%	n/a	40%	27%	113
Motorists generally understand to follow left turn signals at these intersections.	2%	7%	5%	49%	37%	113
I often see motorists making left turns when the bicycle signal is green (and the left-turn signal is red).	23%	27%	24%	18%	7%	111

7.2.3.2 Findings from Video Review

The project evaluated compliance by drivers using video at the three intersections on Dearborn where motor vehicles are controlled with a separate left-turn phase. Figure 7-5 shows the summary of motorist compliance on Dearborn with the left-turn arrow. There are two key considerations when comparing compliance for motor vehicles and for bicyclists. First, motor vehicle compliance is expressed as a percentage of all turning vehicles, but only the first vehicle in the queue has the opportunity to violate the signal; therefore, motor vehicle compliance may be overstated. Second, in calculating bicyclist compliance, only those bicyclists that are required to stop are included (i.e., bicyclists arriving on green are not included) However, this distinction is not made for motor vehicles, which somewhat reduces the error introduced by the first point; though most turning motor vehicles do have to stop so the impact of this is likely minor. In general, the compliance is higher for motor vehicles than bicycles. The highest non-compliance is at Dearborn and Congress.

In the review, it was noted that between 2-6% of motorists start to attempt a turn on the red arrow but then wait in the intersection or crosswalk by exhibiting start/stop behavior than waiting in the crosswalk to turn. This could be a result of some minor confusion (either mistaking the through green or bike signal green as control for the left-turning movement) or just aggressive driving.

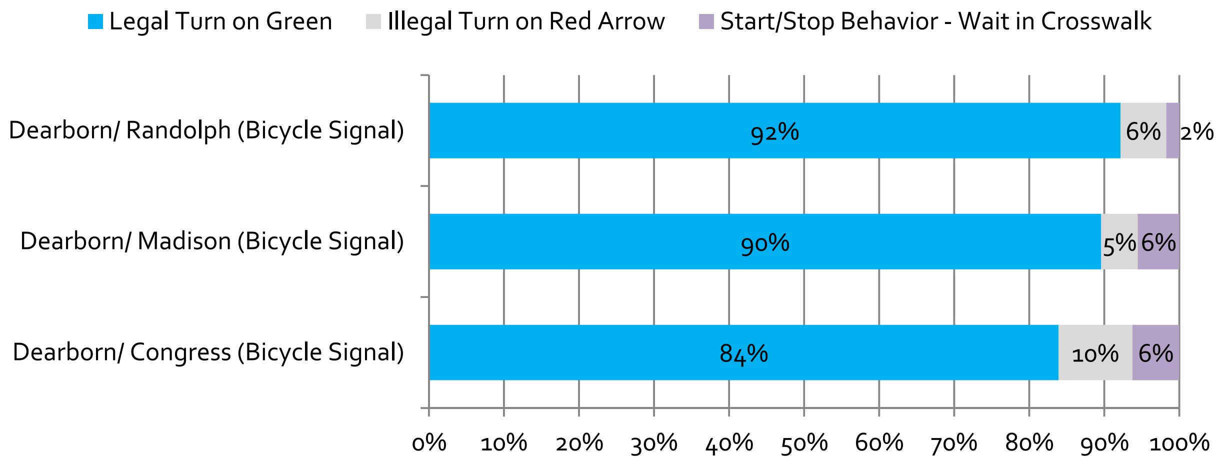


Figure 7-5. Observed Motor Vehicle Driver Compliance with Left-Turn Arrow

7.2.1 Overall Signal Compliance

Figure 7-6 summarizes the compliance of bicyclists at all of the intersections where video data collection was conducted. The compliance is the highest at the Oak/Divisadero intersection in SF, followed closely by the intersections on NE Multnomah in Portland. Compliance is lowest on Milwaukee, L St., and the remaining SF locations. These are all areas with relatively high bike volumes and some of these intersections have low minor street traffic. Many of the non-compliance observations are "jumping" the signal (e.g., starting before green but during the clearance interval for crossing traffic that is sometimes low). Finally, the low compliance at L St is partially explained by the observation that many L St. bicyclists following the leading pedestrian interval. It should be noted the council of the District of Columbia passed an amendment, cited as the "Bicycle Safety Amendment Act of 2013" making it legal for bicyclists to follow the leading pedestrian interval at an intersection.

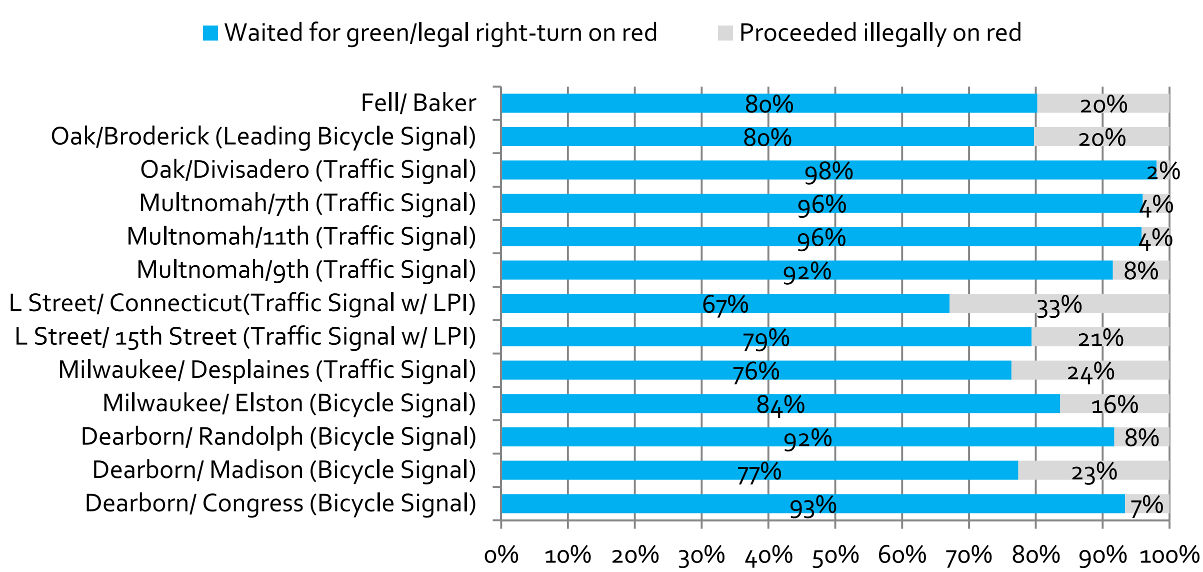


Figure 7-6. Observed Cyclist Compliance with Traffic Signal (All Locations)

7.2.2 Summary of Evaluation Criteria

One alternative to mixing zones is to separate the movements of motor vehicles and bicycles using separate signal phasing, including bicycle traffic signals. By doing so, if all road users comply, there should be no conflicts. This option was used in Chicago and compliance rates were generally high.

- At the five intersections studied with bicycle traffic signals, 77-93% of bicyclists were observed on video to comply with the signal.
- There was recognition that the bicycle symbol in the traffic lens is a good way to communicate that the signal head controls bicycle movements. About 78% of the 148 people who responded to these questions supported this statement.
- At the three Chicago intersections where signal phases for bicycle and motor vehicles are completely separated, between 2-6% of motorists started to attempt a turn on the red arrow but then waited in the intersection or crosswalk. This could be a result of some minor confusion (either mistaking the through green or bike signal green for turning movement) or just aggressive driving.
- Overall compliance by people on bicycles with traffic signals (regular or bicycle-specific) ranged from 67% to 98%. Compliance is lowest in areas with relatively high bike volumes, sometimes at intersections with low traffic on the cross street or with a leading pedestrian interval. Many of the non-compliance observations are "jumping" the signal (e.g., starting before green but during the clearance interval for crossing traffic that is sometimes low).

7.3 Other Elements of Designs

7.3.1 Loading Zones

Providing curb access to some businesses is a challenging design issue for protected facilities. The selected facilities had few designs to consider, but two locations were studied that operated as loading zones. A hotel zone in Washington, D.C., was included in the video review. A screen capture of the hotel loading zone is shown in Figure 7-7. The suggested path width is 4 feet; the total width from the curb to outside edge of the buffer is 9 feet. Survey questions were asked about a design in Portland, but no video was conducted so the results are not presented here (see the Appendix for detailed responses).

The results of the video review for the bicycle path and stopping location for motor vehicles that use the hotel loading zone are shown in Table 7-18. When a vehicle is using the loading zone (as shown in the figure) 48% of the observed bicyclists follow the TBL path, while approximately 40% were forced out of the bike lane due to an improperly stopped vehicle blocking the lane. When there is no vehicle present, about 37% of bicyclists still follow the path (which is high given that the path is out of direction). When vehicles do use the loading zone, just over 60% keep the TBL clear. As shown in the table, about one-third of motorists entering the loading zone stop at a location other than the loading zone. In the bicycle survey, bicyclists were asked their agreement with the statement, "Stopped cars at these loading zones usually allow enough space for bicyclists to pass on the right." The results shown in Table 7-19 are mixed – only about 54% agreed with the statement – and are aligned with the findings from the video review.

Figure 7-7. Hotel Loading Zone Evaluated on L Street in Washington, D.C.

Table 7-18. Cyclists Path and Motor Vehicle Stopping Location, Hotel Loading Zone

Bicycle Use			Motor Vehicle Use	
Through Bicyclist Lane Use	**No Cars Present**	**Cars Present**	**MV Stopping location**	**Cars Present**
In TBL	37%	48%	In TBL	30%
Not in TBL	63%	12%	Keeps TBL Clear	61%
Forced out	0%	40%	In Merge Zone	7%
n	615	128	n	44

Table 7-19. Perceptions of the Loading Zone from Bicyclist Survey

Question	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Stopped cars at these loading zones usually allow enough space for bicyclists to pass on the right (BS).	18%	29%	47%	7%	223

7.3.2 Transit Zones

The design of transit stops on protected bike lanes is a challenging issue. Unfortunately, there was not significant transit activity on the corridors selected for evaluation (partially because cities to date have avoided protected lanes on heavy transit routes). In the Portland bicycle intercept survey, cyclists were asked about what path they would take around a stopped transit bus. The location was also recorded with video. Table 7-20 summarizes the results of this one question and video review. Most respondents (54%) said they would ride around the bus, and that appears to be the case with the video review although the sample is too small (only nine observed bicycle-bus interactions) to draw any real conclusions.

Table 7-20. Transit Stop Analysis

Question / Observation	Stop and wait for the bus to move	Go around the bus on the left	Go up onto the sidewalk to get around	Other	n
SURVEY - If you encountered this bus stopped in front of you, what would you do:	24%	54%	5%	18%	108
VIDEO - Cyclist action at transit stop:	33%	67%	0%	0	9

7.3.3 Width of Facilities

Intercepted bicyclists were asked questions regarding whether the facility was wide enough for them to ride comfortable, to pass another bicyclist, and to ride side-by-side with another bicyclist. They were also asked if they prefer to ride side-by-side when bicycling with another adult. Table 7-21, Table 7-22 and Table 7-23 show the results of this analysis. The typical width of the total bicycle facilities is shown in each table. Note that Rio Grande and Dearborn are two-way facilities.

As shown in Table 7-21, almost all, approximately 97%, of respondents agreed with the statement that “the [facility] is wide enough for me to ride comfortably” and just over three-quarters (77%) selected “strongly agree.” Dearborn, which allows for two-way travel and has a total typical width of 8.5 but the narrowest lanes (5 feet and 4 feet, depending on travel direction) of any study facility, had the lowest agreement rate, but it was still high at 91%. The study facilities in Austin and Washington DC had the highest agreement rates (100% and 99% respectively). The Rio Grande facility is two-way but wide (12 feet).

Slightly fewer, but still nearly all, about 89%, of respondents also agree that there is enough room for bicyclists to pass one another in the study facilities as shown in Table 7-22. Dearborn has the lowest agreement rate, with approximately 58% respondents agreeing there is enough space for passing. It is much lower than the other two-way facility (Rio Grande) The San Francisco and Washington DC study facilities have the highest agreement rates, ranging from 93 to 96%. These are the widest one-way facilities in this study, with widths ranging from 7’3” to 8’.

About two-thirds (67%) of respondents agree that they can ride side-by-side comfortably with another bicyclist in the study facility as shown in Table 7-23. Again, the agreement rate is lowest on Dearborn Street (18%), which is not surprising as there is not physically enough space for bicyclists to ride side-by-side in the same direction if another bicyclist is approaching in the opposite direction. Similarly, the wider San Francisco and Washington DC facilities have the highest agreement rates (76-82%).

Finally, Table 7-24 shows the results when respondents were asked their level of agreement with the statement “I prefer to ride side-by-side when traveling with another adult”. At the same time, just over half, approximately 54% of respondents, indicated that they prefer to ride side-by-side when traveling with another adult, suggesting that designing to allow this to occur may not be a pressing concern on these heavily commuter routes.

In summation, nearly all respondents feel that the study facilities are wide enough to allow for comfortable riding and passing of other bicyclists. These feelings are strongest in the facilities that are over seven feet wide and the lowest on a two-way facility with individual lane widths of five feet or less (Dearborn). Rio Grande Street, the other two-way facility represented in these tables, has responses similar to the one-way facilities. It is differentiated from Dearborn by having wider lanes (5.5 and 6.5 feet) and lower volumes of bicyclists, making passing events less frequent.

Table 7-21 Perceptions of Facility Width from Bicyclist Survey

City	Route	Typ. Width of Bicycle Facility (ft)	The [facility] is wide enough for me to ride comfortably				
			Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Austin	Barton Springs	7	0%	0%	25%	75%	16
	Rio Grande*	12	0%	0%	10%	90%	41
Chicago	Dearborn*	8.5	1%	8%	31%	60%	118
	Milwaukee	7	1%	4%	24%	71%	217
Portland	NE Multnomah	7	0%	3%	19%	78%	110
San Francisco	Oak Street	7.25	2%	2%	17%	80%	247
	Fell Street	7.25	0%	2%	25%	73%	243
Washington	L Street	8	0%	1%	13%	86%	291
Total			1%	3%	20%	77%	1,036

* Two-way facility

Table 7-22 Perceptions of Passing Width from Bicyclist Survey

City	Route	Typ. Width of Bicycle Facility (ft)	The [facility] is wide enough for one bicyclist to pass another				
			Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Austin	Barton Springs	7	0%	19%	44%	38%	16
	Rio Grande*	12	0%	12%	34%	54%	41
Chicago	Dearborn*	8.5	11%	31%	39%	19%	118
	Milwaukee	7	1%	12%	42%	44%	217
Portland	NE Multnomah	7	3%	16%	43%	39%	108
San Francisco	Oak Street	7.25	1%	4%	34%	61%	240
	Fell Street	7.25	2%	5%	31%	62%	242
Washington	L Street	8	0%	4%	23%	73%	289
Total			2%	10%	34%	55%	1,029

* Two-way facility

Table 7-23 Perceptions of Side-by-Side Width from Bicyclist Survey

City	Route	Typ. Width of Bicycle Facility (ft)	The [facility] is wide enough for two people to comfortably ride side-by-side				
			Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Austin	Barton Springs	7	7%	27%	53%	13%	15
	Rio Grande*	12	13%	28%	35%	25%	40
Chicago	Dearborn*	8.5	47%	36%	15%	3%	117
	Milwaukee	7	12%	29%	36%	22%	214
Portland	NE Multnomah	7	10%	33%	39%	19%	101
San Francisco	Oak Street	7.25	3%	18%	40%	39%	234
	Fell Street	7.25	5%	19%	39%	37%	240
Washington	L Street	8	4%	14%	35%	46%	272
Total			10%	23%	36%	31%	1,233

* Two-way facility

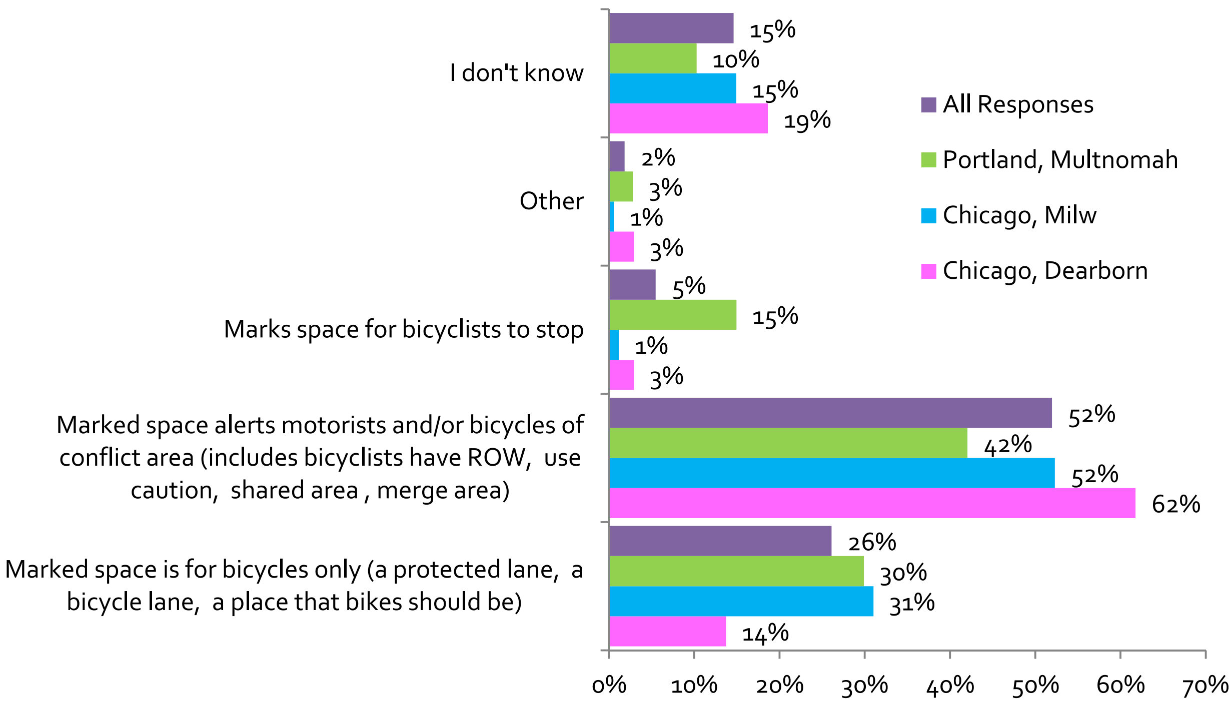
Table 7-24 Preferences of Side-by-Side Riding from Bicyclist Survey

City	Route	If I am bicycling with another adult, I would prefer to ride side-by-side				
		Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n
Austin	Barton Springs	14%	29%	14%	43%	14
	Rio Grande*	5%	29%	26%	39%	38
Chicago	Dearborn*	25%	32%	26%	17%	111
	Milwaukee	20%	34%	30%	16%	210
Portland	NE Multnomah	9%	26%	29%	37%	105
San Francisco	Oak Street	11%	30%	32%	27%	221
	Fell Street	16%	27%	30%	26%	220
Washington	L Street	16%	31%	29%	25%	256
Total		16%	30%	29%	25%	1,175

* Two-way facility

7.3.4 Comprehension of Green Pavement Marking

Intercepted cyclists on NE Multnomah in Portland and on Milwaukee and Dearborn in Chicago were asked an open ended question, "What do you think it means when the pavement is painted green along the bikeway?" The question was asked in the survey prior to any photos. A total of 102 responses from Dearborn, 174 from Milwaukee, and 107 from Multnomah were received. The open-ended responses were coded to five categories that best summarize the responses, which are shown in Figure 7-8. The responses by facility and the overall responses are shown in the figure. The question did not give a specific location or design (e.g., bike box, two-stage turn queue box, intersection marking). In general, the green pavement marking is currently being used in two manners: 1) to mark a potential conflict (e.g., through an intersection) and 2) indicate paths or locations reserved for bicycles (e.g., bike boxes, lanes). The survey responses indicate that both of these interpretations are represented in the responses. There are some contextual differences shown in the figure based on the types of markings in use on that facility and city. Combining all responses, the majority (52%) of the respondents identify the green pavement marking as a conflict area. Only 26% of the respondents suggested that the green pavement marking means the space is exclusive for bicycles. Finally, about 15% of respondents indicated that they did not know if the pavement marking had any meaning at all. Some recent designs have used skip green pavement marking to indicate conflict and a solid coloring for space for bicyclists (this was not asked in the survey).



Note: n=383

Figure 7-8. Stated Meaning of Green Pavement Markings

7.3.5 Minor Intersections

For protected lanes, minor intersections can present an important potential conflict area. Each city designs these locations with slight variations. Unfortunately, budget limited the team's ability to collect video at any minor intersections (the focus was on major intersections). On most surveys, space constraints also limited any detailed questions about minor intersection treatments. However, in the Chicago survey, residents in the Milwaukee survey were asked about a design treatment at minor intersections that features intersection through markings and a post marked "Turning Vehicles Yield to Bikes" mounted in the roadway. In the survey, the photo shown Figure 7-9 was annotated to indicate bike lanes and though vehicle lanes.

Figure 7-9. Image Used in Chicago Milwaukee Survey about Minor Intersections

The results of the response to the questions are summarized in Table 7-25. Most respondents indicated that seeing approaching bicycles when turning right is an issue (53% disagree that they can adequately see approaching bicycles). However, 63% of respondents stated that the sign heightens their awareness of bicycles when turning off Milwaukee Ave.

Table 7-25. Perceptions of Minor Intersection Treatment

Question	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	No Opinion	n
When I want to turn right, I am able to adequately see if there are any approaching cyclists in the bike lane.	25%	28%	32%	11%	4%	276
The “Yield to Bikes” signs have made me pay closer attention to cyclists when turning off Milwaukee Ave.	11%	18%	39%	24%	9%	276

7.3.6 “Look for Bikes” Pavement Markings

On Dearborn in Chicago, pedestrian and bicycle interactions were a known issue. At some intersections the pavement stencil "Look Bikes" was added at some crosswalks, as shown in Figure 7-10 Some locations also included a yellow warning sign on the pavement with a similar message. On the resident survey, for those that indicated that they had walked on Dearborn, a question was asked about how effective they thought these markings would be at warning pedestrians about bicycle traffic. The results are shown in Table 7-26. There was not a strong sense either way on the effectiveness (50% responded on the “effective” side of the scale, 50% responded on the “not effective” scale).

Figure 7-10. Image Used in Chicago Dearborn Survey about "Look for Bikes"

Table 7-26. Perceptions of "Look for Bikes" Pavement Markings of Residents Who Walked on Facility

Question	Not effective at all (1)	(2)	(3)	(4)	(5)	Very effective (6)	n
How effective do you think these markings will be at warning pedestrians about bicycle traffic?	14%	14%	22%	25%	16%	9%	191

8 FINDINGS: SAFETY

Safety of protected lanes is a composite of the travel along the segment and at intersections. Safety can be assessed in two ways: observed measures such as crashes, or surrogate measures such as conflicts and perceptions. Perceptions of safety are likely to influence individuals' decisions on whether and when to use a facility. For this research, changes in perceived safety are derived from the surveys of residents living nearby the facility and from bicyclists intercepted riding along the facility. Due to the very recent installation dates, reported crash data were not available for analysis on most of the facilities. Thus most of the analysis of observed safety comes from the video data for conflicts and near misses.

As noted in other sections of this report, the analysis focuses only on the conflicts or near misses at intersections, not on the segments of the protected lanes themselves (where very few, if any, conflicts with motor vehicles occur). The video data were not available for the before conditions. Therefore, the analysis is cross-sectional—comparing the safety of different protected lane designs at intersections—it is not an evaluation of the change in safety with and without the protected lanes. The selection criteria for the facilities did not allow for an optimal study design so while the analysis compares across designs there is only one of each design type to analyze (which makes inferences about thresholds for the operational variables such as volumes difficult).

In general, there was consistent evidence that the protected facilities improved the perception of safety for people on bicycles (from the survey data). This perception held for both cyclists intercepted riding on the facilities and for residents. In general, the perception of improved safety was strongest for those who were categorized as using a bicycle as their primary mode of transportation. In addition, those residents typed as "Interested but Concerned" and "Enthused and Confident" had the strongest safety perceptions of the new lanes. With respect to the intersection designs, the strongest perception of safety was for the intersections on Dearborn in Chicago where protection is carried all the way to the intersection and bicycle through movements are separated from turning vehicles in time with signalization.

The analysis of the conflict data yielded less conclusive results though no major or substantial conflicts were observed in the 144 hours of video review. Only five minor conflicts were observed at the intersections designs. The absence of any significant conflicts is in itself, a finding. The analysis of the conflicts controlling for exposure so a clear relationship between increasing exposure and conflicts. Two of the mixing zone designs were found to have the highest conflict rates.

The analysis of buffer designs reveal that designs with more physical separation had the highest comfort/safety scores. Thus one clear takeaway is that designs of protected lanes should seek to provide as much protection as possible to increase cyclists comfort. In addition to the type of buffer, further analysis of the comfort level indicates that as the total space provided for bicycles (measuring from the curb face to the edge of the adjacent vehicle lane) the overall comfort score of the facility increased, though this relationship was not particularly strong.

8.1 Perceptions of Residents

The residential survey data showed a very strong perception that the installation of the protected bike lanes increased safety for bicyclists, but more varied perceptions of how the road changed for driving and walking. Table 8-1 shows the percentage of respondents to each residential survey who stated that safety decreased, increased, or did not change. Figure 8-1 shows only the percentage of respondents who thought safety increased for each of the questions by mode. As shown in the figure, nearly 80% of residents surveyed thought that the safety of the bicycling on the street has increased with the installation of protected lanes. The perception of improved safety was consistent across each of the protected facilities even though the designs are quite different. The residents categorize as “Enthused and Confident” and “Interested but Concerned” were most likely to say that the new lanes had increased safety for bicycling (Table 8-2 and Figure 8-2). Overall, the “No way No How” respondents are definitely more negative toward the bike facilities—almost half (47%) believe the facilities made driving less safe. Also of note was that the residents typed as “Strong and Fearless” had strong perceptions of increased safety (79% stated safety had increased).

Perceptions of the change to driving safety on the facility were more varied. Overall, 37% thought driving safety had increased, 30% thought there had been no change, 26% thought safety decreased, and 7% had no opinion. These perceptions were generally consistent except for the facilities evaluated in Chicago. About 53% of residents near Milwaukee and 45% of residents near Dearborn thought that safety for driving decreased. Given that the primary improvement was for bicycling, that some residents thought driving safety improved is notable.

Perceptions of the safety of the walking environment after the installation of the protected lanes were also more varied. Overall, 33% thought safety increased, 48% thought there had been no change, 13% thought safety decreased, and 6% had no opinion. Again, these perceptions varied by facility and context. For the two facilities in Austin, 52% (Bluebonnet) and 44% (Barton Springs) indicated that the facility improved walking safety. On Bluebonnet, the protected lane added walking space where sidewalks were limited, and on Barton Springs part of the cycling facilities included the addition of a shared-use path where there had been only a sidewalk before. In Chicago on Dearborn, 43% of residents surveyed thought safety decreased for walking. In this busy urban core, the addition of bicycling facilities did introduce additional interactions with pedestrians at intersections that did not exist before the two-way cycle track.

Table 8-1. Safety Perceptions of Residents Surveyed, By Nearest Facility

Question and Response		Percent of Residents							
		Austin		Chicago		Portland	San Francisco	DC	
		Barton Springs	Bluebonnet	Dearborn	Milwaukee	Multnomah	Oak/Fell	L Street	Total
Because of the protected bike lanes, the safety of BICYCLING on the street has ...	Decreased	5%	5%	10%	13%	4%	7%	5%	7%
	No Change	5%	7%	6%	7%	8%	5%	6%	6%
	Increased	82%	85%	76%	74%	74%	80%	80%	79%
	n	418	410	189	298	459	507	227	2508
Because of the protected bike lanes, the safety of DRIVING on the street has . . .	Decreased	15%	21%	45%	53%	18%	25%	28%	26%
	No Change	38%	38%	26%	17%	25%	29%	32%	30%
	Increased	43%	38%	23%	28%	45%	38%	30%	37%
	n	417	408	192	297	463	505	228	2510
Because of the protected bike lanes, the safety of WALKING on the street has . . .	Decreased	4%	5%	43%	23%	5%	18%	16%	13%
	No Change	44%	39%	40%	55%	47%	56%	54%	48%
	Increased	44%	52%	15%	19%	37%	21%	27%	33%
	n	418	412	191	299	464	506	230	2520

Note: No opinion responses are not shown. Therefore, percentages do not total 100%.

Figure 8-1. Percent of Residents Stating Safety Increased for Each Mode

Table 8-2. Safety Perceptions of Residents Surveyed, By Cyclist Type

Question and Response		Residents in Each Cyclist Typology: Strong and Fearless	Enthused and Confident	Interested but Concerned	No Way No How	Total
Because of the protected bike lanes, the safety of BICYCLING on the street has ...	Decreased	10%	3%	4%	15%	7%
	No Change	9%	4%	4%	11%	6%
	Increased	76%	87%	88%	59%	80%
	n	114	600	1025	551	2290
Because of the protected bike lanes, the safety of DRIVING on the street has . . .	Decreased	30%	16%	20%	47%	26%
	No Change	25%	31%	34%	25%	31%
	Increased	36%	46%	41%	21%	37%
	n	115	602	1021	551	2289
Because of the protected bike lanes, the safety of WALKING on the street has . . .	Decreased	18%	8%	8%	26%	13%
	No Change	41%	45%	50%	52%	48%
	Increased	37%	42%	37%	17%	33%
	n	115	602	1027	555	2299

Note: No opinion responses are not shown. Therefore, percentages do not total 100%.

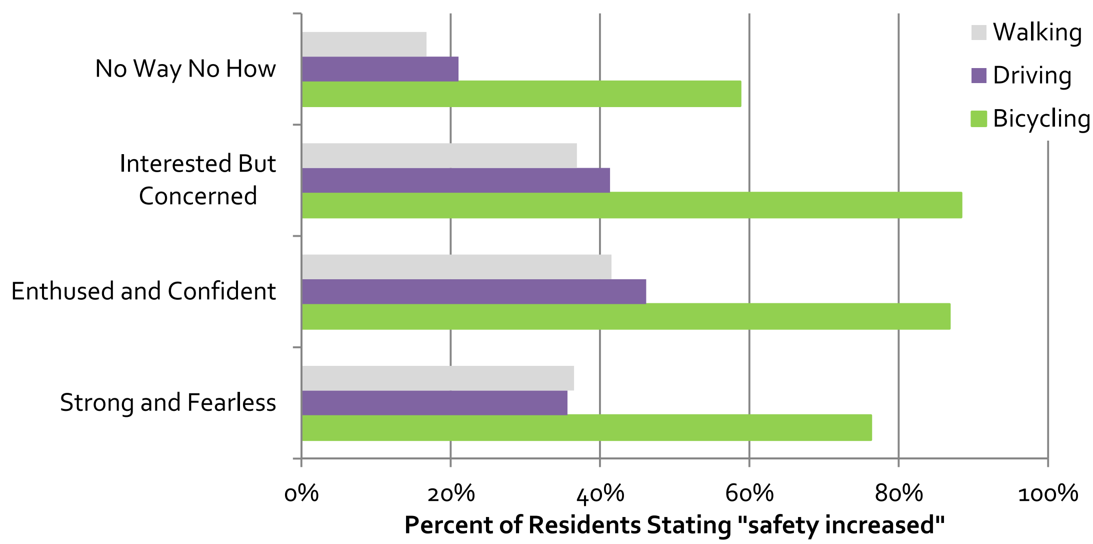


Figure 8-2. Percent of Residents Stating Safety Increased for Each Mode, by Cyclist Type

8.2 Perceptions of Bicyclists

8.2.1 Protected Lanes, General

In the bicyclist intercept survey data, there was an even stronger perception of increased safety for bicyclists. Table 8-3 shows the percentage of survey respondents who stated that safety decreased, increased, or did not change. Table 8-3 also shows the percentage who agreed or disagreed that the protected facility is safer than other facilities in the respective city.

Nearly every intercepted bicyclist (96%) stated that the installation of the protected lane increased the safety of bicycling on the street (70% increased a lot, 26% increased somewhat). There is possibly some self-selection in the intercepted cyclists (i.e. those that think it is unsafe would consider another route). Nearly nine out of 10 (89%) intercepted bicyclists agreed that the protected facilities were "safer" than other facilities in their city. A higher percentage of women agreed (93%) with this statement than men (87%). In Chicago on Dearborn, 99% of intercepted cyclists thought the safety had increased, which could be expected since no facility for bicycles existed before. Even in Portland and Chicago (Milwaukee), where bike lanes previously existed, the percentage of respondents who thought safety increased was 92% and 96%, respectively.

Table 8-3. Safety Perceptions of Bicyclists Surveyed, By Facility

Question and Response		Percent of Total Respondents to Question Intercepted on Facility							
		Austin		Chicago		Port.	SF	DC	Total
		Barton Springs	Rio Grande	Dearborn	Milwaukee	Multnomah	Oak/Fell	L Street	
I feel the safety of bicycling on [STREET] has . . .	Decreased	0%	5%	1%	3%	3%	0%	3%	2%
	No Change	11%	2%	0%	1%	5%	2%	2%	2%
	Increased	89%	93%	99%	96%	92%	98%	95%	96%
	n	18	41	120	224	106	243	293	1045
The [FACILITY] is safer than other [FACILITIES IN CITY].	Disagree	0%	5%	8%	4%	14%	8%	20%	11%
	Agree	100%	95%	92%	96%	86%	92%	80%	89%
	n	13	41	118	211	101	228	242	954
The [buffer] does a good job at protecting bikes from cars.	Disagree	33%	20%	4%	9%	8%	9%	21%	13%
	Agree	67%	80%	96%	91%	92%	91%	79%	87%
	n	15	41	116	218	109	239	292	1030

8.2.2 Intersections

Bicyclists were asked many questions about the design of the various mixing zones at intersections. With respect to safety, bicyclists were asked how safe they felt with bicycling through the intersection. The question asked the bicyclists if they "generally feel safe when bicycling through the intersections." It is acknowledged that term "generally" can introduce latitude into a respondent's answer. Table 8-4 shows the percentage of respondents agreeing with the statement for each intersection. The table is sorted from lowest agreement to highest agreement. The highest agreement is for the Chicago Dearborn intersections, which are signalized for bicycles and there are no legal conflicts. The San Francisco Oak/Broderick and Fell/Broderick intersections had the next highest perceptions of safety, and the L Street intersections had the lowest perception of safety, though a large majority (64%) did feel safe. The differences in perceptions of safety are influenced not only by the design, but also by the volume, speed, and behavior of motor vehicle traffic.

Table 8-4. Safety Perceptions of Bicyclists Surveyed About Intersection Designs

Intersection	I generally feel safe when bicycling through the intersections.		
	Agree	Disagree	n
Turning Zone with Post Restricted Entry and Through Bike Lane (TBL): L Street	64%	35%	284
Intersection w/o Turn Lane: Multnomah / 7th	68%	28%	107
Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Fell/Divisadero	72%	27%	242
Mixing Zone with Yield Entry Markings: Multnomah /9th	73%	26%	107
Turning Zone with Unrestricted Entry and Through Bike Lane (TBL): Oak/ Divisadero	74%	25%	238
Mixing Zone with Sharrow Marking: Oak/Broderick	79%	19%	234
Mixing Zone with Full Green Skip Marking: Fell/Broderick	84%	15%	240
Bicycle-Signalized Intersections: Chicago, Dearborn	92%	2%	117

Note: Rows do not sum to 100% - responses with "No Opinion" not shown

8.2.3 Buffer Designs, Actual

Intercepted bicyclists were asked to state their level of agreement with the statement about the buffer for the facility where they rode (e.g., "The buffer section with parked cars between the traffic lanes and the bike lanes makes me feel safe.") These questions therefore reveal perceptions about the actual buffer design on the facility. Table 8-5 summarizes the mean score for this response, where 1=strongly disagree and 4=strongly agree. The table presents the facilities in order from top to bottom of highest mean score. The facility with the highest score was the shared- use path on the Barton Springs in Austin. Though not a protected on-road facility, it provides a reference point for the other scores. The order of the remaining facilities makes some intuitive sense, though there are so many design variations that it is difficult to draw strong conclusions. One interesting observations is that flexposts got very high ratings even though they provide little actual physical protection from vehicle intrusions cyclists perceive them as an effective means of positive separation. The lowest scoring sections are those buffers that only include paint.

Inspection of Table 8-5 suggests that in addition to the buffer type, additional contexts such as adjacent motor vehicle traffic and facility width might be playing a role in perceptions of safety. The table also includes the dimension measuring from the curb face to the edge of the nearest motor vehicle lane. This is inclusive of the width of the separated facility, the buffer and any space allocated to parking. The mean safety score and the total width are plotted in Figure 8-3. The *y*-axis is zoomed to show the differences in the score. The relationship is not strong but shows an increasing trend with width is observed. Consistent with other work related to perceptions of safety and comfort, the total mean score increases with total width allocated to bicycles. The outlier point (the red square) is labeled as the perceptions for the shared-use path that is adjacent to the Barton Springs facility. The mean score is higher relative to other facilities with the same total width — suggesting that positive separation has a much more significant impact than width alone. Finally, tradeoffs between wider bike spaces to accommodate larger bike volumes, passing, may need to come at the expense of the buffer as long as the buffer is not too narrow. Future work would need to evaluate the actual perceived of these wider facilities with different buffer types.

Table 8-5. Safety Perceptions of Bicyclists Surveyed about Buffer Designs

Facility	Type	Primary Buffer	Typical Buffer Width (ft)	Typical Width - Far Edge of Bicycle Facility to Near Edge of Motor Vehicle (ft.)	Mean Score, Buffer "makes me feel safe"
Austin -Barton Springs	Shared Use Path	Curb, Grass	n/a	10	3.73
Chicago-Dearborn	Two-way	Parked Cars	3	19	3.60
SF-Oak Fell	One-way	Flexposts	5	12.25	3.58
Chicago-Milwaukee	One-way	Parked Cars	2-4'	20	3.56
Austin - Rio Grande	Two-way	Flexposts	4	16	3.54
Portland – NE Multnomah	One-way	Planters	7	14	3.49
Chicago-Dearborn	Two-way	Flexposts	3	11.5	3.49
Chicago-Milwaukee	One-way	Flexposts	2-4'	10	3.43
D.C. - L Street	One-way	Flexposts	3	11	3.42
Austin- Barton Springs	One-way	Flexposts	1.5	8.5	3.31
Portland - NE Multnomah	One-way	Flexposts	3	11	3.20
Chicago-Milwaukee	One-way	Paint	2-4'	10	3.06
Portland - NE Multnomah	One-way	Paint	3	10	3.04

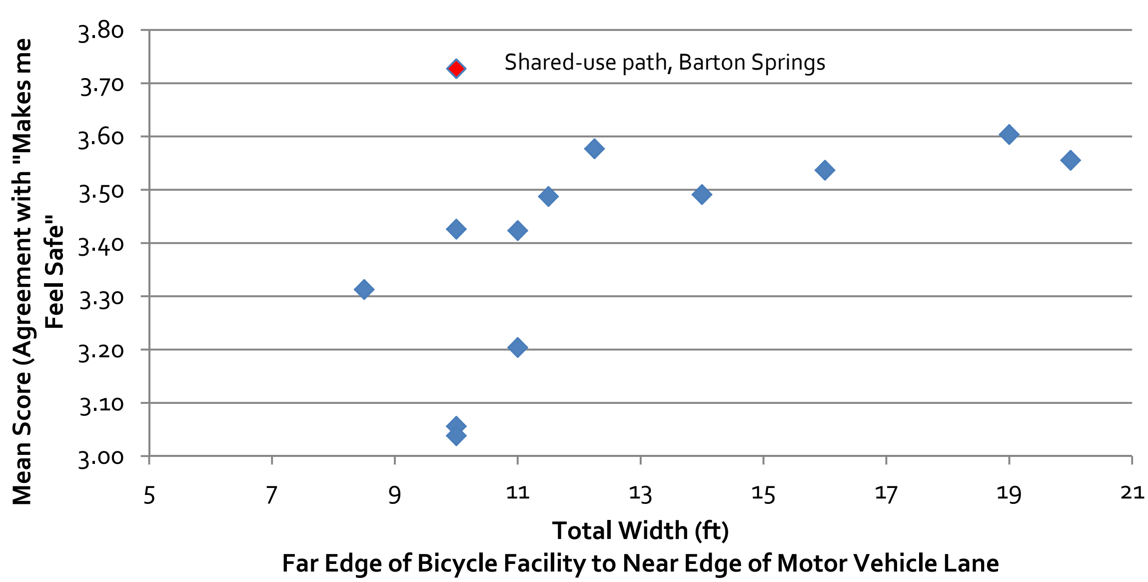


Figure 8-3. Mean Safety Score by Total Facility Width

8.2.4 Responses to Hypothetical Buffer Styles

Bicyclists were also asked to rate how comfortable they would feel on a set of generic routes with varying types of buffers, using diagrams of each proposed buffer type. The dark green areas of the bar represent the percentage of "very comfortable" responses. For reference, respondents' stated level of comfort on the same hypothetical route with a standard bike lane without a buffer is included for comparison at the top of the figure. The remainder of buffers are presented in descending order as ranked by the mean score.

As seen in Figure 8-4, for all of the buffer designs over 80% of bicyclists rated their comfort level on the comfortable end of the scale (4, 5 or 6) rather than on the uncomfortable end of the scale (1, 2 or 3). The planter buffer, plastic flexpost buffer and concrete curb buffer had the highest percentage of bicyclists expressing their comfort in the highest two comfort ratings, with the planter buffer standing out as the buffer rated most comfortable by the highest percentage of respondents. Some respondents may be influenced by aesthetics—the planters present an appealing setting while some consider the flexposts "ugly". It is perhaps surprising that the raised concrete curb (which provides continuous vertical separation and the most defined space for bicycles) rated lower than flexposts or planters. This could be related to the lack of actual experience with a concrete curb or perhaps the perception that the curb limits maneuverability. The parking buffer introduces pedestrian friction (from exiting drivers and passengers) so even though the separation is more defined, this increased interaction may contribute to its lower rating.

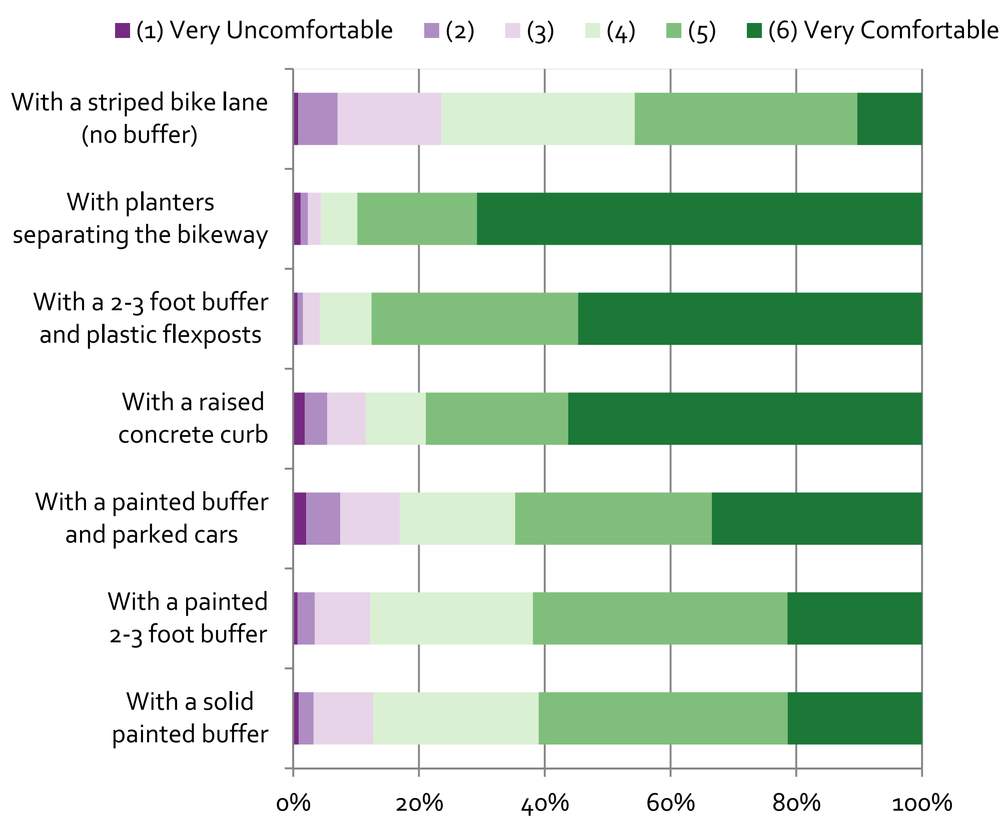


Figure 8-4. Bicyclist Comfort Rating of Generic Buffers

In general, there was a considerable amount of agreement among survey respondents about the level of comfort with the different buffers across the different surveys in each city, as is seen in Figure 8-5. The painted buffer with parked cars lanes had the largest variation in mean response levels between facilities. This may be due to bicyclists' experiences of riding with this type of buffer. For example, San Francisco bicyclists' stated level of comfort with the parked car buffer is the lowest of these cities. Anecdotally, this may be due to experiences of bicycling on JFK drive in Golden Gate Park, where a facility of this type has been implemented and faces the challenge of a high volume of unfamiliar visitors parking along the route. Chicago and DC bicyclists had the highest perception of safety for the parked car buffer, which may be the result of their experience with existing facilities. The lower ratings in Austin may be due to lack of experience; there were no such facilities in the city at the time of the survey.

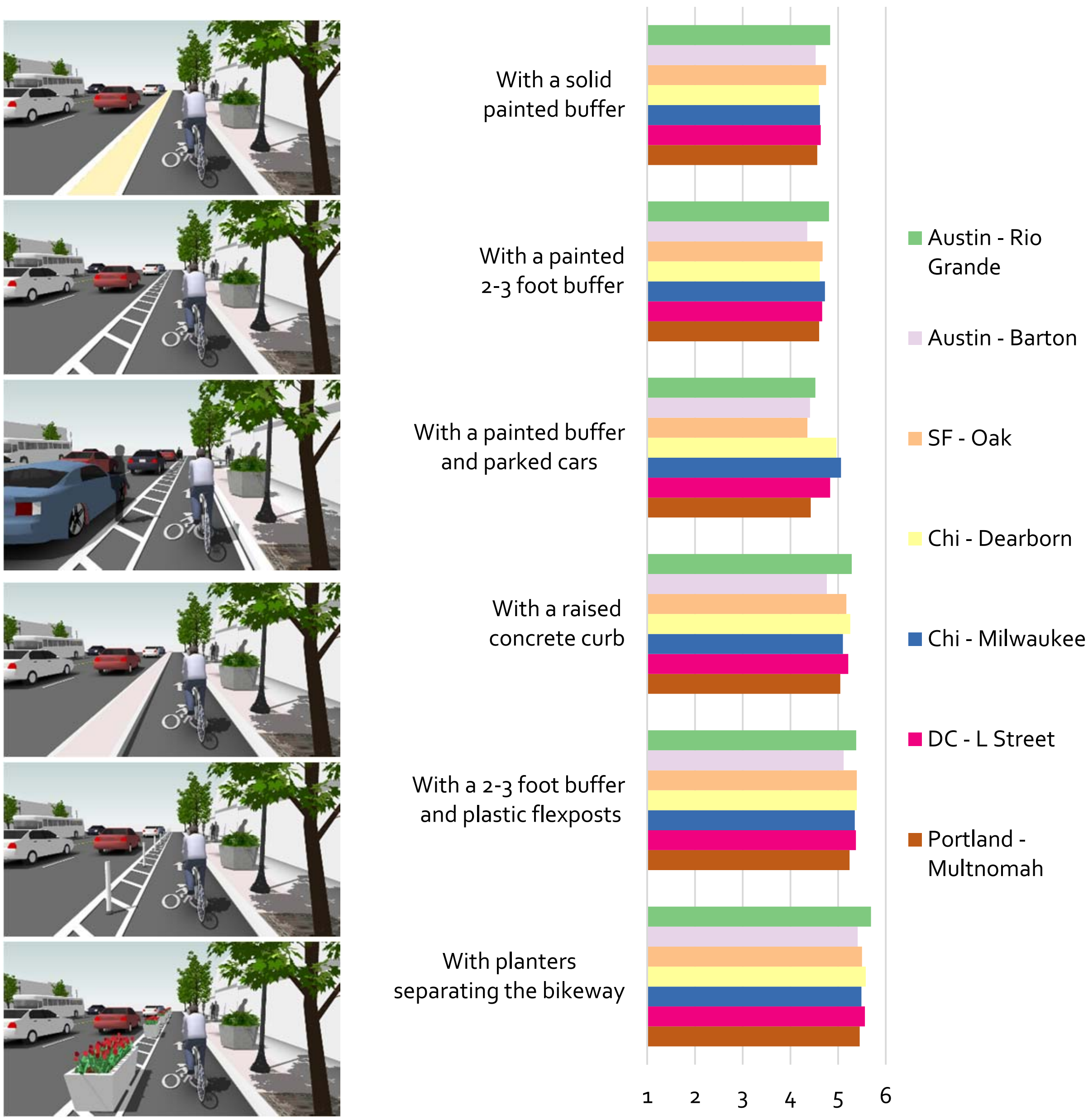


Figure 8-5. Bicyclist Mean Comfort Score of Generic Buffers

8.2.5 Self-Reported Encounters and Perception of Encounters

To understand the types of obstacles riders are encountering, the intercept survey asked bicyclists to indicate how frequently they encounter various types of obstacles when riding in the protected bike lanes, with the option to select either "never," "rarely," "sometimes" or "often" for each item. A follow-up question asked, "How much of a problem is this?" about each item, with possible selections being "not a problem," "minor problem" or "major problem."

Table 8-6 shows the percentage of bicyclists on each facility selecting that they "often" encounter the item in the protected lane, and the percent that feel this is a "major problem." Table cells with responses higher than 33% are shaded grey. These results can offer some help in identifying problem issues to be addressed, but also point to some of the contextual challenges of specific facilities. For example, Dearborn Street in Chicago has considerably more adjacent pedestrian traffic than any other facility location; a large share of bicyclists indicated that they often encounter people walking and waiting in the protected bike lanes and that this is a major problem. Prior to this survey, Chicago took measures to minimize pedestrian activity in the bike lane, though this still arose as a concern. On Milwaukee Avenue, all of the encounter types that involved motor vehicles stopping or waiting in the protected bike lane were mentioned as major problems by more than a third of respondents – it's possible that the heavy bicycle traffic on Milwaukee Avenue results in backups when the protected bike lane is blocked in these situations. On L Street, the lack of parking on the north side of the street means that delivery vehicles must park on an adjacent street, across the street, or, as the survey suggests many are doing, parking in the protected bike lane.

The table also provides some insight into which sort of encounters bicyclists view as more or less acceptable. Although relatively few bicyclists across all facilities "often" encountered cars parking while in the protected lane (8%), a much higher number indicated that this was a major problem (25%). Interestingly, while a higher percentage of bicyclists encountered cars preparing to turn off of or onto the facility route (24% and 13%, respectively), a lower number viewed this as a major problem (16% and 10%, respectively). This implied tolerance toward the encounter likely stems from the locations where bicyclists expect to encounter cars, such as the turning zones along L Street and Oak Street.

Bicyclists were also asked about any collisions or near collisions (defined by the respondent) they had while riding in the protected bike lane. If they had a collision or near collision, survey respondents were able to check whether it was with a person or object; they were allowed to check more than one option. A summary of the responses is shown in Table 8-7. A total of 18 bicyclists, or less than 2% of those surveyed, indicated that they had been involved in a collision. A third of all bicyclists indicated they have been involved in a near collision. If there was a collision, the survey asked the respondent to provide a short narrative. Based on these narratives, we can state that: 1) no injuries were reported (although we did not explicitly ask them to tell us about injuries) and 2) all reported bike-to-bike collisions occurred when one bike stopped for a pedestrian or motor vehicle in the protected bike lane, and another bicycle ran into them. Collisions with turning cars were reported as both the highest collision rate (1.8%) and the highest near collision rate (23%). Encounters with pedestrians had a similarly high near-collision rate at 19%, but a much lower rate of actual collision at 0.4%, which may be due to the great ease of avoiding collisions with pedestrians.

Table 8-6. Self-Reported Frequent Encounters with Obstacles or Other Users

	Barton Springs		Rio Grande		Dearborn		Milwaukee		NE Multnomah		Oak*		Fell*		L Street		Total*	
	Often	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*	*Often*	*Major Prob.*
Cars parking	6%	6%	10%	27%	3%	24%	10%	33%	2%	15%	7%	26%	8%	23%	14%	25%	8%	25%
Cars loading or unloading passengers	0%	13%	17%	24%	15%	32%	21%	37%	10%	21%	12%	22%	7%	20%	22%	30%	15%	27%
Delivery vehicles loading or unloading	0%	25%	22%	32%	15%	28%	22%	42%	30%	31%	18%	29%	14%	30%	45%	50%	25%	36%
Taxis	0%	13%	7%	15%	18%	36%	27%	45%	2%	10%	13%	23%	7%	18%	22%	30%	15%	27%
Cars/trucks driving where they are not supposed to (in the [FACILITY])	6%	19%	12%	27%	5%	26%	10%	34%	1%	17%	3%	23%	12%	25%	11%	31%	8%	27%
Cars/trucks waiting to make turns OFF of [STREET]	25%	25%	15%	15%	13%	15%	27%	23%	14%	12%	12%	6%	22%	22%	41%	15%	24%	16%
Cars/trucks waiting to pull out ONTO [STREET]	19%	38%	24%	22%	8%	10%	24%	21%	11%	5%	5%	4%	12%	13%	13%	5%	13%	10%
People walking in the [FACILITY]	6%	13%	20%	20%	47%	48%	17%	26%	4%	11%	2%	7%	1%	8%	6%	9%	10%	16%
People standing in the [FACILITY] while waiting to cross the street	6%	0%	17%	17%	66%	63%	27%	25%	10%	18%	4%	11%	4%	8%	26%	26%	20%	22%
Bicyclists traveling in the WRONG direction	13%	13%	-	-	-	-	1%	25%	0%	13%	1%	16%	3%	19%	8%	18%	3%	16%
Buses loading and unloading passengers	-	-	-	-	-	-	31%	26%	26%	16%	-	-	-	-	-	-	29%	23%
n	16		41		117		209		105		223		237		288		1,236	

*Oak and Fell respondents are counted twice in the total
Shaded cells indicate more than 1/3 respondents on that facility viewed that item as a "major problem"

Table 8-7. Self-Reported Collisions and Near Collisions

	Barton		Rio Grande		Dearborn		Milwaukee		NE Multnomah		Oak*		Fell*		L Street		Total*	
	Coll.	*Near*	*Coll.*	*Near*	*Coll.*	*Near*	*Coll.*	*Near*	*Coll.*	*Near*	*Coll.*	*Near*	*Coll.*	*Near*	*Coll.*	*Near*	*Coll.*	*Near*
Any Collisions or Near Collisions		18%	**	19%	**2.6% (3)**	6%	**3.3% (7)**	48%	**	38%	**1.3% (3)**	14%	**1.7% (4)**	21%	**1.7% (5)**	36%	**1.8% (18)**	33%
Collisions or near collisions with…																		
Another bicyclist		6%		5%	**0.9%**	16%	**0.5%**	27%		7%	**0.9%**	7%		11%		9%	**0.3%**	12%
A pedestrian		6%		17%	**1.7%**	59%	**1.0%**	25%		19%		5%		4%	**0.3%**	21%	**0.4%**	19%
A turning car		18%	**2.4%**	14%	**0.9%**	24%	**4.3%**	34%	**0.9%**	29%	**0.4%**	1%	**1.7%**	18%	**1.7%**	28%	**1.8%**	23%
A parking car		6%		7%		15%	**0.5%**	12%	**0.9%**	5%		4%		4%	**0.3%**	8%	**0.2%**	7%
A parked car				7%		1%		7%	**0.9%**	4%		1%		3%		9%	**0.1%**	6%
A delivery truck		6%		7%		9%		1%		12%		3%		5%		13%		8%
A bus		6%				3%		15%		6%		1%		1%		1%		4%
A taxi		6%		2%		15%		26%				4%	**0.4%**	3%	**0.3%**	15%	**0.2%**	11%
One of the plastic flexposts		6%	**2.4%**	2%	**0.9%**	3%	**1.0%**	4%		2%		2%	**0.4%**	3%	**0.7%**	2%	**0.6%**	3%
Other stationary object			**2.4%**			2%		1%		4%					**0.3%**	1%	**0.2%**	1%
Something else			**2.4%**	2%		2%	**0.5%**	2%		3%		1%		2%	**0.3%**	3%	**0.2%**	2%
One of the concrete planters	-	-	-	-	-	-	-	-		3%	-	-	-	-	-	-		3%
n	17		42		117		210		108		228		238		287		1,247	

Respondents were able to indirectly indicate if they had been involved in a collision or near-collision at all, and if so, to specify which type of collision, or near-collision. Blank cells are 0%. **Boldface** type indicates any reported collisions. Shaded cells indicate that more than 10% of respondents had experienced a near collision of that type.
*Oak and Fell respondents are counted twice in the total.
** Respondents did not indicate they had been involved in either a collision or near collision with this first question but later but later specified a specific type of collision.

8.3 Conflict Analysis

Safety performance was quantified by a surrogate measure of safety—conflicts between users. Surrogate measures (rather than reported collision data) were used because, in general, motor vehicle-bicycle collisions are rare occurrences, there is significant underreporting of events, and long time periods and a large number of sites are needed for meaningful analysis with reported crash data. The installation dates of the facilities meant that reported collision data were not yet available for most cities at the time of this report. The method used to review and identify conflicts is described in more detail in the methodology section (4.1.3). Each vehicle-bicycle interaction was rated as <u>major</u> (near collision with emergency braking and/or change of direction); <u>substantial</u> (emergency braking and/or change of direction); <u>minor</u> (precautionary braking and/or change of direction); <u>precautionary</u> (a low-risk interaction where a minor change in direction or speed was needed to avoid a conflict); or <u>no conflict</u>. The severity of conflicts was measured by actions of either the motorist or the cyclist. A conflict was defined as series of events that could lead to a collision.

No major or substantial conflicts were identified in the review, so these types are not included in the tables that follow.

8.3.1 Intersections with Turning Vehicles

Table 8-8 summarizes the results of the conflict analysis for the intersections with the various mixing zone designs. Given that none of the conflicts that were observed were emergency or substantial, there is limited information to be drawn from the conflict analysis. The majority of events that are identified in the table are "precautionary" conflicts. It should be stressed that these are very minor events on the conflict scale. Also, note that the San Francisco locations included two additional weekend hours of analysis.

Nonetheless, some additional analysis was done using the exposure information (number of through bicycles and number of turning vehicles) and the total number of conflicts (minor + precautionary). In the video review, it was noted for each turning vehicle if a bicycle was present within the analysis zone (defined as two car lengths back of the merge point). Thus, both the total number of turning vehicles and the turning vehicles when a bicycle was present are known. The second measure (the turning vehicles when a bicycle was present) more accurately represents "opportunity for collision" than total turning vehicles. This measure is less than ideal though, since some of the turning vehicles in this count may not have had the opportunity to interact with bicycles. Nonetheless, is allows for a more nuanced exposure rather than total turning vehicles and is bolded in the Table 8-8 .

To better normalize for exposure the conflicts for exposure, the final rows of Table 8-8 present two calculated conflict rates based using the following equation:

$$Conflict\ Rate = \frac{Conflicts * 1000}{Turning\ Vehicles * Through\ Bicycles}$$

The turning vehicles count is either 1) turning vehicles when a bike was present 2) all turning vehicles. The conflicts include both precautionary and minor. To better visualize the results, the conflict rates are presented in order in Figure 8-6 and plotted against exposure in Figure 8-7.

In the table, the turning zones and mixing zone intersections are grouped. The locations with the two highest rates are mixing zones. At NE Multnomah and 9th there are relatively few bicycles compared to total turning vehicles (219 bicycles, 1,524 turning cars), and the total conflict rate is 0.40 (conflicts per turning vehicles when bikes present * bicycles*1,000). At Oak and Broderick, there are 1,376 bicycles and 323 turning vehicles, and the conflict rate is 0.44. The other mixing zone (Fell / Baker) has the green skip coloring which keeps some vehicles from entering the mixing zone. The largest observed number of conflicts occurs at Oak and Divisadero, with 108 motor vehicle conflicts. However, the rate is the lowest (0.12) and it has the second highest exposure of turning vehicles (1,900) and the highest bicycle volumes (1,609). The other turning zone intersections have similar conflict rates. One observation is that the designs that place vehicles and bikes in the same space have higher conflict rates (though since so many of the conflicts are very minor, it is unclear if there is a safety issue). There are few observed conflicts at these locations with other bicycles or pedestrians.

Table 8-8. Summary of Conflict Analysis from Video Review, Mixing Zones

Observation Type	Number of Observations	Turning Zones with Through Bike Lane (TBL)			Mixing Zones		
		L St / 15th Street	L St / Connecticut Avenue	Oak / Divisadero Street*	NE Multnomah / 9th Street	Fell / Baker *Street	Oak / Broderick Street*
No Conflict	n	456	529	1491	206	1675	1319
	% of total	88.0%	91.2%	92.7%	94.1%	94.1%	95.9%
Precautionary (Motor Vehicle)	n	40	42	106	13	48	57
	% of total	7.7%	7.2%	6.6%	5.9%	2.7%	4.1%
Minor Conflict (Motor Vehicle)	n	0	2	2	0	1	0
	% of total	0.0%	0.3%	0.1%	0.0%	0.1%	0.0%
Precautionary (Pedestrian)	n	10	6	1	0	39	0
	% of total	1.9%	1.0%	0.1%	0.0%	2.2%	0.0%
Minor Conflict (Pedestrian)	n	0	0	0	0	0	0
	% of total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Precautionary (Bike)	n	0	0	0	0	0	0
	% of total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Minor Conflict (Bike)	n	0	0	0	0	0	0
	% of total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Precautionary (Other)	n	12	1	9	0	17	0
	% of total	2.3%	0.2%	0.6%	0.0%	1.0%	0.0%
Minor Conflict (Other)	n	0	0	0	0	0	0
	% of total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total Bicycles		518	580	1609	219	1,780	1376
Number of Turning Motor Vehicles		1978	1348	1900	1524	501	323
Number of Turning Motor Vehicles When Bike Present		599	400	547	148	209	94
Conflict Rate (Turning Vehicles When Bikes Present)		**0.13**	**0.19**	**0.12**	**0.40**	**0.13**	**0.44**
Conflict Rate (All Turning Vehicles)		0.04	0.06	0.04	0.04	0.05	0.13

* Includes 2 additional hours of weekend video

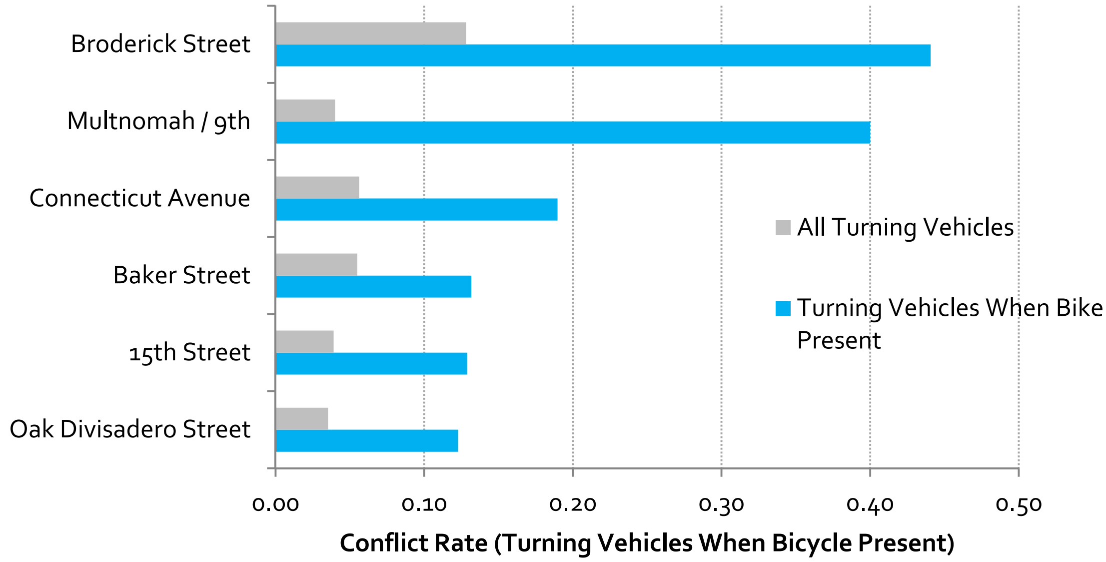


Figure 8-6. Comparison of Conflict Rates at Intersections

A stronger relationship is between the exposure and conflicts is shown in Figure 8-7 and Figure 8-8. In Figure 8-7 the total number of conflicts are shown on the y-axis with the exposure plotted on the x-axis. The total number of conflicts increases with exposure. Figure 8-8 shows the rates.

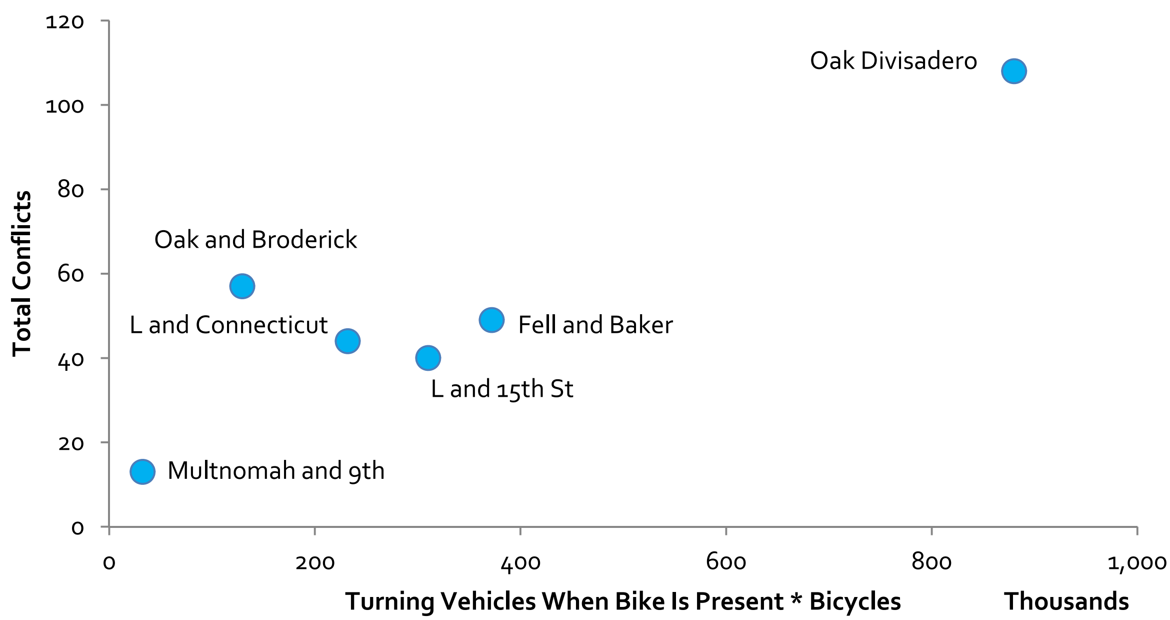


Figure 8-7 Total (Precautionary + Minor) Conflict Rates vs Exposure at Intersections

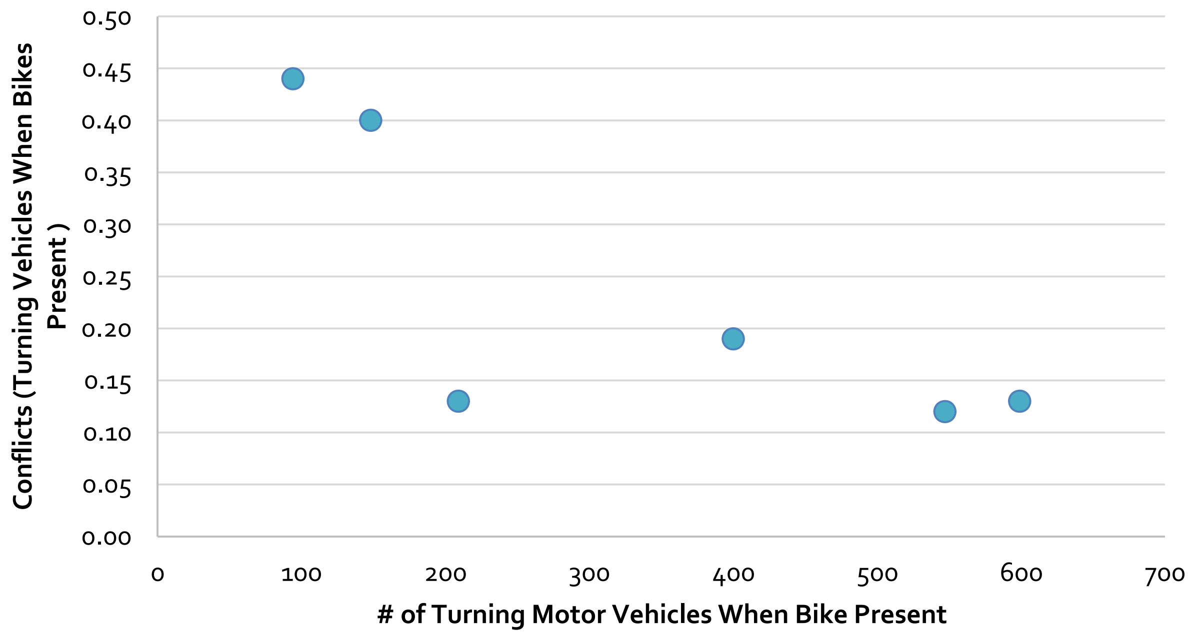


Figure 8-8 Conflict Rates vs Exposure at Intersections

8.3.2 Intersections with Bicycle Signals

Table 8-9 shows the conflict summary at the four signalized intersections in Chicago that were analyzed. There were only two observed minor conflicts; the remainder of the identified conflicts were flagged as precautionary. The conflicts are not normalized by exposure since the intersections are completely signalized, and every conflict that was observed was the result of a traffic control violation by the pedestrian, driver or cyclists (or both). The most precautionary conflicts were identified at Dearborn and Madison with pedestrians. This is consistent with surveyed perceptions about pedestrian and bicycle interactions being an issue on Dearborn.

Table 8-9. Summary of Conflict Analysis from Video Review, Signalized Intersections

Avoidance Maneuvers	Congress Pkwy	Madison Street	Randolph Street	Elston Avenue
No Conflict	955	1919	2297	1328
	90.3%	94.9%	95.0%	97.8%
Precautionary (Motor Vehicle)	39	7	25	2
	3.7%	0.3%	1.0%	0.1%
Minor Conflict (Motor Vehicle)	0	0	1	0
	0.0%	0.0%	.0%	0.0%
Precautionary (Pedestrian)	17	76	67	0
	1.6%	3.8%	2.8%	0.0%
Minor Conflict (Pedestrian)	1	0	0	0
	.1%	0.0%	0.0%	0.0%
Precautionary (Bike)	28	19	23	0
	2.6%	.9%	1.0%	0.0%
Minor Conflict (Bike)	0	0	0	0
	0%	0%	0%	0.0%
Precautionary (Other)	18	2	5	28
	1.7%	.1%	.2%	2.1%
Minor Conflict (Other)	0	0	0	0
	0%	0%	0%	0%
Total	1058	2023	2418	1358
# Turning MV Conflicts	48	34	49	2942

8.3.3 Summary of Conflict Analysis

- In the 144 hours of video analyzed for safety in this research, studying nearly 12,900 bicycles through the intersections, no collisions or near collisions were observed. This included both intersections with turn lanes and intersections with signals for bicycles.
- In the same video analysis, only 6 minor conflicts (defined as precautionary braking and/or change of direction of either the bicycle or motor vehicle) were observed. At the turning and mixing zones analyzed there were 5 minor conflicts and 6,100 bicycles or 1 minor conflict for every 1,200 though bicycles.
- Nearly all observed interactions (conflicts) were deemed precautionary—a low-risk and minor event where a minor change in direction or speed was needed to avoid a conflict. A total of 379 precautionary conflicts with motor vehicles, 216 with pedestrians, 70 with other bicycles were observed.
- There was generally a higher rate of conflicts observed in the mixing zone designs than in the turning zone designs.

9 FINDINGS: RESIDENT PERCEPTIONS

Resident perceptions of the protected bike lanes were generally positive, with a plurality indicating that the facility increased the desirability of their neighborhood. Although residents expressed concerns about how the road changed for walking and driving, most still agreed that the road now works better for all road users. Not surprisingly, people who use bicycles for commuting were more positive toward the facilities. People who commute primarily by car or foot (labeled motorists and pedestrians) also generally supported the changes, but have concerns about congestion and parking.

9.1 Perceptions of Residents about their Neighborhood

All residents were asked a series of questions regarding their general perceptions of their neighborhood with respect to transportation, as shown in Table 9-1. In general, respondents are satisfied with transportation in their neighborhoods and feel changes regarding bicycling have been positive. A strong majority (60%) felt that changes in their neighborhood as a place for bicycling were positive. About twice as many thought that changes have been positive for walking compared with negative (36% vs. 18%, respectively). This contrasts with half (50%) saying that changes in their neighborhood as a place for driving have been negative. The perceptions did vary some by city (Figure 9-1). Portland residents were the least positive about the changes for bicycling; instead they were more likely to say that any changes had no impact. That may be because their neighborhood was already bike-friendly. Portland residents were the most likely to say that they thought bicycling in their neighborhood was safe. Portlanders were also the least negative about changes for driving.

Table 9-1. Perceptions of the Neighborhood and Transportation, by Primary Commute Mode

Question	Response	Primary Commute Mode						Total
		Car/ Truck	Foot	Bicycle	Transit	Mix	Non-commuter	
Overall, my level of satisfaction with transportation in my neighborhood is . . .	Dissatisfied	36%	16%	13%	11%	19%	23%	24%
	Satisfied	64%	84%	87%	89%	81%	77%	76%
Changes to my neighborhood as a place for biking have been . . .	Negative	20%	9%	6%	10%	10%	21%	15%
	Positive	54%	66%	86%	62%	65%	41%	60%
Changes to my neighborhood as a place for walking have been . . .	Negative	21%	20%	8%	11%	15%	23%	18%
	Positive	36%	37%	37%	39%	36%	31%	36%
Changes to my neighborhood as a place for driving have been . . .	Negative	61%	45%	31%	44%	47%	42%	50%
	Positive	8%	8%	8%	9%	10%	11%	9%
Changes to my neighborhood as a place for public transportation have been . . .	Negative	18%	17%	17%	15%	18%	15%	17%
	Positive	16%	25%	17%	32%	23%	23%	21%
Bicycling in my neighborhood is safe.	Disagree	35%	33%	19%	35%	29%	35%	33%
	Agree	60%	63%	81%	58%	66%	51%	62%
n		920	313	157	301	335	237	2,277

Note: Respondents with "Other" primary mode not shown in table due to smaller number, but included in total n row.

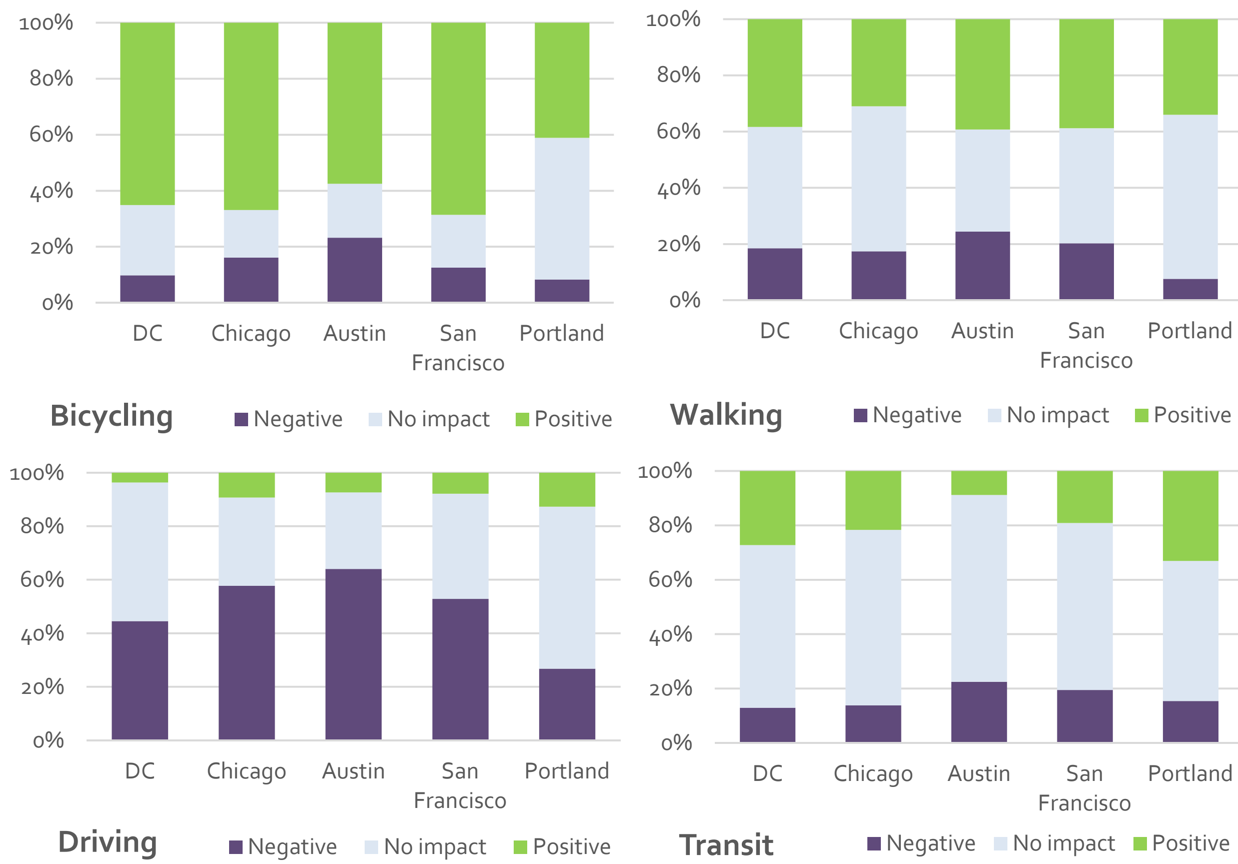


Figure 9-1. Perceptions of Neighborhood Change, by City

Residents were also very positive about bicycle facilities, generally. For example, 75% would support building more protected bike lanes at other locations, and 83% feel that bicycle facilities are a good way to improve public health (Table 9-2). Nearly all (91%) support separating bikes from cars. There were few notable differences between the cities. Chicago residents were the least supportive, though a majority was still supportive; 64% supported building more protected facilities compared to 76-80% for the other cities.

Table 9-2. Perceptions of Bike Facilities, by Primary Commute Mode

Question	Response	Primary Commute Mode						Total
		Car/ Truck	Foot	Bicycle	Transit	Mix	Non-commuter	
I would support building more protected bike lanes at other locations.	Disagree	27%	19%	5%	17%	20%	20%	21%
	Agree	69%	79%	95%	78%	76%	75%	75%
Overall I support separating bikes from cars	Disagree	9%	6%	2%	6%	9%	6%	7%
	Agree	89%	92%	96%	91%	89%	92%	91%
Facilities that encourage bicycling for transportation are a good way to improve public health.	Disagree	13%	6%	1%	7%	8%	11%	10%
	Agree	79%	88%	97%	82%	84%	80%	83%
n		920	313	157	301	335	237	2,277

Note: Respondents with "Other" primary mode not shown in table due to small number, but included in Total.

Asked about the new protected bike lane specifically, responses were also generally positive, as shown in Table 9-3. Those whose primary commute mode was bicycle were generally the most positive about the new facility, though residents who drive to work were nearly always more positive than negative about the lanes. A majority of respondents across most modes felt the street now worked better for all road users, while strong majorities of respondents indicated that the facilities made it clear where bikes and cars should be, and did a good job of protecting bikes from cars. Nearly three times as many residents overall felt the facility increased rather than decreased the desirability of living in their neighborhood (43% vs 14%), with the remainder indicating either no change or no opinion. Over one-third (38%) of the residents felt that the new lane improved the aesthetic appeal of the street, while 26% felt that aesthetics had decreased as a result of the lane. This did vary significantly by city, with Portland residents being the most positive (59% increase and 18% decrease) and Chicago residents the least positive (28% increase and 46% decrease). The former is likely due to the inclusion of planters with flowers in the buffer area.

Table 9-3. Perceptions about the New Facility, by Primary Commute Mode

Question	Response	Car/ Truck	Foot	Bicycle	Transit	Mix	Non-commuter	Total
Because of the protected bike lanes, the desirability of living in my neighborhood has . . .	Decreased	18%	13%	3%	12%	11%	14%	14%
	Increased	39%	45%	66%	43%	47%	36%	43%
Because of the protected bike lanes, the aesthetic appeal of the street has . . .	Decreased	33%	29%	10%	23%	23%	27%	26%
	Increased	32%	40%	61%	43%	38%	45%	38%
Because of the protected bike lanes, the number of people I see riding bikes on the street has . . .	Decreased	2%	0%	0%	1%	2%	2%	1%
	Increased	58%	75%	82%	73%	71%	49%	65%
Because of the protected bike lanes, how well the street works for all people has . . .	Decreased	30%	28%	8%	24%	27%	25%	26%
	Increased	53%	59%	83%	54%	55%	46%	56%
The protected bike lanes' design makes it clear where cars can be and where the designated bicycle lanes are.	Disagree	14%	18%	9%	16%	16%	13%	15%
	Agree	83%	81%	91%	82%	81%	82%	83%
The buffer does a good job at protecting bikes from cars.	Disagree	19%	18%	10%	15%	16%	17%	17%
	Agree	77%	79%	89%	79%	82%	73%	78%
The protected bike lanes improve the predictability of drivers and bicyclists.	Disagree	28%	26%	10%	24%	25%	26%	25%
	Agree	66%	70%	86%	70%	69%	64%	69%
n		920	313	157	301	335	237	2,277

Note: Respondents with "Other" primary mode not shown in table (n=14), but included in Total.

9.2 Motorist Perceptions

Resident surveys asked respondents if they had driven a motor vehicle on the facility route since its construction and, if so, to answer a series of questions on their driving experience. An average of 86% of respondents indicated that they had driven on the route. Select responses are shown in Table 9-4. Responses were mixed, but several trends emerged. Relatively few motorists avoided driving on these routes, with the exception of Dearborn Street and Milwaukee Avenue in Chicago, where around a third of respondents indicated they avoid those streets. A majority of respondents noted that they noticed fewer bicyclists riding in the same lanes as cars, and that bicyclists were now riding more safely and predictably. Respondents were more negative about issues of delay/congestion, difficulty of turning on and off the street, and the impact of the facility on finding parking. Overall, 31% said that it took them longer to drive on the street since the lanes were built, and 36% said that the impact on traffic congestion has been negative. Similar shares expressed concerns over turning on and off of the street. As with the question of avoiding the route with the new facility, Dearborn Street and Milwaukee Avenue were consistently among the most negative.

In all cities, drivers were most negative about the impact on parking, with 44% saying that is has negatively impacted their ability to find a parking space and 45% saying it is stressful to park on the street. However, as shown in Figure 9-2, the opinions are not closely correlated with the actual magnitude of the change in parking availability. For example, as a result of the lane in Portland (NE Multnomah), the city added 27 parking spaces. However, 30% of the residents still felt that the lane made parking more difficult to find. Similarly, parking reduction was minimal on Dearborn in Chicago (21 spaces lost in over one mile), yet 41% said that it was more difficult to find a spot.

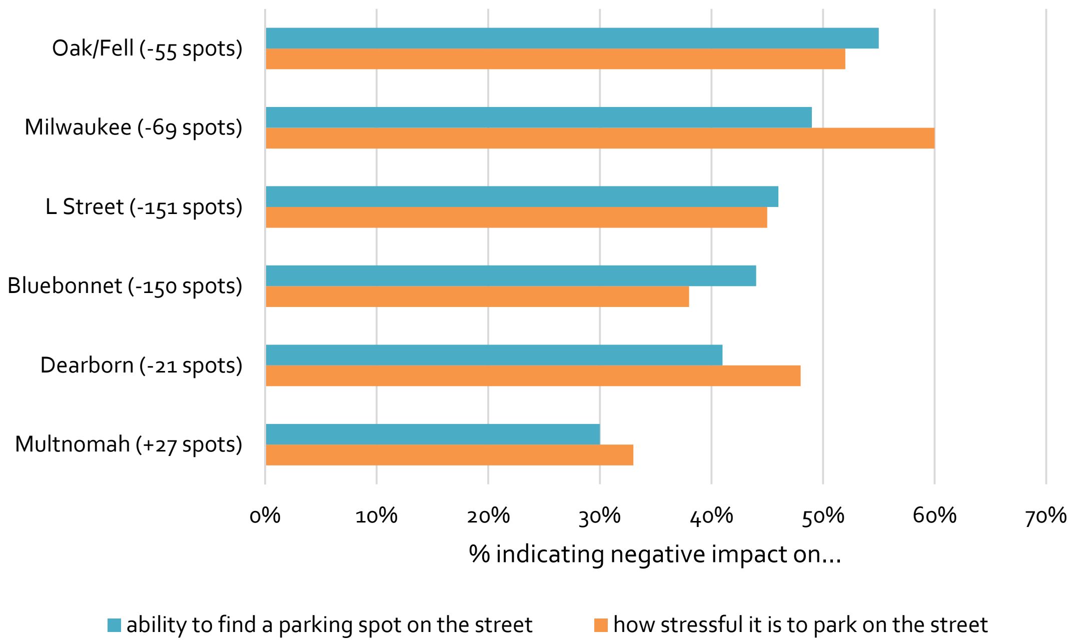


Figure 9-2. Percent of Residents Self-Reporting Negative Effects on Parking, by Facility and Change in Number of Spaces

Table 9-4. Motorist Perceptions of New Bicycle Facilities

Question	Response	Austin		Chicago		Portland	San Francisco		Wash. DC	
		Barton Springs	Bluebonnet	Dearborn	Milwaukee	NE Multnomah	Oak	Fell	L Street	Total
I have driven a motor vehicle on this section of [the street] since the protected bike lanes were built.		393 (92%)	389 (93%)	146 (76%)	277 (92%)	369 (79%)	435 (87%)		165 (73%)	2,174 (86%)
Do you ever avoid driving on the street because of the protected bikeway?		6%	9%	33%	36%	14%	11%	10%	14%	14%
Since the protected bike lanes were built, the number of bicyclists riding in the same lanes with cars on the street has . . .	Decreased	44%	54%	61%	59%	43%	50%	56%	54%	52%
	Increased	22%	20%	22%	29%	16%	28%	22%	23%	23%
Since the protected bike lanes were built, how safe and predictable bicyclists are acting has . . .	Decreased	5%	6%	16%	26%	7%	18%		15%	12%
	Increased	58%	59%	53%	44%	48%	54%		52%	53%
Since the protected bike lanes were built, the amount of time it takes me to drive on this street has . . .	Decreased	9%	7%	12%	12%	10%	10%	9%	13%	10%
	Increased	18%	15%	54%	63%	32%	22%	20%	27%	31%
The impact of the protected bike lanes on traffic congestion has been . . .	Negative	19%	17%	61%	68%	36%	-		39%	36%
	Positive	14%	9%	5%	8%	14%	-		9%	11%
The impact of the protected bike lanes on my ability to turn off of the street at signalized intersections has been . . .	Negative	26%	-	67%	67%	26%	35%		48%	40%
	Positive	7%	-	10%	8%	16%	20%		15%	13%
The impact of the protected bike lanes on my ability to turn off of the street into alleys, driveways, and parking lots has been . . .	Negative	26%	26%	45%	69%	27%	36%		37%	36%
	Positive	6%	7%	5%	5%	13%	11%		8%	8%
The impact of the protected bike lanes on my ability to pull onto the street from alleys, driveways, and parking lots has been . . .	Negative	22%	29%	47%	68%	24%	32%		31%	34%
	Positive	6%	9%	3%	5%	16%	9%		8%	9%
The impact of the protected bike lanes on my ability to find a parking spot on the street has been . . .	Negative	-	44%	41%	49%	30%	55%		46%	44%
	Positive	-	4%	8%	4%	9%	1%		4%	5%
The impact of the protected bike lanes on how stressful it is to park a car on the street has been . . .	Negative	-	38%	48%	60%	33%	52%		45%	45%
	Positive	-	3%	7%	3%	9%	2%		4%	4%

9.3 Pedestrian Perceptions

Residents were asked if they had walked on the facility route since its construction, and 48-99% had done so (Table 9-5). These pedestrians have mixed perceptions of the facilities. Half of pedestrian respondents indicated that there are fewer bicyclists on sidewalks now because of the lanes, and twice as many respondents indicated that their satisfaction with the walking environment had increased (36%) as opposed to decreased (15%). Consistent with the motorist section of the resident survey, more respondents felt that motorist speeds had decreased (27%) versus increased (6%) – likely a negative finding for people driving on the street, but a positive one for people walking on the street. On routes with unsignalized crosswalks, however, six out of 10 respondents indicated that bicyclists “rarely” or “never” stop for pedestrians at these locations. However, for some of the facilities, a significantly higher share of the pedestrians said that their sense of safety while crossing the street had increased; this was true for Barton Springs, Bluebonnet, NE Multnomah, and L Street. The opposite was true for residents who walked along Dearborn and Milwaukee in Chicago. San Francisco residents were about evenly split on this question.

Table 9-5. Pedestrian Perceptions of New Bicycle Facilities

Question	Response	Austin		Chicago		PDX	SF	DC	Total
		Barton Springs	Bluebonnet	Dearborn	Milwaukee	NE Multnomah	Oak/Fell	L Street	
I have walked on this section of [street] since the facility was built.		200	285	194	266	341	471	222	1979
		48%	68%	99%	89%	73%	94%	97%	78%
Do you ever walk or jog in the protected bike lanes, rather than on the sidewalk?		7%	42%	10%	9%	3%	3%	7%	11%
How often do bicyclists in the bike lanes stop for pedestrians at unsignalized intersections?	"Usually" or "Sometimes"	-	46%	-	21%	51%	-	-	41%
	"Rarely" or "Never"	-	54%	-	79%	49%	-	-	59%
Because of the protected bike lanes, drivers' speeds on this street have generally . . .	Decreased	17%	25%	28%	46%	40%	16%	17%	27%
	Increased	7%	6%	5%	7%	4%	8%	5%	6%
Because of the protected bike lanes, the number of bicyclists riding on the sidewalk has . . .	Decreased	50%	66%	47%	41%	45%	47%	48%	49%
	Increased	19%	7%	17%	20%	12%	19%	19%	16%
Because of the protected bike lanes, my satisfaction with the walking environment on this street has . . .	Decreased	6%	10%	29%	25%	7%	18%	11%	15%
	Increased	58%	49%	17%	19%	37%	33%	36%	36%
Because of the protected bike lanes, my sense of safety when crossing this street has . . .	Decreased	5%	9%	45%	37%	8%	22%	19%	20%
	Increased	43%	34%	18%	17%	35%	24%	27%	28%

10 FINDINGS: APPEAL TO DIFFERENT GROUPS

In most large U.S. cities, including those in this study, the people who regularly bicycle for transportation are not representative of the general population. As seen in the demographics of our bicyclist intercept surveys, people riding bicycles are more likely to be male and younger. However, large increases in bicycling will only occur if a broader range of people ride regularly. Separated facilities are often considered to have the most potential effect on people who are uncomfortable bicycling with few or no dedicated bicycling facilities and mixing with high speeds and volumes of traffic. Therefore, they may help increase the diversity of riders. Moreover, significant investments in new infrastructure will likely require broad political support. This section aims to better understand whether different groups of people, particularly those who do not typically ride now, support protected bike lanes and whether they might bicycle more if such lanes are provided. To do so, we examine survey responses by bicyclist typology, gender, and age. Most of the analysis uses the resident survey because it provides a broader spectrum of people and opinions.

10.1 Interest in Bicycling

A majority of the residents (58%) surveyed indicated that they were interested in bicycling more often for transportation, including 57% of people who primarily commute by car/truck (Table 10-1). Even larger shares, including 61% of people who drive to work, said that they would be more likely to ride a bicycle if they were separated from motor vehicles by a barrier.

Table 10-1. Interest in Bicycling, by Primary Commute Mode

Question	Response	Primary Commute Mode						Total
		Car/ Truck	Foot	Bicycle	Transit	Mix	Non-commuter	
I would like to bicycle more often for transportation.	Disagree	32%	28%	5%	32%	21%	39%	29%
	Agree	57%	60%	90%	52%	69%	33%	58%
I would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier.	Disagree	29%	21%	15%	22%	25%	27%	25%
	Agree	61%	69%	78%	63%	64%	44%	62%
n		920	313	157	301	335	237	2,277

Note: Respondents with "Other" primary mode not shown in table due to the low number, but included in Total.

10.2 Bicyclist Typology

As described in Section 5.2.1, most residents were defined as being either *Enthused and Confident* (27%) or *Interested but Concerned* (43%) based upon their stated level of comfort bicycling on different types of environments and their interest in and ability to bicycle. These categories were the most likely to say that they would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier (Figure 10-1). In particular, 85% of the *Interested but Concerned* agreed with this statement. The *Strong and Fearless* were about evenly split, with 43% agreeing that they would bicycle more with the separation and 41% disagreeing.

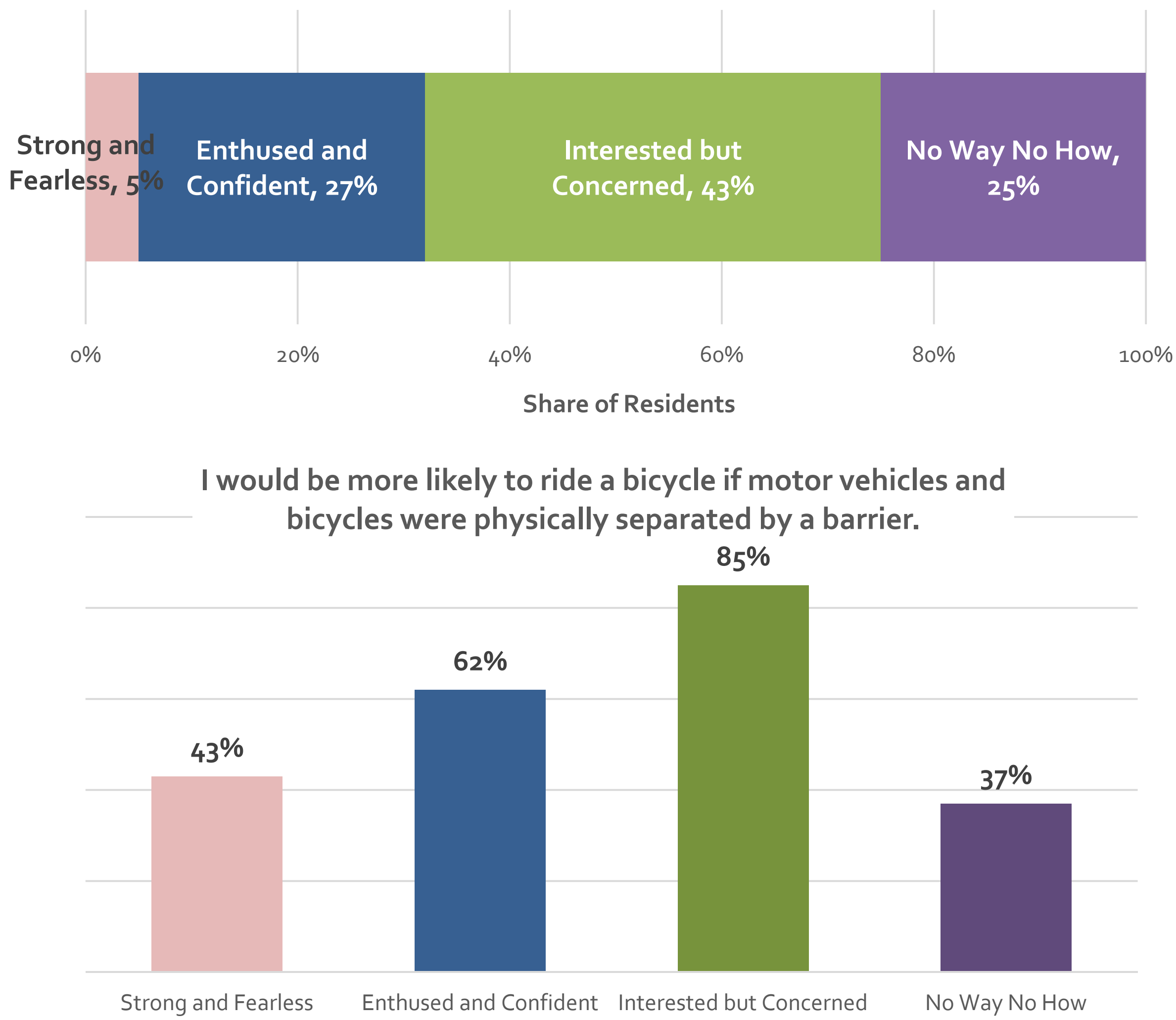


Figure 10-1. Types of Cyclists and Potential Effect of Protected Lanes

These differences are often mirrored in responses to questions about support for more protected lanes and opinions about how well they work (Table 10-2). The *Strong and Fearless* were generally not overly supportive of the protected bike lanes. This likely reflects a more vehicular cycling experience or preference that helps define this group. This is not to say that the *Strong and Fearless* felt negatively about the facilities; rather, this group only reported moderate changes in attitudes or behavior of either themselves or others because of the facility.

On the other end of the spectrum, the *No How Now Way* group displayed significantly more negative attitudes toward the facilities. For example, with the statement, "Because of the protected bike lanes, the desirability of living in my neighborhood has decreased/stayed the same/increased," about half of the first three types felt their neighborhood desirability had increased due to the facilities, while only 20% of *No How No Way* felt the same. The *No How No Way* group, however, despite reporting relatively low support for building more protected bike lanes at other locations (49% support, versus 74-87% in the other groups), reported strong support (81%) for separating bikes from cars.

Perhaps of greatest interest is the *Interested but Concerned* group. By definition, they are the largest group, and have interest in but measured caution about bicycling. On nearly every measure, they equal or surpass the *Enthused and Confident* group in their positive view of the changes due to the protected bike lanes. They report the highest levels of support for protected bike lanes, with 87% supporting building more protected bike lanes at other locations, and 96% responding that overall, they support separating bikes from cars (Table 10-2).

Table 10-2. Support for Separated Facilities, By Cyclist Type (Residents)

Question and Response		Cyclist Typology			
		Strong and Fearless	Enthused and Confident	Interested but Concerned	No Way No How
I would support building more protected bike lanes at other locations.	Disagree	21%	13%	11%	46%
	Agree	74%	84%	87%	49%
Overall, I support separating bikes from cars.	Disagree	13%	5%	3%	15%
	Agree	83%	94%	96%	81%
Because of the protected bike lanes, the desirability of living in my neighborhood has…	Decreased	10%	7%	8%	29%
	Increased	50%	54%	53%	20%
Over time, my opinion of the protected bike lanes has become …	More negative	20%	11%	13%	45%
	Not changed	21%	23%	28%	30%
	More positive	59%	65%	58%	25%
The protected bike lanes' design makes it clear where cars can be and where the designated bicycle lanes are.	Disagree	13%	8%	13%	25%
	Agree	85%	90%	86%	73%
The buffer effectively separates bikes from cars.	Disagree	13%	5%	12%	28%
	Agree	85%	93%	86%	69%
The buffer does a good job at protecting bikes from cars.	Disagree	17	7%	14%	31%
	Agree	80%	90%	83%	63%
The protected bike lanes improve the predictability of drivers and bicyclists.	Disagree	19%	14%	20%	43%
	Agree	76%	81%	74%	50%
The protected bike lanes make it clear where bicyclists and pedestrians should be.	Disagree	20%	8%	14%	26%
	Agree	74%	90%	82%	69%
The protected bike lanes effectively separate bicyclists from pedestrians.	Disagree	35%	15%	21%	44%
	Agree	57%	77%	71%	49%
	n	96-103	514-544	812-866	479-495

Note: n varies due to non-response to individual questions

On measures of the effectiveness and design of the protected bike lanes, there were fewer differences between groups. While the *No How No Way* group was generally less positive, the differences were smaller than other attitude questions, with the exception of the questions of improved predictability of drivers and bicyclists and the separation of bicyclists from pedestrians.

The residents were also asked if they had bicycled on the new protected bike lane and over half of them had. These residents then answered some of the same questions that the intercepted cyclists did on their survey. The *Enthused and Confident* and *Interested but Concerned* groups were most likely to say that they were bicycling more frequently on the street with the lane and more often because of the new lanes (Table 10-3).

Table 10-3. Change in Bicycling, By Cyclist Type (Residents)

Question	Strong and Fearless	Enthused and Confident	Interested But Concerned	No Way No How*	All
Because of the [protected bike lane], the likelihood that I will choose to bicycle on this street as opposed to other streets has . . .					
Decreased a Lot	5%	1%	3%	23%	4%
Decreased Somewhat	0%	1%	1%	11%	1%
Not Changed	52%	19%	18%	43%	22%
Increased Somewhat	22%	29%	37%	23%	32%
Increased a Lot	21%	49%	41%	0%	40%
n	58	287	383	35	763
Because of the [protected bike lane], how often I ride a bicycle overall has . . .					
Decreased a Lot	2%	0%	1%	20%	2%
Decreased Somewhat	4%	0%	3%	3%	2%
Not Changed	75%	54%	52%	70%	55%
Increased Somewhat	11%	29%	31%	7%	28%
Increased a Lot	9%	16%	12%	0%	13%
n	55	283	379	30	747

*A small share of residents categorized as *No Way No How* did state that they bicycled on the facility and answered these questions. This may indicate that our method of typing the respondents is not perfect and/or that some respondents did not answer questions accurately.

Similar patterns are seen among the intercepted cyclists (Table 10-4). The *Enthused and Confident* and *Interested but Concerned* were more likely to say that the protected bike lane had increased how safe they feel bicycling on the street by “a lot” compared to the *Strong and Fearless*. These two groups were also more likely to say that how often they rode a bicycle overall had increased (somewhat or a lot) because of the new lanes.

Table 10-4. Change in Bicycling, By Cyclist Type (Cyclists)

Question and Response	Strong and Fearless	Enthused and Confident	Interested But Concerned	All
I feel the safety of bicycling on [STREET] has . . .				
Decreased a Lot	1%	1%	1%	1%
Decreased Somewhat	0%	2%	1%	1%
Not Changed	2%	3%	1%	2%
Increased Somewhat	40%	23%	27%	26%
Increased a Lot	57%	71%	70%	69%
n	81	377	521	979
How often I ride a bicycle overall has . . .				
Decreased a Lot	0%	0%	1%	2%
Decreased Somewhat	0%	0%	0%	0%
Not Changed	82%	70%	67%	70%
Increased Somewhat	9%	14%	19%	16%
Increased a Lot	10%	15%	14%	14%
n	82	375	516	973
Before the new facility, how would you have made this trip				
By bicycle, using this same route	72%	65%	56%	61%
By bicycle, using another route - (Please specify which route):	24%	25%	31%	28%
By Other Mode	4%	9%	12%	10%
Would not have taken trip	0%	2%	1%	1%
I would go out of my way to ride on [STREET] compared to other streets.				
Strongly Disagree	8%	4%	2%	3%
Somewhat Disagree	20%	11%	10%	11%
Somewhat Agree	37%	45%	48%	46%
Strongly Agree	35%	40%	39%	39%
n	79	361	508	948

*A small share of residents categorized as *No Way No How* did state that they bicycled on the facility and answered these questions. This may indicate that our method of typing the respondents is not perfect and/or that some respondents did not answer questions accurately.

10.3 Gender

Just under one-third (32%) of the cyclists who completed the intercept survey were women. Overall, women were significantly more likely to say that they had increased their overall amount of cycling a lot because of the protected lanes (Figure 10-2). The gender difference varied by city, with the largest differences seen in Austin, San Francisco, and Washington, D.C. Despite these differences, intercepted women cyclists were not more likely to feel that the lane had increased how safe they felt on the street. However, they were more likely to strongly agree that they go out of their way to ride on this street.

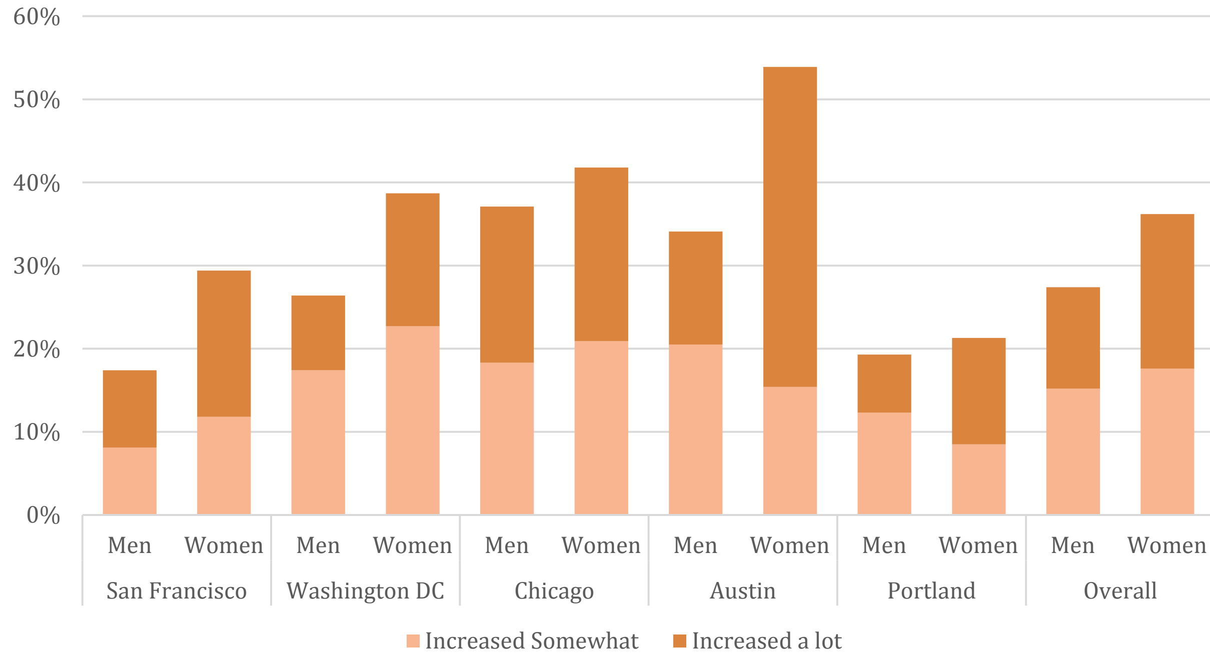


Figure 10-2. Increase in Overall Bicycling due to Protected Lanes, by Gender (Cyclist Intercept Survey)

The residents displayed few gender differences in attitudes toward the facilities. In responses about the effectiveness or clarity of the design, there were no notable differences by gender. Additionally, there were no significant gender differences in support for protected bike lanes. Men and women reported nearly identical amounts of agreement with the statement, "I would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier" (63% and 62%, respectively).

Men and women were nearly identical in their attitudes toward the impact of the protected bike lanes on safety of driving or bicycling (Table 10-5). Women were slightly less positive in their attitudes about the facilities' impact on the neighborhood or street, but were no more neutral or negative than men (they were more likely to respond "No opinion") (Table 10-5).

Table 10-5. Residents' Perception of Facility, by Gender

Because of the protected bike lanes:	Response	Male	Female
the desirability of living in my neighborhood has …	Decreased	13%	14%
	Not Changed	32%	34%
	Increased	47%	41%
the aesthetic appeal of the street has …	Decreased	27%	28%
	Not Changed	26%	29%
	Increased	44%	36%
the safety of driving on the street has …	Decreased	25%	29%
	Not Changed	30%	26%
	Increased	38%	37%
the safety of bicycling on the street has …	Decreased	7%	7%
	Not Changed	6%	6%
	Increased	80%	77%
how well the street works for all people has …	Decreased	25%	27%
	Not Changed	9%	9%
	Increased	61%	53%
	n	940	1079

10.4 Age

Attitudes toward the facilities were compared across age groups. The youngest respondents tended to be the most positive toward the facilities, and each subsequent group reported slightly less positive views of the protected bike lanes. For example, all groups felt the facility had a more positive impact on the safety of bicycling versus driving, but on both measures, the magnitude of the positive attitude diminished, and the negative attitude increased, with age. The only real outlier on the measure of increased bicycling safety was the 55-64 age group, with 13% reporting that the safety of bicycling had decreased (Table 10-6).

Table 10-6. Safety by Age of Respondent

Question	Response	Age Group						Total
		18-24	25-34	35-44	45-54	55-64	65+	
Because of the protected bike lanes, the safety of driving on the street has …	Decreased	12%	20%	26%	28%	32%	32%	26%
	Not Changed	15%	30%	32%	29%	29%	21%	29%
	Increased	62%	42%	37%	37%	32%	37%	38%
	n	34	507	459	351	339	303	1993
Because of the protected bike lanes, the safety of bicycling on the street has …	Decreased	0%	4%	4%	8%	13%	6%	6%
	Not Changed	3%	3%	5%	5%	6%	10%	6%
	Increased	91%	86%	83%	79%	73%	67%	79%
	n	34	508	460	352	340	298	1992

All of the age groups were generally positive about the effectiveness and clarity of the design of the protected bike lanes, although the attitudes demonstrated that slight negative linear relationship with age. All groups showed moderately to highly strong support of building more protected bike lanes at other locations, with support declining with age group (Table 10-7). The responses to the question, "Overall, I support separating bikes from cars" were overwhelmingly positive, ranging from 84% to 100%. All of the groups were more likely than not to report being more likely to ride a bicycle if cars and bicycles were separated, except for the oldest age group; one-third responded that they had no opinion on this question.

Table 10-7. Support for Protected Lanes by Age of Respondent

Question	Response	Age Group						Total
		18-24	25-34	35-44	45-54	55-64	65+	
I would support building more protected bike lanes at other locations.	Disagree	0%	12%	18%	23%	27%	26%	20%
	Agree	97%	84%	79%	74%	69%	66%	76%
	n	35	521	471	359	364	318	2068
Overall, I support separating bikes from cars.	Disagree	0%	4%	8%	6%	9%	8%	7%
	Agree	100%	94%	90%	93%	88%	89%	91%
	n	35	520	470	361	365	316	2067
I would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier.	Disagree	11%	18%	24%	27%	28%	32%	25%
	Agree	77%	74%	65%	65%	61%	38%	63%
	n	35	525	477	361	371	304	2073

11 FINDINGS: ECONOMIC EFFECTS

The construction of these protected bike lanes were not specifically undertaken with the goal of producing an economic impact. However, some recent studies have shown that bicycle related infrastructure can contribute to local economic vitality (see discussion in Chapter 2 of this report).

Further analyses of tax data and development patterns will require a longer timeframe to play out, but this survey data does provide an insight into decisions about visiting local businesses. For example, among people who have ridden a bicycle on the facility route there appears to be an added incentive to visit businesses along the route. Respondents of the bicyclist intercept survey and residents who indicated that they had biked on the facility were asked to indicate if the frequency with which they stop at shops and businesses along the route had decreased, not changed, or increased due to the new protected bike lane. About one in five respondents indicated that they stopped at businesses more frequently now, while about 6% of residents who had bicycled on the new facility indicated they stop at businesses less frequently now.

Looking at all residents sampled in the survey, including those who have never bicycled on the facility, there appears to be more variety based on which city and facility you look at. In Chicago, more respondents indicated that they would be less likely to visit a business on the corridor than would be more likely to do the same (although most indicated that there has been no change in the likelihood). In each of the other cities, more people indicated they would be more likely to visit a business now. Barton Springs shows the most dramatic impact, with over one in four residents saying they would be more likely to visit a business along the route now, with only 2% indicating they would be less likely to do so.

Table 11-1. Frequency/Likelihood of Visiting Businesses

Question		Austin Barton Springs	Austin Rio Grande	Chicago Dearborn	Chicago Milwaukee	Portland NE Multnomah	San Francisco Oak Fell	DC L Street	Total
Because of the protected bike lanes, how often I stop at shops and businesses on this street has									
Bicyclists	Decreased	0%	8%	0%	1%	0%	0%	0%	1%
	Increased	11%	18%	20%	22%	12%	13%	24%	19%
	n	18	38	115	221	104	229	280	1005
Residents who Bicycled on Facility	Decreased	7%	-	6%	10%	5%	6%	4%	6%
	Increased	24%	-	14%	21%	13%	18%	42%	20%
	n	45	-	66	121	175	234	77	718
Since the protected bike lanes were built, are you more or less likely to visit a business on the corridor?									
Residents	Less likely	2%	-	11%	21%	5%	7%	7%	9%
	More likely	27%	-	8%	10%	12%	11%	15%	12%
	n	86	-	193	294	463	503	232	1771

There are several challenges in identifying connections between bicycle facilities and economic changes. These changes may be subtle or tied to an overall change in character of a corridor or neighborhood. For example, on NE Multnomah Street in Portland, residential development and increased appeal for commercial development has picked up recently. Anecdotal evidence suggests this development is tied to a growing sense of the street and neighborhood's increasing livability and vitality. The study team had originally planned to examine these effects through establishment-level sales tax data but found suitable facilities with available data limited in the facilities selects. A follow-up analysis to this report, and will look at changes in economic activity through sales tax collection data before and after the installation of protected bike lanes in several locations.

12 CONCLUSIONS

The overall objective of this research is to evaluate U.S. protected bicycle lanes (cycle tracks) in terms of their use, perception, benefits, and impacts. This research examines protected bicycle lanes in five cities: Austin, TX; Chicago, IL; Portland, OR; San Francisco, CA; and Washington, D.C., using video, surveys of intercepted bicyclists and nearby residents, and count data. The key findings of this research are summarized below.

12.1 Changes in Ridership

The research evaluated the change in people bicycling on the protected lanes using observed count data prior to and after installation.

- The analysis estimated that ridership increased from +21% to +171% within one year of building the protected lanes. The increases appear to be greater than overall increases in bicycle commuting in each city.
- The wide range of the increases is explained by context of the facility in each city's network and the existing number of cyclists using the route. These factors influence whether new bicyclists are using the route, diverting from other routes, or would have biked on that route anyway, and, therefore, the magnitude of the change. Established routes (e.g. Milwaukee) that are key connections saw lower growth than new connections (e.g. Dearborn).
- Counts were taken not long after the lanes were implemented (one year or less) and it is not clear how ridership will change over time. It is reasonable to expect that as people learn about the facilities, and if complementary routes create fuller networks of protected facilities, ridership would continue to increase, perhaps more from new riders rather than existing riders changing routes.

The responses from the survey provide some insight into how much of the increase in ridership at each facility likely came from new riders (i.e., riders who, absent the protected bike lane, would have travelled via a different mode or would not have taken the trip) and some from riders diverted from other nearby streets (i.e., riders who were attracted to the route because of the facility, but would have chosen to ride a bicycle for that trip regardless).

- Overall, about 10% of the intercepted cyclists stated that they would have made the trip they were making by another mode and 1% would not have made the trip, indicating that there are some new riders attracted to the facilities. The remainder would have bicycled on a different route (24%) or the same route (65%).
- Bicyclists self-reported that they rode more frequently on the facility after installation. Just over 49% of bicyclists indicated that they were traveling on the respective routes more frequently than they were prior to protected lanes. The percentage ranged between 28% for Fell Street in San Francisco and 31% for Milwaukee Avenue in Chicago and 86% for Dearborn Street, where the street appears to be much more attractive for bicycling than it was before and now accommodates two-way riding.

- Nearly a quarter of bicyclists intercepted on the facilities stated that their overall frequency of bicycling increased because of the new protected lanes. On Dearborn Street, over half of respondents indicated that their bicycling had increased because of the new protected bike lanes, while Barton Springs, Rio Grande, Milwaukee and L Street all had around a third of respondents state the same.

12.2 Safety

Safety of protected lanes is a composite of the travel along the segment and at intersections. Safety can be assessed in two ways: observed measures such as crashes, or surrogate measures such as conflicts and perceptions. Perceptions of safety are likely to influence individuals' decisions on whether and when to use a facility. For this research, changes in perceived safety are derived from the surveys of residents living nearby the facility and from bicyclists intercepted along the facility. Due to the very recent installation dates, reported crash data were not available for analysis on most of the facilities. Thus most of the analysis of observed safety comes from the video data for conflicts and near misses.

Overall we did not observe any notable safety problems, and survey respondents had strong feelings that safety had improved. Taken together, these findings (when combined with the results of prior work) suggest that concerns about safety should not inhibit the installation and development of protected bike lanes—though intersection design does matter, and must therefore be carefully considered.

12.2.1 Stated Perceptions of Safety

There was consistent evidence that the protected facilities improved the perception of safety for people on bicycles. This perception held for both cyclists intercepted riding on the facilities and for residents. Perceptions of the change to the safety of driving and walking on the facility were more varied.

- Nearly every intercepted bicyclist (96%) and 79% of residents stated that the installation of the protected lane increased the safety of bicycling on the street. These strong perceptions of improved safety did not vary substantially between the cities, despite the different designs used.

- Nearly nine out of 10 (89%) intercepted bicyclists agreed that the protected facilities were "safer" than other facilities in their city. A higher percentage of women agreed (93%) with this statement than men (87%)

- Perceptions of the safety of driving on the facility were more varied. Overall, 37% thought the safety of driving had increased; 30% thought there had been no change; 26% thought safety decreased; and 7% had no opinion. The perceptions varied by facility.

- Perceptions of the safety of the walking environment after the installation of the protected lanes were also varied, but were more positive than negative. Overall, 33% thought safety increased; 48% thought there had been no change; 13% thought safety decreased; and 6% had no opinion. These perceptions varied by facility.

- An important finding is that nearly all cyclists (92%) who used the intersections with separate bicycle signal phases agreed that they felt “safe” when riding through the intersection. This exceeded all other intersection designs and is the only design evaluated where the protected lane carries all the way to the intersection.

12.2.2 Observed Safety

Due to the very recent installation dates, reported crash data were not available for analysis on most of the facilities. Observed safety is drawn from observation of the video data taken at the intersections studied.

- In the 144 hours of video analyzed for safety in this research, studying nearly 12,900 bicycles through the intersections, no collisions or near collisions were observed. This included both intersections with turn lanes and intersections with signals for bicycles.
- In the same video analysis, only 6 minor conflicts (defined as precautionary braking and/or change of direction of either the bicycle or motor vehicle) were observed. At the turning and mixing zones analyzed there were 5 minor conflicts in 6,100 though bicycles or 1 minor conflict for every 1,200 though bicycles.
- Nearly all observed interactions (conflicts) were deemed precautionary—a low-risk and minor event where a minor change in direction or speed was needed to avoid a conflict. A total of 379 precautionary conflicts with motor vehicles, 216 with pedestrians, 70 with other bicycles were observed.
- There was generally a higher rate of conflicts observed in the mixing zone designs than in the turning zone designs.

12.3 Design-Related

12.3.1 Buffer Designs

The survey assessed bicyclists’ perceptions of different buffer designs based upon their stated preferences for the actual facilities where they rode and some hypothetical designs presented through diagrams. Both methods reveal that bicyclists have a preference order in terms of the degree of protection that affects comfort.

- Designs with more physical separation had the highest scores. Buffers with vertical physical objects (those that would be considered protected lanes - e.g. with flexposts, planters, curbs, or parked cars) all resulted in considerably higher comfort levels than buffers created only with paint.
- Flexpost buffers got very high ratings even though they provide little actual physical protection from vehicle intrusions— cyclists perceive them as an effective means of positive separation.
- Any type of buffer shows a considerable increase in self-reported comfort levels over a striped bike lane.

One clear takeaway is that designs of protected lanes should seek to provide as much protection as possible to increase cyclists' comfort.

12.3.2 Intersections

To understand how well the intersections worked, the research analyzed motorists and bicycles using video ("observed behavior") as well as asking comprehension-related questions in the surveys. In general, three different design approaches were evaluated. First, some designs require the bicycles and turning vehicles to "mix" in the same space. These designs are called "mixing zones." The second approach moves the through bicycle from the protected lane near the curb to the left or right of the turning traffic into a narrow through bike lane. These are called "turning zones." There is a defined turn/merge gap for this maneuver and the lanes are marked with dotted lines recognizing that larger vehicles may encroach on the bike lane due to the narrow widths of the turning lanes. The third design involves signalization to separate the bicycle and turning vehicle movements.

To evaluate the designs, we extracted vehicle and bicycle paths and behaviors through the intersections and compared them to the path required or intended by the design.

- For the turning zones, the design using the through bike lane (TBL) works well for its intended purpose. The TBLs help position cyclists and reduce confusion compared to sharrows in mixing zones. The design in Washington D.C. (where vehicles have a limited entry into the turning lane) had high correct lane use by turning vehicles (87%) and by through bicyclists (91%). This suggests a clear benefit of the restricted entry approach and creating a semi-protected through bicycle lane.

- For the mixing zones, evaluation of the video found that in the *Mixing Zone with Yield Markings* design in Portland, OR (generally following the NACTO Design Guidance) nearly all (93%) of the turning vehicles used the lane as intended—the highest compliance of any design. However, only 63% of observed bicycles correctly used the mixing zone when a car was present (they chose to go around vehicle in the buffer space to left). This is not necessarily a critical issue and hatching this space would likely change this observed behavior. However, the observed behavior does suggest a preference of giving cyclists space with a TBL.

- When comparing the turning and mixing zone intersection designs, the video revealed that a low of 1% to a high of 18% of the turning vehicles at mixing zones actually turned from the wrong lane. The high incorrect rate was at the *Mixing Zone with Green Coloring* at Fell and Baker in San Francisco, which has since been removed and replaced with another design. The *Mixing Zone with Yield Markings* design in Portland and the *Turning Zone with Post-Restricted Entry and TBL* in Washington, D.C. had the fewest vehicles observed turning from the wrong lanes (2% and 1% respectively) indicating that clear marking of the vehicle entry point to the turning lane is beneficial.

- Based on observed behaviors, green pavement marking is effective at communicating the space that should be used by bicycles and that over use of green marking may result in some drivers avoiding the space. Open-ended survey questions reveal that bicyclists' have various interpretations of the green pavement markings. About 52% think the green marking indicates conflict, 26% think that the marks the space for bicycles only, and 15% don't know.

One design approach is to separate the conflicting movements of turning motor vehicles and through bicycles using signal phasing. By doing so, if all road users comply, there should be no conflicts. This option was used in Chicago on the two-way facility. Compliance rates by drivers and bicycles to the traffic control were comparable and users appeared to comprehend the design.

- At the three intersections on Dearborn studied with bicycle traffic signals, 77-93% of observed bicyclists complied with the signal and 84-92% of observed motorists complied with the left-turn signal.
- At the three Chicago intersections where signal phases for bicycle and motor vehicles are completely separated, 2-6% of motorists started to attempt a turn on the red arrow but then waited in the intersection or crosswalk. This could be a result of some minor confusion (either mistaking the through green or bike signal green for turning movement) or just aggressive driving.

12.4 Support for the Protected Lane Concept

Support for the protected lanes among residents was generally strong.

- Three in four residents (75%) said they would support building more protected bike lanes at other locations. This support was strong even among residents who reported "car/truck" as their primary commute mode (69% agreement).
- Overall, 91% of surveyed residents agreed with the statement, "I support separating bikes from cars." This agreement was high among primary users of all modes (driving, walking, transit, and bicycling).
- Younger respondents were more likely to have a positive view of the changes, while older respondents were somewhat more likely to feel that the safety of driving had been negatively affected, somewhat less likely to think the lanes made bicycling safer, and have somewhat less support for building protected bike lanes at other locations.

12.5 Potential to Attract New Riders

Based on earlier work and answers to survey questions, residential respondents were assigned into a "cyclist typology" (*Geller, 2009; Dill and McNeil, 2012*). Residents were grouped into four categories: *Strong and Fearless*, *Enthused and Confident*, *Interested but Concerned*, and *No Way No How*. Attitudes toward the protected bike lanes were examined for differences among the four types.

- Of all respondents to the resident survey, nearly two-thirds agreed with the statement, "I would be more likely to ride a bicycle if motor vehicles and bicycles were physically separated by a barrier." Agreement was higher for residents in the *Interested but Concerned* segment (85%).

- *Interested but Concerned* residents had the highest perception of improved safety due to the installation of the protected lanes and the highest agreement with the statement, “I support separating bikes from cars.”
- Among bicyclists, both men and women indicated that the amount they are riding a bicycle overall has increased because of the protected bike lanes, but the increase was larger for women.

12.6 Perceptions of People Driving

The specific impacts to motor vehicle travel vary between the cities, depending on the before-and-after context. In general, motorists like the separation of bikes, but have some negative reactions to how changes impact driving.

- Asked if the protected bike lanes had changed the predictability of roadway users, 53% of those who had driven a motor vehicle on the street stated the predictability of bicycles and motorists had increased. This suggests support for the clear ordering of the street space for all users.
- Only 14% of respondents indicated that they ever avoided driving on the street because of the protected bikeway. Dearborn Street and Milwaukee Avenue in Chicago had the highest rates of respondents indicating they had avoided those streets (about one-third).
- About 31% of residents who drove on the street stated that since the protected bike lanes were built the amount of time it takes to drive on this street has increased, 10% indicated it decreased, and 59% indicated no change. Similarly, when asked about the impact of the protected bike lanes on traffic congestion, 36% of respondents indicated that it has been “negative” while 11% said “positive.” For both these measures, the negative perceptions were much higher in Chicago.
- Parking is a key issue when street space is reassigned and cities. The impact to parking was the most negative perception, with about 30-55% of residents indicating the impacts to parking were negative, even in cases where a minimal amount of parking was removed, or parking was increased.

12.7 Impacts to Neighborhood Desirability and Economic Activity

On the resident and bicycle surveys, questions were asked to provide insight into the impact of the protected lanes on neighborhood desirability and economic activity. The key conclusions are:

- Nearly three times as many residents felt that the protected bike lanes had led to an increase in the desirability of living in their neighborhood, as opposed to a decrease in desirability (43% vs 14%). The remainder stated there had been no change in desirability.
- Over half the residents surveyed (56%) felt that the street works better for “all people” due to the protected bike lanes, while only 26% felt the street works less well.
- Approximately 19% of intercepted bicyclists and 20% of residents who had bicycled on the street stated that how often they stop at shops and businesses increased after the

installation of the protected bike lanes. Few respondents indicated their frequency decreased (1% and 6%, respectively); most indicated no change.

- Similarly, approximately 12% of the residents stated that they are more likely to visit a business on the corridor since the protected bike lanes were built—9% indicated they were less likely and most self-reported no change.

12.8 Lessons for Future Evaluation of Bicycle Facilities

While this research provided a substantial amount of evidence about preferences and perceptions of people driving, walking and bicycling on the study streets, evidence on the long-term safety performance of these facilities will have to come at a later date. This would be a key next step in establishing the overall safety – especially if comparable analysis could be developed for other facilities (e.g., bike lanes).

Clearly, one limitation of this research effort was the challenge of systematically assessing a change in the number of people using the facility on bicycles. This could be improved by requiring longer duration counts and aligning the time periods. One approach might be to do the following:

- One-week count in the before period at location, roughly the same week of the year;
- One-week count in the after period at location, roughly the same week of the year. After counts could be done annually for a few years;
- One or more control locations to measure changes on parallel routes and city-wide change. This could be done with before-and-after counts of the same duration or by using permanent counters, making corrections for weather or other events if needed.

Another gap in the evaluation was the limited information collected about transit interactions. On some streets, this will be a major issue for the installation of a protected lane. Future work should seek to identify and evaluate various transit stops designs. Similarly, the treatments of minor intersections and driveways could use more detailed evaluations.

Finally, these facilities studied were generally more temporary protected lanes (i.e. using paint and flex posts). Newer designs such as Seattle's First Hill Streetcar cycle track on Broadway, New York City's 8th and 9th Aves, St. Petersburg's Florida are all more hardscape heavy (permanent infrastructure). Future research should examine these facilities to contrast the difference with these facilities studied.

In evaluating how well the design features of the facilities work, both comprehension and compliance perceptions from the survey responses and observations from the video were examined. The findings from these two sources were not always consistent. This indicates that relying solely on survey methods to assess comprehension may lead to unreliable findings.

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