Executive Summary

Lessons from the Green Lanes:

Evaluating Protected Bike Lanes in the U.S.

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Introduction

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).

Figure ES-1. Map of Study Cities

These five cities participated in the inaugural "Green Lane Project" (GLP) sponsored by People for Bikes (formerly known as Bikes Belong).

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

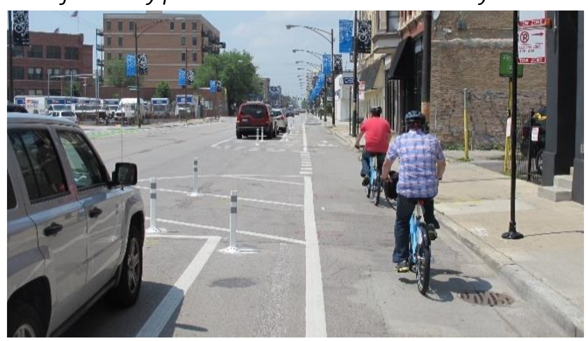
Two-way protected bike lane on one-way street

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 & 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).

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.

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

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		●	●	

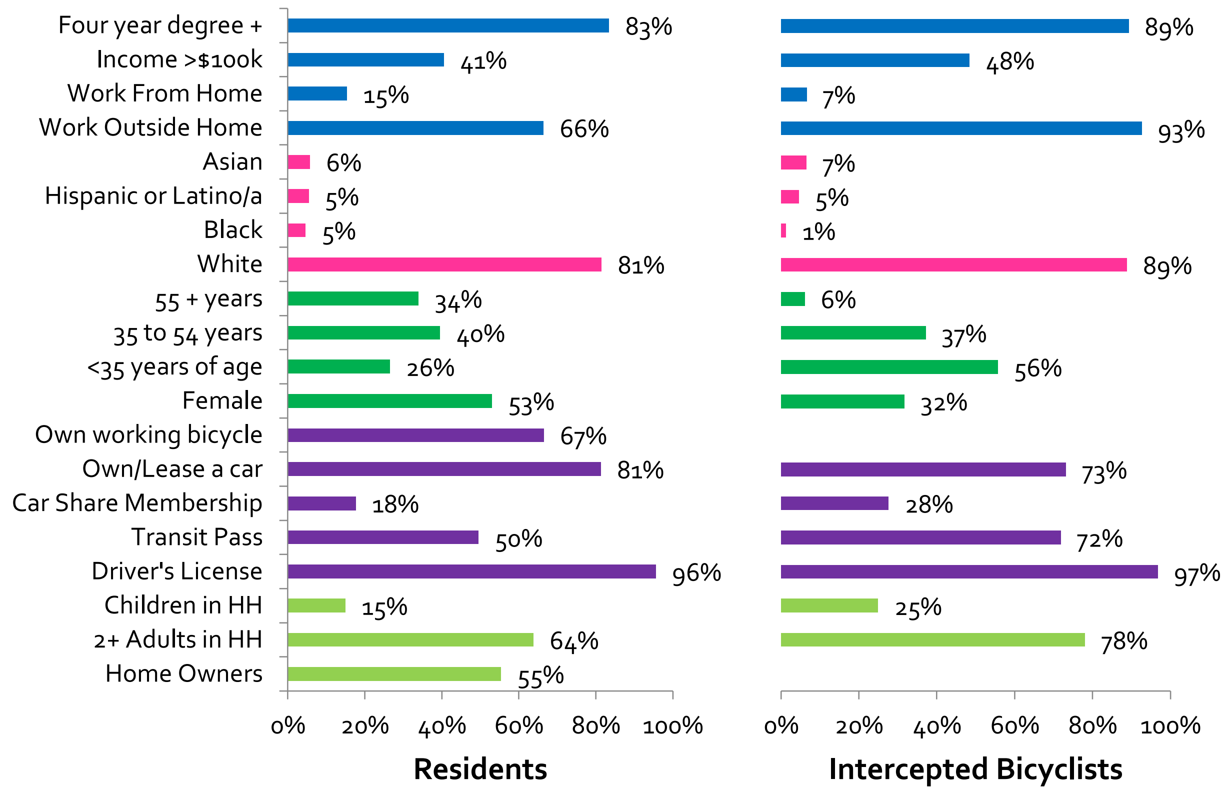


Figure ES-3. Resident and Bicyclist Survey Respondent Demographics

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).

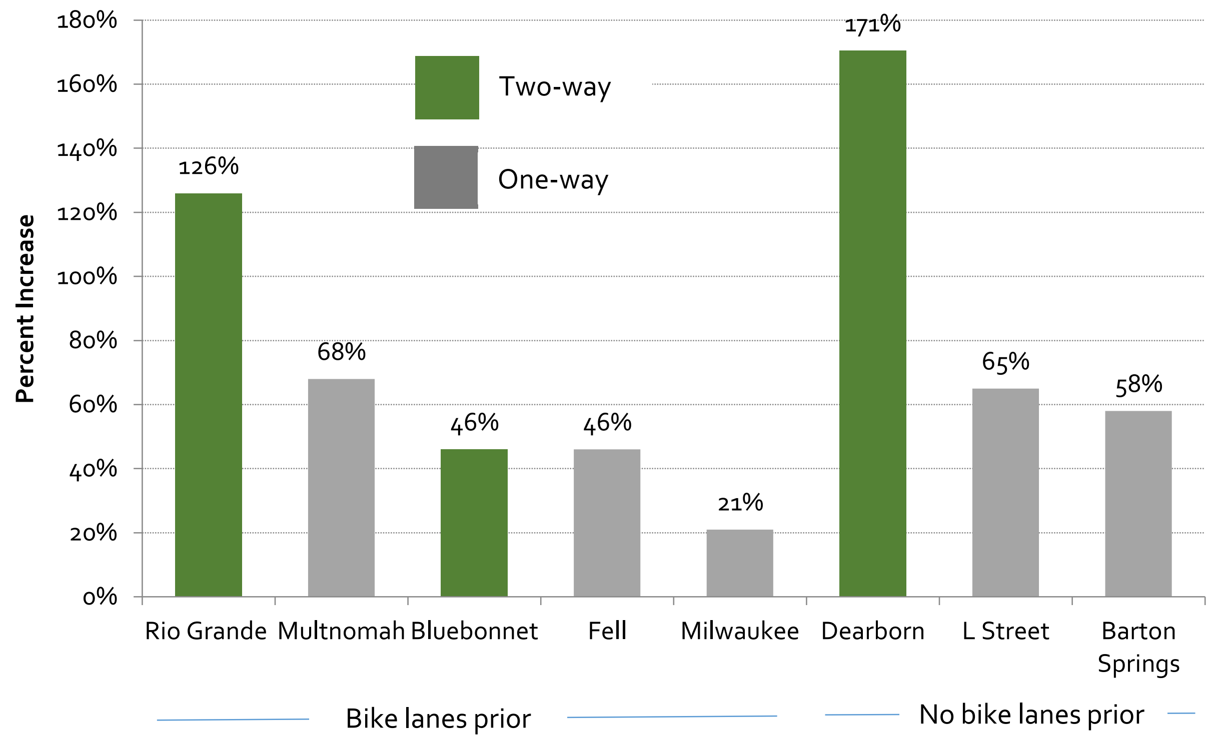


Figure ES-4. Change in Observed Bicycle Volumes

Findings: Changes in Ridership *(continued)*

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%).

- 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.

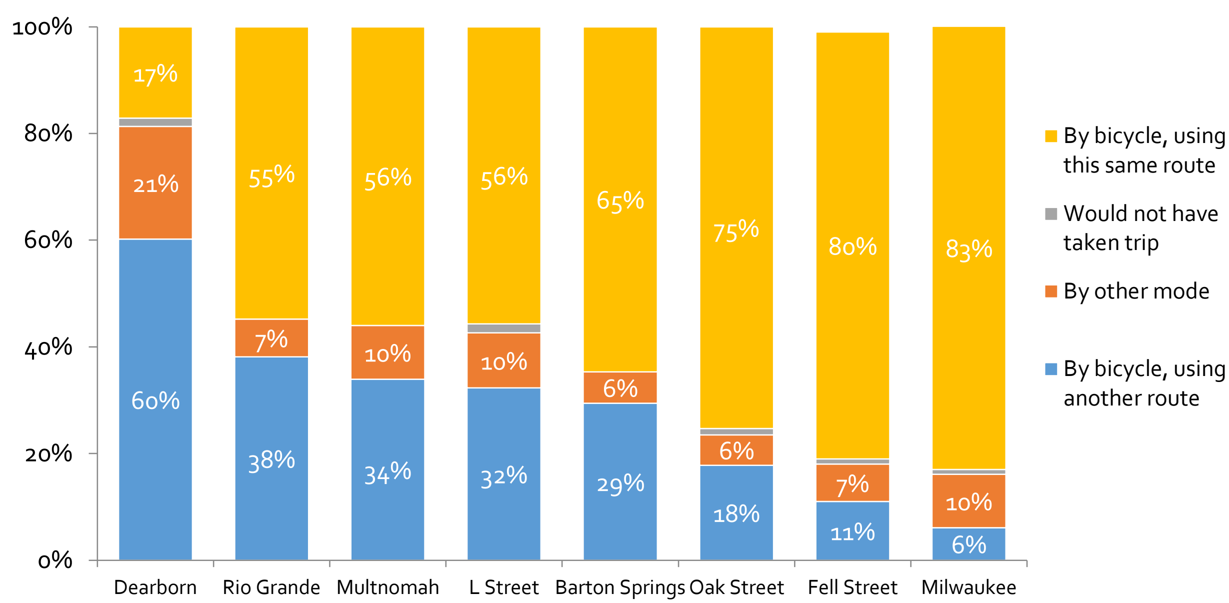


Figure ES-5. Before the new facility was built, how would you have made this trip?

Findings: Effectiveness of 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.

...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.

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

		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.

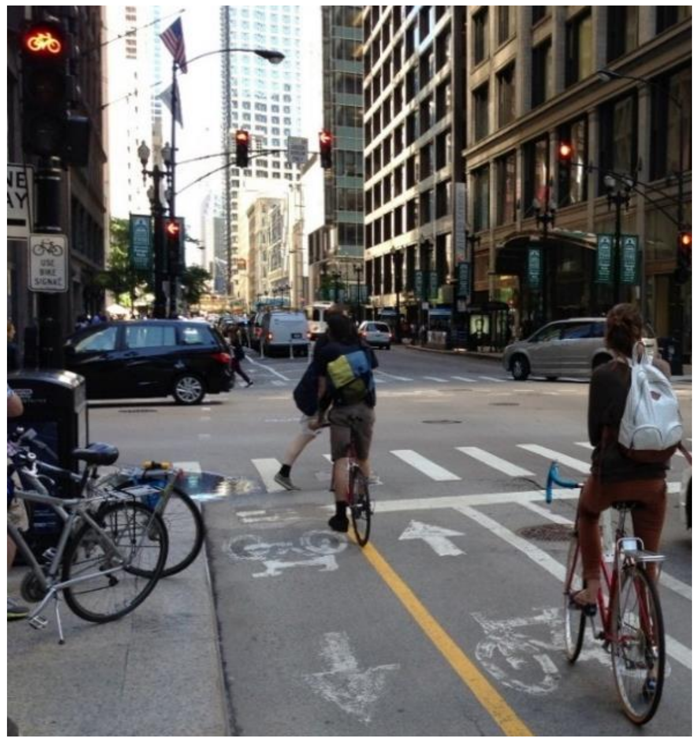


Figure ES-6. Bicyclists wait at a bike signal on Dearborn Street.

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.

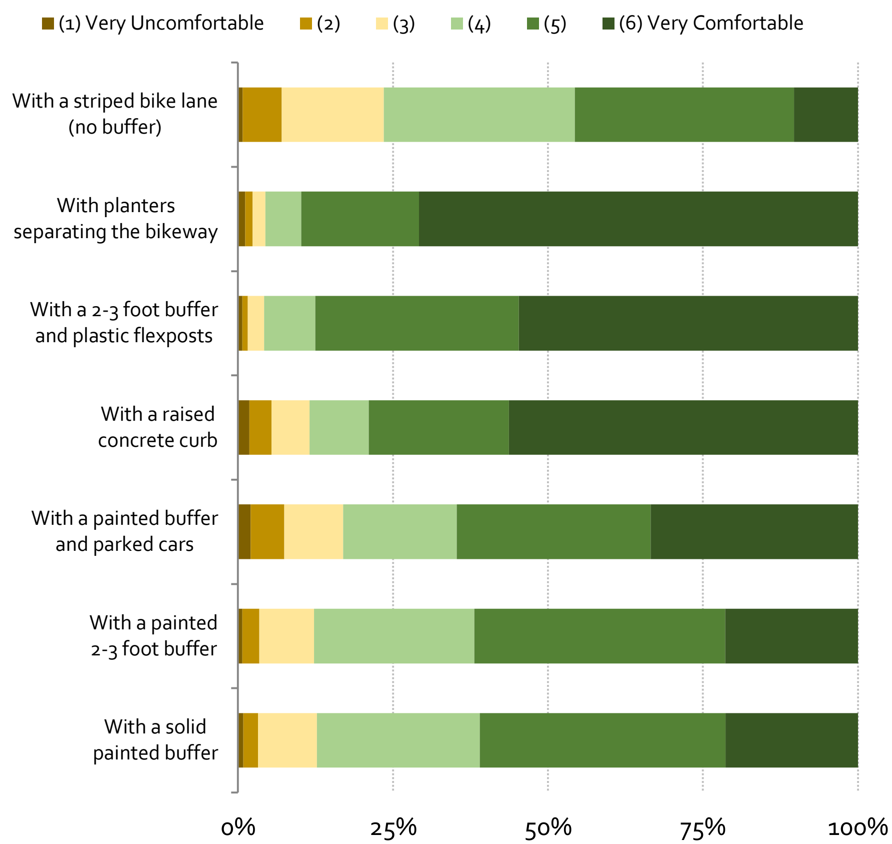


Figure ES-7. Bicyclists' Stated Comfort Level with Hypothetical Buffer Options

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.
- 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.

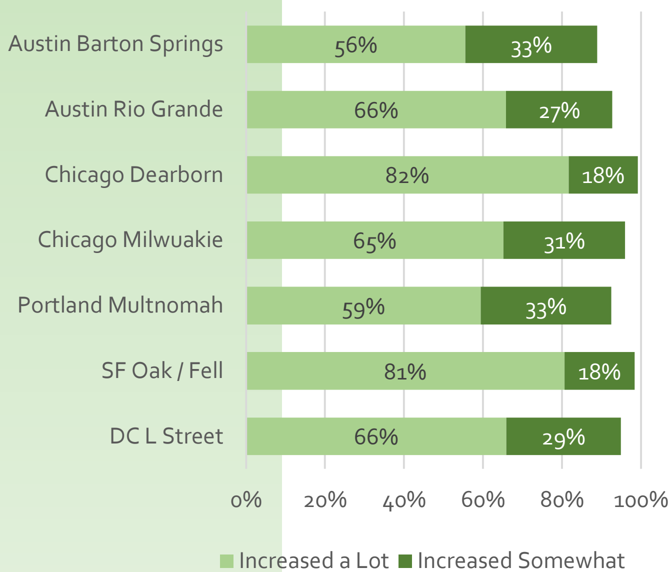


Figure ES-8. Bicyclists: "I feel the safety of bicycling on ______ has . . ."

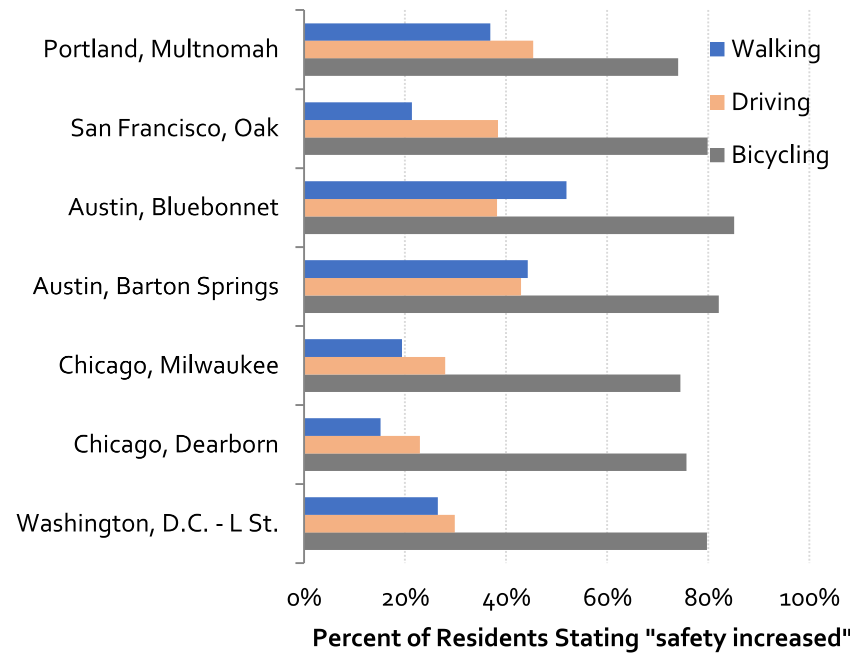


Figure ES-9. Residents: "Because of the protected bike lanes, the safety of _____ on the street has increased"

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.

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.

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).
- 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.

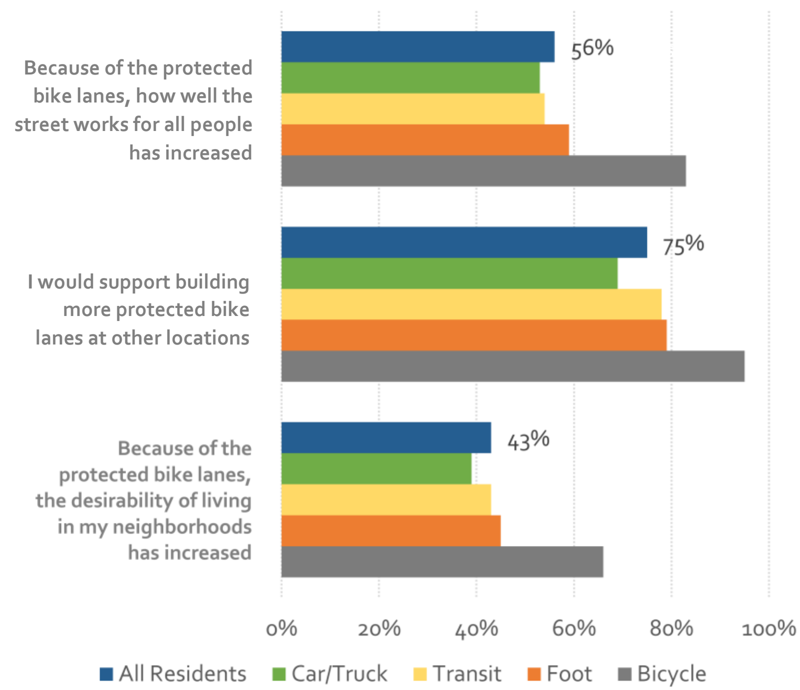


Figure ES 1. Residents' Opinions of Protected Bike Lanes, by Commute Mode

Three in four residents (75%) said they would support building more protected bike lanes at other locations.

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: 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.

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."

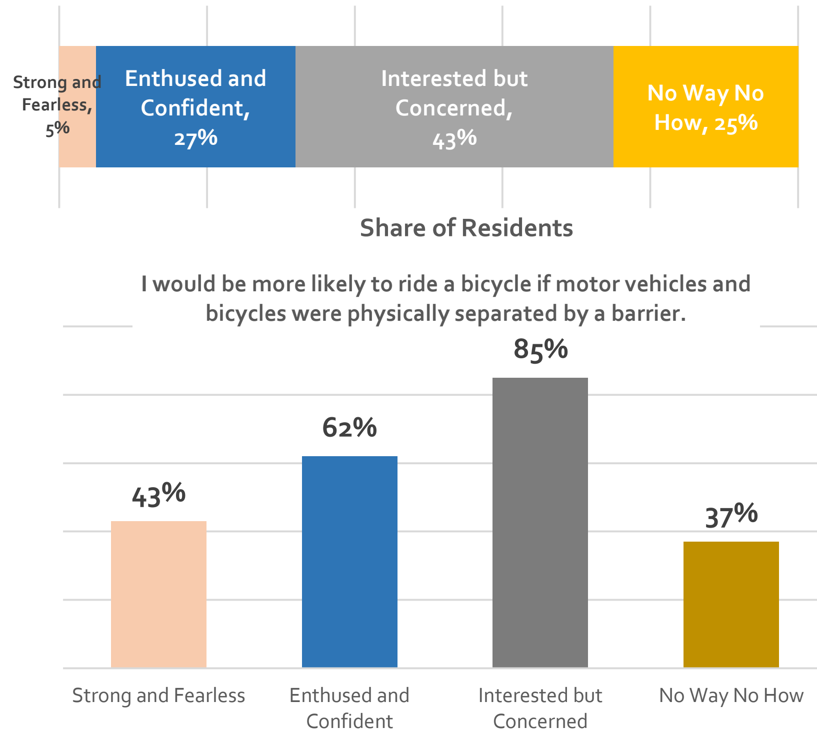


Figure ES-2. Residents' Likelihood of Riding with Physical Separation by Type of Cyclist