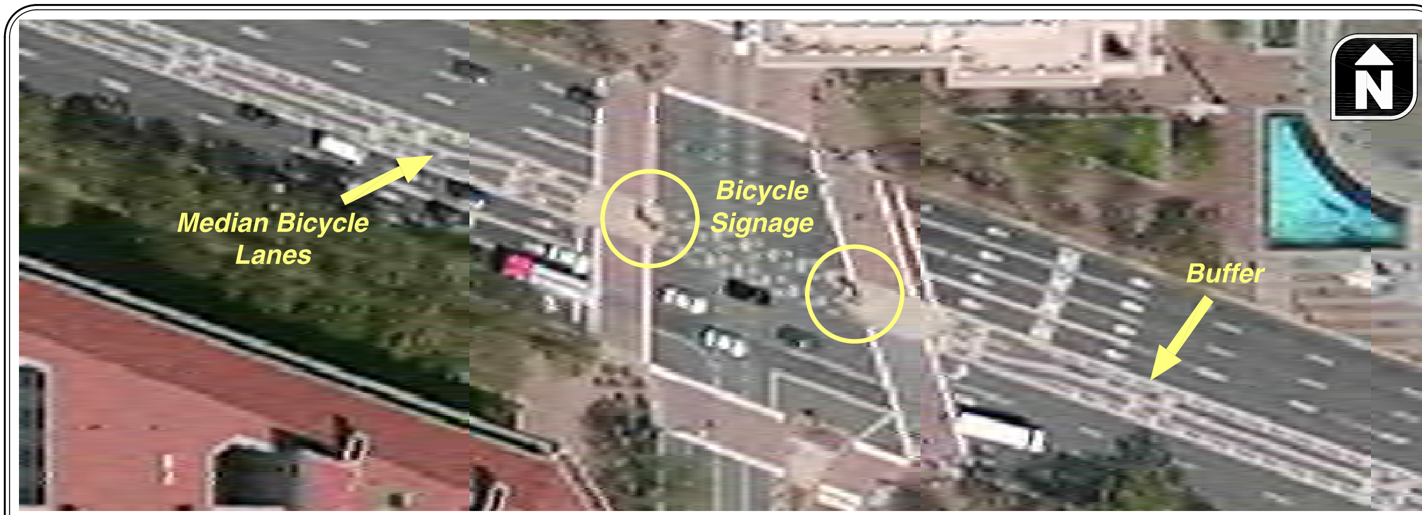
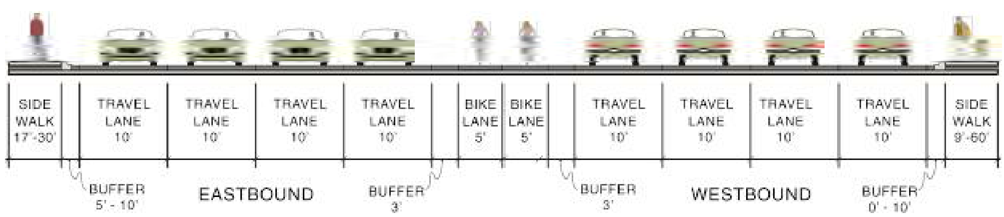
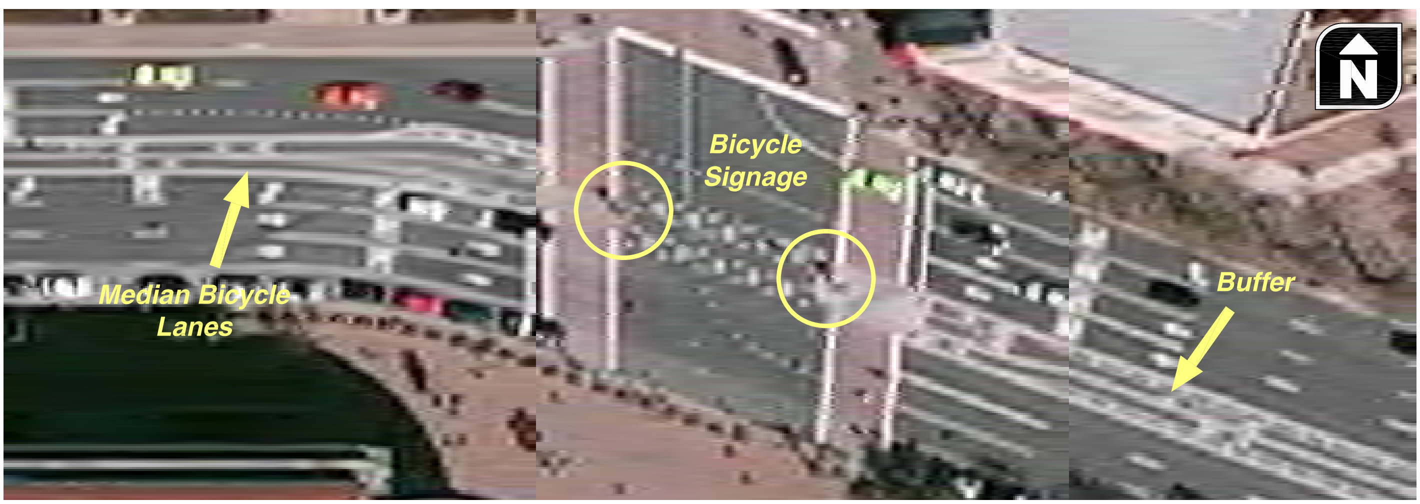


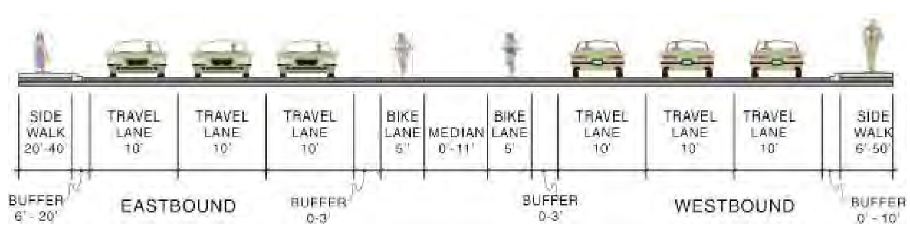
6TH STREET TO 10TH STREET
TYPICAL LANE CONFIGURATION
FIGURE **5A**



6TH STREET TO 10TH STREET
TYPICAL CROSS SECTION
FIGURE **5B**



10TH STREET TO 15TH STREET
TYPICAL LANE CONFIGURATION
FIGURE **5C**

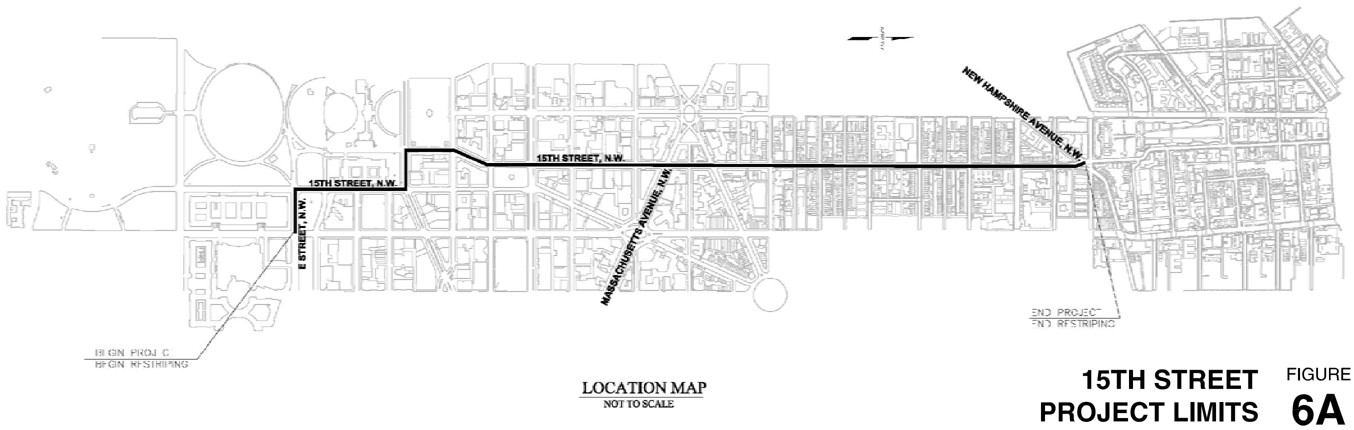


10TH STREET TO 15TH STREET
TYPICAL CROSS SECTION
FIGURE **5D**

PENNSYLVANIA AVENUE NW FROM 3RD STREET NW TO 15TH STREET NW
BICYCLE FACILITIES AND CROSS SECTIONS
WASHINGTON, DISTRICT OF COLUMBIA

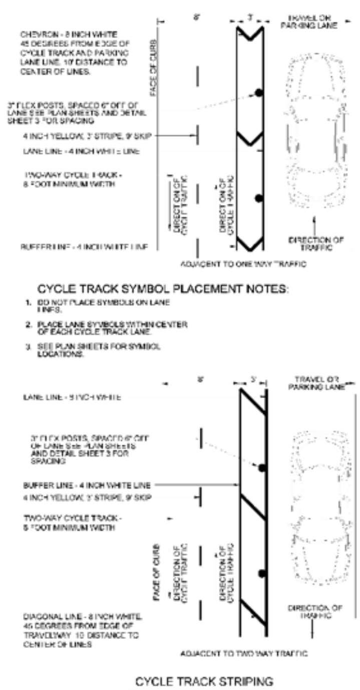
FIGURE **5**

H:\projfile\11404 - DDOT Innovative Bike Facility Evaluation\dwgs\figs\11404_fig01.dwg Jan 06, 2012 - 6:35pm - atanaka Layout Tab: 05

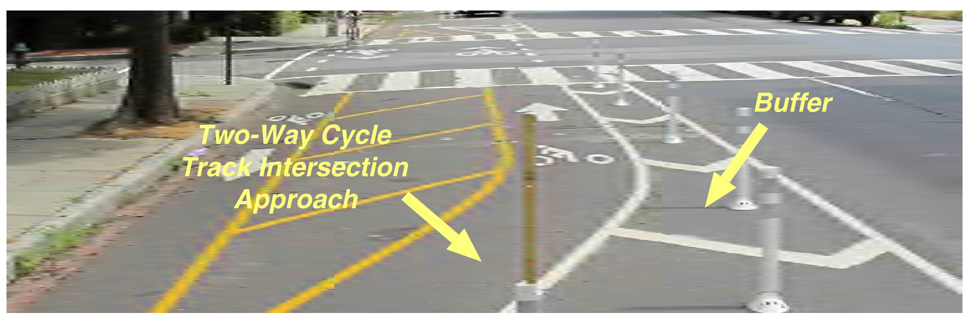


15TH STREET PROJECT LIMITS — FIGURE **6A**

TWO-WAY CYCLE TRACK NEAR F STREET INTERSECTION — FIGURE **6B**



PAVEMENT MARKING DETAILS — FIGURE **6C**



CYCLE TRACK APPROACH AT CHURCH STREET INTERSECTION — FIGURE **6D**

SOUTHBOUND CYCLE TRACK ACROSS R STREET INTERSECTION — FIGURE **6E**

15TH STREET NW FROM E STREET NW/PENNSYLVANIA AVENUE NW TO V STREET NW
BICYCLE FACILITY PROJECT LIMITS AND DETAILS
WASHINGTON, DISTRICT OF COLUMBIA

FIGURE **6**

15th Street is a two-way street south of Massachusetts Avenue and a one-way northbound street north of Massachusetts Avenue. Before the cycle track installation, bicyclists shared the roadway with vehicular traffic, and there were no accommodations for southbound bicyclists north of Massachusetts Avenue. DDOT installed the two-way cycle track both to allow for southbound bicycling along the corridor and to provide a separated facility to increase the comfort of cyclists riding in both directions.

The two-way cycle track was installed in two phases. In November 2009, DDOT installed a one-way southbound cycle track between Massachusetts Avenue and U Street, and in November 2010, DDOT expanded the facility to a two-way cycle track between E Street/Pennsylvania Avenue and V Street. The current two-way cycle track is eight feet wide with a three-foot buffer between the cycle track and vehicular traffic or parked vehicles, and is located on the west side of the roadway. There are white, flexible channelizing posts installed within the three-foot buffer to further delineate the dedicated cyclist space to motorists. Figure 6B is a picture of the constructed two-way cycle track with buffer, and Figure 6C shows the typical pavement marking details for the cycle track.

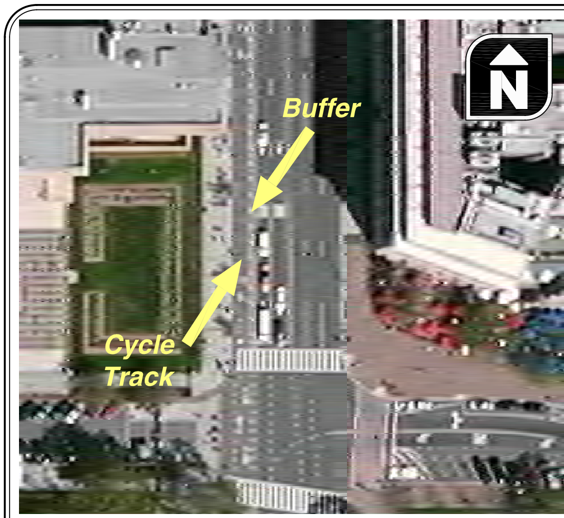
At intersections along the one-way section of 15th Street the approaching cycle track is diverted away from the sidewalk, creating a seven-foot buffer between the two directions of bicycle traffic. This design was implemented by prohibiting on-street parking in the intersections' vicinity. The design is intended to make cyclists more visible to motor vehicles making left turns from 15th Street onto intersecting roadways.

At intersections along the two-way section of 15th Street, no buffer is provided between the two cycle track directions. Dashed striping and shared lane markings are used through intersections to alert motorists to the presence of cyclists and to guide cyclists through the intersections. Figure 6D shows the cycle track configuration approaching an intersection in the one-way section, and Figure 6E shows the pavement markings provided through the intersections.

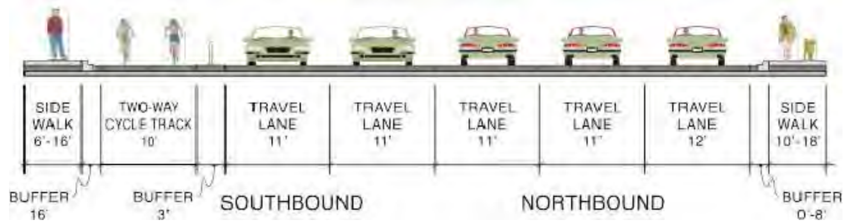
Figure 7A and Figure 7B display the typical lane configurations and cross sections for 15th Street between E Street/Pennsylvania Avenue and New York Avenue, Figure 7C and Figure 7D display the typical lane configurations and cross sections between H Street and Massachusetts Avenue, and Figure 7E and Figure 7F display the typical lane configurations and cross sections between Massachusetts Avenue and U Street. The cross section varies along 15th Street, so the figures portray the typical cross section found along the segment of interest.

The following primary changes were made to the 15th Street corridor:

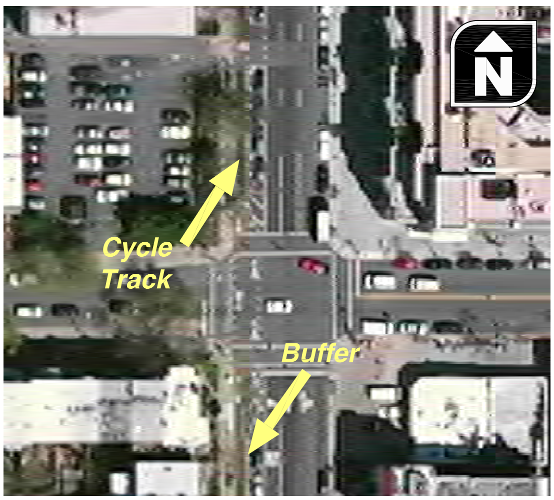
- *Cycle tracks* were constructed on the west side of the roadway with a buffer (as shown in Figure 6B). The cycle track was designed to provide added safety and comfort for bicyclists traveling along 15th Street by separating all cyclists from vehicular traffic.
- *Shared lane markings* were added through intersections to indicate the likely presence of bicyclists to motorists and indicate the need for turning motorists to yield to cyclists (as shown in Figure 6E).
- *STOP FOR PEDESTRIAN markings* were added at mid-block crosswalks and T-intersections to indicate to bicyclists to yield to crossing pedestrians (as shown in Figure 6B).
- *Bicycle signs* were added for way-finding and to direct bicyclist turning movements.
- *Left-turn restrictions* were instituted to reduce potential conflicts between cyclists and left-turn vehicles at locations where left-turns had previously been permitted. Left turns were eliminated at some signals, while others remained using protected left-turn phases.
- *Signal timing changes* were made to accommodate bicyclists. In addition to the protected left-turn phases at intersections mentioned above, additional time was provided for bicyclists to enter the intersection prior to motor vehicle movement.



E ST TO NEW YORK AVE
TYPICAL LANE CONFIG.
FIGURE **7A**

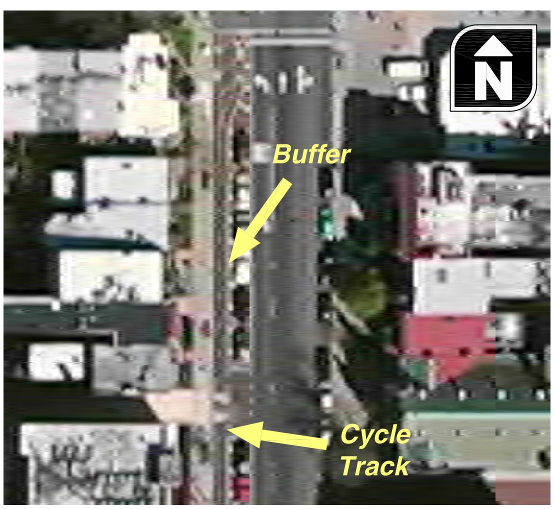


E STREET TO NEW YORK AVENUE
TYPICAL CROSS SECTION
FIGURE **7B**

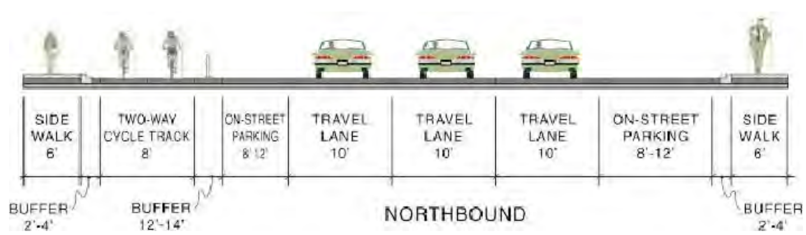


H ST TO MASSACHUSETTS AVE
TYPICAL LANE CONFIG.
FIGURE **7C**

H STREET TO MASSACHUSETTS AVENUE
TYPICAL CROSS SECTION
FIGURE **7D**



MASSACHUSETTS AVE TO U ST
TYPICAL LANE CONFIG.
FIGURE **7E**



MASSACHUSETTS AVENUE TO U STREET
TYPICAL CROSS SECTION
FIGURE **7F**

15TH STREET NW FROM E STREET NW/PENNSYLVANIA AVENUE NW TO V STREET NW
BICYCLE FACILITIES AND CROSS SECTIONS
WASHINGTON, DISTRICT OF COLUMBIA

FIGURE **7**

Section 3
Study Methodology

STUDY METHODOLOGY

Several types of evaluation were conducted for each location to determine the effect of the bicycle facilities. Table 2 summarizes the evaluations performed and data used for each facility. Data used for the analyses were collected by DDOT and Kittelson & Associates, Inc. (KAI) for conditions before and after bicycle facility installation. A short description of the evaluations is provided below, with subsequent sections providing the evaluation results.

Table 2 Facility Evaluation Summary

Type of Analysis	16th / U/ New Hampshire	Pennsylvania Avenue	15th Street	Data Collected for Analysis
BICYCLE FACILITIES				
Volume Analysis	✓	✓	✓	• Bicycle counts
Highway Capacity Manual 2010 Multi-Modal Level of Service		✓	✓	• Motor vehicle counts • Lane geometry and cross section • Speed data • Pavement condition
Danish Bicycle Level of Service		✓	✓	• Motor vehicle counts • Lane geometry and cross section • Speed data • Pavement condition • Land use information
Bicycle Environmental Quality Index		✓	✓	• Motor vehicle counts • Lane geometry and cross section • Speed data • Land use information
Bicycle Corridor Travel Time		✓	✓	• Signal timing data
Crash Analysis	✓	✓	✓	• Crash data
Survey Analysis	✓	✓	✓	• User intercept surveys • Surrounding neighborhood surveys
Video Analysis	✓	✓	✓	• Study area video
MOTOR VEHICLE FACILITIES				
Volume Analysis	✓	✓	✓	• Motor vehicle counts
Highway Capacity Manual 2000 Arterial Level of Service	✓	✓	✓	• Motor vehicle counts • Pedestrian counts • Lane geometry and cross section • Speed data

Type of Analysis	16th / U/ New Hampshire	Pennsylvania Avenue	15th Street	Data Collected for Analysis
				• Signal timing and phasing
Travel Time Analysis			√	• Drive time data
Survey Analysis	√	√	√	• Surrounding neighborhood surveys
Video Analysis	√	√	√	• Study area video
PEDESTRIAN FACILITIES				
Highway Capacity Manual 2010 Multi-Modal Level of Service		√	√	• Motor vehicle counts • Pedestrian counts • Lane geometry and cross section • Speed data
Survey Analysis	√	√	√	• User intercept surveys • Surrounding neighborhood surveys
Video Analysis	√	√	√	• Study area video

Volume Analysis

DDOT anticipated that installing bicycle facilities could influence both vehicular and bicycle volumes. Before-and-after traffic volumes were analyzed to determine trends along the study roadways.

DATA COLLECTION

Volume data were collected for motorized vehicles and bicycles both before and after the bicycle facilities were installed. For projects completed in multiple stages (e.g., 15th Street cycle track), volume data were collected before facility installation, after phase one of the project was completed, and after phase two was completed.

Synchro reports for 16th Street/U Street/New Hampshire Avenue, Pennsylvania Avenue, and 15th Street are available in Appendices A1, B1, and C1, respectively. The reports contain the motorized vehicle volumes used in the volume analysis. Appendices A2, B2, and C2 contain the bicycle volume data used in the analysis for 16th Street/U Street/New Hampshire Avenue, Pennsylvania Avenue, and 15th Street, respectively.

Highway Capacity Manual Multi-Modal Level of Service

A *Highway Capacity Manual* (HCM) 2010 multi-modal level of service (MMLOS) evaluation was completed for the Pennsylvania Avenue and 15th Street corridors (Reference 3). This type of level-of-service (LOS) evaluation assesses the quality of service experienced by all roadway users: pedestrians, bicyclists, drivers, and transit riders. MMLOS was calculated for each roadway segment (i.e., street sections between signalized intersections) for conditions before and after installation of the final phase of the bicycle facilities.

There are many factors that affect MMLOS, which vary depending on the type of user being evaluated. In general, bicycle LOS calculations consider cross-section dimensions, intersection crossing distance, number of driveways and access points, motorized vehicle volumes and speeds, heavy vehicle presence, on-street parking, and pavement condition.

The factors associated with motor vehicle LOS are the number of stops made by vehicles and the presence of left-turn lanes.

Pedestrian LOS is based on pedestrian density; sidewalk width and horizontal separation from the street; presence of street trees, occupied on-street parking, or other physical barriers; motorized vehicle volumes; conflicts with turning vehicles at signalized intersections; average wait time at signals; and ability to cross the street between signalized intersections.

MMLOS also provides a method for evaluating transit LOS. Transit LOS was not evaluated for either 15th Street or Pennsylvania Avenue because there is no transit service provided on 15th Street and because the bicycle facilities did not affect transit service (or pedestrian access to transit service) on Pennsylvania Avenue. The analyses performed for this study were meant to provide insight into changes resulting from the bicycle facilities, so no transit MMLOS evaluation was required on either study corridor.

The MMLOS methodology develops LOS scores for each type of user, which correspond to traditional LOS letters as follows for the pedestrian and bicycle methodologies:

A = <2.00	D = 3.50 – 4.25
B = 2.00 – 2.75	E = 4.25 – 5.00
C = 2.75 – 3.50	F = > 5.00

DATA COLLECTION

The data required for the MMLOS evaluation include motor vehicle, bicycle, and pedestrian counts, speed data, and lane geometry and cross-section information. DDOT and KAI collected data for the facilities for conditions before and after the final phase of installation of the bicycle facilities. *Appendices B3 and C3 contain data for the MMLOS evaluation for Pennsylvania Avenue and 15th Street, respectively.*

Danish Bicycle Level of Service

A cumulative logit regression model was developed for the Danish Road Directorate to determine the level of bicyclist satisfaction related to bicycle facilities along road segments (between intersections) using data from Denmark. The model predicts the percentage split among six levels of satisfaction, and a LOS letter is calculated using the splits. Descriptions of the specific variables used in the Danish Bicycle LOS model are available in the report "Pedestrian and Bicycle Level of Service on Roadway Segments" (Reference 4). The factors applied in the model include motor vehicle volumes, average speeds, land use type, cross-section dimensions, presence of sidewalks, medians, bus stops, and vegetation, number of travel lanes, pedestrian and bicycle volumes, and the number of parked vehicles. The variables with the largest effect on bicyclist satisfaction are the type and width of the bicycle facility and the distance to motor vehicles in the nearest drive lane and pedestrians. The Danish bicycle LOS model was incorporated into this evaluation because it accounts for bicycle facility types such as cycle tracks that are not accounted for in the HCM MMLOS model due to a current lack of such facilities in the United States.

DATA COLLECTION

The Danish Bicycle LOS method requires motorized vehicle counts, speed data, and cross-section, pavement condition, and land use information. The data used as part of this evaluation were collected before and after the final installation of the bicycle facilities. *Appendices B4 and C4 contain Danish Bicycle LOS analysis data for Pennsylvania Avenue and 15th Street, respectively.*

Bicycle Environmental Quality Index

Bicycle Environmental Quality Index (BEQI) indicator values were determined by the San Francisco Department of Public Health Environmental Health Section using survey responses from bicycle experts and members of the bicycle community. Survey respondents ranked the importance of an indicator variable for bicycle quality and the relative importance of the indicator response categories within each indicator variable. A discussion of the specific variables included in the model is available in the reports "Bicycle Environmental Quality Index Data Collection Manual" (Reference 5) and "Bicycle Environmental Quality Index (BEQI), Draft Report 2009" (Reference 6). The information used in the model includes the presence of a marked bicycle facility, connectivity, driveway cuts, traffic calming, bicycle signs, lighting, vegetation, and bicycle parking, along with bicycle facility width, pavement type, posted speed, motorized vehicle volumes, and cross-section, line-of-sight, and land use information.

The maximum BEQI score, calculated based on the variables listed above, is 100 points. The following levels of quality are identified, based on the number of points achieved:

- 100 – 81: Highest quality, many important bicycle conditions present
- 80 – 61: High quality, some important bicycle conditions present
- 60 – 41: Average quality, bicycle conditions present but room for improvement
- 40 – 21: Low quality, minimal bicycle conditions
- 20 – 0: Poor quality, bicycle conditions absent

DATA COLLECTION

The data used for the BEQI evaluation were collected before and after the final installation of the bicycle facilities. *Appendices B5 and C5 contain BEQI analysis data for Pennsylvania Avenue and 15th Street, respectively.*

Bicycle Corridor Travel Time (Signal Progression)

KAI completed a bicycle progression analysis to assess bicyclists' ability to travel along Pennsylvania Avenue and 15th Street without impedance due to signal timing constraints. Note that signal timing changes were not generally within the scope of the initial design; the signal progression analysis serves instead to assess how well the existing signal timing works for cyclists and to identify potential opportunities for improvement.

The progression analysis was completed for traffic conditions along Pennsylvania Avenue and 15th Street after the installation of the cycle facilities, using the signal timing parameters given in Synchro files provided by DDOT.

For each time period (weekday a.m. and weekday p.m.), a progression analysis was completed in both directions (eastbound and westbound for Pennsylvania Avenue, northbound and southbound for 15th Street) for bike speeds of 10 miles per hour (mph) and 15 mph.

For analysis purposes, the Pennsylvania Avenue corridor was split into two sections: (1) 3rd Street to 9th Street and (2) 9th Street to 15th Street. The 15th Street corridor was split into three sections: (1) between Lower E Street and I Street, (2) between I Street and Rhode Island Avenue, and (3) between Rhode Island Avenue and V Street. The progression analysis for each section began at the start of a green signal.

Bike acceleration start-up times were not considered in this analysis. Because the speed of a bicycle is difficult to keep constant, it is assumed that travel times are averages and that a two to three second difference would not significantly change the overall results and trends. The analysis assumed that half the bikes reaching an intersection during a clearance interval proceeded through the intersection.

DATA COLLECTION

The progression analysis evaluated conditions using the existing signal timing parameters along the study corridors, as reflected in the Synchro files provided by DDOT. *Appendices B6 and C6 contain the bicycle progression analysis data for Pennsylvania Avenue and 15th Street, respectively.*

Highway Capacity Manual Motor Vehicle Level of Service

Motor vehicle levels of service were calculated for each study location using the HCM 2000 (Reference 7) methodology for the a.m. and p.m. peak periods. Levels of service were evaluated to determine if there was a change in operations for vehicular traffic resulting from the installation of the bicycle facilities. Intersection LOS was calculated for the 16th Street/U Street/New Hampshire Avenue intersection and arterial LOS were calculated for Pennsylvania Avenue and 15th Street.

DATA COLLECTION

The HCM 2000 methodology requires motor vehicle, bicycle, and pedestrian counts, lane geometry, speed data, and signal timing and phasing information to calculate intersection and arterial LOS. The data were collected for conditions before and after installation of the final phase of the bicycle facilities. *Appendix A1 contains the intersection LOS results for the 16th Street/U Street/New Hampshire Avenue intersection, and Appendices B7 and C7 contain the arterial LOS results for Pennsylvania Avenue and 15th Street, respectively.*

Motor Vehicle Travel Time Analysis

The amount of time spent traveling and the amount of time spent stopped on each roadway segment along 15th Street was recorded for segments between Massachusetts Avenue and E Street for the southbound direction and between E Street and Euclid Street for the northbound direction. The overall corridor speeds were calculated based on the length of the corridor and the amount of time spent traveling and stopped along the corridor.

DATA COLLECTION

Three travel time runs were completed in each direction (northbound and southbound) on 15th Street before and after the bicycle facilities were installed (during the a.m., midday, and p.m. peak hours). *Appendix C8 contains the travel time analysis data.*

Crash Analysis

Crash data were evaluated for each study corridor using crash reports from the DDOT Traffic Accident Reporting and Analysis System. The crashes were analyzed to determine if the number of crashes or crash severity changed after installation of the bicycle facilities.

DATA COLLECTION

Crash data from 2005 through 2011 were obtained for the study intersections. Generally, four years of data were available from before the bicycle facilities were installed and one year of data was available from after the bicycle facilities were installed. For the section of 15th Street that was installed in two phases, crash data were collected for periods after the first phase and after the second phase. *Appendices A3, B8, and C9 contain crash data for the 16th Street/U Street/New Hampshire Avenue intersection, Pennsylvania Avenue, and 15th Street, respectively.*

Survey Analysis

Facility users and surrounding neighborhood residents were surveyed about the bicycle facilities at the 16th Street/U Street/New Hampshire Avenue intersection and on the Pennsylvania Avenue and 15th Street corridors. The findings were analyzed to understand the experiences, behaviors, attitudes, and perceptions of users and area residents regarding the new bicycle facilities.

A major component of each of the surveys involved asking respondents to indicate their level of agreement with a series of statements pertaining to their experiences and opinions. Response options included “strongly agree,” “somewhat agree,” “somewhat disagree,” and “strongly disagree.” Respondents were also able to select “no opinion.” The results of the surveys are reported using several different measures: (1) percentages of respondents selecting each answer, (2) total percentage of respondents indicating that they agree with the statement (either somewhat or strongly), and (3) average responses calculated by assigning a “1” to strongly disagree through “4” for strongly agree.

DATA COLLECTION

Cyclist Surveys

In September and October 2011, cyclists were intercepted on each of the facilities and given a postcard directing them to an online survey. As a means of ensuring that only those cyclists who received a card were able to complete a survey, a unique code from the postcard was needed to access the survey, and could only be used once. As an incentive, cyclists who completed the survey by a certain date were offered to be entered into a raffle for a free iPad2. The demographics of the cyclist survey respondents are shown in Table 3. Most of the cyclists were young (under 35 years) and nearly two-thirds were men. Bicycle counts from June 2011 indicate that the survey sample is representative of the cycling population. The bicycle counts revealed that 66 percent of cyclists traveling on 15th Street were male and 70 percent of cyclists traveling on Pennsylvania Avenue were male. This split between male and female cyclists is consistent with other large U.S. cities. The cyclists who participated in the survey were also predominantly white, which does not reflect the city's demographics (see Table 6 for more information on the demographics of the study area). *An example of the cyclist survey can be found in Appendix D1.*

Table 3 Cyclist Survey Demographics

Facility	# of Respondents		Gender		Age			Race			
	Postcards Distributed	Completed	Male	Female	18 to 34	35 to 54	55+	White	African-American	Asian	Other
16th Street/U Street/NH Avenue	336	154	63%	37%	63%	31%	5%	92%	2%	3%	3%
Pennsylvania Avenue	360	165	62%	38%	53%	38%	9%	87%	1%	4%	8%
15th Street	400	186	60%	40%	63%	32%	5%	89%	1%	6%	4%

Pedestrian Surveys

Pedestrians were intercepted on Pennsylvania Avenue and 15th Street and asked to complete a two-page survey. Respondents on each route were asked about how often they walk on the street, and if/how the experience has changed with the new bicycle facilities. As an incentive for taking the survey, pedestrians were offered a free energy bar. The demographics of the pedestrian survey respondents are included in Table 4. *Appendix D2 contains an example of the pedestrian survey.*

Table 4 Pedestrian Survey Demographics

Facility	# of Respondents	Gender		Age			DC Residents
		Male	Female	18 to 34	35 to 54	55+	
Pennsylvania Avenue	104	49%	51%	34%	39%	27%	74%
15th Street	135	52%	48%	41%	40%	19%	85%

Neighborhood Resident Surveys

Neighborhood residents living in close proximity to the new facilities were sent a paper survey in the mail. The mailing list was purchased from InfoUSA and included a name and address for one adult per household for all households within a 0.1- or 0.2-mile radius of the facilities (with a cap of 2,000 addresses per facility). The surveys asked about the respondents' opinions, use, and understanding of the specific facilities, as well as basic demographic information. Survey packets contained a short letter introducing the study, a survey, a postage-paid return envelope, and a raffle entry slip. The survey was labeled as the "DC Neighborhood Street Project" with a logo that included a bicycle, car, and pedestrian. The invitation and introductory text did not focus on bicycle facilities in order to reduce response bias. Respondents were offered the opportunity to be entered into a drawing for a free iPad2 if they completed a survey by a certain date.

- The 16th Street/U Street/New Hampshire Avenue intersection survey went to every household within a 0.1-mile buffer of the intersection and contra-flow bike lanes. The survey was eight pages long and also included questions about the 15th Street cycle track.
- The Pennsylvania Avenue survey went to every household within a 0.2-mile buffer of the center bike lanes. The larger buffer was used in this case in order to get a large enough sample size due to lower residential densities along the corridor. The survey was four pages long.
- The 15th Street survey went to 2,000 randomly selected households within a 0.1-mile buffer of the cycle track. The survey was four pages long.

Survey packets were mailed on September 13, 2011, and recipients were asked to complete the surveys by September 30th. A second round of packets was mailed to those who had not yet responded on October 8, 2011, with a due date of October 21st.

The response rates were reasonable for a mail survey: 25 percent for the 16th Street/U Street/New Hampshire Avenue intersection, 18 percent for Pennsylvania Avenue, and 26 percent for 15th Street (as shown in Table 5). Compared to the cyclist survey respondents, the residential survey respondents were more evenly split between men and women, and about 80 percent were white (as shown in Table 6). Table 6 also shows the overall racial make-up of the neighborhoods to which surveys were sent; whites were somewhat over-represented in the survey results. Home owners in the area were over-represented compared to renters.

Appendix D3 includes an example of the neighborhood resident surveys for the 16th Street/U Street/New Hampshire Avenue intersection, Pennsylvania Avenue, and 15th Street. See Reference 8 and Reference 9 for more information on typical survey response rates.

Table 5 Resident Survey Mailing Response Rates

Facility	Original Sample Size	Surveys Delivered[1]	Completed Surveys (1st Mailing)	Completed Surveys (2nd Mailing)	Total Completed	Response Rate
16th Street/U Street/New Hampshire Avenue	1,663	1,550	297	91	388	25%
Pennsylvania Avenue	1,008	888	108	49	157	18%
15th Street	2,000	1,798	346	130	476	26%
Total	***4,671***	***4,236***	***751***	***270***	***1,021***	***24%***

[1]This figure omits the surveys that were returned by the Postal Service as undeliverable.

Table 6 Resident Survey Demographics

Facility	Gender		Age			Race (Adjacent Blocks Census Data)[1]				
	Male	Female	18 to 34	35 to 54	55+	White	African-American	Asian	Other	Home Owners
16th Street/U Street/New Hampshire Avenue	50%	50%	46%	36%	18%	82% (63%)	7% (22%)	4% (5%)	7% (9%)	39% (28%)
Pennsylvania Avenue	43%	57%	39%	32%	29%	82% (60%)	3% (19%)	10% (15%)	5% (6%)	55% (23%)
15th Street	56%	44%	41%	38%	21%	79% (66%)	10% (17%)	4% (8%)	7% (8%)	55% (29%)

[1]2010 US Census. Adjacent block groups used for comparison include: 16th Street/U Street/New Hampshire Avenue (42.01.1; 43.00.1; 43.00.2); Pennsylvania Avenue (62.02.1; 58.00.1; 58.00.2; 59.00.1); and 15th Street (43.00.1; 43.00.2; 52.01.1; 52.01.2; 52.01.3; 52.01.4; 101.00.1; 101.00.2). Due to the low population in the direct vicinity of Pennsylvania Avenue, these block groups include areas considerably outside the survey area.

Business Surveys

Working with the DowntownDC Business Improvement District (BID), an online survey was sent to property management contacts at 43 properties known to be located directly on or in the near vicinity of the 15th Street cycle track and the Pennsylvania Avenue center bike lanes. Contacts were asked to complete a short survey on how the new facilities have impacted business operations for the property and tenants. Contacts were also asked to forward the survey to tenant businesses. A follow-up email was sent to encourage more responses.

A total of 16 properties and/or businesses responded. Thirteen respondents indicated they were either very or somewhat familiar with the 15th Street cycle track; of those, nine properties/businesses were located directly on 15th Street. All respondents indicated that they were familiar with the Pennsylvania Avenue center bike lanes, although only three properties/businesses were located directly on Pennsylvania Avenue.

All respondents, with one exception, were property or building facility managers or owners. The one exception was an officer of a non-profit tenant. Asked what type of business was operated at the property, responses ranged from law offices (6 responses), professional associations (8), financial firms and government agencies (4 each), non-profit organizations (5), restaurants and cafes (7), retail (6), and parking lots/garages (9).

Video Analysis

The objective of the video analysis was to empirically quantify user behavior on the new facilities. These behaviors include bicyclist compliance with traffic laws, bicyclist interactions with other road users including motorists and pedestrians, overall bicyclist behavior when using the new treatments, and driver compliance with protected left-turns. In addition, the video was used to count the number of bicyclists using the bicycle facilities. In total, 6,414 cyclists were observed across the facilities (some of these are multiple observations of the same cyclist along different portions of a corridor).

DATA COLLECTION

On each facility, a subset of intersections was videotaped on one weekday and on one weekend day. Cameras were mounted on poles near each intersection. Multiple cameras were placed at each intersection to provide a complete field of view. For each intersection, six hours of video were evaluated, including two morning peak hours (7:00 a.m. to 9:00 a.m.), two evening peak hours (5:00 p.m. to 7:00 p.m.), and two weekend midday hours (12:00 p.m. to 2 p.m.). *Field of view snapshots for each analyzed intersection are included in Appendices A4, B9, and C10 for the 16th Street/U Street/New Hampshire Avenue intersection, Pennsylvania Avenue corridor, and 15th Street corridor, respectively.*

Intersection of 16th Street/U Street/New Hampshire Avenue

KAI and Portland State University (PSU) reviewed six hours of video at the 16th Street/U Street/New Hampshire Avenue intersection.

Pennsylvania Avenue

PSU reviewed six hours of video at five intersections along the center bike lanes route (a total of 30 hours), including the intersections of Pennsylvania Avenue and 6th Street, 9th Street, 11th Street, 12th Street, and 13th Street.

15th Street

PSU reviewed six hours of video at five locations along the cycle track route (a total of 30 hours), including the intersections of 15th Street and R Street, Massachusetts Avenue, K Street, and Pennsylvania Avenue, along with an alley turn-off into a large parking garage between L and M Streets.

Each cyclist was logged at each intersection. Where applicable, reviewers noted the direction and lane in which the cyclist arrived and departed the intersection, the signal phase at arrival, compliance with the signal, and any congestion or other traffic in the intersection. On Pennsylvania Avenue and 15th Street, other users of the bicycle facilities (e.g., Segway riders and joggers) were also logged.

Reviewers noted any time a cyclist or motor vehicle was forced to make an emergency change of direction or emergency change of speed in order to avoid a collision (i.e., a "near-collision"). Video reviewers were instructed to be liberal in marking near-collisions in the initial review. Subsequently, a panel of two researchers observed any noted near-collisions and rated the severity of the conflict to ensure consistency. No collisions were observed.

Table 7 lists the intersections and dates evaluated for the video analysis.

Table 7 Video Analysis Intersections and Dates

		Weekday		Weekend		
Facility	**Intersection**	**Date**	**# Hours Reviewed**	**Date**	**# Hours Reviewed**	**Total Observed Cyclists**
New Hampshire Avenue	16th Street/U Street	11/3/2010	4	11/6/2010	2	298
Pennsylvania Avenue	6th Street	6/16/2011	4	6/18/2011	2	415
	9th Street	6/16/2011	4	6/18/2011	2	413
	11th Street	6/16/2011	4	6/18/2011	2	410
	12th Street	6/16/2011	4	6/18/2011	2	423
	13th Street	6/16/2011	4	6/18/2011	2	443
15th Street	Pennsylvania Avenue	6/16/2011	4	6/18/2011	2	826
	K Street	7/14/2011	4	7/16/2011	2	723
	Massachusetts Avenue	7/14/2011	4	7/16/2011	2	893
	R Street	7/14/2011	4	7/16/2011	2	860
	Between L Street and M Street (Alley)	7/14/2011	4	7/16/2011	2	710

Section 4

Evaluation of the Intersection of 16th Street NW/U Street NW/New Hampshire Avenue NW

16TH STREET NW/U STREET NW/NEW HAMPSHIRE AVENUE NW

DDOT installed bicycle boxes, bicycle signals, bicycle detection, shared lane markings, and contra flow bicycle lanes at the 16th Street/U Street/New Hampshire Avenue intersection.

Data Collection

DDOT provided data (mostly for conditions before the bicycle facilities were installed) for the 16th Street/U Street/New Hampshire Avenue intersection, including:

- Bicycle counts from May 2009 and April/May 2010,
- Turning movement counts for motor vehicles from May 2009 and April/May 2010,
- Pedestrian counts from May 2009 and April/May 2010,
- Crash data from 2006 through 2011,
- Signal timing and phasing information, and
- Video of the intersection.

Similar data were required for conditions after the bicycle facilities were installed. KAI acquired the following data (mostly for conditions after the bicycle facilities were installed) for the 16th Street/U Street/New Hampshire Avenue intersection, including:

- Bicyclist, pedestrian, and motor vehicle counts during the weekday a.m. and p.m. peak hours,
- Video during the weekday a.m. and p.m. peak hours and the Saturday midday peak hours,
- Traffic signal timing data,
- User intercept surveys, and
- Surrounding neighborhood surveys.

Intersection Analysis

VOLUME ANALYSIS

Bicycle Volumes

An assessment of bicyclist volumes was completed as part of the facility evaluation at 16th Street/U Street/New Hampshire Avenue. Table 8 shows the a.m. and p.m. peak hour through bicyclist volumes counted on New Hampshire Avenue south of U Street during May 2009, April 2010, and April 2012. The bicyclist counts include all bicyclists both inside and *outside* the designated bicycle facilities. Between April 2010 and April 2012, there was a 133 percent increase in the number of bicyclists traveling on New Hampshire Avenue during the a.m. peak hour and a 185 percent increase during the p.m. peak hour.

Table 8 New Hampshire Avenue Peak Hour Bicycle Volumes Counted South of U Street

Time Period	Before Installation of Bicycle Facilities (Bicyclists)				After Installation of Bicycle Facilities (Bicyclists)		Percent Change from April 2010 to April 2012
	May 2009		April 2010		April 2012		
	Northbound	Southbound	Northbound	Southbound	Northbound	Southbound	
AM Peak Hour	23	17[1]	3	87	5	205	(+) 133%
PM Peak Hour	23	17[1]	16	23	77	34	(+)185%

[1] Southbound volumes are estimated based on southbound volumes traveling along the north leg of New Hampshire Avenue.

Motor Vehicle Volumes

Motor vehicle volumes were also assessed at the 16th Street/U Street/New Hampshire Avenue intersection to determine if there were any changes caused by the bicycle facility installation. Table 9 shows the p.m. peak hour motor vehicle volumes at the intersection before and after installation of the bicycle facilities. There was a one percent decrease in motor vehicle volumes between May 2009 and April 2012.

Table 9 16th Street/U Street/New Hampshire Avenue PM Peak Hour Motor Vehicle Volumes

Before Installation of Bicycle Facilities (Vehicles)	After Installation of Bicycle Facilities (Vehicles)	Percent Change from May 2009 to April 2012
May 2009	April 2012	
2,824	2,787	(-) 1%

OPERATIONS ANALYSIS

Motor Vehicle Level of Service

KAI reviewed HCM motor vehicle LOS operations with the current intersection configuration based on counts performed in May 2010. While accommodating bicyclists was the purpose of the new bicycle facilities, DDOT wants to maintain a multimodal environment at the 16th Street/U Street/New Hampshire Avenue intersection. Table 10 includes information on the average delay and corresponding LOS experienced by drivers before and after installation of the bicycle facilities, along with intersection volume-to-capacity (v/c) ratios.

The operations analysis only evaluated the effect of the signal timing changes made at the 16th Street/U Street/New Hampshire Avenue intersection. The volumes used in the before and after analyses remained the same to be conservative, but an 11-second bicycle phase (7 second green and 4 second yellow) was added to the signal timing for conditions after the bicycle facilities were installed. For the a.m. peak hour analysis, the bicycle phase was accommodated by taking ten seconds from the eastbound/westbound movements and one second from the northbound/southbound movements. For the p.m. peak hour analysis, the bicycle phase was accommodated by taking nine seconds from the northbound/southbound movements and two seconds from the eastbound/westbound movements.

The LOS remained consistent after the addition of the bicycle phase. However, the delay and v/c ratios increased, as indicated by the red cells in the table below. This increase in delay and v/c ratios is expected given the reduction in green time allocated to the motor vehicle phases. Overall, the motor vehicle operations remained similar after installation of the bicycle facilities during the p.m.. The analysis of operations during the a.m. period increased average delay and the volume to capacity ratio, indicating the potential for queue spillback and cycle failures.

Table 10 16th Street/U Street/New Hampshire Avenue HCM Motor Vehicle LOS

AM Peak Hour						PM Peak Hour					
Before Installation of Bicycle Facilities			After Installation of Bicycle Facilities			Before Installation of Bicycle Facilities			After Installation of Bicycle Facilities		
LOS	Delay (Sec)	V/C	LOS	Delay (Sec)	V/C	LOS	Delay (Sec)	V/C	LOS	Delay (Sec)	V/C
E	56.2	0.91	E	75.8	1.03	C	26.0	0.70	C	33.8	0.79

Other key findings of the operations analysis include:

- The biggest queuing issue is found at the southbound movement during the a.m. peak hour. All other movements in the a.m. and p.m. peak hours operate under capacity.
- Northbound and southbound left turns are prohibited during weekday peak hours, thus limiting the impact the turns would otherwise have on the intersection.
- The eastbound left-turn movement could more easily be removed than the westbound left-turn movement, as the westbound left-turn volumes are considerably higher. When removing left turns at an intersection, consideration must be given to the new path that motorists take to turn left. Eastbound left-turns could probably be accommodated on 15th Street, while the elimination of the westbound left-turn lane would force motorists to make a left turn at 17th Street, which is a one-lane local street.

CRASH ANALYSIS

Crash data from the 16th Street/U Street/New Hampshire Avenue intersection, as well as the New Hampshire Avenue/T Street and New Hampshire Avenue/V Street intersections, were obtained from the DDOT Traffic Accident Reporting and Analysis System for periods before and after installation of the existing bicycle facilities. The New Hampshire Avenue/T Street intersection is southwest of the study intersection, and the New Hampshire Avenue/V Street intersection is northeast of the study intersection. Crash data from 2006 through 2010 were provided for conditions before the bicycle facilities were installed, and crash data from 2010 through 2011 were provided for conditions after the bicycle facilities were installed.

Table 11 shows the number of crashes and crashes per year for the three intersections by type and severity for conditions before the bicycle facilities were installed, while Table 12 shows the number of crashes and crashes per year by type and severity for conditions after the bicycle facilities were installed. Crashes per year are summarized to normalize the crash data across different time periods before and after installation of the bicycle facilities. Red cells indicate types and severities of crashes that have more crashes per year after installation of the bicycle facilities, and green cells indicate fewer crashes per year after installation of the bicycle facilities.

Table 11 New Hampshire Avenue Crashes Per Year Before Installation of the Bicycle Facilities (All Crashes)

Cross Street		Total	Fatal	Injury	PDO[1]	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
T Street	Crashes	8	0	0	8	2	0	0	4	0	2
	Crashes Per Year	2.0	0.0	0.0	2.0	0.5	0.0	0.0	1.0	0.0	0.5
16th Street/U Street	Crashes	73	0	18	55	13	3	20	21	1	15
	Crashes Per Year	18.3	0.0	4.5	13.8	3.3	0.8	5.0	5.3	0.3	3.8
V Street	Crashes	4	0	1	3	0	2	0	1	0	1
	Crashes Per Year	1.0	0.0	0.3	0.8	0.0	0.5	0.0	0.3	0.0	0.3

[1]PDO = Property Damage Only

Table 12 New Hampshire Avenue Crashes Per Year After Installation of the Bicycle Facilities (All Crashes)

Cross Street		Total	Fatal	Injury	PDO[1]	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
T Street	Crashes	0	0	0	0	0	0	0	0	0	0
	Crashes Per Year	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16th Street/U Street	Crashes	24	0	7	17	2	4	1	9	0	8
	Crashes Per Year	22.2	0.0	6.5	15.7	1.8	3.7	0.9	8.3	0.0	7.4
V Street	Crashes	2	0	0	2	0	0	1	1	0	0
	Crashes Per Year	1.8	0.0	0.0	1.8	0.0	0.0	0.9	0.9	0.0	0.0

[1]PDO = Property Damage Only

The crashes per year were calculated over a 48-month period for conditions before installation of the bicycle facilities and compared to crashes per year calculated over a 13-month period for conditions after installation. It is difficult to identify conclusions based on only one year of data from after the facilities were constructed. However, the total crashes per year did increase by approximately 4 crashes per year at 16th Street/U Street/New Hampshire Avenue in the first year after installation of the bicycle facilities.

Table 13 summarizes the number of bicyclists and pedestrians involved in crashes per year before and after installation of the bicycle facilities. Because of the increase in cyclist volumes before and after installation, cyclist crashes were adjusted for exposure. During the p.m. peak hour, cyclist volumes increased by 185 percent overall (based on northbound *and* southbound volumes on New Hampshire Avenue) after installation of the bicycle facilities at the 16th Street/U Street/New Hampshire Avenue intersection. Table 13 includes a column for "adjusted" bicyclist crashes per year for the after condition that is more directly comparable to the bicyclist crashes per year before the facilities were installed, considering the increased volume of bicyclists using the facility.

Using the crashes per year adjusted for bicyclist exposure, the number of crashes per year involving bicyclists remained similar before and after installation of the bicycle facilities. The crashes involving bicyclists increased by approximately one crash per year at the 16th Street/U Street/New Hampshire Avenue intersection, while no crashes were reported at the New Hampshire/T Street or New Hampshire Avenue/V Street intersections after the bicycle facilities were installed.

The increase in total crashes per year after installation of the bicycle facilities indicates that additional evaluation should be considered at the 16th Street/U Street/New Hampshire Avenue intersection with regard to how vehicles interact with the bicycle facilities. Crashes directly involving bicyclists do not appear to have increased greatly after installation of the bicycle facilities. However, the total number of bicycle crashes is far too small to draw definitive conclusions, and one year of data after installation does not provide conclusive information for the crash patterns occurring along the corridor. It is recommended that crash reports be evaluated in future years to monitor trends in cyclist crashes.

This research also recommends several operational changes to increase bicyclist compliance with the signal (fewer than 20 percent of cyclists obey the bicycle signal indication), as described in detail in subsequent sections. The lack of compliance could contribute to bicycle crashes.

Table 13 New Hampshire Avenue Bicyclists and Pedestrians Per Year Involved in Crashes

	Before Installation of the Bicycle Facilities				After Installation of the Bicycle Facilities				
	Crashes Involving Pedestrians		Crashes Involving Bicyclists		Crashes Involving Pedestrians		Crashes Involving Bicyclists		
Cross Street	Crashes	Crashes Per Year	Crashes	Crashes Per Year	Crashes	Crashes Per Year	Crashes	Crashes Per Year	Adjusted Crashes Per Year[1]
T Street	0	0.0	0	0.0	0	0.0	0	0.0	0.0
16th Street/ U Street	5	1.3	4	1.0	0	0.0	5	4.6	1.6
V Street	0	0.0	1	0.3	0	0.0	0	0.0	0.0

[1]Adjusted to reflect increase in cyclist volumes from before to after condition.

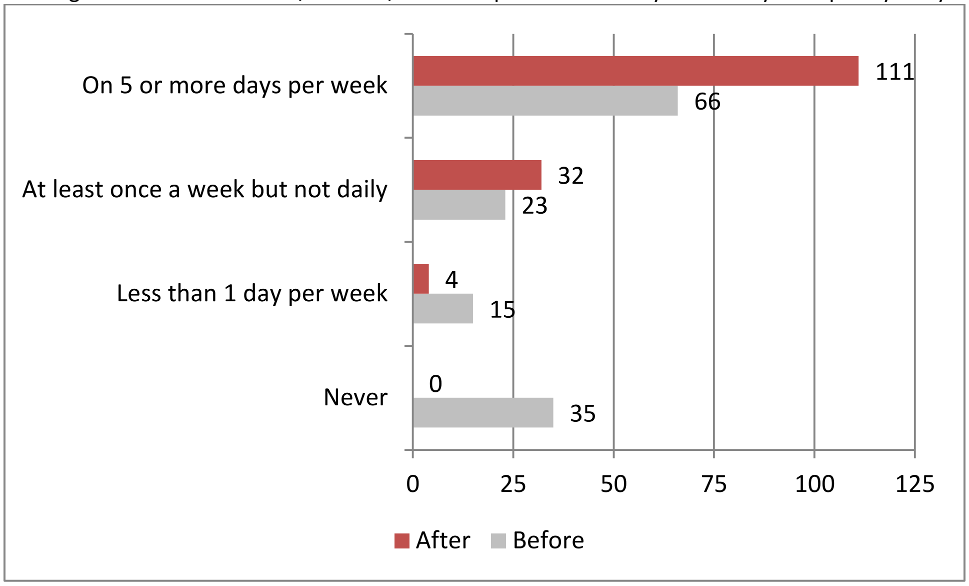
SURVEY ANALYSIS

Cyclist Intercept Survey

Sample Characteristics

Respondents were asked how often they bicycled through the intersection both before and after the bicycle facilities were installed, as shown in Figure 8. Over 20 percent of the respondents indicated that they had never cycled through the intersection prior to the installation and another 10 percent only cycled through less than once per week. In contrast, all but 3 percent of the respondents indicated that they now use the intersection at least once per week or more. This change could reflect a combination of multiple factors, including: cyclists shifting their routes; cycling more because of the improved bicycle facilities; and reflect an overall increase in bicycling within the District.

Figure 8 16th Street/U Street/New Hampshire Avenue Cyclist Survey - Frequency of Cycling



Perceptions of Safety and Ease

Overall, respondents indicated that they felt that cycling through the intersection was safer and easier with the new facilities, although the contra-flow bike lanes received more positive responses than the bike signals and bike boxes, as shown in Table 14. Asked to indicate their agreement with statements on the safety and ease of bicycling with the new facilities, over two-thirds of respondents stated that they "strongly agree" that the contra-flow lanes make riding safer and easier. While a strong majority of respondents agreed that the bike signals and bike boxes made the intersection safer and easier, less than one-third "strongly" agreed on either measure (only 28 percent and 31 percent, respectively). No cyclists reported experiencing a collision while bicycling in the new facilities.

Table 14 16th Street/U Street/New Hampshire Avenue Cyclist Survey - Perceptions of Safety and Ease

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I feel safer riding on this block as a cyclist because of the contra-flow bike lane.	5%	3%	22%	70%	151	6	92%	3.6
The contra flow bicycle lane has made riding on this block easier for me as a cyclist.	5%	3%	15%	77%	151	6	93%	3.7
I feel safer when going through this intersection as a cyclist because of the bike signal and bike box.	5%	18%	46%	31%	147	6	77%	3.0
The bicycle signal and bike box have made riding through this intersection easier for me as a cyclist.	5%	21%	46%	28%	146	7	74%	3.0

Understanding and Compliance

Cyclists were asked a series of questions about their understanding and use of the new facilities. Cyclists were first asked to self-report what path they use to cross the intersection. The previous question asked which direction they approach the intersection from, so respondents were only presented one set of pictures. Seventy-two percent of respondents were heading southbound (SB) through the intersection, while 27 percent were headed northbound (NB). Table 15 shows the self-reported paths through the intersection taken by cyclists, including those crossing into the bike box before proceeding across U Street, those moving diagonally through the intersection, and those using the crosswalks.

Table 15 16th Street/U Street/New Hampshire Avenue Cyclist Survey - Self-Described Path through Intersection Compared to Observed Path

	A: Crossed 16th Street, entered the bike box, then crossed U Street.	B. Crossed the intersection diagonally.	C: Used the crosswalks - crossed 16th Street then crossed U Street.	D: Used the crosswalks - crossed U Street then crossed 16th Street.	Other
Self-described path of survey respondents, NB Cyclists (n[1]=42)					
	Total of A, B, and C: 50%[2]			45%	5%
Video Review (n=122)	44%	2%	2%	51%	-
Self-described path of survey respondents, SB Cyclists (n=113)					
	40%	10%	7%	35%	9%
Video Review (n=176)	51%	9%	5%	35%	-

[1] n = Number of cyclists

[2] Due to a survey error, NB cyclists were asked a different version of the question that included wording about waiting for the bicycle signal. If responses are best matched, combining A, B, and C responses totals 50%, D totals 45%, and other responses total 5%.

Most cyclists stated that they moved through the intersection in a way other than the way it was designed. For southbound cyclists, the distribution of self-reported and observed paths is nearly identical. In the survey, responses to A were meant to capture those users who were using the facility as intended. Only 7 percent of NB cyclists self-reported that they cross 16th Street into the bike box before proceeding north, while 40 percent of SB cyclists reported crossing 16th Street into the bike box before proceeding south. Cyclists stating they move diagonally are most likely using the bike signal to enter the traffic stream on 16th Street but using a more direct path through the intersection. These cyclists made up 17 percent of NB and 10 percent of SB cyclists. Nearly three-quarters (71 percent) of NB cyclists self-reported using the crosswalks, while 42 percent of SB cyclists use the crosswalks.

In addition, most cyclists stated that they chose not to wait for the bike signal to cross 16th Street. Of the 48 cyclists indicating that they moved into the bike box from the contra-flow bike lane, only 23 percent responded that they waited for the bike signal to change, while 77 percent stated that they simply went when there was a gap in traffic. Survey respondents identified an issue with the in-pavement loops detecting the presence of a bicycle. When asked how often the bicycle signal reliably detects their presence as a northbound or southbound cyclist so that they get a green signal, 49 percent indicated never or rarely (14 percent and 35 percent, respectively), 34 percent indicated on most trips or on almost every trip (23 percent and 11 percent, respectively), while 17 percent did not remember. The quality of the video did not allow the research team to investigate if cyclists were stopped in an incorrect location, if this is an issue with the detector, or if cyclists simply were too impatient to wait for the signal. Note that the research team observed several apparent detector errors during field visits.

Several levels of agreement questions were asked about specific elements of the facility to provide context for why people may choose not to use the bike signal and bike box as intended. As shown in Table 16, 78 percent of cyclists indicated that they either “somewhat agreed” or “strongly agreed” with the following statement: “It’s not worth my time to wait for the bike signal.” About two-thirds of respondents indicated that they often encounter cars turning left off of U Street as they attempt to move into the bike box (68 percent) or often see motor vehicles stopped inside the bike boxes (63 percent).

Table 16 16th Street/U Street/New Hampshire Avenue Cyclist Survey – Bike Signal and Bike Box

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongl y Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
It's not worth my time to wait for the bike signal.	4%	18%	41%	37%	147	5	78%	3.1
When crossing 16th Street to get in the bike box after I get the green signal, I often encounter cars that have just turned left off of U Street.	7%	24%	44%	24%	107	44	68%	2.9
I often see motor vehicles stopped inside the bike box at red lights.	13%	24%	25%	38%	130	22	63%	2.9

Resident Survey

Sample Characteristics and General Opinions

Of the 388 respondents, 60 percent were the sole occupant of their residence and 96 percent did not have children living in the household. Sixty percent of respondents rent their homes, while 39 percent own and 1 percent stated their status as "other." Eighty-four percent of respondents indicated that they work outside their home zip code.

Nearly all of the survey respondents (95 percent) indicated that their neighborhood has been improving in recent years. Fewer than half of respondents indicated that they view bicycling in Washington, D.C. as safe (46 percent), but a strong majority support investments in projects that encourage the use of bicycles for transportation (82 percent agreed) and that improve the safety of bicycling (89 percent agreed). Table 17 provides an overview of opinions on their neighborhood, bicycling safety, and investments.

Table 17 16th Street/U Street/New Hampshire Avenue Resident Survey - General Opinions on the Neighborhood, Bicycling, and Investment

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
My neighborhood has improved in the last 2 years.	1%	4%	40%	55%	332	54	95%	3.5
Washington, D.C. should be investing in projects that encourage more people to ride bicycles for transportation.	7%	11%	31%	51%	354	31	82%	3.3
Bicycling is an important part of the Washington transportation system.	6%	12%	32%	50%	358	27	82%	3.3
Bicycling in Washington, D.C. is safe.	18%	35%	38%	9%	343	41	46%	2.4
Washington, D.C. should be investing in projects that improve the safety of bicycling.	4%	7%	28%	61%	360	26	89%	3.5

Understanding and Support of New Facilities

All respondents were asked questions pertaining to their self-described understanding of how the new bicycle facilities function. Most people indicated that they understand how the facilities work, although the bike box appeared to be understood by fewer people (about 62 percent) than the contra-flow bike lanes (75 percent) and bike signal (68 percent). Although respondents are split on whether the new facilities provide them with more transportation options, they nonetheless generally support the new facilities (83 percent) and view them as a valuable asset to the neighborhood (81 percent). Table 18 provides questions pertaining to the respondents understanding of the various facilities and support of the new features.

Table 18 16th Street/U Street/New Hampshire Avenue Resident Survey - Understanding and Support of New Facilities

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I understand how the contra-flow bike lanes work.	12%	13%	38%	38%	351	29	75%	3.0
I understand how the bike box works.	16%	22%	35%	27%	344	36	62%	2.7
I understand how the bike signal works.	11%	21%	31%	37%	344	34	68%	2.9
I have more transportation options because of the new bicycle features at 16th and U Street.	23%	25%	24%	28%	294	87	52%	2.6
I support the new bicycle features at 16th and U Street.	9%	9%	34%	49%	337	43	83%	3.2
The new bicycle features at 16th and U Street are a valuable asset to my neighborhood.	8%	11%	35%	46%	325	55	81%	3.2
I see many people riding bicycles through the intersection at 16th and U Street.	3%	6%	31%	61%	350	31	91%	3.5

Motorist Experience with New Facilities

Seventy-four percent of respondents (289) indicated that they had driven through the intersection of 16th Street/U Street/New Hampshire Avenue in the past year, and 160 respondents stated that they drive through the intersection at least once per week. Fifty-six percent of respondents stated that they own one or more motor vehicles.

For the purposes of this analysis, only residents who indicated that they own a motor vehicle were included as "motorists." (Full results for all respondents who indicated they had driven through the intersection in the past year are included in Appendix D3). As seen in Table 19, motorist opinions were generally positive or neutral on the impact the new facilities have had on driving through the intersection. Sixty-seven percent indicated that the contra-flow bike lanes don't affect them as motorists, while 70 percent indicated that the bike box and bike signal do not affect them as motorists. Few respondents indicated that the facilities were responsible for increased congestion (27 percent), signal delay (34 percent) or increased challenge when parking (39 percent).

Table 19 16th Street/U Street/New Hampshire Avenue Resident Survey – Driving Questions

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I feel that the contra-flow bike lanes don't affect me as a driver.	13%	21%	43%	23%	174	24	66%	2.8
I think traffic congestion has gotten worse at this intersection as a result of the bike facilities.	13%	19%	45%	24%	174	25	68%	2.8
I feel that the bike signal and box doesn't affect me as a driver.	36%	37%	12%	15%	156	45	27%	2.1
I feel like I have to wait longer for a green light since the bicycle signal was added.	32%	33%	22%	12%	157	43	34%	2.1
Parking is more challenging with the new bicycle facilities.	33%	28%	19%	20%	164	37	39%	2.3

Cyclist Experience with New Facilities

Thirty-three percent of respondents (128) indicated that they had bicycled through the intersection of 16th Street/U Street/New Hampshire Avenue in the past year, and 84 respondents stated that they bicycle through the intersection at least once per week.

As seen in Table 20, 92 percent of respondents of those self-reported as cyclists indicated that the intersection is a useful bicycle connection, and most respondents indicated that they feel safer cycling through the intersection because of the changes (75 percent agreed). These responses are comparable to the cyclists surveyed via the intercept method (Table 14). In contrast, two-thirds of these cyclists agreed ("somewhat" or "strongly") that they followed the markings and signal through the intersection as intended. Either cyclists who are residents in the neighborhood behave differently and/or cyclists surveyed via the intercept method portrayed their behavior more accurately. The latter explanation is more likely and may be attributed to differences in the question wording and structure. The intercept survey was more detailed and specific; the resident survey did not indicate a specific route or path.

Table 20 16th Street/U Street/New Hampshire Avenue Resident Survey – Cycling Questions

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
The intersection of 16th and U Streets is a useful connection to get to the places I need to go by bicycle.	0%	8%	38%	55%	119	13	92%	3.8
I feel safer riding on this block as a cyclist because of the changes to the intersection.	9%	16%	48%	27%	121	12	75%	2.9
The new features at this intersection make for a better environment for bicycling in Washington DC.	3%	8%	36%	52%	118	13	88%	3.3
As a bicyclist, I understand the purpose of the new bicycle markings and signals.	5%	13%	41%	42%	128	2	83%	3.2
When bicycling through this intersection, I follow the markings and signals as intended.	9%	24%	31%	36%	124	6	67%	2.9

Pedestrian Experience with New Facilities

Ninety-three percent of respondents (361) indicated that they had walked through the intersection of 16th Street/U Street/New Hampshire Avenue in the past year, and 336 respondents stated that they walk through the intersection at least once per week.

Most pedestrians indicated agreement with the statement that the “changes to this intersection don’t affect me as a pedestrian” (69 percent). Respondents were split on whether they are now encountering fewer cyclists in the crosswalks (49 percent) and on the sidewalks (57 percent). Table 21 provides pedestrian responses.

Table 21 16th Street/U Street/New Hampshire Avenue Resident Survey – Walking Questions

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
The changes made to this intersection don't affect me as a pedestrian.	12%	19%	32%	37%	354	15	69%	2.9
When walking through this intersection, I encounter fewer cyclists in the crosswalks now than before the changes were made.	20%	31%	34%	15%	249	120	49%	2.4
There are fewer cyclists riding on the sidewalk now.	21%	22%	37%	20%	308	60	57%	2.6

VIDEO ANALYSIS

A total of 298 cyclists were observed crossing U Street at the intersection of 16th Street/U Street/New Hampshire Avenue. A video of these cyclists was provided to the research team. Due to the placement of the camera and video quality, many details about the behavior of cyclists were difficult, if not impossible, to quantify with any certainty. For example, the stopping position of cyclists waiting for the bicycle signal could not be seen in the video. The phase indication of the bicycle signal could also not be seen and needed to be inferred from the operation of the other phases. The observations focused primarily on the paths that cyclists chose through the intersection and conflicts with motor vehicles during these maneuvers. Observations during the a.m. peak period focused on southbound bicyclists on New Hampshire Avenue, while the p.m. analysis focused on northbound bicyclists (to capture peak travel direction). Table 22 summarizes the analysis findings.

Video taken before the bicycle facilities were provided as well, but due to the poor quality of the images, the research team did not include this video in the analysis.

Table 22 Behavior of Bicyclists Arriving at 16th Street/U Street via New Hampshire Avenue

Direction	Total Bicyclists Observed	Intersection Crossing Method			Used Bike Signal	Stop Location (Bicyclists Using Bike Facility)		
		Crosswalk[1]	Bike Facility	Diagonal		In Crosswalk	In Bike Box	No Stop
Southbound Peak	144	40%	51%	9%	29	72%	4%	24%
Southbound Non-Peak	32	41%	50%	9%	3	25%	13%	63%
SB Subtotal	***176***	***40%***	***51%***	***9%***	***32***	***63%***	***6%***	***31%***
Northbound Peak	104	53%	44%	3%	13	50%	22%	28%
Northbound Non-Peak	18	56%	44%	0%	3	38%	13%	50%
NB Subtotal	***122***	***53%***	***44%***	***2%***	***16***	***48%***	***20%***	***31%***
TOTAL	***298***	***45%***	***48%***	***6%***	***48***	***58%***	***11%***	***31%***

[1] The crosswalk path that bicyclists used crosses New Hampshire Avenue and U Street (during the 16th Street green) and then crosses 16th Street (during the U Street green).

Pathway through the Intersection

Nearly half (45 percent) of all bicyclists cross the intersection via crosswalk (usually crossing U Street first, then 16th Street) rather than using the bicycle signal–bike box path ("bike facility"). About 48 percent moved into the bike box before crossing U Street, though most of these cyclists did not use the bike signal to cross 16th Street, instead crossing when they saw a gap in traffic. In the video review, this occasionally led to conflicts with turning vehicles from 16th Street.

A small percentage of bicyclists (19 out of 298) crossed the intersection diagonally, with most of those (12 of 19) starting on the bike signal green. Note that because the bicycle phase is exclusive, cyclists traversing the intersection in this manner face no conflicting traffic.

Signal Use

Most cyclists opted not to wait to use the bicycle signal. Overall, about 16 percent (48 of 298) of observed cyclists used the bicycle signal to cross the intersection (18 percent of southbound cyclists and 13 percent of northbound cyclists). Eight additional cyclists were observed waiting for the bike signal but decided to cross before the signal turned green, either by using the crosswalks or crossing 16th during a gap in traffic.

Most bicyclists that do use the bike signal (42 out of 48) were able to cross the intersection without stopping, either by crossing diagonally or moving into the bike box and continuing across U Street on the 16th Street green signal.

Stopping Locations

For cyclists that used the bike facility, few bicyclists chose a stopping position that was within the boundaries of the bike box for queuing. Of the 90 cyclists that rode through the bike box and stopped, 74 stopped in the crosswalk rather than in the bike box. Most of these cyclists crossed 16th Street during a gap in traffic, rather than waiting for the bike signal.

Interactions with Other Users

Southbound cyclists faced several challenges in crossing 16th Street to move into the bike box. Cyclist interactions with motor vehicles where one or more road users were forced to maneuver around one another or take evasive action were noted. All observed evasive actions were categorized as precautionary, rather than emergency actions, and no near-collisions or collisions were observed.

Four of the 32 southbound bicyclists observed using the signal experienced interactions with red-light running eastbound left-turns, forcing them to navigate out of the skip-stripe bike lane or to wait to cross until after the bicycle signal had turned to red and traffic on 16th Street was about to begin moving. Two other cyclists experienced interactions with motor vehicles making right turns off of U Street onto 16th Street northbound (one of these was categorized as requiring emergency reaction, but it appears the cyclist did not have the right-of-way).

Sixteen cyclists (18 percent of those cycling through the bike box) encountered motor vehicles blocking the bike box. Of these, half opted to cross in the crosswalks, 25 percent crossed diagonally, and 25 percent managed to move into the bike box. Five cyclists crossing 16th Street toward the bike box without using the bike signal experienced interactions with southbound traffic on 16th Street

Northbound cyclists (4 percent of those cycling through the bike box) encountered fewer challenges. On two occasions, cyclists encountered motor vehicles blocking the bike box. There were no observed interactions with turning or through motor vehicle traffic.

Key Findings

The analysis suggests several key findings related to bicycle operations and safety:

- **Bicycle volumes increased after installation of the bicycle facilities.** Between April 2010 (before the bicycle facilities were installed) and April 2012 (after the bicycle facilities were installed), there was a 133 percent increase in the number of bicyclists traveling on New Hampshire Avenue during the a.m. peak hour and a 185 percent increase during the p.m. peak hour.
- **Motor vehicle volumes remained approximately constant after installation of the bicycle facilities.** There was a one percent decrease between May 2009 (before the bicycle facilities were installed) and April 2012 (after the bicycle facilities were installed).
- **Motor vehicle intersection level of service (LOS) remained the same before and after the bicycle facilities were installed.** Reduced green time for the motor vehicle signal phases increased delay and the volume-to-capacity (v/c) ratio only slightly during the p.m. period, but resulted in somewhat larger impacts during the a.m. peak.
- **Few cyclists are using the bike box and bike signal as intended to cross the intersection.** The video revealed that fewer than 20 percent of bicyclists use the bicycle signal to cross the intersection. This percentage is consistent for southbound and northbound travel. Over 40 percent of bicyclists cross the intersection via crosswalks (usually first crossing U Street, then 16th Street) rather than using the bicycle facility. The cyclist intercept survey confirmed these findings. More than three-quarters of surveyed cyclists indicated that it was not worth the time to wait for the signal with the present signal timing.
- **Few cyclists are using the bike box as intended, although it may still achieve its purpose.** The video revealed that 82 percent of bicyclists stopped in the crosswalk, rather than waiting in the box. However, video evidence showed that fewer than 15 percent of cyclists using the bike box encountered motor vehicle stopped in the box, suggesting that the bike box may be effective at providing separation between bicyclists and motorists and providing cyclists with space to maneuver.
- **Cyclists using the bike signal often encounter motor vehicles, but are able to navigate through.** Four of the 32 southbound bicyclists (13 percent) observed using the signal experienced interactions with late motorist eastbound left-turns from U Street (who turned left on red). Despite this, most bicyclists that do use the bike signal (42 out of 48) were able to cross the intersection without stopping, either by crossing diagonally or proceeding during the 16th Street green. Note that a small percentage of bicyclists (19 out of 298) used the bike signal to cross the intersection diagonally (without first traveling to the box).
- **More bicycle crashes per year were observed at the intersection after installation of the bicycle facilities.** There were 5 bicycle crashes at the intersection during the first 13 months after implementation, compared to a total of 4 bicycle crashes during the previous 4 years. The

low number of total crashes and limited length of time observed for the after period (13 months) is too short to draw definitive conclusions. The number of crashes per year (adjusted for the increase bicyclist volumes) remained approximately the same before and after installation of the bicycle facilities. Crash patterns should continue to be monitored, particularly as operational changes are made to the intersection to improve bicyclist compliance.

- **Perceptions of the facility are generally positive from both cyclists and motorists.** Cyclists reported enthusiastic agreement that the contra-flow bike lanes make cycling safer and easier on New Hampshire. The bicycle signal and bike box elicited generally positive responses regarding safety and ease, although significantly lower than the response to the contra-flow lanes. Motorists did not indicate that the new bicycle facilities caused any problems in terms of added congestion, delay, or parking challenges.
- **Residents responding to the survey support more investments in bicycle facilities.** Many area residents do not believe bicycling in Washington, D.C. is safe, but a strong majority support investments in encouraging bicycling for transportation and improving the safety of bicycling.

Based on these findings, the team makes the following preliminary recommendations:

Preliminary Recommendations

The following preliminary recommendations were developed based on review of the traffic volumes, traffic operations, and crash, video, and survey data:

- Restrict trucks making eastbound right turns onto New Hampshire Avenue from U Street due to the new reduced turning radius.
- Increase the street cross-section width at the southwest New Hampshire intersection entrance to make room for the future bike lane. Supplement the increased width with a permanent barrier between motorists and bicyclists.
- Paint the bike boxes and dashed bike lanes leading to the bike boxes green. The green may increase the share of cyclists stopping in the box, rather than in the crosswalk, where conflicts with pedestrians can occur.
- The stop bars on 16th Street are not recommended for modification. They are currently located approximately 10 feet back from the crosswalks, providing an angled bicycle box area between the stop bar and crosswalks. They are recommended to remain in approximately the same position under any reconstruction plan to allow unimpeded bicycle access to the bike boxes.

- The dashed bike lanes crossing 16th Street should be located as close as possible to the crosswalk to increase visibility of cyclists to turning motorists (subject to other geometric design constraints.
- Consider adding medians (with bike openings) on both 16th Street approaches to increase pedestrian safety by providing a refuge from turning vehicles.
- Add a push-button for cyclists and/or improved bicyclist detection, or alter the signal timing to provide a green bike phase every cycle (see signal phasing modifications below).
- Near-side bicycle signal heads should be mounted lower for improved visibility. Consider installing smaller lenses (e.g., 4-inch) for the near-side bicycle signal heads. Small, low-mounted near-side bike signal heads are used successfully in northern Europe in similar situations.
- Modify signal phasing to reduce delay for all users and more closely reflect the way that cyclists currently use the intersection:
    - Provide a green bike signal that operates concurrently with green time on U Street. For consistency with the MUTCD meaning of a green ball for autos (i.e., allows through movement and turns except as modified by signing/striping/etc.), signing (e.g., "BIKES CROSS 16TH ST ON GREEN 🚲") should be installed to make it clearer that the bike signal doesn't allow protected movement all the way through the intersection. Green painted bike lanes and boxes would also reinforce this message.
    - Provide a three second solid yellow bike signal before the all-red bike signal.
    - Eliminate the exclusive bike phase; bicycles would receive the same amount of green time that U Street currently receives, which would reduce cyclist delay considerably. Furthermore, the time currently used by the exclusive bicycle phase would be returned to 16th and U Streets, which should improve motorized vehicle operations to close to "before" conditions.
    - Install a flashing yellow right-turn arrow for eastbound and westbound right turning vehicles.
    - Implement a flashing yellow arrow indication for the westbound left-turning movement during its permissive phase, and install a "TURNING VEHICLES YIELD TO BIKES" sign.
    - Prohibit eastbound left-turns to minimize conflicts with bicyclists.
    - Consider adding a short leading pedestrian/bicycle interval in advance of the U Street green indication. The length of any leading pedestrian/bicycle interval should be limited to avoid encouraging aggressive cyclists to cross the full intersection diagonally during the lead phase. Note that a leading pedestrian/bicycle interval would require eliminating the leading westbound left-turn phase (as there is no dedicated left-turn lane).

  - Temporarily use NEW TRAFFIC PATTERN AHEAD signs on the New Hampshire Avenue intersection approaches to inform bicyclists about the changed bicycle signal phasing.

- An alternative to the recommended signal timing modifications would be to implement an exclusive bicycle and pedestrian phase to allow cyclists to cross the intersection diagonally during the bicycle green phase. The length of the exclusive phase should be based on the needed pedestrian clearance interval for perpendicular crossing (using a walking speed of 3.5 feet/second). Pedestrians will also be allowed to cross during the U Street and 16th Street green phases (similar to the exclusive pedestrian phase at 7th Street/H Street in Chinatown).

  This alternative has the benefit of eliminating conflicts between cyclists and motor vehicles, but will likely require a longer cycle length with longer delays for both motorists and cyclists compared to the preferred alternative.

Section 5

Evaluation of Pennsylvania Avenue NW from 3rd Street NW to 15th Street NW

PENNSYLVANIA AVENUE NW FROM 3RD STREET NW TO 15TH STREET NW

In June 2010, bicycle lanes were installed in the center of the Pennsylvania Avenue roadway between 3rd Street and 15th Street. Study corridor segments from 6th Street to 10th Street and 10th Street to 15th Street are evaluated in this section.

Data Collection

DDOT provided data from before (and some data from after) the bicycle facilities were installed on Pennsylvania Avenue, including:

- Turning movement counts for motor vehicles from December 2009,
- Pedestrian counts from December 2009,
- Bicyclist counts from December 2009, April 2010, September 2010, and June 2011,
- Crash data from 2006 through 2011, and
- Signal timing and phasing information.

Similar data were required for the period after the bicycle facilities were installed. KAI acquired the following data for Pennsylvania Avenue, including:

- Bicyclist, pedestrian, and motor vehicle counts at signalized intersections during the weekday a.m. and p.m. peak hours and the Saturday midday peak hours,
- Video at signalized intersections during the weekday a.m. and p.m. peak hours and the Saturday midday peak hours,
- Traffic signal timing data,
- User intercept surveys, and
- Surrounding neighborhood surveys.

Corridor Analysis

VOLUME ANALYSIS

Bicycle Volumes

Table 23 and 0 show the a.m. and p.m. peak hour bicyclist volumes, respectively, counted between 6th Street and 7th Street and between 14th Street and 15th Street during December 2009, April 2010, September 2010, and June 2011. Figure 9 and Figure 10 graph the change in bicyclist volumes along Pennsylvania Avenue for the a.m. and p.m. peak hours, respectively. The bicyclist counts included all bicyclists traveling along Pennsylvania Avenue both inside and *outside* the designated bicycle facilities.

The data indicate that more bicyclists began using Pennsylvania Avenue after the bicycle facilities were installed, as shown by the growth percentages in the tables below. However, seasonal factors could contribute to some of the increased bicycle traffic. The counts before the bicycle facilities were installed were taken during the winter and spring, while the counts after the facilities were constructed were taken during summer and fall months. Due to seasonal variation in bicycle volumes, caution should be used in making direct comparisons between these counts.

Counts from April 2010 were compared to counts from June 2011 to compare volumes during similar seasons. Between 6th Street and 7th Street, there was a 221 percent increase in a.m. peak hour volumes after the bicycle facilities were installed and a 237 percent increase in p.m. peak hour volumes. Between 14th Street and 15th Street, there was a 315 percent increase in a.m. peak hour volumes after the bicycle facilities were installed and a 241 percent increase in p.m. peak hour volumes.

Table 23 Pennsylvania Avenue AM Peak Hour Bicycle Volumes

Between Intersections	Before Installation of the Bicycle Facilities (Bicyclists)		After Installation of the Bicycle Facilities (Bicyclists)		Percent Change from April 2010 to June 2011
	December 2009	April 2010	September 2010	June 2011	
6th Street and 7th Street	25	52	83	167	(+) 221%
14th Street and 15th Street	18	41	69	170	(+) 315%

Figure 9 Pennsylvania Avenue AM Peak Hour Bicycle Volumes

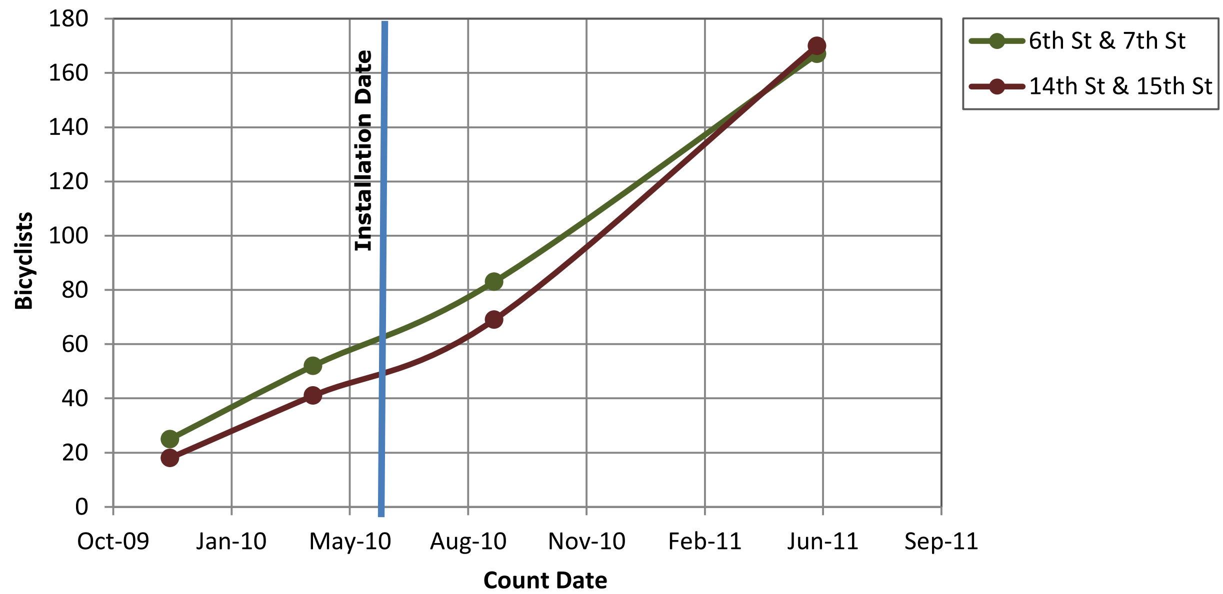
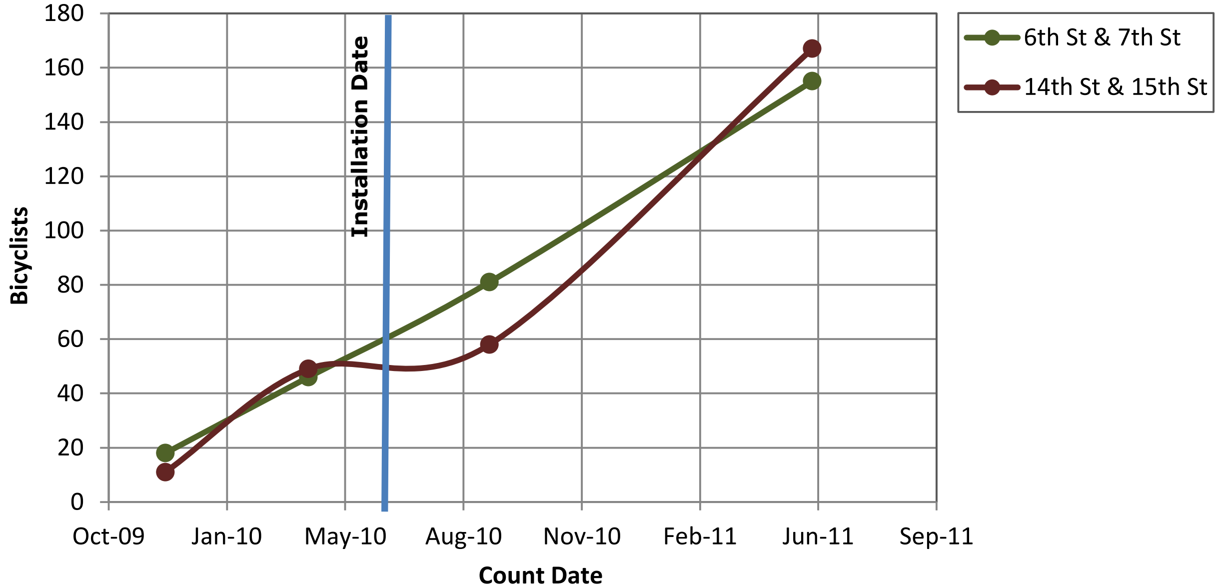


Table 24 Pennsylvania Avenue PM Peak Hour Bicycle Volumes

Between Intersections	Before Installation of the Bicycle Facilities (Bicyclists)		After Installation of the Bicycle Facilities (Bicyclists)		Percent Change from April 2010 to June 2011
	December 2009	April 2010	September 2010	June 2011	
6th Street and 7th Street	18	46	81	155	(+) 237%
14th Street and 15th Street	11	49	58	167	(+) 241%

Figure 10 Pennsylvania Avenue PM Peak Hour Bicycle Volumes



Motorized Vehicle Volumes

Motorized vehicle volumes were also assessed along Pennsylvania Avenue to determine if there were any changes caused by the bicycle facility installation. Table 25 shows the average p.m. peak hour motorized vehicle through volumes between intersections on Pennsylvania Avenue for intersections between 6th Street and 10th Street and between 10th Street and 15th Street. The counts indicate that fewer motorized vehicles used Pennsylvania Avenue after the bicycle facilities were installed. Several reasons may have contributed to these decreased motorized-vehicle volumes. Left turns were restricted (and missing left-turn restriction signs replaced) at a number of intersections along the corridor. In addition, motorized-vehicle volumes on Pennsylvania Avenue may vary daily or seasonally, or construction activities in the area could have caused drivers to divert away from Pennsylvania Avenue on the day that the counts were taken.

Table 25 Pennsylvania Avenue Average PM Peak Hour Motorized Vehicle Through Volumes Between Intersections

Corridor Segment	Before Installation of Bicycle Facilities (Vehicles)	After Installation of Bicycle Facilities (Vehicles)	Percent Change from October 2009 to June 2011
	October 2009	June 2011	
6th Street to 10th Street	2,201	1,733	(-) 21.3%
10th Street to 15th Street	1,561	1,332	(-) 14.7%

OPERATIONS ANALYSIS

Highway Capacity Manual Multi-Modal Level of Service

Pennsylvania Avenue was evaluated in both directions using the bicycle LOS component of the HCM MMLOS before and after implementation of the center median bike lanes. The bike lanes improved the LOS significantly for each segment along the facility, with every segment along the corridor providing LOS A. However, the calculation methods for the entire facility, which includes both intersection and segment components, only show a slight improvement in overall LOS. Table 26illustrates the results of the MMLOS evaluation in each direction.

Table 26 Pennsylvania Avenue HCM Bicycle LOS

Segment	Direction	Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		Score[1]	LOS	Score[1]	LOS
6th Street to 10th Street	Westbound	3.97	D	3.11	C
	Eastbound	4.00	D	3.06	C
10th Street to 15th Street	Westbound	3.83	D	3.02	C
	Eastbound	3.70	D	2.98	C

[1] MMLOS scores are defined in the Study Methodology section of this report.

Installation of the dedicated bike lanes in the center median of Pennsylvania Avenue offers cyclists physical separation from vehicle traffic, improving the users' perception of the corridor. Without the bike lanes, cyclists traveled in mixed traffic on a busy street with six to eight lanes, which produced a poor LOS score. Despite the improvements on a segment-by-segment perspective, the MMLOS methods only yield a small improvement over the entire facility (from LOS D to LOS C) due to the construction of the model, which makes achieving an LOS A or B score nearly impossible. In addition, the HCM MMLOS procedures were not calibrated to be able to account for innovative bicycle facilities, such as cycle tracks or buffered bike lanes.

Because of the limitations of the HCM MMLOS procedures, the research team also applied two other bicycle facility analysis methods: Danish Bicycle LOS and the Bicycle Environment Quality Index (developed by the City of San Francisco).

Danish Bicycle Level of Service

The bicycle facilities were evaluated using the Danish Bicycle LOS method, which evaluated the westbound and eastbound bicycle facilities separately. The model was calibrated on facilities that included both cycle tracks and buffered bike lanes, making it applicable for use on Pennsylvania Avenue. Overall, the Danish Bicycle LOS model indicates that the LOS experienced by bicyclists improved significantly along Pennsylvania Avenue with the addition of the bicycle facilities, as shown in Table 27. At present, the Danish method only addresses conditions between intersections (similar to the HCM bicycle LOS for segments); an updated version that also considers intersection conditions is expected to be published in spring 2012.

Before the installation of the bicycle lanes, Pennsylvania Avenue was rated as having Bicycle LOS E on both segments. After the bicycle lanes were installed, the rating improved to Bicycle LOS C on both segments. Figure 11 and 12 confirm this improvement in LOS rating through the percentage splits between the six levels of satisfaction. They reveal that the percentage of bicyclists estimated to be at least "a little satisfied" with the facilities on Pennsylvania Avenue increased after the installation of the bicycle facilities from approximately 20 percent to over 60 percent.

Table 27 Pennsylvania Avenue Danish Bicycle LOS

Segment	Direction	Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		LOS	Rating	LOS	Rating
6th Street to 10th Street	Westbound	E	Poor	C	Average
	Eastbound	E	Poor	C	Average
10th Street to 15th Street	Westbound	E	Poor	C	Average
	Eastbound	E	Average	C	Average

Figure 11 Danish Bicycle LOS Predicted Satisfaction for Pennsylvania Avenue (Between 6th Street and 10th Street)

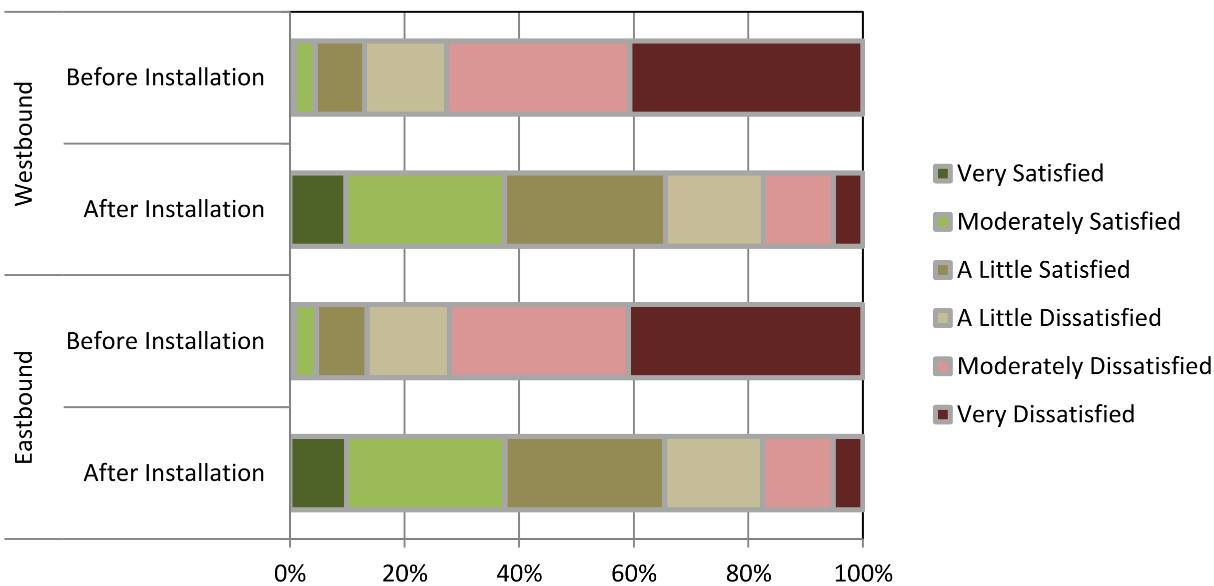
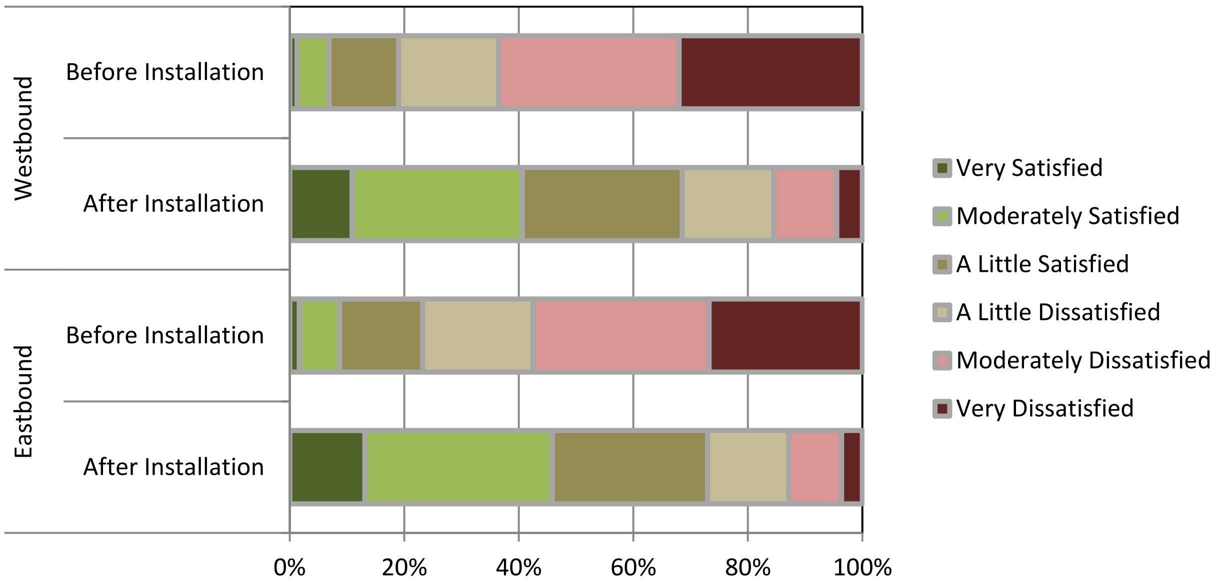


Figure 12 Danish Bicycle LOS Predicted Satisfaction for Pennsylvania Avenue (Between 10th Street and 15th Street)



Bicycle Environmental Quality Index

The BEQI model indicates that the conditions experienced by bicyclists improved along Pennsylvania Avenue with the addition of the bicycle facilities, as shown in Table 28. Before installation of the bicycle facilities, Pennsylvania Avenue was ranked as having average bicycle facilities on both segments with scores of approximately 45 out of 100, and after installation of the bicycle lanes, the corridor is ranked as having high quality bicycle facilities on both segments, with scores of approximately 70 out of 100.

Table 28 Pennsylvania Avenue BEQI Scores

Segment	Direction	Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		Score	Quality	Score	Quality
6th Street to 10th Street	Westbound	46	Average	72	High
	Eastbound	45	Average	71	High
10th Street to 15th Street	Westbound	47	Average	72	High
	Eastbound	46	Average	72	High

Highway Capacity Manual 2000 Arterial Level of Service

HCM 2000 arterial LOS was calculated for motorized vehicles for each segment between signalized intersections along the Pennsylvania Avenue corridor. While accommodating bicyclists was the purpose of the new bicycle facilities, DDOT wants to maintain a multimodal environment along Pennsylvania Avenue. The operations analysis took into account changes to the volumes, lane configurations, and signal phasing and timing (specifically related to changes made for the left turns).

Table 29 includes information on the arterial speeds and corresponding LOS experienced by drivers on each corridor study segment in both the eastbound and westbound directions.

The red cells in the table show the speeds and LOS that worsened after the bicycle facilities were installed, and the green cells show the speeds and LOS that improved after installation of the bicycle facilities. Overall, the differences observed between conditions before and after installation of the bicycle facilities are minor. The analysis indicates that conditions have remained relatively the same for motor vehicles traveling along Pennsylvania Avenue.

Table 29 Pennsylvania Avenue HCM Motor Vehicle Arterial LOS

		AM Peak Hour				PM Peak Hour			
		Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities		Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
Segment	Direction	LOS	Speed (mi/h)	LOS	Speed (mi/h)	LOS	Speed (mi/h)	LOS	Speed (mi/h)
6th Street to 10th Street	Westbound	D	12.8	C	13.7	C	13.0	D	10.8
	Eastbound	D	11.8	E	7.4	D	9.4	D	9.5
10th Street to 15th Street	Westbound	F	6.5	E	7.2	E	7.0	E	7.9
	Eastbound	E	8.6	E	8.8	E	7.5	E	8.7

BICYCLE PROGRESSION

The Pennsylvania Avenue corridor was split into two sections for the bicycle progression analysis: (1) 3rd Street to 9th Street and (2) 9th Street to 15th Street. The corridor was split into sections because many bicyclists do not ride along the entire corridor but rather through one section. Each section began at the start of a green signal. For each time period (weekday a.m. and weekday p.m. peak hours), progression was analyzed for both directions (eastbound and westbound) for bike speeds of 10 miles per hour (mph) and 15 mph. It was assumed that half the bicyclists that reach an intersection during a clearance interval proceed through the intersection. Bike acceleration start-up times were not considered in this analysis.

The percentage of free flow speed was calculated for each segment based on the length of the corridor segment and the total travel time. Free flow speeds of 10 mph and 15 mph were used to assess the LOS experienced by bicyclists. (The percentage of free-flow speed thresholds for motor vehicle LOS on two-lane highways were used to assess bicycle LOS because no corresponding thresholds have been defined for bicycles.) The results for Pennsylvania Avenue are shown in Figure 13 and Figure 14.

Figure 13 and Figure 14 reveal that bicyclists experience less delay on Pennsylvania Avenue between 10th Street and 15th Street than between 3rd Street and 9th Street. During the a.m. peak period, bicyclists are generally able to achieve a more consistent progression speed with less delay by traveling at 10 mph. The only exception to this is during the a.m. peak period for bicyclists traveling eastbound between 10th Street and 15th Street. During the p.m. peak period, bicyclists are generally able to achieve a greater percentage of free flow speed by traveling closer to 15 mph.

Figure 13 Percentage of Free Flow Speed for Bicyclists on Pennsylvania Avenue (Between 3rd Street and 9th Street)

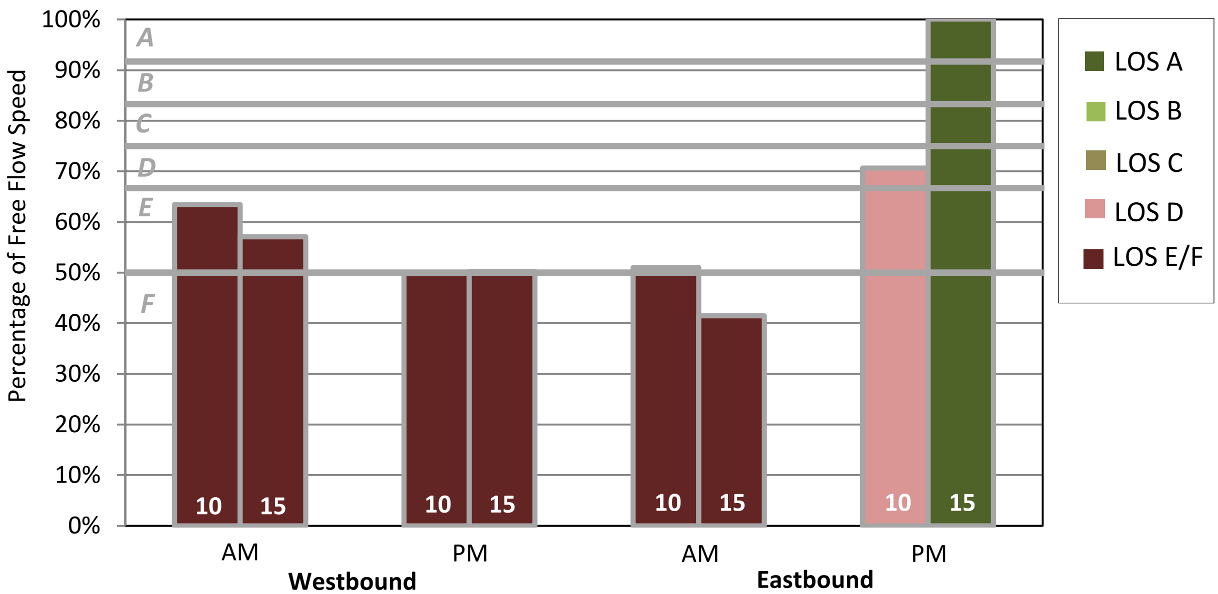
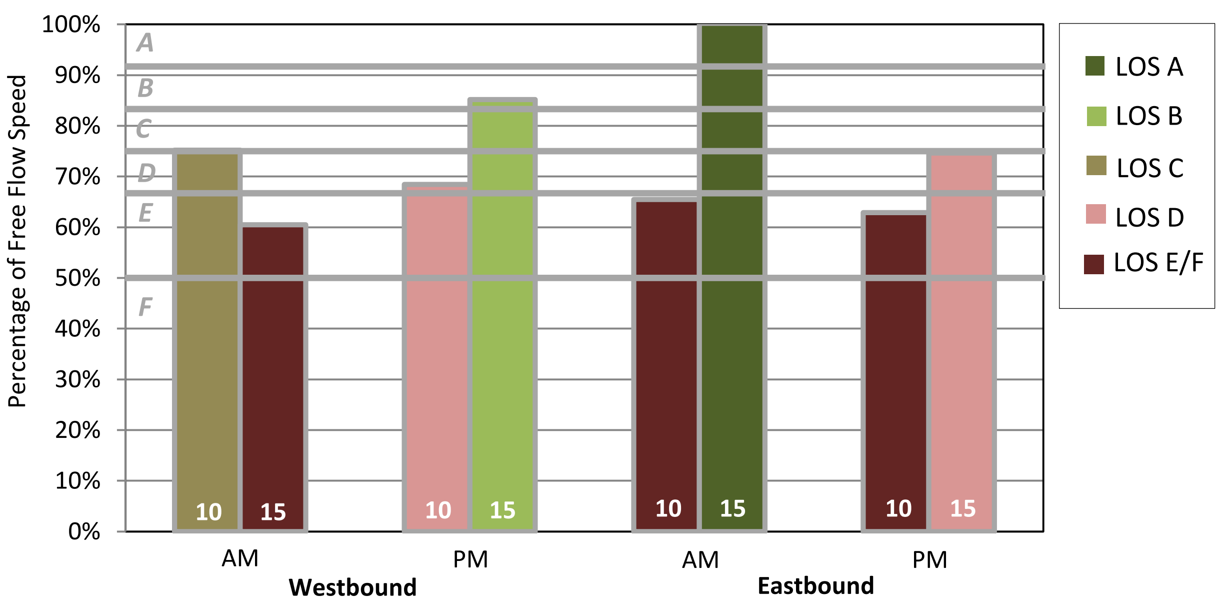


Figure 14 Percentage of Free Flow Speed for Bicyclists on Pennsylvania Avenue (Between 9th Street and 15th Street)



Bicyclist progression is only one of many performance measures used to establish signal timing, but should be an important consideration, particularly on high-volume bicycle routes. The progression analysis shown here indicates that existing signal timing works fairly well for cyclists (at typical cycling speeds) between 10th Street and 15th Street, but creates considerably more signal delay for cyclists between 3rd Street and 9th Street. Future signal re-timing along the corridor should seek opportunities to improve bicycle progression.

CRASH ANALYSIS

Crash data from the Pennsylvania Avenue corridor were obtained from before and after installation of the bicycle facilities. Crash data from 2006 to 2010 were provided from the DDOT Traffic Accident Reporting and Analysis System for conditions before the bicycle facilities were installed, and crash data from 2010 to 2011 were provided for conditions after the bicycle facilities were installed.

Table 30 shows the number of crashes and crashes per year by type and severity for the two analysis segments for conditions before the bicycle facilities were installed, while Table 31 shows similar information for conditions after the bicycle facilities were installed. Crashes per year are summarized to normalize the crash data across different time periods before and after installation of the bicycle facilities. The crashes per year were calculated over a 48-month period for conditions before installation of the bicycle facilities and compared to crashes per year calculated over a 14-month period for conditions after installation. Red cells indicate types and severities of crashes that have more crashes per year after installation of the bicycle facilities, and green cells indicate fewer crashes per year after installation of the bicycle facilities.

The crash rates were higher in the year after construction of the bicycle facilities than in the four years prior to construction. Accounting for motor vehicle volumes, the total number of crashes increased by approximately 28 crashes per year between 6th Street and 10th Street and increased by approximately 38 crashes per year between 11th Street and 15th Street. One year of data from after the facilities were constructed does not provide a comprehensive view of conditions after installation of the facilities, as crashes are random events that can vary considerably from one year to the next. Crashes should continue to be monitored at these locations in order to compare longer-term crash patterns.

Table 30 Pennsylvania Avenue Crashes Per Year Before Installation of the Bicycle Facilities (All Crashes)

Roadway Segment		Total	Fatal	Injury	PDO	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
6th Street to 10th Street	Crashes	186	1	55	130	32	18	27	56	1	52
	Crashes Per Year	46.5	0.3	13.8	32.5	8.0	4.5	6.8	14.0	0.3	13.0
11th Street to 15th Street	Crashes	145	0	27	118	37	12	19	36	2	39
	Crashes Per Year	36.3	0.0	6.8	29.5	9.3	3.0	4.8	9.0	0.5	9.8

Table 31 Pennsylvania Avenue Crashes Per Year After Installation of the Bicycle Facilities (All Crashes)

Roadway Segment		Total	Fatal	Injury	PDO	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
6th Street to 10th Street	Crashes	68	0	17	51	9	5	11	20	0	23
	Crashes Per Year	58.3	0.0	14.6	43.7	7.7	4.3	9.4	17.1	0.0	19.7
11th Street to 15th Street	Crashes	74	0	16	58	9	2	8	32	1	22
	Crashes Per Year	63.4	0.0	13.7	49.7	7.7	1.7	6.9	27.4	0.9	18.9

Table 32 shows the number of bicyclists and pedestrians involved in crashes per year before and after installation of the bicycle facilities. Because of the dramatic increase in cyclist volumes before and after installation, cyclist crashes were adjusted for exposure. There was a 237 percent increase in bicyclist volumes between 6th Street and 7th Street during the p.m. peak hour, and there was a 241 percent increase in bicyclist volumes between 14th Street and 15th Street during the p.m. peak hour. Table 32 includes a column for "adjusted" bicyclist crashes per year for the after condition that is more directly comparable to the bicyclist crashes per year before the facilities were installed, considering the increased volume of bicyclists using the facility.

Using the crashes per year adjusted for bicyclist exposure, the crashes involving bicyclists increased by approximately two crashes per year between 6th Street and 10th Street and increased by approximately one crash per year between 11th Street and 15th Street after installation of the bicycle facilities. The increase in total crashes per year and crashes per year involving bicyclists after installation of the bicycle facilities indicates that additional evaluation should be considered along Pennsylvania Avenue. However, the total number of bicycle crashes is small and one year of data after installation does not provide conclusive information for the crash patterns occurring along the corridor. It is recommended that crash reports be evaluated in future years to monitor trends in cyclist crashes.

Table 32 Pennsylvania Avenue Average Number of Bicyclists and Pedestrians Per Year Involved in Crashes

	Before Installation of the Bicycle Facilities				After Installation of the Bicycle Facilities				
	Crashes Involving Pedestrians		Crashes Involving Bicyclists		Crashes Involving Pedestrians		Crashes Involving Bicyclists		
Cross Street	Crashes	Crashes Per Year	Crashes	Crashes Per Year	Crashes	Crashes Per Year	Crashes	Crashes Per Year	Adjusted Crashes Per Year[1]
6th Street to 10th Street	23	5.8	6	1.5	5	4.3	9	7.7	2.3
11th Street to 15th Street	6	1.5	3	0.8	5	4.3	7	6.0	1.8

[1]Adjusted to reflect increase in cyclist volumes from before to after condition.

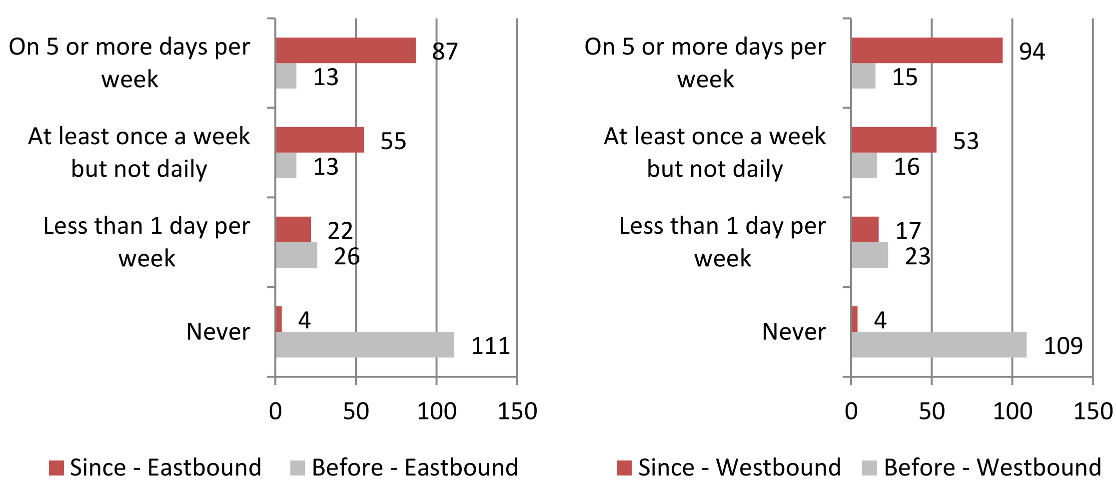
SURVEY ANALYSIS

Cyclist Intercept Survey

Riding Frequency

Self-reported frequency of cycling on Pennsylvania Avenue shows a significant increase between the periods before and after installation of the bicycle facilities, as shown in Figure 15. This change could reflect a combination of multiple factors, including: cyclists shifting their routes; cycling more because of the improved bicycle facilities; and reflect an overall increase in bicycling within the District.

Figure 15 Self-Reported Frequency of Cycling on Pennsylvania Avenue Before and After the Bicycle Facility Installation



Perceptions of Safety and Ease

Safety and Ease

Overall, respondents indicated that they feel safer and more at ease cycling on Pennsylvania Avenue with the center bike lanes, as shown in Table 33. Among all respondents (165), there was a high level of agreement that the center bike lanes make riding a bicycle in Washington, D.C. less stressful (93 percent agreement), safer (94 percent), easier (94 percent), and more convenient (93 percent). Of cyclists who rode a bicycle on Pennsylvania Avenue both before and after installation of the bicycle facilities (62), 90 percent indicated that they feel safer cycling on Pennsylvania Avenue now, while 94 percent indicated that cycling is now easier and 92 percent indicated that cycling is now more convenient. Asked if they think "the Pennsylvania center bike lanes are working well," 157 (96 percent) agreed, while only 7 (4 percent) said they were not working well.

Cyclists also indicated that they would choose to ride on Pennsylvania Avenue over other streets. While 92 percent of all respondents agreed that the center bike lanes are a useful connection in getting places they want to go, 86 percent further indicated that they would go out of their way to ride on Pennsylvania Avenue as opposed to other streets.

Table 33 Pennsylvania Avenue Cyclist Survey – Sense of Safety and Ease

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
Riding a bicycle in Washington, D.C. is less stressful because of the Pennsylvania Avenue bike lanes.	4%	2%	24%	70%	165	2	93%	3.6
The center bike lanes have made cycling in and around Washington, D.C. safer for me as a cyclist.	4%	2%	21%	73%	166	1	94%	3.6
The center bike lanes have made cycling in and around Washington, D.C. easier for me as a cyclist.	4%	2%	23%	71%	163	3	94%	3.6
The center bike lanes have made cycling in and around Washington, D.C. more convenient for me as a cyclist.	4%	4%	24%	69%	165	2	93%	3.6
I feel safer cycling on Pennsylvania Avenue because of the center bike lanes.[1]	5%	5%	29%	61%	62	0	90%	3.5
The center bike lanes have made cycling on Pennsylvania Avenue easier for me as a cyclist.[1]	5%	2%	19%	74%	62	0	94%	3.6

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
The center bike lanes have made cycling on Pennsylvania Avenue more convenient for me as a cyclist.[1]	5%	3%	22%	70%	60	2	92%	3.6
The center bike lanes are a useful connection for me in getting places I want to go.	4%	4%	22%	70%	165	2	92%	3.6
I would go out of my way to ride on Pennsylvania Avenue as opposed to other streets.	6%	8%	32%	54%	165	2	86%	3.3

[1] Only asked of respondents who indicated they had cycled on Pennsylvania Avenue before the center bike lanes were installed.

Comfort

Cyclists generally indicated that they felt comfortable riding in the center bike lanes. Eighty-eight percent indicated that there is adequate separation between the center bike lanes and moving cars, although only 70 percent agreed that they feel protected from turning cars (and only 22 percent strongly agreed). There was nearly unanimous agreement (99 percent) that the bike lanes are wide enough for cyclists moving in opposite directions to pass one another comfortably, and 88 percent agreed that a fast cyclist could comfortably pass a slower cyclist. Table 34 provides cyclist responses on sense of comfort questions.

Table 34 Pennsylvania Avenue Cyclist Survey – Sense of Comfort

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I feel that there is adequate separation between the center bike lanes and between moving cars.	1%	10%	33%	55%	162	0	88%	3.4
When riding in the center bike lanes, I feel protected from turning cars.	7%	23%	48%	22%	162	0	70%	2.9
The center bike lanes are wide enough for two cyclists going opposite directions to pass comfortably.	0%	1%	15%	85%	162	0	99%	3.8
The center bike lanes are wide enough for a fast cyclist to comfortably pass a slow cyclist.	2%	10%	46%	42%	161	1	88%	3.3

Understanding and Compliance

Cyclists were asked a series of questions about their understanding and use of the new facilities, including what signal they should follow, what their stopping position should be, how to access/egress the center bike lanes, and whether they have had any collisions or near collisions.

Signal Selection

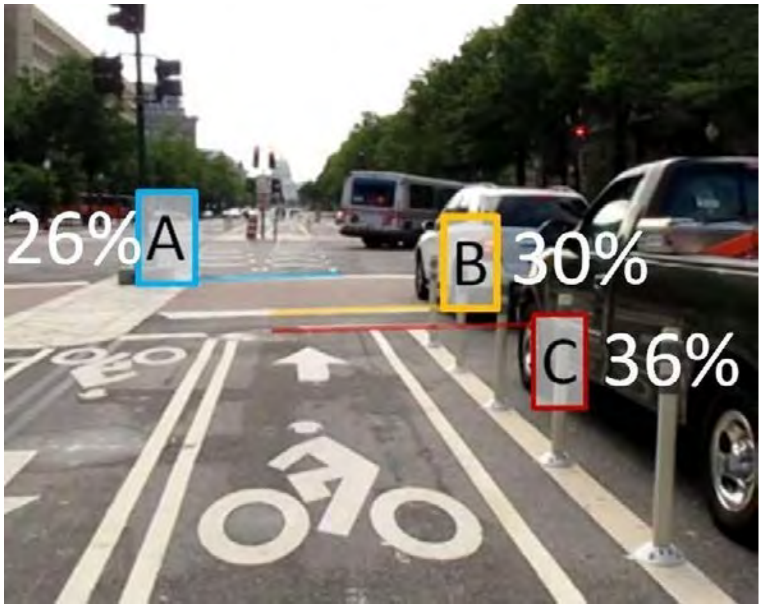
To assess cyclists' understanding of which traffic signal that they should follow when riding in the center bike lanes, survey respondents were shown a picture of an intersection along the route and asked to select the signal that applies to them as a cyclist. Every respondent correctly identified the appropriate signal, which is highlighted in Figure 16.

Figure 16 Pennsylvania Avenue Cyclist Survey – Signal Identification

Stopping Location

Cyclists were asked where they stop and wait when they arrive at an intersection on a red light. As seen in Figure 17, 36 percent indicated that they would stop behind the white stop bar, which is the intended stopping location for cyclists in the center bike lanes. Thirty percent indicated that they would stop behind the crosswalk. An additional 26 percent indicated that they would stop in the crosswalk area, before the intersection, with 8 percent selecting "other" as a stopping location. Note that bikes stopped in the crosswalk area may potentially face conflicts not only with pedestrians, but with left-turning heavy vehicles.

Figure 17 Pennsylvania Avenue Cyclist Survey – Stated Stopping Location

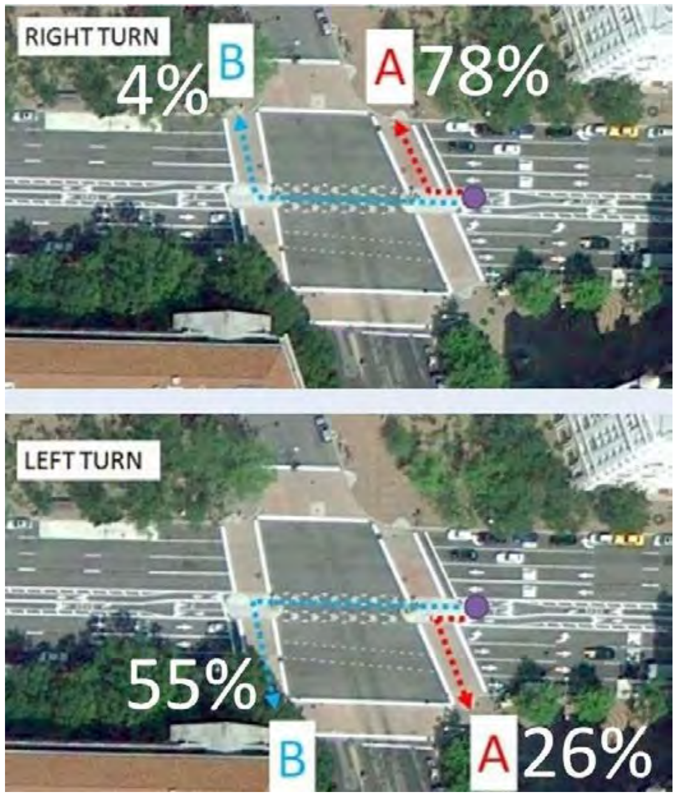


Access/Egress

Cyclists were asked to indicate their level of agreement with the statement "accessing the center bike lanes from surrounding streets is difficult"; 36 percent indicated that they agreed, while 64 percent indicated that they disagreed. To understand how cyclists exit the cycle track, respondents were asked how they normally complete left or right turns: (1) using the crosswalk on the near side of the intersection; (2) the crosswalk on the far side of the intersection; or (3) "other". Responses are shown in Figure 18.

For right turns, 78 percent indicated they use the crosswalk on the near side of the street, 4 percent use the far side crosswalk, and 17 percent selected other. For left turns, 26 percent indicated they would use the near side, 55 percent the far side, and 19 percent other. For those that selected "other", the most common responses involved moving into the traffic lane to turn and choosing a path opportunistically based on whether the signal is red or green upon arrival at the intersection. Respondents were presented with a picture of the bike box on 4th Street at Pennsylvania and asked if they had ever ridden through the box; 19 percent of respondents indicated that they had.

Figure 18 Pennsylvania Avenue Cyclist Survey – Stated Egress Path for a Right Turn and a Left Turn



Conflicts, Collisions and Near Collisions

Table 35 provides the stated frequency of collisions and near collisions with various road users or other objects. Of the 164 respondents, half or more indicated that they had experienced near collisions with a pedestrian (54 percent) or a turning motor vehicle (50 percent). Among respondents that indicated they were involved in a near collision with "something else", 16 people mentioned vehicles making U-turns and eight mentioned cabs/taxis. The definition of "near collision" is based on each respondent's interpretation, which likely includes a wide variety of definitions. In comparison, a "near collision" was narrowly defined in the video review as an interaction in which a cyclist or another road user had to take an emergency evasive action (either a change or direction or speed) in order to avoid a collision – no collisions and two conflicts ("near collisions") were observed. Some cyclists actually reported being involved in collisions with a pedestrian, a turning motor vehicle, or something else (two respondents in each case; no details were provided about the "something else").

Table 35 Pennsylvania Avenue Cyclist Survey – Stated Frequency of Collisions and Near Collisions

	Collision		Near Collision	
Another Bicyclist	0	0%	33	20%
A Pedestrian	2	1%	89	54%
A Turning Motor Vehicle	2	1%	82	50%
A Parking Motor Vehicle	0	0%	11	7%
A Delivery Truck	0	0%	11	7%
A Non-Moving Object (specify)	0	0%	3	2%
Something Else (specify)	2	1%	17	10%
Number of Respondents	164		164	

Cyclists were asked how often they encounter other vehicles or users and potential conflicts as they ride in the center bike lanes. As shown in Table 36, of the scenarios posed, cyclists self-reported that they most commonly encounter pedestrians waiting in the medians and walking in the center bike lanes, followed by emergency vehicles parking in the lanes and cars driving in the lanes. This was confirmed by the video observations, which showed that encounters with pedestrians on median islands were the most common obstacle facing cyclists in the center bike lanes (though these interactions with pedestrians were still observed relatively infrequently, occurring on just 1.4% of cyclists passages through intersections).

Table 36 Pennsylvania Avenue Cyclist Survey – Stated Frequency of Center Bike Lane Barriers/Encounters

Please indicate how often you have observed the following on your trips in the Pennsylvania Avenue center bike lanes:	Never	Rarely	On Most Trips	On Almost Every Trip	Number of Respond.	No Opinion
Passenger cars parked in the center bike lanes.	41%	56%	3%	0%	162	2
Passenger cars loading and unloading in the center bike lanes.	57%	41%	2%	0%	162	2
Delivery vehicles loading and unloading in the center bike lanes.	59%	38%	4%	0%	162	2
Emergency/safety vehicles parked in the center bike lanes.	22%	63%	14%	1%	162	2
Pedestrians waiting to cross Pennsylvania Avenue in the center bike lanes when bicycles have a green signal.	1%	17%	43%	40%	163	0
Too many cyclists in the center bike lanes.	32%	63%	5%	0%	161	1
Motor vehicles driving in the center bike lanes.	36%	54%	7%	4%	162	2
Pedestrians walking in the center bike lanes.	13%	60%	18%	9%	163	1

Resident Survey

Sample Characteristics and General Opinions

Of the 157 respondents, 96 percent did not have children and 45 percent were the sole adult in the households. Fifty-four percent own their homes, while 46 percent rent, and 84 percent work outside their home zip code.

Respondents were asked a series of questions to understand general opinions on the neighborhood, transportation investments, and bicycling. Responses, as shown in Table 37, indicate that residents believe their neighborhood is improving, and around three-quarters agreed that Washington, D.C. should invest in encouraging bicycling for transportation and in improving the safety of bicycling. Opinions were mixed on whether bicycling is an important part of the transportation system in Washington. Finally, two out of three respondents disagreed with the statement "bicycling in Washington, D.C. is safe."

Table 37 Pennsylvania Avenue Resident Survey – General Opinions on the Neighborhood, Bicycling, and Investment

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
My neighborhood has improved in the last 2 years.	3%	6%	39%	52%	122	33	91%	3.4
Washington DC should be investing in projects that encourage more people to ride bicycles for transportation.	18%	9%	34%	39%	140	17	74%	3.0
Bicycling is an important part of the Washington transportation system.	18%	21%	33%	28%	141	15	60%	2.7
Bicycling in Washington DC is safe.	34%	33%	25%	7%	123	33	33%	2.1
Washington DC should be investing in projects that improve the safety of bicycling.	15%	9%	25%	51%	140	15	76%	3.1

Support of Center Bike Lanes

All respondents were asked several questions pertaining to support of the center bike lane. As shown in Table 38, 75 percent of respondents indicated that they "support" the center bike lanes, while just over 70 percent indicated that they viewed the center bike lanes as a valuable asset to the neighborhood. Sixty-five percent of respondents indicated that they see "many people riding bicycles in the center bike lanes."

Table 38 Pennsylvania Avenue Resident Survey – General Support of Center Bike Lanes

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I support the center bike lanes on Pennsylvania Avenue.	18%	8%	27%	47%	142	14	75%	3.0
The center bike lanes on Pennsylvania Avenue are a valuable asset to my neighborhood.	20%	9%	30%	41%	134	21	71%	2.9
I see many people riding bicycles in the center bike lanes on Pennsylvania Avenue.	12%	23%	43%	22%	139	14	65%	2.7

Motorist Experience with the Center Bike Lanes

Seventy-six percent (112) of the Pennsylvania Avenue resident survey respondents indicated that they had driven on this section Pennsylvania Avenue within the past year, while 40 percent indicated that they do so at least once per week. Sixty-two percent of respondents indicated that they own at least one motor vehicle.

For the purposes of the analysis presented in the report, only residents who indicated that they own a motor vehicle were included as a "motorist." (full results for all respondents that indicated they had driven on Pennsylvania Avenue in the past year are included in Appendix D3). As shown in Table 39, motorist results show some positive findings and some mixed findings. Sixty-nine percent of motorists indicated that there are fewer cyclists riding in the car lanes, while 40 percent indicated that traffic congestion has gotten worse as a result of the center bike lanes. Eighty-four percent indicated that they liked the additional separation between motor vehicles and bicycles. Meanwhile, half of the respondents indicated that the restriction on U-turns is a major inconvenience (note that U-turns were always prohibited, but several missing signs were replaced when the bicycle facility was installed). Only 56 percent indicated that signals, signs and street markings "make it clear who has the right-of-way at intersections on Pennsylvania Avenue."

Table 39 Pennsylvania Avenue Resident Survey – Questions about Driving

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I think there are fewer cyclists riding in the car lanes since the center bike lanes were installed.	13%	18%	45%	24%	62	24	69%	2.8
My perception is that traffic congestion has gotten worse as a result of the center bike lanes.	29%	32%	10%	30%	63	24	40%	2.4
It is a major inconvenience that cars are not allowed to make U-turns on Pennsylvania Avenue.	31%	18%	26%	26%	74	10	51%	2.5
Intersection signals, signs and street markings make it clear who has the right-of-way at intersections on Pennsylvania Avenue.	23%	21%	39%	17%	71	13	56%	2.5
Overall, I like that bicycles are separated from the motor vehicle traffic.	8%	9%	38%	46%	79	8	84%	3.2

Cyclist Experience with the Center Bike Lanes

Of respondents to the Pennsylvania Avenue resident survey, only 34 people (23 percent) indicated that they had bicycled on Pennsylvania Avenue in the past year, while 22 people do so at least once per week. Of this sample, 92 percent indicated that the center bike lanes make them feel safer cycling on Pennsylvania Avenue, while 86 percent indicated that the bike lanes are a useful connection in getting places they want to go.

Pedestrian Experience with the Center Bike Lanes

Nearly all neighborhood survey respondents (96 percent or 144 residents) have walked on Pennsylvania Avenue in the past year, while 76 percent do so at least once per week. Respondents who had walked on Pennsylvania Avenue in the past year were asked a series of questions about that experience. Pedestrian responses from the neighborhood survey are included in the discussion of the pedestrian intercept survey below. Both groups of pedestrians were generally in agreement.

Pedestrian Intercept Survey

In addition to the 144 respondents to the resident survey that indicated they walked on Pennsylvania Avenue in the past year, an intercept survey was directed to pedestrians walking along or across Pennsylvania Avenue. The intercept survey yielded 104 responses, and answers to both the pedestrian-related resident surveys and pedestrian intercept surveys are included in Table 40.

Of the intercept survey participants, 49 percent of respondents were men, while 75 percent were residents of Washington, D.C. Asked about their level of agreement with the following statement: "I support public investment in bicycling facilities," 92 percent of respondents to the pedestrian intercept survey indicated that they agreed.

Table 40 Pennsylvania Avenue Pedestrian Level of Agreement[1]

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
Based on my observations, there are fewer cyclists riding on the sidewalk after the center bike lanes were installed.	12%	14%	42%	33%	169	55	75%	3.0
I feel that crossing Pennsylvania Avenue is more difficult with the center bike lanes.	43%	24%	20%	13%	207	20	33%	2.0
When crossing Pennsylvania Avenue, I sometimes have to wait in the median for another light cycle.	11%	18%	38%	33%	228	24	71%	2.9
I think that most cyclists want to wait in the median for a green light in the same place pedestrians want to wait.	16%	19%	42%	23%	187	62	65%	2.7

[1] Totals combine information from neighborhood survey respondents who indicated that they have walked on Pennsylvania Avenue in the past year and respondents to the pedestrian intercept survey.

There are mixed findings from pedestrians, suggesting that there are fewer interactions with cyclists on sidewalks but more interactions occurring at the medians where the center bike lanes cross the crosswalks on Pennsylvania Avenue. Seventy-five percent of pedestrian respondents indicated that there are fewer cyclists on sidewalks now, and around two-thirds disagreed that crossing Pennsylvania Avenue is more difficult now. However, nearly 65 percent of pedestrians think that cyclists and pedestrians end up waiting in the same space in the center medians.

Note that the pedestrian intercept survey and the pedestrian section of the neighborhood survey asked some of the same questions; totals are combined in those cases.

Collisions and Near Collisions

The pedestrian intercept survey asked respondents if they were involved or witnessed a collision or near-collision between a cyclist and a pedestrian in the center bike lanes. One respondent stated that they had been involved in a collision with a cyclist, while three indicated that they had witnessed a collision. Nine respondents (about 9 percent) indicated that they had been involved in a near-collision with a cyclist.

Business Survey Analysis/Results (Pennsylvania Avenue and 15th Street Combined)

This section provides a combined response to the business survey for both Pennsylvania Avenue and 15th Street, as the respondents were the same and several questions overlap. All respondents were asked to provide some general opinions about support for the facilities and investments in bicycle facilities. As seen in Table 41, respondents broadly agree that business should encourage employees to get to work by means other than driving alone (80 percent agreed), though are more split on other measures. A slight majority either somewhat or strongly agreed that they support public investment in bike facilities (57 percent) and efforts to improve on-street bicycling facilities (61 percent). Respondents split on specific support of the cycle track (58 percent support) and the center bike lanes (50 percent support). Note that a significant minority of the business survey respondents (approximately one-third) strongly *did not* support the bicycle facilities.

Table 41 Property/Business General Opinions and Support of Facilities

Statement	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	Responses	% Agree	Mean
Downtown businesses should encourage their employees to get to work by means other than driving alone	7%	13%	33%	47%	15	80%	3.2
I support public investment in bicycling facilities	21%	21%	14%	43%	14	57%	2.8
I support the cycle track on 15th Street	33%	8%	25%	33%	12	58%	2.6
I support the center bike lanes on Pennsylvania Ave	36%	14%	14%	36%	14	50%	2.5
I would support future efforts to improve on-street bicycling facilities in D.C.	23%	15%	15%	46%	13	62%	2.8

Those respondents indicating that they were familiar with the Pennsylvania Avenue center bike lanes were presented with further statements about the facility and asked to state their level of agreement with each statement. Most notably, 90 percent of respondents (and 100 percent of those directly on Pennsylvania Avenue) agreed that the center bike lanes “do not affect my property/business.” Respondents from properties directly on Pennsylvania Avenue had a more positive view of the facilities than those located off Pennsylvania. Statements and levels of agreement are provided in Table 42.

Table 42 Property/Business Pennsylvania Avenue Center Bike Lanes Statements

The Penn Ave center bike lanes . . .	Property Location	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n	% Agree	Mean
. . . make downtown DC more attractive for tenants/ employees	Off Penn	22%	33%	33%	11%	9	44%	2.3
	Directly on Penn	0%	33%	33%	33%	3	67%	3.0
	Total	*17%*	*33%*	*33%*	*17%*	*12*	50%	*2.5*
. . . increase bike and foot traffic to my property/business	Off Penn	43%	14%	29%	14%	7	43%	2.1
	Directly on Penn	33%	0%	33%	33%	3	67%	2.7
	Total	*40%*	*10%*	*30%*	*20%*	*10*	50%	*2.3*
. . . are an important part of downtown DC's bicycle network	Off Penn	20%	30%	50%	0%	10	50%	2.3
	Directly on Penn	0%	0%	67%	33%	3	100%	3.3
	Total	*15%*	*23%*	*54%*	*8%*	*13*	62%	*2.5*
. . . are often used by cyclists	Off Penn	43%	14%	43%	0%	7	43%	2.0
	Directly on Penn	33%	0%	33%	33%	3	67%	2.7
	Total	*40%*	*10%*	*40%*	*10%*	*10*	50%	*2.2*
. . . are a waste of road space	Off Penn	0%	38%	25%	38%	8	63%	3.0
	Directly on Penn	67%	0%	33%	0%	3	33%	1.7
	Total	*18%*	*27%*	*27%*	*27%*	*11*	55%	*2.6*
. . . do not affect my property/business	Off Penn	0%	13%	50%	38%	8	88%	3.3
	Directly on Penn	0%	0%	33%	67%	3	100%	3.7
	Total	*0%*	*9%*	*45%*	*45%*	*11*	91%	*3.4*

Those respondents indicating that they were familiar with the 15th Street cycle track were presented with further statements about the facility and asked to state their level of agreement with each statement. Generally, those respondents from properties located directly on 15th Street had a more negative view than those located off the facility (from half a block to four blocks off 15th Street). Respondents were split on whether the cycle track made parking more difficult for tenants/employees or customers, or made deliveries more challenging. The survey indicated that 3 out of 5 respondents located directly on the 15th Street cycle track felt that it makes deliveries to their property/business more challenging. While this is a very small number of respondents, it suggests that delivery issues along cycle tracks require close attention. Ideally, loading would occur on side streets. If side-street deliveries are not possible, the location of loading should be determined on a case-by-case basis. The statement that generated the greatest agreement was that the cycle track is often used by cyclists (83 percent agreed). Table 43 provides statements and levels of agreement.

Table 43 Property/Business 15th Street Cycle Track Statements

The 15th St. cycle track . . .	Property Location	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	n	% Agree	Mean
. . . makes downtown DC more attractive for tenants/employees	Off 15th	0%	25%	25%	50%	4	75%	3.3
	Directly on 15th	43%	29%	14%	14%	7	29%	2.0
	Total	*27%*	*27%*	*18%*	*27%*	*11*	45%	*2.5*
. . . makes parking more difficult for tenants/employees	Off 15th	25%	25%	25%	25%	4	50%	2.5
	Directly on 15th	17%	33%	17%	33%	6	50%	2.7
	Total	*20%*	*30%*	*20%*	*30%*	*10*	50%	*2.6*
. . . makes parking more difficult for customers	Off 15th	25%	25%	25%	25%	4	50%	2.5
	Directly on 15th	17%	17%	33%	33%	6	67%	2.8
	Total	*20%*	*20%*	*30%*	*30%*	*10*	60%	*2.7*
. . . increases bike and foot traffic to my property/business	Off 15th	0%	0%	25%	75%	4	100%	3.8
	Directly on 15th	75%	0%	0%	25%	4	25%	1.8
	Total	*38%*	*0%*	*13%*	*50%*	*8*	63%	*2.8*
. . . makes deliveries to my property/business more challenging	Off 15th	25%	25%	25%	25%	4	50%	2.5
	Directly on 15th	40%	0%	0%	60%	5	60%	2.8
	Total	*33%*	*11%*	*11%*	*44%*	*9*	56%	*2.7*
. . . is an important part of downtown DC’s bicycle network	Off 15th	0%	50%	0%	50%	4	50%	3.0
	Directly on 15th	14%	29%	43%	14%	7	57%	2.6
	Total	*9%*	*36%*	*27%*	*27%*	*11*	55%	*2.7*
. . . is often used by cyclists	Off 15th	0%	0%	75%	25%	4	100%	3.3
	Directly on 15th	13%	13%	38%	38%	8	75%	3.0
	Total	*8%*	*8%*	*50%*	*33%*	*12*	83%	*3.1*
. . . is a waste of road space	Off 15th	25%	50%	25%	0%	4	25%	2.0
	Directly on 15th	14%	14%	29%	43%	7	71%	3.0
	Total	*18%*	*27%*	*27%*	*27%*	*11*	55%	*2.6*
. . . does not affect my property/business	Off 15th	0%	0%	33%	67%	3	100%	3.7
	Directly on 15th	43%	43%	14%	0%	7	14%	1.7
	Total	*30%*	*30%*	*20%*	*20%*	*10*	40%	*2.3*

VIDEO ANALYSIS

Cyclist Counts

Table 44 shows the cyclist count at each intersection by hour. The counts are shown by direction of travel. Counts average between about 50 and 100 cyclists per hour at both peak and midday hours. There were slightly more westbound cyclists during the a.m. peak (particularly for intersections closer to the Capitol), and slightly more eastbound cyclists during the p.m. peak. Midday traffic also tended to be composed of slightly more eastbound cyclist traffic; however, at all times there was a substantial flow of cyclist traffic in both directions.

Table 44 Pennsylvania Avenue Video Analysis Cyclist Counts

Intersection	Date	Time	Direction (Leaving Intersection) East	West	North[1]	South[1]	Total
6th Street / Pennsylvania Avenue	6/16/2011 (Thursday)	7-8am	12	37	2	0	51
		8-9am	29	71	5	0	105
		5-6pm	40	25	1	0	66
		6-7pm	44	24	2	0	70
	6/18/2011 (Saturday)	12-1pm	46	28	1	0	75
		1-2pm	28	19	0	1	48
		Subtotal	*199*	*204*	*11*	*1*	*415*
9th Street / Pennsylvania Avenue	6/16/2011 (Thursday)	7-8am	22	32	0	2	56
		8-9am	27	45	0	1	73
		5-6pm	40	22	1	0	63
		6-7pm	45	28	0	1	74
	6/18/2011 (Saturday)	12-1pm	55	29	10	0	94
		1-2pm	36	15	0	2	53
		Subtotal	*225*	*171*	*11*	*6*	*413*
11th Street / Pennsylvania Avenue	6/16/2011 (Thursday)	7-8am	17	33	2	0	52
		8-9am	42	39	5	1	87
		5-6pm	39	26	1	0	66
		6-7pm	39	31	3	0	73
	6/18/2011 (Saturday)	12-1pm	45	32	2	0	79
		1-2pm	29	24	0	0	53
		Subtotal	*211*	*185*	*13*	*1*	*410*
12th Street / Pennsylvania Avenue	6/16/2011 (Thursday)	7-8am	15	31	2	0	48
		8-9am	39	37	1	0	77
		5-6pm	40	32	1	4	77
		6-7pm	41	33	3	4	81
	6/18/2011 (Saturday)	12-1pm	43	35	3	3	84
		1-2pm	30	24	1	1	56
		Subtotal	*208*	*192*	*11*	*12*	*423*
13th Street / Pennsylvania Avenue	6/16/2011 (Thursday)	7-8am	17	29	2	0	48
		8-9am	47	31	8	1	87
		5-6pm	39	34	6	1	80
		6-7pm	39	41	5	0	85
	6/18/2011 (Saturday)	12-1pm	42	32	7	0	81
		1-2pm	31	20	11	0	62
		Subtotal	*215*	*187*	*39*	*2*	*443*
Total			***1,058***	***939***	***85***	***22***	***2,104***

[1] Cyclists leaving the center bike lanes and turning north or south were counted in this tally. Cross cyclists (who did not travel on the center bike lanes) were not counted.

Other Users

Segway riders (presumably mostly from tour groups) were frequently observed in the Pennsylvania Avenue center bike lanes, with 96 Segways observed in the 30 hours of video analyzed. Several pedestrians and joggers were also observed using the center bike lanes.

Cyclist Signal Compliance

For each cyclist arriving on a red signal, signal compliance was recorded. Overall, 42 percent of cyclists violate the red signal indication, but this varied greatly by intersection. At the 11th Street/Pennsylvania Avenue intersection, a "T" intersection in which 11th Street does not continue south of Pennsylvania, the overall violation rate is as high as 60 percent. Table 45 provides cyclist signal compliance and violation data along Pennsylvania Avenue, presented for eastbound and westbound cyclists for each two-hour period of analysis. At intersections where motorists receive a left-turn arrow (and through traffic is stopped), cyclist violations that occur during this interval are noted separately.

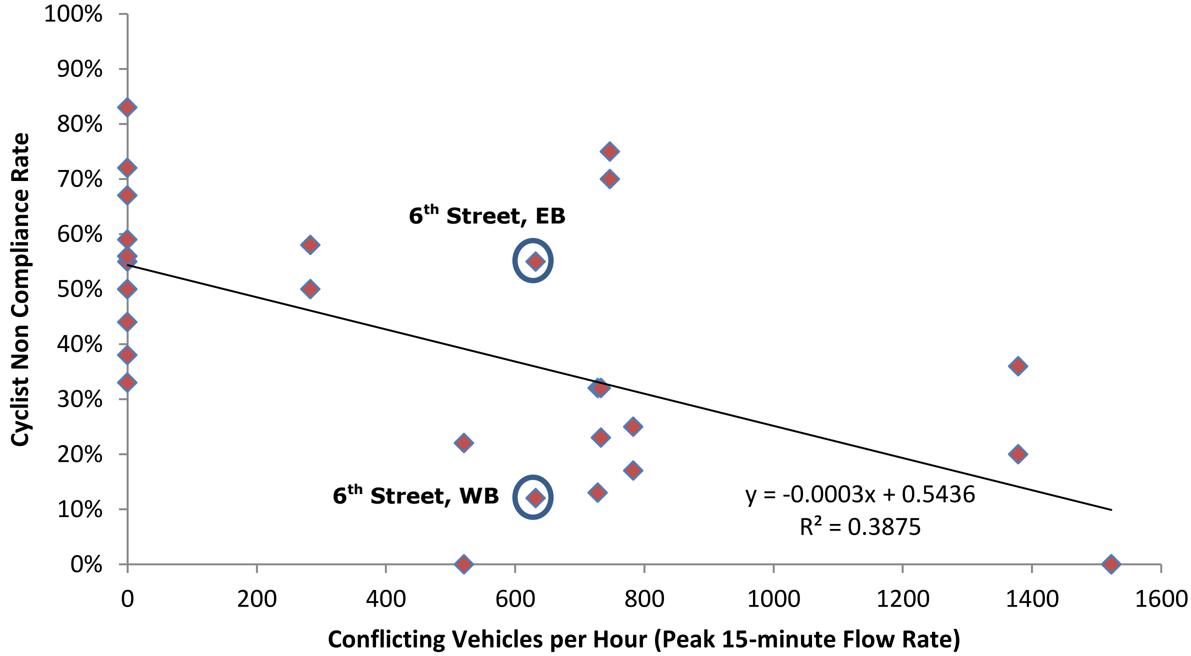
Figure 19 shows a plot of the observed violation rate at each intersection and time period (7:00 a.m. to 9:00 a.m., 5:00 p.m. to 7:00 p.m., and 12:00 p.m. to 2:00 p.m.) against the total conflicting entering peak 15-minute motor vehicle flow rate (vehicles per hour (vph)). For a two-way cross street, this is the sum of the entering approach peak 15-minute flow rates for the conflicting street (through traffic only). These counts were taken from the turning movement counts conducted the same day but not necessarily during the exact same time period of the violations. The figure suggests a positive relationship between the conflicting volumes and compliance rate (i.e., higher conflicting volumes result in better compliance). This partially, though not completely, explains the very high non-compliance rates. Note that the fitted linear regression line in the figure is intended to show the trend of the individual data points more clearly and is not the result of modeling analysis (since there are multiple observations of the same intersection).

Table 45 Pennsylvania Avenue Cyclist Signal Compliance and Violations

Date	Time	Dir.	Cyclist Count	Arriving on Green or Yellow	Arriving on Red	No Violation	Signal Violation, Red Signal	Signal Violation, Green Left-Turn Arrow[1]	Total Signal Violation	% Violations
6th Street/Pennsylvania Avenue										
6/16/2011	7-9am	EB	42	13	29	13	12	4	16	55%
		WB	111	70	41	36	5	0	5	12%
	5-7pm	EB	84	62	19	13	5	1	6	32%
		WB	50	32	16	14	2	0	2	13%
6/18/2011	12-2pm	EB	73	33	40	17	3	20	23	58%
		WB	49	35	14	7	7	0	7	50%
	Subtotal		*409*	*245*	*159*	*100*	*34*	*25*	*59*	*37%*
9th Street/Pennsylvania Avenue										
6/16/2011	7-9am	EB	48	15	33	10	23	0	23	70%
		WB	78	66	12	3	9	0	9	75%
	5-7pm	EB	83	39	44	35	9	0	9	20%
		WB	51	29	22	14	8	0	8	36%
6/18/2011	12-2pm	EB	99	56	43	33	10	0	10	23%
		WB	46	27	19	13	6	0	6	32%
	Subtotal		*405*	*232*	*173*	*108*	*65*	*0*	*65*	*38%*
11th Street/Pennsylvania Avenue										
6/16/2011	7-9am	EB	55	49	6	1	5	0	5	83%
		WB	78	14	64	29	35	0	35	55%
	5-7pm	EB	77	65	12	4	4	4	8	67%
		WB	60	36	24	15	9	0	9	38%
6/18/2011	12-2pm	EB	73	20	53	15	17	21	38	72%
		WB	56	34	22	9	13	0	13	59%
	Subtotal		*399*	*218*	*181*	*73*	*83*	*25*	*108*	*60%*
12th Street/Pennsylvania Avenue										
6/16/2011	7-9am	EB	55	51	4	4	0	0	0	0%
		WB	70	51	19	19	0	0	0	0%
	5-7pm	EB	82	42	40	30	10	0	10	25%
		WB	62	44	18	15	3	0	3	17%
6/18/2011	12-2pm	EB	73	46	27	21	6	0	6	22%
		WB	59	52	7	7	0	0	0	0%
	Subtotal		*401*	*286*	*115*	*96*	*19*	*0*	*19*	*17%*
13th Street/Pennsylvania Avenue										
6/16/2011	7-9am	EB	69	63	6	3	3	0	3	50%
		WB	57	25	32	14	11	7	18	56%
	5-7pm	EB	83	45	38	19	12	7	19	50%
		WB	67	40	27	15	12	0	12	44%
6/18/2011	12-2pm	EB	64	48	16	7	9	0	9	56%
		WB	62	41	21	14	7	0	7	33%
	Subtotal		*402*	*262*	*140*	*72*	*54*	*14*	*68*	*49%*
Total			***2,016***	***1,243***	***768***	***449***	***255***	***64***	***319***	***42%***

[1] The intersections of Pennsylvania Avenue at 6th Street, 11th Street, and 13th Street have exclusive turn signals for eastbound motorists turning north.

Figure 19 Pennsylvania Avenue Cyclist Non-Compliance Rate Versus Total Entering 15-Minute Peak Hour Conflicting Flow Rate (vph)



As shown in Figure 19, the rate of cyclists violating signals decreases with increasing numbers of conflicting vehicles. Other factors also contribute to a cyclist's decision to cross during the red phase, such as gaps in crossing traffic progression and signal delay for bicycles. The delay calculations used in the progression analysis were not sufficient to produce statistically significant results, but there is anecdotal evidence that signal delay affects compliance rates. For example, at the 6th Street/Pennsylvania Avenue intersection, 55 percent of cyclists violated the signal while traveling eastbound in the a.m. peak period, whereas only 12 percent of westbound cyclists crossed against the signal. Cyclists in both directions face the same volume of conflicting traffic (632 vehicles), but eastbound bicyclists experience an average signal delay nearly four times as long (38 seconds versus 10 seconds).

Cyclist Stopping Locations

Of the 768 cyclists arriving at an intersection on a red light, 508 stopped (although a fraction of the 508 continued again before the light turned green). Of those that stopped, 17 percent stopped behind the painted stop bar preceding the median and crosswalk. However, 76 percent stopped either in the median or in the crosswalk, with most of the remainder stopping in the intersection, placing them potentially in conflict with left-turning vehicles.

Cyclist Collisions and Near-Collisions

During the 30 hours of video reviewed, no collisions were observed. Two conflicts were observed involving cyclists leaving or accessing the center bike lanes on Pennsylvania Avenue:

- At 13th Street, a westbound pedicab attempted to turn north off of the cycle track pulled in front of traffic lanes just as the light changed to green. Both the pedicab and a car that had just started to move yielded to one another; this was not categorized as an emergency action.
- At Pennsylvania Avenue and 15th Street, a cyclist attempted to access the center bike lanes via the crosswalk just as the signal turned green for traffic on Pennsylvania Avenue. A car that had just started to move came to an emergency stop to avoid a collision.

Video reviewers also noted each time a cyclist had to navigate around motor vehicles or pedestrian as they rode in the center bike lanes. Cyclists in the Pennsylvania Avenue center bike lanes encountered relatively few obstacles. Pedestrian encounters were the most frequent at 12th and 13th Streets, with 1.9 percent and 4.3 percent of cyclists at those intersections, respectively, needing to navigate around people crossing or waiting in the median. Less than 1 percent of cyclists at other intersections encountered pedestrians in the bike lanes. Table 46 summarizes the types of cyclist obstacle encounters noted on Pennsylvania Avenue.

Table 46 Pennsylvania Avenue Cyclist Obstacle Encounters

Encounter Type	Frequency	Percent of Total Observed Cyclists
Bicyclist encounters left turning car coming from opposite direction	3	0.1%
Bicyclist encounters left turning car coming from same direction	2	0.1%
Bicyclist encounters cross traffic	16	0.8%
Bicyclist encounters pedestrian	28	1.4%
Combined (all encounters)	49	2.3%
Number of Respondents	2,104	

Key Findings

- **Bicycle volumes increased by approximately 200 percent after the bicycle facilities were installed.** Bicycle counts were taken between 6th Street and 7th Street and between 14th Street and 15th Street during the a.m. and p.m. peak hours in April 2010 and June 2011. All locations and time periods experienced significant bicycle volume growth after installation of the bicycle facilities.

- **Arterial LOS was similar for motor vehicles on Pennsylvania Avenue before and after the bicycle facilities were installed.** The study segments remained at LOS E or better during both the a.m. and p.m. peak hours, even after left turns were restricted and through movement green time was reduced on Pennsylvania Avenue at several intersections. The minimal change partially reflects the extensive work done prior to installation to adjust corridor signal timing.
- **The corridor experienced decreased motorized vehicle volumes after the bicycle facilities were installed.** Between October 2009 and June 2011, there was a 21.3 percent decrease in volumes between 6th Street and 10th Street during the p.m. peak hour, and a 14.7 percent decrease in volumes between 10th Street and 15th Street during the p.m. peak hour. The reason for the decrease is not entirely clear, but may have resulted from the different times of year that the counts were taken, and/or driver route choice changes due to the turn restrictions.
- **Danish Bicycle LOS and Bicycle Environmental Quality Index (BEQI) analyses all show significantly improved operations for cyclists with the median bike facilities.** The Danish Bicycle LOS improved from LOS E before the bicycle facilities were installed to LOS C after installation. The BEQI index indicated that the bicycling environment went from being "Average" before facility installation to "High Quality" after installation. The BEQI scores (out of 100) improved from approximately 45 (out of 100) before installation to 70 after installation.
- **Signal timing for bicycles generally works well between 10th Street and 15th Street, but results in large delays to cyclists between 3rd Street and 9th Street.** The speed-based LOS experienced by bicycles, based on existing signal timing and cyclist travel speeds of 10–15 mph is LOS E or F between 3rd Street and 9th Street, LOS A to D between 10th Street and 15th Street.
- **The frequency of bicycle crashes experienced along Pennsylvania Avenue increased after the bicycle facilities were installed.** There were 16 bicycle crashes on the corridor during the first 14 months after implementation, compared to a total of 9 bicycle crashes during the previous 4 years. This represents an increase in crash frequency, even when taking into account the observed tripling of cyclist volume on the corridor. The low number of total crashes and limited length of time observed for the after period (14 months) is too short to draw definitive conclusions; however, DDOT should continue to monitor crash patterns to identify potential safety improvements along the corridor.
- **No collisions were directly observed in the video data and relatively few were self-reported in the cyclist surveys.** Video observations revealed occasional instances of cyclists and pedestrians navigating around one another at intersection crosswalk medians, and more than half of cyclists reported experiencing "near-collisions" with pedestrians. About half of

cyclists reported experiencing "near-collisions" with turning motor vehicles, although there were none observed in the six hours of video analyzed.

- **Cyclists understand how they are supposed to behave at the intersections, but frequently do not comply.** All surveyed cyclists understood that they should follow the through-traffic motor vehicle signal. However, the video data revealed a high violation rate. In the observed data, an average of 42 percent of cyclists arriving on a red signal violated the signal (though this varied substantially by intersection and by cross street volume). Compared to the data in the few published studies available on cyclist compliance with bicycle-specific traffic signals, this is a high violation rate, and is very high compared with motorist compliance.
- **Most cyclists stopping at red lights stop in the crosswalk or median area, rather than behind the white stop bar.** This pattern could result in potential collisions with left-turning vehicles and blocking pedestrians trying to use the crosswalk.
- **Cyclists overwhelmingly indicated that they felt riding a bicycle on Pennsylvania Avenue with the center bike lanes is safer and easier**, and that the center bike lanes provide a useful connection for getting around Washington, D.C. on a bicycle.
- **Nearly three in four residents indicated that they "support" the center bike lanes and believe them to be a valuable asset to the neighborhood.** They also support investment in encouraging cycling and improving the safety of cycling, although there was a greater amount of differing opinions for this facility than for the other facilities evaluated.
- **Motorists support the separation between bikes and cars provided by the center bike lanes, but have some concerns.** About half the respondents indicated that restrictions on U-turns are a major inconvenience along the route (note that U-turns were always prohibited, but several missing signs were replaced when the bicycle facility was installed). Nearly half of respondents indicated that signals, signs, and street markings do not make it clear who has the right-of-way at intersections.
- **Pedestrians find there are fewer cyclists riding on sidewalks now**. While pedestrian responses indicate that there may now be some competition for space at medians along Pennsylvania Avenue, only one respondent reported being involved in a collision with a cyclist in the center bike lanes.

Preliminary Recommendations

Based on these findings, the team makes the following preliminary recommendations:

- Improve legibility of signals, signs, and markings. Only 56 percent of drivers indicated it was clear who has the right-of-way at intersections. Bicycle signals clarifying the separation of bicycle movements from left-turns could help improve legibility.
- Add bicycle signals to create independent vehicle and bicycle through phases. Since the bicycle lane is positioned to the left of the vehicle left-turn lane, the lanes must operate with different signal phases. Through motorists, who drive to the right of the left-turn lane, do not conflict with turning vehicles, but currently must wait since they share a signal head with bicyclists. Adding a bicycle signal and bicycle through phase would permit independent operation of the through bicycle and vehicle phases and increase green time for through vehicles, and would make it easier to adjust signal timing to accommodate both cyclist and motor vehicle progression.
- Resize and reposition bicycle signs. The bicycle signs create a sight distance obstruction and could be made smaller. In the longer term, taller signal poles would allow the signs to be placed higher to increase visibility.
- Consider additional pavement markings to reduce pedestrian/bicyclist conflicts. For instance, "WAIT HERE" or "STOP HERE" pavement markings prior to the stop bar in the cycle track (between the stop bar and the bike symbol) could be used to encourage cyclists to stop at the proper location. Similarly, bike stencils in the crosswalk where the cycle track crosses the crosswalk (similar to those used at driveways along 15th Street) could help to indicate the presence of the cycle track to pedestrians.
- Include cyclist progression analysis as an explicit performance measure in future signal re-timing along Pennsylvania Avenue. In particular, eastbound bicyclists experience poor progression in the a.m. peak period and westbound cyclists experience poor progression in both peak periods.
- Continue monitoring crash patterns and bicycle volumes along the corridor. Crash rates were higher in the year after the construction of the center median bike lanes compared with the prior four years. However, the post-construction sample is only one year, which does not provide a comprehensive view of crash patterns.
- DDOT should consider a cyclist education and enforcement campaign to encourage compliance with traffic signals.

Section 6
Evaluation of 15th Street NW from E Street NW/Pennsylvania Avenue NW to V Street NW

15TH STREET NW FROM E STREET NW/PENNSYLVANIA AVENUE NW TO V STREET NW

DDOT installed a two-way cycle track on 15th Street between E Street/Pennsylvania Avenue and V Street in November 2010.

Data Collection

DDOT provided data from before the bicycle facilities were installed on 15th Street, including:

- Motor vehicle counts for select study intersections from dates ranging between September 2003 and July 2010,
- Bicyclist counts for conditions before the cycle track was installed from October 2009, bicyclist counts for conditions after the one-way cycle track was installed from April, July, and September 2010, and bicyclist counts for conditions after the two-way cycle track was installed from April 2011,
- Crash data from 2005 through 2011,
- Speed reports from July 2009 and July 2010,
- User intercept surveys from June 2010, and
- Travel time information from Fall 2010.

Similar data were required after the bicycle facilities were installed. KAI acquired the following data for 15th Street:

- Bicyclist, pedestrian, and motor vehicle counts at signalized intersections during the weekday a.m. and p.m. peak hours and the Saturday midday peak hours,
- Video at signalized intersections, for the purpose of quantifying bicyclist, pedestrian, and motorist behavior and conflicts between intersection users, during the weekday a.m. and p.m. peak hours and the Saturday midday peak hours,
- Traffic signal timing data,
- User intercept surveys,
- Surrounding neighborhood surveys, and
- Motor vehicle drive-time analyses during the weekday a.m., midday, and p.m. peak periods.

Corridor Analysis

VOLUME ANALYSIS

Bicycle Volumes

Table 47 and Table 48 show the a.m. and p.m. peak hour bicyclist volumes, respectively, counted between K Street and L Street, between P Street and Church Street, and between T Street and Swann Street during October 2009, April 2010, July 2010, September 2010, April 2011, and June 2011. Figure 20 and Figure 21 graph the change in bicyclist volumes along 15th Street for the a.m. and p.m. peak hours, respectively. The bicyclist counts included all bicyclists traveling along 15th Street inside and *outside* the designated bicycle facilities.

The data indicate that more bicyclists began using 15th Street after installation of the one-way cycle track and, in general, even more began traveling along the corridor after installation of the two-way cycle track. Note that seasonal variations in bicyclist volume likely accounts for some of the observed differences, and counts taken during different seasons may not be directly comparable.

Table 47 15th Street AM Peak Hour Bicycle Volumes

Between Intersections	Before Installation of Bicycle Facilities (Bicycles)	After Installation of the One-Way Cycle Track (Bicycles)			After Installation of the Two-Way Cycle Track (Bicycles)		Percent Change from April 2010 to June 2011	Percent Change from September 2010 to June 2011
	October 2009	April 2010	July 2010	September 2010	April 2011	June 2011		
K Street and L Street	-	-	-	92	129	113	-	(+) 23%
P Street and Church Street	-	95	142	138	166	118	(+) 24%	(-) 14%
T Street and Swann Street	-	44	98	68	113	78	(+) 77%	(+) 15%

Figure 20 15th Street AM Peak Hour Bicycle Volumes

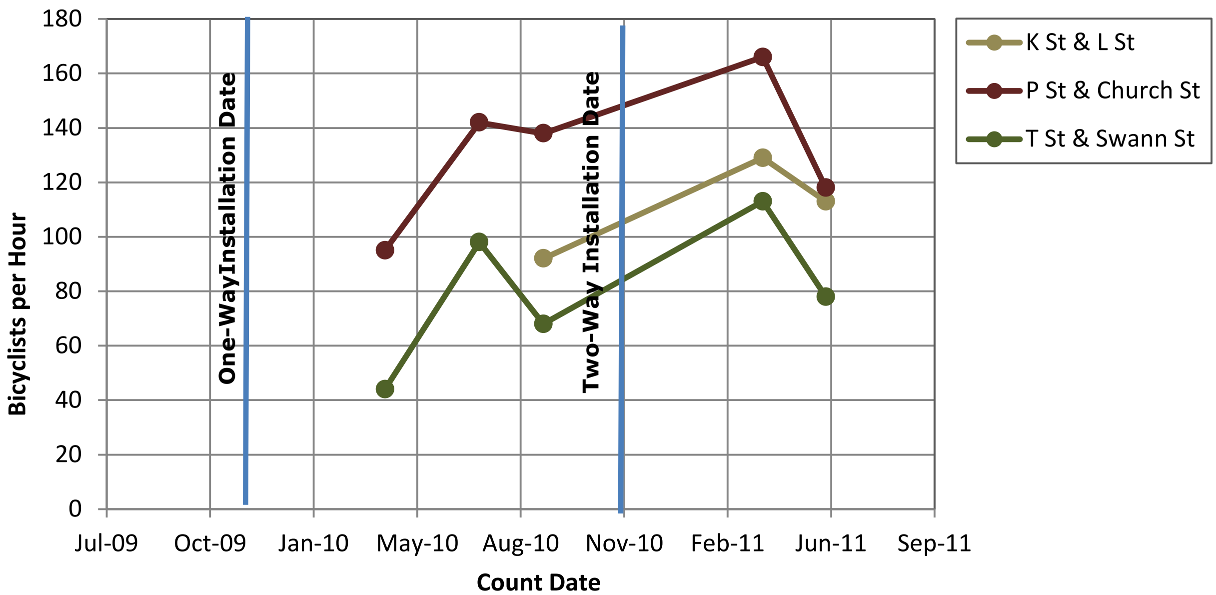
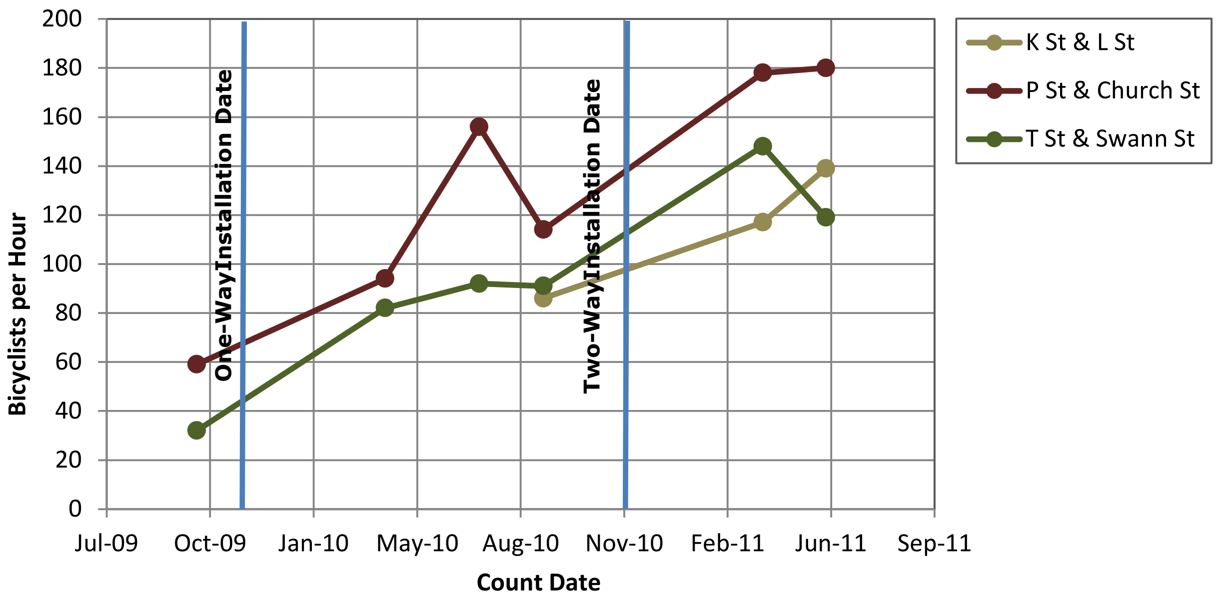


Table 48 15th Street PM Peak Hour Bicycle Volumes

Between Intersections	Before Installation of Bicycle Facilities (Bicycles)	After Installation of the One-Way Cycle Track (Bicycles)			After Installation of the Two-Way Cycle Track (Bicycles)		Percent Change from October 2009 to June 2011	Percent Change from September 2010 to June 2011
	October 2009	April 2010	July 2010	September 2010	April 2011	June 2011		
K Street and L Street	-	-	-	86	117	139	-	(+) 62%
P Street and Church Street	59	94	156	114	178	180	(+) 205%	(+) 58%
T Street and Swann Street	32	82	92	91	148	119	(+) 272%	(+) 31%

Figure 21 15th Street PM Peak Hour Bicycle Volumes



Motorized Vehicle Volumes

As a supplement to evaluating bicyclist volumes, motorized vehicle volumes were also assessed along 15th Street to determine if there were any changes caused by the bicycle facility installation. Table 49 shows the average p.m. peak hour motorized vehicle through volumes between intersections on 15th Street for intersections between E Street and New York Avenue, between H Street and Massachusetts Avenue, and between Rhode Island Avenue and U Street. These counts indicate that traffic volumes increased on 15th Street between E Street and Massachusetts Avenue after the bicycle facilities were installed, but that volumes decreased between Rhode Island Avenue and U Street after installation.

Table 49 15th Street PM Peak Hour Average Motor vehicle Through Volumes Between Intersections

Intersection	Before Installation of Bicycle Facilities (Vehicles)	After Installation of Bicycle Facilities (Vehicles)	Percent Change between September 2007 and July 2011
	September 2007	July 2011	
E Street to New York Avenue	1,779	1,851	(+) 4.0%
H Street to Massachusetts Avenue	948	1,044	(+) 10.1%
Rhode Island Avenue to U Street	1,268	1,253	(-) 1.2%

OPERATIONS ANALYSIS

Highway Capacity Manual 2010 Multi-Modal Level of Service

15th Street was evaluated in both directions using the bicycle LOS component of the HCM MMLOS before and after implementation of the curb-side, bidirectional cycle track. Because there were no provisions for southbound bicycle travel north of Massachusetts Avenue before implementation of the cycle track, no LOS comparison could be conducted for those segments. The results of the MMLOS evaluation are illustrated in Table 50.

Table 50 15th Street HCM Bicycle LOS

Segment	Direction	Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		Score[1]	LOS	Score[1]	LOS
Lower E Street to New York Avenue	Northbound	3.84	D	3.27	C
	Southbound	3.67	D	3.64	D
H Street to Massachusetts Avenue	Northbound	3.48	C	3.45	C
	Southbound	3.37	C	3.73	D
Massachusetts Avenue to S Street	Northbound	4.34	E	3.96	D
	Southbound	N/A	N/A	4.55	E
S Street to U Street	Northbound	4.52	E	4.17	D
	Southbound	N/A	N/A	4.52	E

[1] MMLOS scores are defined in the Study Methodology section of this report.

The HCM MMLOS analysis produced several counterintuitive results where the LOS score actually decreased or stayed nearly the same after implementation of the two-way cycle track. There are several reasons for these results. First, the MMLOS analysis procedures were not calibrated with data on cycle tracks; as a result, the 15th Street cycle track is analyzed as a standard bike lane with additional buffer from traffic. Also, the pavement quality for southbound riders is poor, which negatively impacts the LOS for those users in the model, offsetting the benefits provided by the cycle track .

Because of the limitations of the HCM MMLOS procedure, the research team also applied two other bicycle facility analysis methods: Danish Bicycle LOS and the Bicycle Environment Quality Index. A progression analysis was also conducted because none of the LOS analysis methods consider signal coordination.

Danish Bicycle Level of Service

The bicycle facilities were evaluated using the Danish Bicycle LOS method, with the procedure applied separately for the southbound and northbound bicycle facilities (both located on the west side of the street). The only segment along 15th Street that does not have new bicycle facilities is the segment between H Street and New York Avenue. Bicyclists are able to ride through a park for this section of 15th Street, so no on-street facilities exist.

Overall, the Danish Bicycle LOS analysis indicates that the LOS experienced by bicyclists improved along 15th Street with the addition of the bicycle facilities, as shown in Table 51. Before the bicycle facilities were installed, 15th Street provided LOS D or E on the three segments; after the bicycle track was installed, 15th Street provided LOS A or B. The Danish Bicycle LOS model predicts that nearly all bicyclists will indicate that they are at least a little satisfied with the facilities on 15th Street after installation. Figure 22, Figure 23, and Figure 24 show the percentage split between the six levels of satisfaction for conditions before and after installation of the bicycle facilities.

Table 51 15th Street Danish Bicycle LOS

Segment	Direction	Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		LOS	Rating	LOS	Rating
Lower E Street to New York Avenue	Northbound	E	Average	A	Good
	Southbound	E	Average	A	Good
H Street to Massachusetts Avenue	Northbound	D	Average	B	Good
	Southbound	D	Average	A	Good
Massachusetts Avenue to U Street	Northbound	E	Average	A	Good
	Southbound	N/A	N/A	A	Good

Figure 22 Percentage of Free Flow Speed for Bicyclists on 15th Street (Between Lower E Street and New York Avenue)

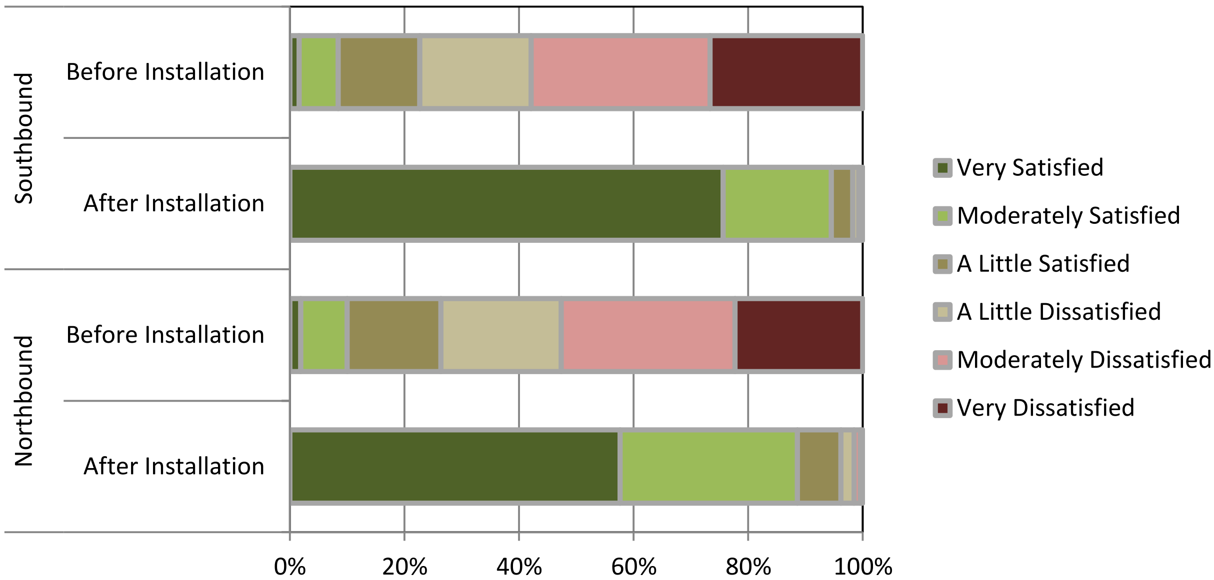


Figure 23 Percentage of Free Flow Speed for Bicyclists on 15th Street (Between H Street and Massachusetts Avenue)

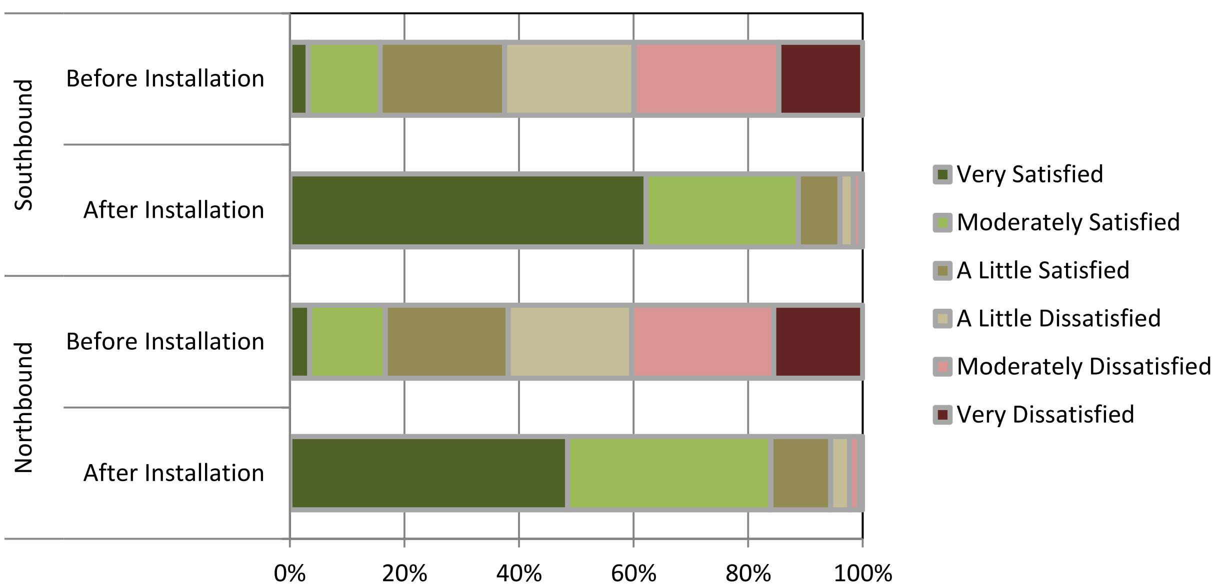
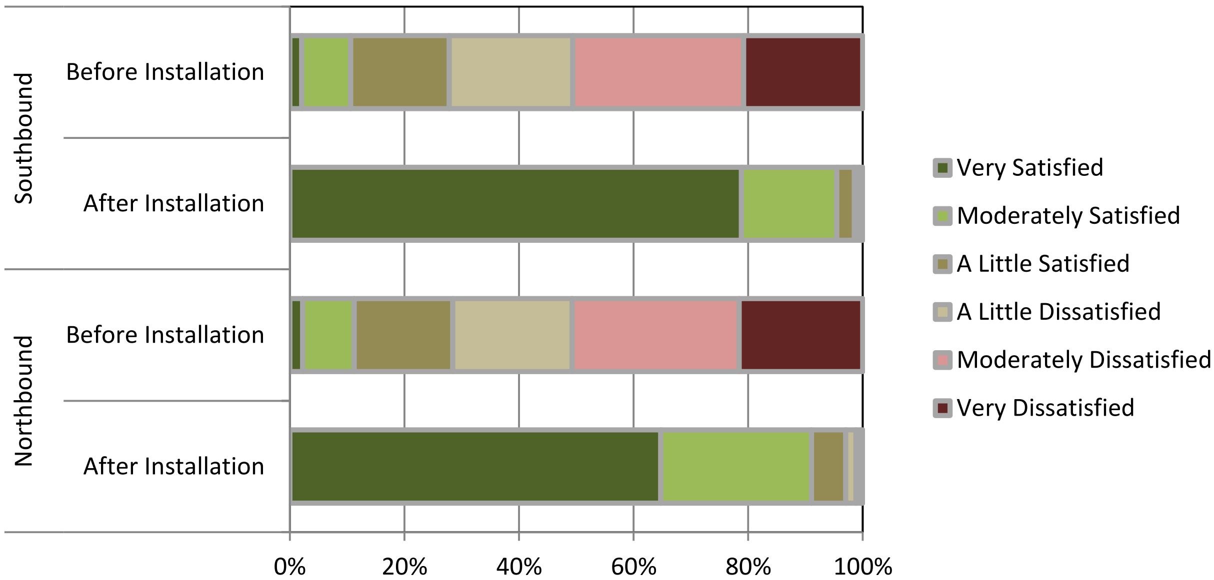


Figure 24 Percentage of Free Flow Speed for Bicyclists on 15th Street (Between Massachusetts Avenue and U Street)



Bicycle Environmental Quality Index

The BEQI model indicates that the conditions experienced by bicyclists improved along 15th Street with the addition of the bicycle facilities, as shown in Table 52. 15th Street was ranked as having average-quality bicycle facilities before installation of the cycle track, with scores of approximately 45 out of 100. After the installation of the cycle track, 15th Street was ranked as providing high- to highest-quality bicycle facilities with scores of approximately 75 out of 100.

Table 52 15th Street BEQI Scores

Segment	Direction	Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		Score	Quality	Score	Quality
Lower E Street to New York Avenue	Northbound	45.6	Average	75.2	High
	Southbound	43.5	Average	77.0	High
H Street to Massachusetts Avenue	Northbound	44.8	Average	77.0	High
	Southbound	45.9	Average	79.8	High
Massachusetts Avenue to U Street	Northbound	43.3	Average	75.4	High
	Southbound	44.9	Average	79.6	High

Highway Capacity Manual 2000 Motorized Vehicle Level of Service

HCM motorized vehicle arterial LOS was analyzed for each segment between signalized intersections along 15th Street. While accommodating bicyclists was the purpose of the new bicycle facilities, DDOT wants to maintain a multimodal environment along 15th Street. Table 53 includes information on the arterial speed and corresponding LOS experienced by drivers on each corridor study segment. The operations analysis took into account changes in the volumes, lane configurations, and signal phasing and timing (specifically related to changes made for the left turns). The red cells in the table show the speeds and LOS that worsened after the bicycle facilities were installed, and the green cells show the speeds and LOS that improved after installation of the bicycle facilities.

The reduced capacity at some intersections and the reduced green time allocated to motor vehicles caused some additional delay for drivers. For example, at the intersection of 15th Street/R Street, where a northbound through-left lane was converted to an exclusive left-turn lane and made a protected movement, the delay for left-turning vehicles went from 3.2 seconds to 34.9 seconds. However, the delay for the northbound *approach* as a whole increased from only 3.2 seconds to 6.8 seconds, given the much higher through volume relative to the left-turning volume. Overall, the differences observed between conditions before and after installation of the bicycle facilities were minor. The analysis predicts that conditions have remained relatively similar for motor vehicles traveling along 15th Street.

Table 53 15th Street HCM Motor Vehicle Arterial LOS

Segment	Direction	AM Peak Hour				PM Peak Hour			
		Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities		Before Installation of Bicycle Facilities		After Installation of Bicycle Facilities	
		LOS	Speed (mi/h)	LOS	Speed (mi/h)	LOS	Speed (mi/h)	LOS	Speed (mi/h)
E Street to H Street	Northbound	E	7.2	E	7.3	E	8.7	E	8.1
	Southbound	D	11.9	D	11.3	E	8.7	E	8.1
H Street to Massachusetts Avenue	Northbound	E	8.7	E	8.1	F	5.0	E	7.4
	Southbound	E	8.4	E	8.0	E	8.0	F	6.3
Massachusetts Avenue to U Street	Northbound	D	12.6	D	10.4	D	9.7	D	11.3

BICYCLE PROGRESSION ANALYSIS

For each time period (weekday a.m. and weekday p.m. peak hours), a progression analysis was completed in both directions (northbound and southbound) for bike speeds of 10 mph and 15 mph. The 15th Street corridor was split into three sections for the bicycle progression analysis: (1) Lower E Street to I Street, (2) I Street to Rhode Island Avenue, and (3) Rhode Island Avenue to V Street. The corridor was split into sections because many bicyclists do not ride along the entire corridor but rather through one or two sections. Each section begins at the start of a green signal. It was assumed that half the bicyclists that reach an intersection during a clearance interval would proceed through the intersection.

The percentage of free flow speed was calculated for each segment based on the length of the corridor segment and the total travel time. Free flow speeds of 10 mph and 15 mph were used to assess the level of service experienced by bicyclists. (The percentage of free-flow speed parameters for motor vehicle LOS on two-lane highways were used to assess bicycle LOS because no such service measure yet exists for bicycles.) The results for 15th Street are shown in 0, Figure 26, and 0.

The figures reveal that bicyclists experience less delay on 15th Street between Lower E Street and I Street than between I Street and Rhode Island Avenue or between Rhode Island Avenue and U Street. Bicyclists riding at 15 mph between Lower E Street and I Street can achieve LOS D or better, but bicyclists traveling between I Street and U Street generally experience LOS E.

Bicyclist progression is only one of many performance measures used to establish signal timing, but should be an important consideration, particularly on high-volume bicycle routes. The progression analysis shown here indicates that existing signal timing works fairly well for cyclists (at typical cycling speeds) between Lower E Street and I Street, but creates considerably more signal delay for cyclists between I Street and U Street elsewhere along the corridor. This is particularly true for southbound cyclists north of Massachusetts Avenue, where the current signal timing favorsnorthbound progression of motor vehicles.

During the next corridor re-timing, the potential to re-time signals to accommodate bicycle traffic in both directions should be considered, although this must be balanced with the need to maintain northbound progression for motor vehicles. This also suggests general signal timing challenges for installing two-way bicycle facilities on one-way corridors.

Figure 25 Percentage of Free Flow Speed on 15th Street (Between Lower E Street and I Street)

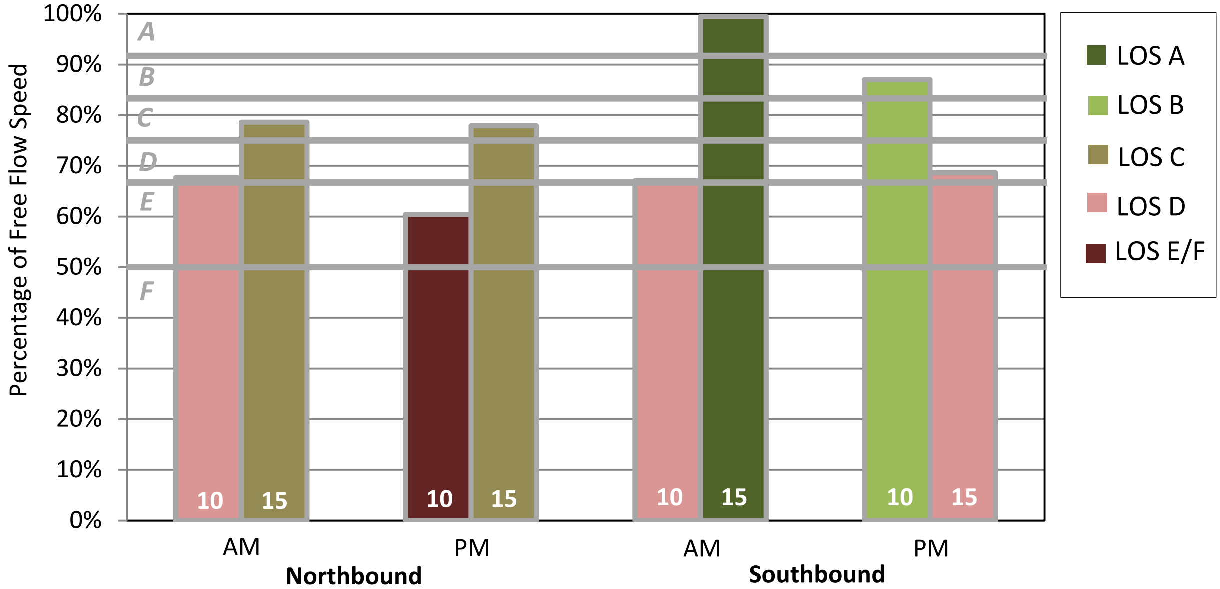


Figure 26 Percentage of Free Flow Speed on 15th Street (Between I Street and Rhode Island Avenue)

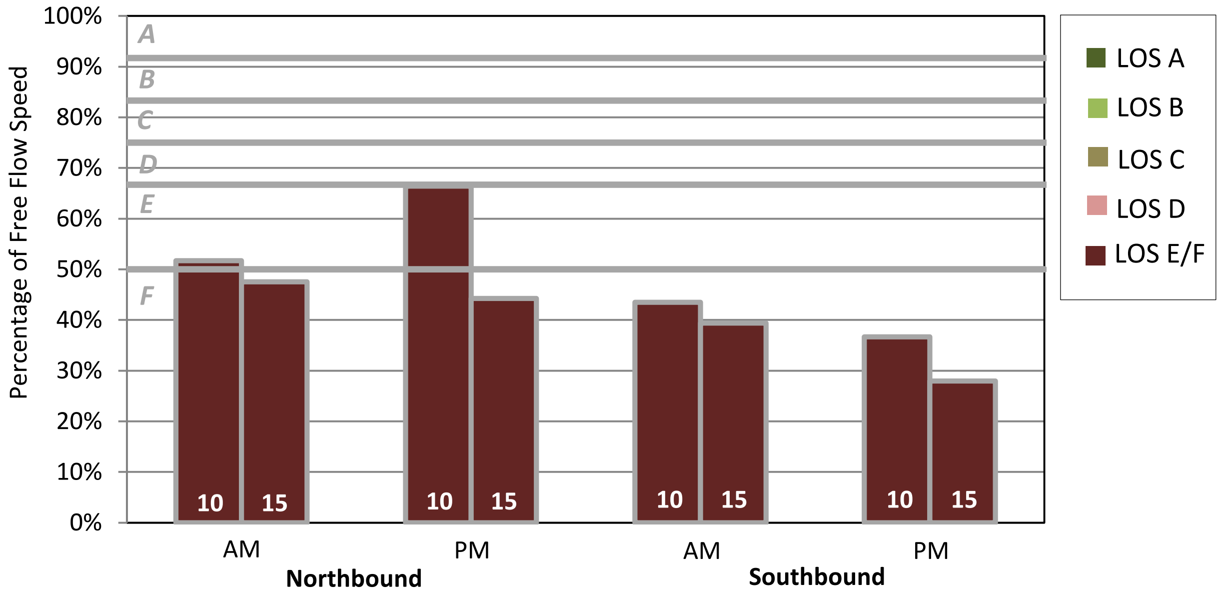
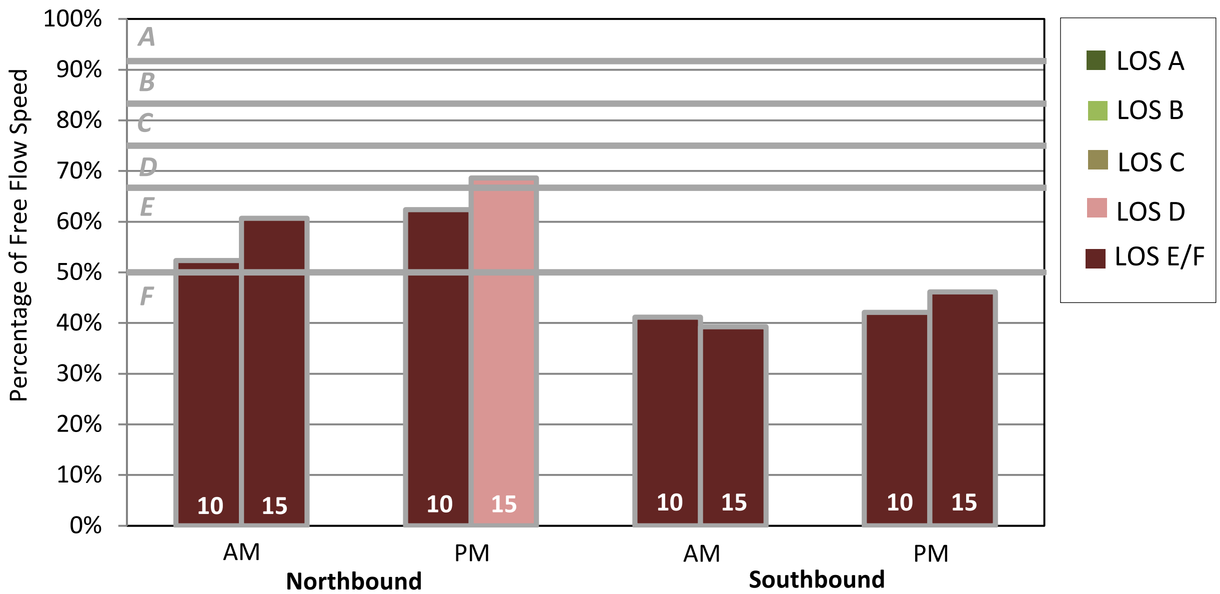


Figure 27 Percentage of Free Flow Speed on 15th Street (Rhode Island Avenue and U Street)



MOTORIZED VEHICLE TRAVEL TIME

The average corridor speeds achieved along 15th Street are listed in Table 54 in miles per hour (mph). After the bicycle facilities were installed, the average corridor speeds for the northbound direction were faster during the a.m. and midday peak periods but 1.3 mph slower during the p.m. peak hour. The average corridor speeds for the southbound direction were faster during the midday peak hour but 0.8 mph slower during the a.m. and p.m. peak periods after installation of the bicycle facilities. Overall, the bicycle facilities did not slow the travel speeds along 15th Street by more than 14 percent, and some of the time periods experienced increased travel speeds after the installation of the bicycle facilities.

Table 54 Corridor Speeds for Motor Vehicle Traffic Along 15th Street

Runs	AM Peak		Midday Peak		PM Peak	
	Before	After	Before	After	Before	After
Northbound #1	11.0	14.2	9.0	10.2	11.6	8.6
Northbound #2	11.6	11.3	8.7	11.4	8.9	7.9
Northbound #3	11.2	9.4	10.9	11.6	7.5	7.4
Average	***11.3***	***11.6***	***9.5***	***11.1***	***9.3***	***8.0***
Southbound #1	9.0	9.0	6.6	9.3	7.7	8.2
Southbound #2	8.0	9.3	6.3	7.3	7.2	6.8
Southbound #3	13.1	9.4	6.2	7.1	7.5	4.9
Average	***10.0***	***9.2***	***6.3***	***7.9***	***7.5***	***6.7***

CRASH ANALYSIS

Crash data for the 15th Street corridor were obtained from before installation of the bicycle facilities, after installation of the one-way cycle track, and after installation of the two-way cycle track. For the purpose of this analysis, the corridor was split into three sections: (1) E Street to New York Avenue, (2) H Street to Massachusetts Avenue, and (3) N Street to U Street. Crash data from 2005 to 2009 from the DDOT Traffic Accident Reporting and Analysis System were used for conditions before the bicycle facilities were installed, crash data from 2009 to 2010 were used for conditions after the one-way cycle track was installed, and crash data from 2010 to 2011 were used for conditions after the two-way cycle track was installed.

Table 55 shows crashes per year for the three segments by type and severity for conditions before the bicycle facilities were installed. Table 56 shows crashes per year by type and severity for conditions after the one-way cycle track was installed, and Table 57 shows crashes per year by type and severity for conditions after the two-way cycle track was installed. Crashes per year are summarized in order to normalize the crash data across different time periods before and after installation of the bicycle facilities. The crashes per month were calculated over a 48-month period for conditions before installation of the bicycle facilities and compared to crashes per month calculated over a 12-month period for conditions after installation of the one-way cycle track and for a 10-month period for conditions after installation of the two-way cycle track.

Red cells indicate types and severities of crashes that have more crashes per month after installation of the bicycle facilities, and green cells indicate types and severities of crashes that have fewer crashes per month after installation of the bicycle facilities.

Overall, the bicycle facilities do not appear to have caused significant changes in crash patterns, although crash frequency increased in two of the three segments. However, two years of data from after the facilities were constructed does not provide a comprehensive view of conditions after installation of the facilities, and crashes should continue to be monitored at these locations in order to compare longer-term crash patterns.

Table 55 15th Street Crashes per Year Before Installation of the Bicycle Facilities (All Crashes)

Roadway Segment		Total	Fatal	Injury	PDO	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
E Street to New York Avenue	Crashes	204	0	43	161	47	9	19	50	7	72
	Crashes Per Year	51.0	0.0	10.8	40.3	11.8	2.3	4.8	12.5	1.8	18.0
H Street to Massachusetts Avenue	Crashes	127	0	25	102	24	12	25	30	1	35
	Crashes Per Year	31.8	0.0	6.3	25.5	6.0	3.0	6.3	7.5	0.3	8.8
N Street to U Street	Crashes	194	0	30	164	19	18	32	64	3	58
	Crashes Per Year	48.5	0.0	7.5	41.0	4.8	4.5	8.0	16.0	0.8	14.5

Table 56 15th Street Crashes per Year After Installation of the One-Way Cycle Track (All Crashes)

Roadway Segment		Total	Fatal	Injury	PDO	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
E Street to New York Avenue	Crashes	34	0	6	28	4	3	9	6	3	9
	Crashes Per Year	34.0	0.0	6.0	28.0	4.0	3.0	9.0	6.0	3.0	9.0
H Street to Massachusetts Avenue	Crashes	53	0	13	40	10	6	11	12	2	12
	Crashes Per Year	53.0	0.0	13.0	40.0	10.0	6.0	11.0	12.0	2.0	12.0
N Street to U Street	Crashes	55	0	13	42	11	6	9	19	0	10
	Crashes Per Year	55.0	0.0	13.0	42.0	11.0	6.0	9.0	19.0	0.0	10.0

Table 57 15th Street Crashes per Year After Installation of the Two-Way Cycle Track (All Crashes)

Roadway Segment		Total	Fatal	Injury	PDO	Rear End	Angle	Turning	Side Swipe	Head On	Misc.
E Street to New York Avenue	Crashes	28	0	7	21	5	1	2	6	0	14
	Crashes Per Year	33.6	0.0	8.4	25.2	6.0	1.2	2.4	7.2	0.0	16.8
H Street to Massachusetts Avenue	Crashes	37	0	8	29	6	1	3	12	0	15
	Crashes Per Year	44.4	0.0	9.6	34.8	7.2	1.2	3.6	14.4	0.0	18.0
N Street to U Street	Crashes	55	0	13	42	5	4	6	30	2	8
	Crashes Per Year	66.0	0.0	15.6	50.4	6.0	4.8	7.2	36.0	2.4	9.6

With regard to crashes that involved bicyclists and pedestrians, Table 58 shows the number of bicyclists and pedestrians involved in crashes per year before and after installation of the bicycle facilities. Because of the dramatic increase in cyclist volumes before and after installation, bicycle crashes were adjusted for exposure.

After installation of the one-way cycle track, there was a 93 percent increase in bicyclist volumes between P Street and Church Street during the p.m. peak hour, and there was a 184 percent increase in bicyclist volumes between T Street and Swann Street during the p.m. peak hour. After installation of the two-way cycle track, there was a 205 percent increase (from before conditions) in bicyclist volumes between P Street and Church Street during the p.m. peak hour, and there was a 272 percent increase (from before conditions) in bicyclist volumes between T Street and Swann Street during the p.m. peak hour. No bicyclist volumes were available between K Street and L Street from before the bicyclist facilities were installed. Similar growth rates exist between installation of the one-way cycle track and two-way cycle track for the segments between K Street and L Street and between P Street and Church Street. The growth rates found between P Street and Church Street were used to estimate growth for the northern segments of 15th Street.

Table 58 includes a row for "adjusted" bicyclist crashes per year for the after condition that is directly comparable to the bicyclist crashes per year before the facilities were installed considering exposure. Using the adjusted crash frequency, the number of crashes involving bicyclists remained similar after installation of the bicycle facilities. One year of data after installation does not provide conclusive information for the crash patterns occurring along the corridor. However, it appears that crashes involving bicyclists remain a relatively rare event along 15th Street. It is recommended that crash reports continue to be evaluated in future years.

Table 58 15th Street Bicyclists and Pedestrians Per Year Involved in Crashes

Cross Street		Before Installation of Bicycle Facilities		After Installation of the One-Way Cycle Track		After Installation of the Two-Way Cycle Track	
		Crashes Involving Pedestrians	Crashes Involving Bicyclists	Crashes Involving Pedestrians	Crashes Involving Bicyclists	Crashes Involving Pedestrians	Crashes Involving Bicyclists
E Street to New York Avenue	Crashes	9	7	2	3	0	3
	Crashes Per Year	2.3	1.8	2.0	3.0	0.0	3.6
	Adjusted Crashes per Year	-	-	-	1.6	-	1.2
H Street to Massachusetts Avenue	Crashes	10	4	4	4	4	2
	Crashes Per Year	2.5	1.0	4.0	4.0	4.8	2.4
	Adjusted Crashes per Year	-	-	-	2.1	-	0.8
N Street to U Street	Crashes	6	9	2	5	2	8
	Crashes Per Year	1.5	2.3	2.0	5.0	2.4	9.6
	Adjusted Crashes per Year	-	-	-	1.8	-	2.6

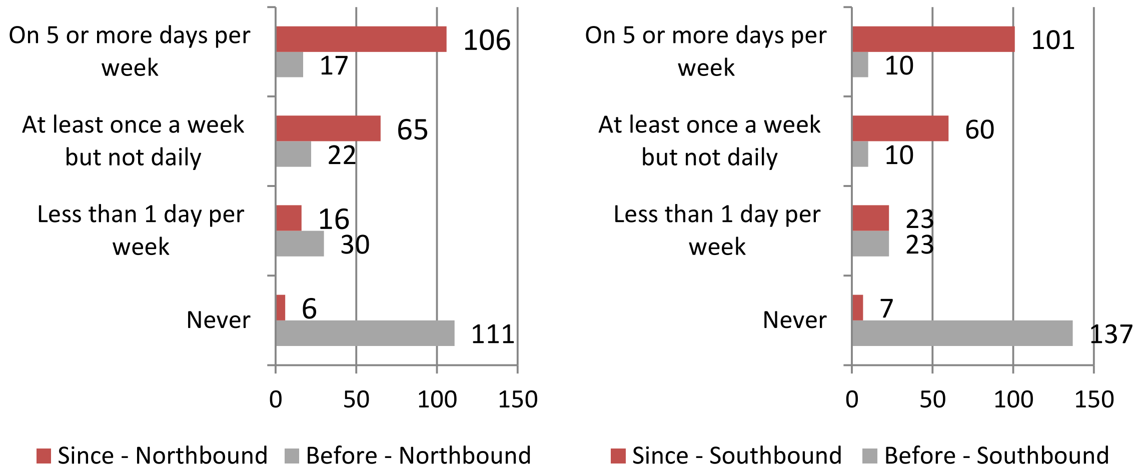
SURVEY ANALYSIS

Cyclist Intercept Survey

Riding Frequency

Based on self-reported frequency of cycling on 15th Street, cycling usage of 15th Street significantly increased between the periods before and after installation of the cycle track, as shown in Figure 28. This usage could be new riders or cyclists attracted from other routes.

Figure 28 Self-Reported Frequency of Cycling on 15th Street Before and After Installation of the Cycle Track



Perceptions of Safety and Ease

Safety and Ease

Overall, respondents indicated that they feel safer and more at ease cycling on 15th Street with the cycle track, as shown in Table 59. Among all respondents (201), there was a high level of agreement that the two-way cycle track makes riding a bicycle in Washington, D.C. safer (96 percent), easier (98 percent), and more convenient (98 percent). Of cyclists who rode a bicycle on 15th Street both before and after the cycle track was installed (89), 97 percent indicated that they feel safer cycling on 15th Street now, while 98 percent indicated that cycling is now easier and 97 percent indicated that cycling is now more convenient.

Cyclists also indicated that they would choose to ride on 15th Street over other streets. While 99 percent of all respondents agreed that the cycle track is a useful connection in getting places they want to go, 93 percent further indicated that they would go out of their way to ride on 15th Street as opposed to other streets.

Table 59 15th Street Cyclist Survey - Sense of Safety and Ease

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
The 15th Street cycle track has made cycling in and around Washington, D.C. safer for me as a cyclist.	1%	3%	16%	80%	191	2	96%	3.8
The 15th Street cycle track has made cycling in and around Washington, D.C. easier for me as a cyclist.	1%	1%	18%	80%	191	2	98%	3.8
The 15th Street cycle track has made cycling in and around Washington, D.C. more convenient for me as a cyclist.	1%	1%	20%	78%	188	4	98%	3.7
I feel safer cycling on 15th Street because of the cycle track.[1]	1%	2%	27%	70%	89	0	97%	3.7
The 15th Street cycle track has made cycling on 15th Street easier for me as a cyclist.[1]	1%	1%	16%	82%	89	0	98%	3.8
The 15th Street cycle track has made cycling on 15th Street more convenient for me as a cyclist.[1]	1%	2%	15%	82%	88	1	97%	3.8
The 15th street cycle track is a useful connection for me in getting places I want to go.	1%	0%	17%	82%	191	2	99%	3.8
I would go out of my way to ride on 15th Street as opposed to other streets.	3%	4%	40%	53%	190	1	93%	3.4

[1] Only asked of respondents who indicated they had cycled on 15th Street before the cycle track was installed.

Comfort

Cyclists generally indicated that they felt comfortable riding in the cycle track. Nearly all respondents (97 percent) indicated that the plastic flex-posts between the cycle track and parking and traffic lanes make them feel safe. When asked about the width of the cycle track, 92 percent indicated that the cycle track is wide enough when traveling northbound, while 85 percent indicated the same when traveling southbound. Three in four cyclists indicated that there is enough width for a fast cyclist to pass a slower cyclist. Cyclists also expressed a stronger "liking" for riding in the cycle track north of Massachusetts Avenue (where 15th Street is a one-way street). Table 60 provides cyclist survey results on level of comfort factors.

Table 60 15th Street Cyclist Survey - Sense of Comfort

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
The plastic flex-posts between the parking/traffic lanes and the cycle track make me feel safer when riding in the cycle track.	2%	2%	31%	66%	186	5	97%	3.6
When traveling southbound (riding closest to the curb), I feel that the cycle track is wide enough.	6%	9%	41%	44%	180	11	85%	3.2
When traveling northbound (riding closest to parked vehicles), I feel that cycle track is wide enough.	3%	5%	41%	51%	185	6	92%	3.4
The cycle track is wide enough for a fast cyclist to comfortably pass a slow cyclist.	5%	20%	45%	30%	188	2	75%	3.0
I like riding on the cycle track north of Massachusetts Avenue (more residential area).	1%	2%	23%	74%	166	24	98%	3.7
I like riding on the cycle track south of Massachusetts Avenue (downtown area).	1%	10%	37%	52%	164	25	88%	3.4

Debris in the Cycle Track

Cyclists were asked several questions about debris in the cycle track. As shown in Table 61, cyclists were split on whether snow, leaves, and other debris were a regular problem in the cycle track. Twelve cyclists indicated that they had experienced collisions or near-collisions with sticks or branches from trees in the cycle track.

Table 61 15th Street Cyclist Survey - Debris

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
During the winter, snow is quickly removed from the cycle track.	21%	38%	31%	10%	48	143	42%	2.3
Leaves and other debris in the cycle track are a regular problem.	15%	41%	33%	10%	162	28	44%	2.4

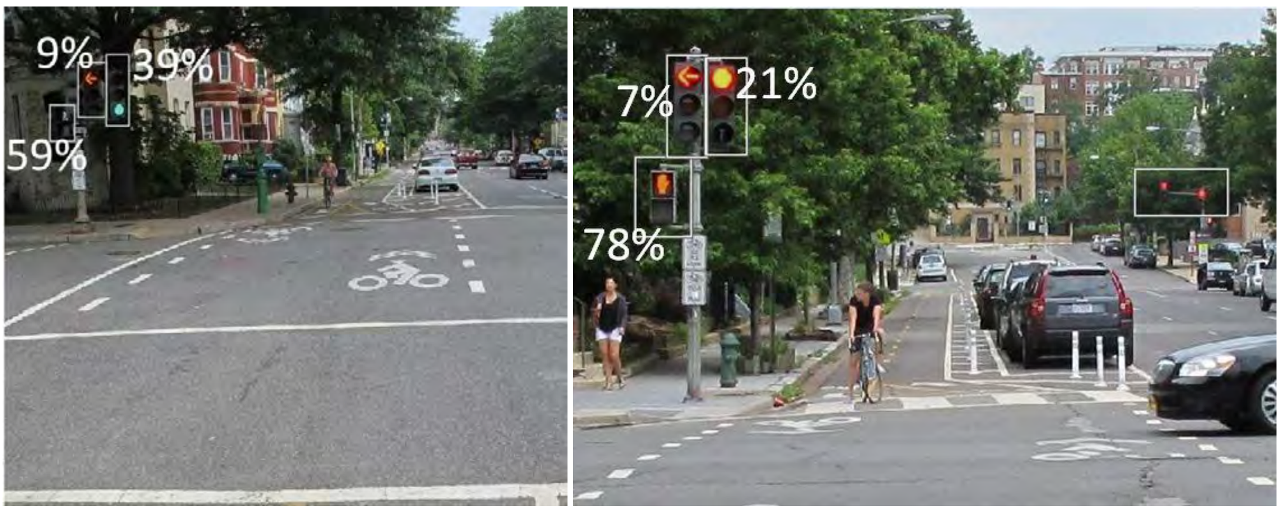
Understanding and Compliance

Cyclists were asked a series of questions about their understanding and use of the new facilities, including what signal they should follow and whether they have had any collisions or near-collisions.

Signal Selection

To assess cyclists' understanding of which traffic signal that they should follow when riding in the 15th Street cycle track, survey respondents were shown pictures of two intersections along the route and asked to select the signal at each that applies to them as a cyclist. A sign on each signal post instructs cyclists to follow the pedestrian head signal (although it is not necessarily legible in the photographs). The pictures and respondent selections to the question are provided in Figure 29.

Figure 29 15th Street Cyclist Survey - Signal Selection



The question text was as follows: "In the picture below, click on the traffic display that you would look at to know when it is your turn to proceed through the intersections. Assume you are traveling in the direction the picture is taken." Multiple selections were allowed. In each case, the pedestrian signal is located on the bottom left. While the majority of respondents answered correctly (the pedestrian signal controls bicycle movements), a significant percentage indicated they would follow the motor vehicle signal (21 percent and 39 percent). This is potentially a critical misinterpretation because the green ball indication stays active for through traffic when the left-turn arrow allows protected left turns across the two-way cycle track. Cyclists following the green ball indication would be at risk. Some respondents indicated that they use the left-turn arrow for their indication. If used in conjunction with the through signal, this is potentially a correct response. Overall, the survey responses reveal some potential problems with controlling cyclists with the pedestrian signal indication. The survey did not ask a similar question for SB traffic (which can only see pedestrian indications).

Conflicts, Collisions, and Near-Collisions

Table 62 provides the stated frequency of collisions and near-collisions with various road users or other objects. Of 164 respondents, half or more indicated that they had experienced near-collisions with a pedestrian (54 percent) or a turning motor vehicle (53 percent). Cyclists reported being involved in collisions with other cyclists, pedestrians, turning motor vehicles, and parked motor vehicles. Again, the definition of near-miss is self-interpreted and can include a wide range of interactions. Several respondents indicated that they had been involved in collisions with non-moving objects and "something else"; these respondents were able to specify the object involved in the collision and tree branches, sticks, and potholes were the most frequently cited. In comparison, the video review revealed that nearly 17% of cyclists encountered obstacles (including pedestrians, turning vehicles, and cross traffic) to navigate around, though relatively few near-collisions were observed (see "Cyclist Collisions and Near Collisions" in the 15th Street Video Analysis section).

Table 62 15th Street Cyclist Survey - Stated Frequency of Collisions and Near-Collisions

	Collision		Near-Collision	
Another cyclist	3	2%	58	29%
A pedestrian	8	4%	106	54%
A turning motor vehicle	5	3%	104	53%
A parked motor vehicle	3	3%	21	11%
A delivery truck	0	0%	37	19%
A non-moving object	5	3%	15	8%
Something else	3	2%	10	5%

Cyclists were asked how often they encountered certain barriers or potential conflicts as they ride in the cycle track. As shown in Table 63, of the scenarios posed, cyclists most commonly encountered pedestrians waiting in the cycle track and walking in the cycle track.

Table 63 15th Street Cyclist Survey - Stated Frequency of Cycle Track Barriers/Encounters

Please indicate how often you have observed the following to happen on your trips on the 15th Street cycle track:	Never	Rarely	On Most Trips	On Almost Every Trip	Number of Respond.	No Opinion
Passenger cars parked in the cycle track.	34%	62%	4%	1%	190	1
Passenger cars loading and unloading in the cycle track.	18%	64%	16%	2%	190	1
Delivery vehicles loading and unloading in the cycle track.	16%	64%	17%	4%	187	3
Motor vehicles driving in the cycle track.	66%	32%	2%	0%	190	1
Motor vehicles waiting in the cycle track to make right or left turns.	27%	41%	22%	9%	188	3
Pedestrians walking in the cycle track.	3%	41%	36%	19%	190	1
Pedestrians waiting to cross 15th Street standing in the cycle track rather than on the sidewalk.	2%	27%	44%	27%	190	1
Too many cyclists trying to ride in the cycle track.	24%	60%	12%	4%	187	4

Intersection of Pennsylvania Avenue and 15th Street

The intersection of Pennsylvania Avenue and 15th Street is the intersection of two new bicycle facilities, the center bike lanes on Pennsylvania Avenue and the cycle track on 15th Street. Respondents of both surveys who recalled riding a bicycle through the intersection (240) were asked a series of questions about the intersection. Overall, 87 percent of respondents indicated that the intersection is an important connection to getting where they want to go.

Asked about the bicycle signals at the intersection, 75 percent of the respondents agreed that, when waiting to cross 15th street as a cyclist, the bike signal is clearly visible; while 84 percent indicated that they are able to make it through the intersection during the time the bike signal remains green. However, fewer than half of respondents (49 percent) agreed that they never encounter motor vehicles in the intersection when the bike signal is green. Sixty-nine percent indicated that they have adequate space to wait safely for the signal to turn green. A green bike box at the intersection for eastbound cyclists from 15th Street could help to address this issue.

Resident Survey

The 15th Street Resident Survey and the 16th Street/U Street/New Hampshire Avenue Resident Survey asked the same questions about the 15th Street cycle track. Responses from both mailings are combined in the discussion below.

Sample Characteristics and General Opinions

Home ownership among respondents was at 52 percent of the sample, while 93 percent did not have children. Eighty-four percent work outside their home zip code.

Table 64 provides general opinions from residents on their neighborhood and bicycling. Respondents nearly all indicated that they believe their neighborhood has improved in the past two years (94 percent). About four in five respondents agreed that D.C. should be investing in projects that encourage people to ride bicycles for transportation and that bicycling is an important part of the Washington, D.C. transportation system. Fewer than half indicated that bicycling in D.C. is currently safe, and 89 percent felt D.C. should be investing in projects that improve the safety of bicycling.

Table 64 15th Street Resident Survey - General Opinions on the Neighborhood, Bicycling, and Investment

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
My neighborhood has improved in the last 2 years.	3%	4%	33%	61%	756	104	94%	3.5
Washington, D.C. should be investing in projects that encourage more people to ride bicycles for transportation.	8%	12%	30%	50%	789	70	81%	3.2
Bicycling is an important part of the Washington transportation system.	6%	13%	34%	47%	802	57	81%	3.2
Bicycling in Washington, D.C. is safe.	20%	36%	37%	8%	767	93	45%	2.3
Washington, D.C. should be investing in projects that improve the safety of bicycling.	5%	6%	30%	59%	801	60	89%	3.4

Support of Cycle Track

A strong majority of residents indicated that they support the facility and believe that they are frequently used by cyclists, as shown in Table 65. Asked about their general support for the cycle track, 84 percent of respondents indicated that they support the facility, while nearly as many (83 percent) indicating that the cycle track is a valuable asset to the neighborhood. More than nine out of ten respondents (91 percent) indicated that they see many people riding bicycles in the cycle track.

Table 65 15th Street Resident Survey - Support for Cycle Track

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I support the 15th Street cycle track.	10%	6%	22%	62%	804	45	84%	3.4
The cycle track on 15th Street is a valuable asset to my neighborhood.	10%	7%	24%	59%	782	63	83%	3.3
I see many people riding bicycles in the 15th Street cycle track.	3%	5%	26%	65%	796	50	91%	3.5

Motorist Experience with the Cycle Track

Of the resident survey respondents, 73 percent (604) indicated that they had driven on 15th Street in the past year, while 387 (46 percent of all respondents) indicated that they drive on 15th Street at least once per week. Sixty percent indicated that they own one or more cars.

For the purposes of this analysis, only residents who indicated that they own a motor vehicle were included as "motorists" (full results for all respondents that indicated that had driven on 15th Street in the past year are included in Appendix D3). As seen in Table 66, most respondents indicated that there are fewer cyclists in the car lanes now (82 percent), and 38 percent felt that traffic congestion is worse as a result of the cycle track. Most (92 percent) indicated that they like that bicycle and motor vehicles are separated with the cycle track.

Asked about the inconvenience caused by having to wait for a green arrow to make a left turn off of 15th Street, just over half of respondents indicated that it was a major inconvenience. Sixty-six percent indicated that turning off of 15th Street into alleys, driveways, and parking garages is difficult with the cycle track, although a similar number (60 percent) felt that intersection signals, signs, and street markings make it clear who has right-of-way at intersections.

Table 66 15th Street Resident Survey – Driving Questions

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I think there are fewer cyclists riding in the car lanes since the cycle track was installed.	7%	11%	32%	50%	419	43	82%	3.3
My perception is that traffic congestion has gotten worse as a result of the cycle track.	30%	32%	18%	20%	403	58	38%	2.3
Overall, I like that bicycles are separated from the motor vehicle traffic.	3%	5%	31%	61%	449	15	92%	3.5
It is a major inconvenience that drivers must wait for a green arrow before turning left off of 15th Street.	23%	24%	24%	29%	441	24	53%	2.6
Turning off 15th Street into alleys, driveways, and parking garages is difficult with the cycle track.	11%	23%	36%	31%	379	87	66%	2.9
Intersection signals, signs, and street markings make it clear who has the right-of-way (bike or cars) at intersections on 15th Street.	15%	25%	37%	23%	447	18	60%	2.7

Cyclist Experience with the Cycle Track

Of respondents to the 15th Street Resident Survey, 308 (37 percent) rode a bicycle on 15th Street in the past year, while 209 (25 percent) ride on 15th Street at least once per week. Of this sample, the responses were very favorable, with 92 percent indicating that they feel safer cycling on 15th Street with the cycle track; 94 percent feel it is easier and an equal number feel it's more convenient with the cycle track. Ninety percent feel the cycle track is a useful connection for getting them places they want to go. As with the cyclist intercept survey, slightly more respondents indicate they like riding on the cycle track north of Massachusetts Avenue than south of Massachusetts Avenue (95 percent to 86 percent). Responses to questions about bicycling on 15th Street are included in Table 67.

Table 67 15th Street Resident Survey – Bicycling Questions

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
I feel safer cycling on 15th Street because of the cycle track.	2%	6%	15%	78%	323	7	92%	3.7
The 15th Street cycle track has made cycling on 15th Street easier for me as a cyclist.	1%	4%	16%	78%	319	11	94%	3.7
The 15th Street cycle track has made cycling on 15th Street more convenient for me as a cyclist.	1%	5%	18%	76%	317	14	94%	3.7
The 15th street cycle track is a useful connection for me in getting places I want to go.	3%	7%	28%	63%	302	28	90%	3.5
I like riding on the cycle track north of Massachusetts Avenue (residential area).	3%	2%	22%	73%	282	49	95%	3.7
I like riding on the cycle track south of Massachusetts Avenue (downtown area).	3%	11%	33%	53%	262	68	86%	3.4

Pedestrian Experience with the Cycle Track

Ninety-three percent of resident respondents (758) indicated that they had walked on 15th Street in the past year, while 79 percent indicated that they do so at least once per week. Pedestrian responses from the resident survey are included in the discussion of the pedestrian intercept survey, with which they largely agreed.

Pedestrian Intercept Survey

In addition to the 758 respondents to the resident survey that indicated they walked on 15th Street in the past year, a pedestrian intercept survey was conducted of pedestrians walking along or across 15th Street. The intercept survey yielded 130 responses, and answers to both the pedestrian-related resident surveys and pedestrian intercept surveys are included in Table 68.

Among the positive findings from pedestrians are that 80 percent agree that there are fewer cyclists riding on sidewalks now, while 76 percent agree that the cycle track has made the streetscape better when walking on the sidewalk. Pedestrians were also asked about the leading pedestrian indication, which provides them several seconds of walking time before the traffic signal for cars turns green, and 94 percent of pedestrians indicated that they like this feature. The vast majority of respondents (94 percent) indicated that they support public investment in bicycling facilities.

Pedestrians were also asked about their agreement on whether crossing 15th Street is more difficult or if they feel safer when crossing 15th Street with the cycle track. For both questions, pedestrians had mixed responses, with 43 percent agreeing that crossing is more difficult and 45 percent indicating that they feel safer crossing 15th Street now. Only 46 percent of pedestrians stated that cyclists generally stop for pedestrians, while about two-thirds agreed that intersection signals, signs, and street markings make it clear who has the right-of-way. Table 68 presents the pedestrian questions from the intercept survey and neighborhood survey.

Table 68 15th Street - Pedestrian Questions

	Strongly Disagree (1)	Somewhat Disagree (2)	Somewhat Agree (3)	Strongly Agree (4)	Number of Respond.	No Opinion	% Agree	Mean
Based on my observations, there are fewer cyclists riding on the sidewalk after the cycle track was installed.	9%	11%	40%	41%	794	119	80%	3.1
I believe that the cycle track has made the streetscape better when walking on the 15th Street sidewalk.	10%	14%	37%	40%	781	131	76%	3.1
I like that the walk signal appears a few seconds before the traffic signal turns green for cars.	3%	3%	27%	66%	790	131	94%	3.6
I feel that crossing 15th Street as a pedestrian is more difficult now because of the cycle track.	32%	25%	28%	15%	870	44	43%	2.3
I feel safer crossing 15th Street now because of the cycle track.	19%	36%	28%	17%	690	220	45%	2.4
Based on my observations, cyclists in the cycle track generally stop for pedestrians at crosswalks.	28%	26%	33%	13%	860	68	46%	2.3
Intersection signals, signs, and street markings make it clear who has the right-of-way at intersections on 15th Street.	11%	24%	41%	24%	862	67	65%	2.8

Self-Reported Collisions or Near-Collisions

The pedestrian intercept survey asked respondents if they were involved or witnessed a collision or near-collision between a cyclist and a pedestrian in the cycle track. No respondents indicated that they had been involved in a collision with a cyclist, although four people indicated that they had witnessed a collision. Twenty-eight respondents (about 22 percent) indicated that they had been involved in a near collision with a cyclist.

Business Survey Analysis/Results (Pennsylvania Avenue and 15th Street Combined)

See discussion in Pennsylvania Avenue section for a combined summary of the business survey results for 15th Street and Pennsylvania Avenue.

VIDEO ANALYSIS

Cyclist Counts

Cyclist counts show the cycle track to have a directional split related to peak travel directions. In the morning, most traffic is southbound traffic, and in the evening, most traffic is northbound. During the peak hours (8:00 a.m. to 9:00 a.m. and 5:00 p.m. to 7:00 p.m.), 150 to 220 cyclist per hour were observed. Table 69 shows the cyclist counts at each intersection by hour and direction of travel.

Table 69 15th Street Video Analysis Cyclist Counts at Intersections

			Direction (Leaving Intersection)				
Intersection	**Date**	**Time**	**East[1]**	**West[1]**	**North**	**South**	**Total**
15th Street / R Street	7/14/2011 (Thursday)	7-8am	2	7	19	54	82
		8-9am	0	13	11	153	177
		5-6pm	1	16	139	29	185
		6-7pm	7	38	154	31	230
	7/16/2011 (Sunday)	12-1pm	1	8	41	40	90
		1-2pm	1	10	41	44	96
		Subtotal	*12*	*92*	*401*	*355*	*860*
15th Street / Massachusetts Avenue	7/14/2011 (Thursday)	7-8am	2	0	12	80	94
		8-9am	6	2	7	205	220
		5-6pm	3	11	153	38	205
		6-7pm	5	9	167	36	217
	7/16/2011 (Sunday)	12-1pm	2	1	29	39	71
		1-2pm	6	2	24	54	86
		Subtotal	*24*	*25*	*392*	*452*	*893*
15th Street / K Street	7/14/2011 (Thursday)	7-8am	0	1	12	63	76
		8-9am	3	8	27	155	193
		5-6pm	4	2	106	62	174
		6-7pm	2	3	123	46	174
	7/16/2011 (Sunday)	12-1pm	1	0	12	32	45
		1-2pm	0	0	17	44	61
		Subtotal	*10*	*14*	*297*	*402*	*723*
15th Street / Lower E Street	7/14/2011 (Thursday)	7-8am	24	3	32	37	96
		8-9am	56	9	24	62	151
		5-6pm	43	7	51	43	144
		6-7pm	29	4	41	78	152
	7/16/2011 (Sunday)	12-1pm	29	0	35	75	139
		1-2pm	32	0	37	75	144
		Subtotal	*213*	*23*	*220*	*370*	*826*
Total			***259***	***154***	***1,310***	***1,579***	***3,302***

[1] Cyclists leaving the cycle track and turning east or west are counted in this tally. Cross cyclists (who did not travel on the cycle track) are not counted, with the exception of 15th Street at Pennsylvania Avenue.

Other Users

Some non-cyclist users of the cycle track were observed. Their numbers were low. Several joggers and pedestrians with strollers were observed using the cycle track, as were rollerbladers, skateboarders, and wheelchair users; however, in each of these cases, only one to two users were observed for each group. Fifteen Segway riders were observed riding in the cycle track, with all but one of these observations occurring at the intersection of 15th Street and Pennsylvania Avenue. These are presumably tour groups. In addition, eight motor-scooters were observed in the cycle track during the hours reviewed.

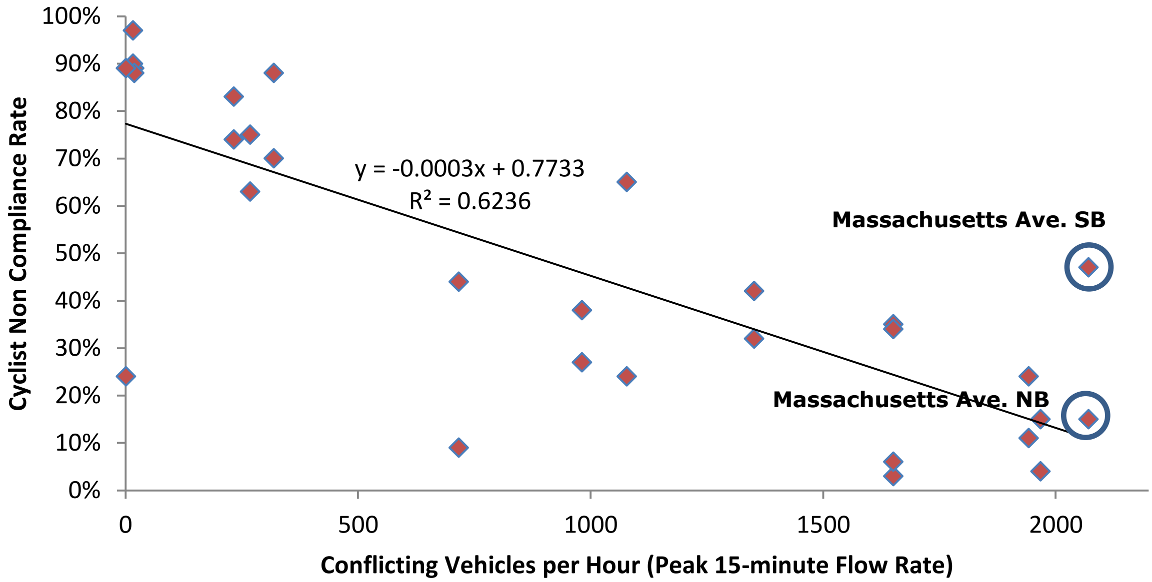
Cyclist Compliance with Signal

For each cyclist arriving at an intersection on a red signal, signal compliance was recorded. Overall, violations averaged 41 percent of those cyclists arriving on red; however, violations vary significantly by intersection and show a strong relationship to cyclist delay, progression, and cross street volumes. Figure 30 summarizes the total counts of cyclists, the counts by arrival phase, and the counts by type of violation.

Two intersections had particularly high violation rates. R Street is a low traffic one-way street with large periods of time when no cross-traffic is present, and experienced 74 percent violations. At the intersection of 15th Street and Pennsylvania Avenue, limited traffic enters or exits the parking facility to the west subject to Secret Service control, resulting in a "T" like intersection for cyclists traveling north and south. Cyclist violations were 83 percent at this location. At all other locations, violations were between 21 percent and 33 percent of cyclists arriving on red lights, including cyclists crossing 15th Street at Pennsylvania Avenue (33 percent violations).

Figure 30 shows a plot of the observed violation rate against the total conflicting entering peak 15-minute motor vehicle flow rate (in vehicles per hour, vph), based on data from each intersection for each study time period (7:00 a.m. to 9:00 a.m., 12:00 p.m. to 2:00 p.m., and 5:00 p.m. to 7:00 p.m.) . For a two-way cross street, the flow represents the sum of through vehicle peak 15-minute flow rate from both directions . These counts were taken from the turning movement counts conducted by Quality Counts. Note that the fitted linear regression line in the figure is intended to show the trend of the individual data points more clearly and is not the result of modeling analysis. The graph suggests a negative relationship between the conflicting volumes and compliance rate. The largest observed violation rates occur at the intersections with the lowest conflicting motor vehicle volumes.

Figure 30 Cyclist Non-Compliance Rate Versus Total Entering 15-minute Peak Hour Conflicting Flow Rate



The correlation between conflicting volume and cyclists' non-compliance rates is negative, and the data fit fairly well. Other factors also contribute to a cyclist's decision to cross during the red phase, such as gaps in cross street traffic progression and a cyclist's anticipated signal delay. The delay calculations used in the progression analysis were not sufficient to produce statistically significant results, but there is anecdotal evidence that signal delay affects compliance rates. For example, the intersection of 15th Street/Massachusetts Avenue has very high levels of conflicting traffic (2,071 vehicles during the a.m. peak period). However, cyclists traveling southbound on 15th Street experience over a minute of signal delay at Massachusetts Avenue, on average, resulting in nearly half of all cyclists (47 percent) violating the signal. Northbound cyclists, who experience better signal progression in general, were only observed to cross against the red phase about 15 percent of the time.

Table 70 15th Street Cyclist Signal Compliance and Violations

Date	Time	Dir.	Cyclist Count	Arriving on Green or Yellow	Arriving on Red	No Violation	Signal Violation, Red Signal	Signal Violation, Green Left-Turn Arrow[1]	Total Signal Violation	% Arrive on Red	% Violations
15th Street/Massachusetts Avenue											
7/14/2011	7-9am	NB	19	6	13	11	2	0	2	68%	15%
		SB	293	36	257	137	36	84	120	88%	47%
	5-7pm	NB	332	29	303	269	24	10	34	91%	11%
		SB	75	7	68	52	13	3	16	91%	24%
7/16/2011	12-2pm	NB	52	26	26	15	6	5	11	50%	42%
		SB	95	21	74	50	16	8	24	78%	32%
	Mass Sub		*866*	*125*	*741*	*534*	*97*	*110*	*207*	*86%*	*28%*
15th Street/K Street											
7/14/2011	7-9am	NB	42	3	39	38	1	-	1	93%	3%
		SB	220	67	153	101	52	-	52	70%	34%
	5-7pm	NB	211	131	80	52	28	-	28	38%	35%
		SB	112	22	90	85	5	-	5	80%	6%
7/16/2011	12-2pm	NB	23	3	20	17	3	-	3	87%	15%
		SB	75	25	50	48	2		2	67%	4%
	K Sub		*683*	*251*	*432*	*341*	*91*	*0*	*91*	*63%*	*21%*
15th Street/R Street											
7/14/2011	7-9am	NB	36	20	16	2	9	5	14	44%	88%
		SB	180	94	86	26	33	27	60	48%	70%
	5-7pm	NB	343	139	204	51	118	35	153	59%	75%
		SB	62	16	46	17	26	3	29	74%	63%
7/16/2011	12-2pm	NB	84	30	54	9	28	17	45	64%	83%
		SB	81	27	54	14	35	5	40	67%	74%
	R Sub		*786*	*326*	*460*	*119*	*249*	*92*	*341*	*59%*	*74%*
15th Street/Pennsylvania Avenue (Only Cyclists Crossing 15th Street to/from Pennsylvania Avenue)											
6/16/2011	7-9am	EB	77	36	41	31	10	0	10	53%	24%
		WB	44	18	26	9	8	9	17	59%	65%
	5-7pm	EB	71	19	52	38	14	0	14	73%	27%
		WB	74	24	50	31	13	6	19	68%	38%
6/18/2011	12-2pm	EB	61	18	43	24	19	0	19	70%	44%
		WB	52	9	43	39	3	1	4	83%	9%
	Penn Sub1		*379*	*124*	*255*	*172*	*67*	*16*	*83*	*67%*	*33%*
15th Street/Pennsylvania Avenue (Other Cyclists - Not Going to/from Pennsylvania Avenue)											
6/16/2011	7-9am	NB	74	55	19	2	17	-	17	26%	89%
		SB	52	44	8	1	7	-	7	15%	88%
	5-7pm	NB	39	18	21	2	19	-	19	54%	90%
		SB	112	75	37	1	36	-	36	33%	97%
6/18/2011	12-2pm	NB	46	29	17	13	4	-	4	37%	24%
		SB	124	87	36	4	32	-	32	29%	89%
	Penn Sub2		*447*	*308*	*138*	*23*	*115*	*0*	*115*	*31%*	*83%*
Total			***3,161***	***1,134***	***2,026***	***1,189***	***619***	***218***	***837***	***64%***	***41%***

[1] Signal violations on green motor vehicle left-turn arrows were not differentiated from general signal violations at the 15th Street/K Street intersection.

Motorist Turn Arrow Signal Compliance

At locations where a left-turn arrow controls motor vehicle left turns across the cycle track, motorist violations of the arrow were recorded. Only violations occurring during the walk (or flashing don't walk) pedestrian signal, when bicycles and pedestrians have the right-of-way in the intersection, were considered. For the two intersections on 15th Street reviewed for this type of compliance, 12 percent of all left-turning cars at 15th Street and Massachusetts Avenue turned on a red arrow and 5 percent of left-turning cars at 15th Street and R Street made the turn on a red arrow, as shown in Table 71.

Table 71 15th Street - Motorist Left-Turn Arrow Compliance and Violations

Date	Time	Violations	No Violation	Total Left Turns	% Violations
15th Street/Massachusetts Avenue					
14-Jul	7-8am	3	20	23	13%
	8-9am	2	25	27	7%
	5-6pm	11	49	60	18%
	6-7pm	4	56	60	7%
16-Jul	12-1pm	5	12	17	29%
	1-2pm	0	14	14	0%
Total		***25***	***176***	***201***	***12%***
15th Street/R Street					
14-Jul	7-8am	4	26	30	13%
	8-9am	6	35	41	15%
	5-6pm	1	109	110	1%
	6-7pm	5	109	114	4%
16-Jul	12-1pm	2	49	51	4%
	1-2pm	3	64	67	4%
Total		***21***	***392***	***413***	***5%***

Cyclist Collisions and Near-Collisions

During the thirty hours of video reviewed, no collisions were observed. There were also few conflicts observed.

- 15th Street at Massachusetts Avenue: Despite a lot of weaving and navigation around pedestrians, cross traffic blocking the bike lanes (during congestion), and northbound traffic turning left onto Massachusetts Avenue, no interactions were observed in which cyclists (or other road users) had to take an emergency action to avoid a collision.
- 15th Street at K Street: This intersection also contained many instances of cyclists weaving and navigating around pedestrians, cross traffic, and turning motor vehicles. One cyclist was observed making an abrupt stop to avoid a collision with a motor vehicle stuck in the bike lanes due to congestion, although the stop was not categorized as an emergency stop.
- 15th Street at R Street: We observed several conflicts between northbound cyclists and motor vehicles making left turns at 15th Street and R Street. In one instance, a cyclist was forced to abruptly maneuver around a taxi making a left turn on a red arrow, although the action was not categorized as an emergency change of direction. Three cyclists who continued north despite a

"DON'T WALK" pedestrian indication produced conflicts with motor vehicles making left turns: two of these required emergency actions to avoid a collision (in one case the cyclist stopped suddenly to allow the car to pass, and in the other the cyclist made a fast change of direction to move around the turning car).

Video reviewers also noted each time a cyclist had to navigate around motor vehicles or pedestrians as they rode in the cycle track. Cyclists encountered many obstacles at busier cross streets. For example, over a quarter of observed cyclists at the intersection of 15th Street and Massachusetts Avenue had to navigate around cross traffic in the cycle track—usually this was caused by cross traffic that had not cleared the intersection due to congestion. At 15th Street and K Street, 22 percent of observed cyclists had to navigate around cross traffic. Table 72 summarizes the types of cyclist encounters noted on 15th Street.

Table 72 15th Street Cyclist Obstacle Encounters

Encounter Type	Frequency	Rate
Bicyclist encounters a left-turning car coming from same direction	31	0.8%
Bicyclist encounters a left-turning car coming from opposite direction	44	1.1%
Bicyclist encounters cross traffic (including cars turning right)	531	13.2%
Bicyclist encounters pedestrian	59	1.5%
Bicyclist encounters right-turning car coming from same direction	8	0.2%
Bicyclist encounters right-turning car coming from opposite direction	2	0.0%
Combined	675	16.8%
Number of Observed Bicyclists	4,012	

15th Street at Alley between L Street and M Street

At the alley between L Street and M Street, which leads into a large parking facility, 710 cyclists were observed. Of those, 19 cyclists passed when a car was preparing to turn into or out of the alley. None of these interactions resulted in collisions or near-collisions, and in most cases, the motorist yielded until all bicycle traffic had cleared before proceeding.

Cyclist Use of Chicanes at 15th Street/R Street

Of cyclists recorded on the cycle track at 15th Street and R Street, 463 approached the intersection heading north. Chicane use was measured by noting cyclists that remained in the bike lane as it moved out toward the motor vehicle traffic lane. Sixty-four percent of cyclists used the chicane as intended.

Key Findings

- **The data indicate that more bicyclists began using 15th Street after the one-way cycle track was installed and, in general, even more began traveling along the corridor after the two-way cycle track was installed.** After the two-way cycle track was installed, there was a 205 percent increase in bicycle volumes (from before conditions) between P Street and Church Street during the p.m. peak hour, and there was a 272 percent increase in bicyclist volumes (from before conditions) between T Street and Swann Street during the p.m. peak hour.
- **Motor vehicle counts show that volumes have remained relatively constant on 15th Street before and after the bicycle facilities were installed.** Between September 2007 (before the bicycle facilities were installed) and July 2011 (after the two-way cycle track installation), there was a 4.0 percent increase in motor vehicle volumes between E Street and New York Avenue, a 10.1 percent increase in motor vehicle volumes between H Street and Massachusetts Avenue, and a 1.2 percent decrease in motor vehicle volumes between Rhode Island Avenue and U Street.
- **Motor vehicle operations show only minor changes before and after the bicycle facilities were installed.** Most segments remained at LOS D or E, based on the *Highway Capacity Manual 2000*'s urban streets method.
- **Overall, the bicycle facilities did not significantly change motor vehicle travel speeds along 15th Street**. Analysis of travel time runs done both before and after installation of the cycle tracks showed no significant difference in corridor travel time for motor vehicles.
- **The Danish Bicycle LOS analysis indicates that bicyclists experienced a better LOS after the new facilities were installed.** Before installation, 15th Street was rated as having Bicycle LOS D and E on the three study segments; after installation, 15th Street was rated as providing Bicycle LOS A and B. The model predicts that nearly all bicyclists will indicate being at least "a little satisfied" with the facilities on 15th Street after installation.
- **The BEQI index analysis ranked 15th Street as having "average" quality bicycle facilities before the cycle track installation and "high" to "highest" quality bicycle facilities after installation.** Before installation, 15th Street received scores of approximately 45 out of 100. After installation, 15th Street received scores of approximately 75 out of 100.
- **Bicyclists experience less delay on 15th Street between Lower E Street and I Street than between I Street and U Street.** Bicyclists riding at 15 mph between Lower E Street and I Street can achieve LOS D or better based on average travel speed, but bicyclists traveling between I Street and U Street generally experience significant signal delay.

- **The number of crashes involving bicyclists remained similar after the bicycle facilities were installed**, after accounting for the substantial increase in bicyclist volume. Thirteen crashes involving cyclists occurred in the first 14 months after installation of the two-way cycle track, compared to 20 crashes over the 4 years prior to cycle track implementation. As cyclist volumes approximately doubled over this same time period, this represents no significant change in crashes per cyclist. One year of data after installation does not provide conclusive information for the crash patterns occurring along the corridor. However, it appears that crashes involving bicyclists remain a relatively rare event along 15th Street. It is recommended that crash reports continue to be evaluated in future years.
- **There are potential issues with the existing design, which uses the pedestrian signal to control cyclist movements.** According to the survey responses, many cyclists (approximately 20–30 percent) watch the through motor vehicle green, which could result in conflicts with left-turning vehicles during the protected left-turn phase. In addition to comprehension, violations of the pedestrian signal by cyclists are high, especially by southbound cyclists.
- **Red-light running by cyclists is high, with over 40 percent of cyclists observed disobeying signals.** Compared to the data in the few published studies available on cyclist compliance with bicycle-specific traffic signals, this is a high violation rate, and is very high compared with motorist compliance. Violation rates differed considerably by intersection, and are highest at intersections with (1) low volumes of conflicting traffic and/or (2) high levels of signal delay.
- **Cyclists encounter many pedestrians and, during congested periods, it is not uncommon for cross traffic to block the intersection.** Generally, cyclists navigate around pedestrians and stopped traffic without needing to resort to emergency actions to avoid collisions. This appears to be a convenience, rather than safety issue, due in part to very low turning vehicle speeds.
- **Cyclists overwhelmingly feel that riding on 15th Street with the cycle track is much safer and easier now**, that it is a useful connection, and that they would go out of their way to ride on the cycle track as opposed to other streets.
- **Residents support investments that encourage people to bicycle for transportation and improve the safety of bicycling.** Over 80 percent of residents support the cycle track and view it as a valuable asset to the neighborhood.
- **Motorist attitudes are generally favorable toward the cycle track.** The like that it provides separate spaces for cars and bicycles, and most don't find that traffic congestion has gotten worse. However, just under half of motorists find waiting for a green arrow to make a left turn to be a major inconvenience, and about two-thirds find turning off 15th Street into alleys to be difficult with the cycle track.

- **Pedestrians indicated that they are encountering fewer cyclists on sidewalks**, although some do not feel cyclists are yielding to pedestrians in the crosswalks.

Preliminary Recommendations

Based on these findings, the team makes the following preliminary recommendations:

- Add bicycle signal heads to control bicycle traffic for both northbound and southbound movements, rather than using pedestrian signals. Many cyclists do not understand that they should use the pedestrian signals as their traffic control. Installing bicycle signals at these intersections, which will require additional or modified FHWA experimentation requests, will improve signal control clarity and potentially reduce crash risks.
- Consider installing a flashing yellow left turn signal for motorists. A flashing yellow arrow for left-turning motorists may help convey through bicycle priority and reduce risk of crashes. Implementing this as an experimental treatment at one or more intersections would allow a review of its effectiveness before full corridor implementation.
- Consider using green colored pavement at unsignalized conflict areas (e.g., driveway crossings), in addition to the existing stencils, to alert motorists of the presence of the bicycle facility.
- Green pavement might also be appropriate through intersections to provide a visual cue to motorists to watch for potential conflicts and not block the intersection while waiting to turn.
- Improve pavement conditions for southbound cyclists through repaving, widening, and/or removing the gutter.
- Improve signal progression for southbound cyclists north of Massachusetts Avenue to the extent possible. Traffic signals on the one-way portion of 15th Street are timed for one-way northbound traffic, which results in frequent stops for southbound cyclists. Signals should be retimed to accommodate bicycle traffic in both directions, although this must be balanced with the need to maintain northbound progression for motor vehicles, and potentially cross-street progression.
- Add pedestrian islands to crossings north of Massachusetts Avenue. Providing storage for crossing pedestrians will reduce conflicts between cyclists and pedestrians standing in the cycle track.
- Consider using a green bike box at the intersection of Pennsylvania Avenue/15th Street for eastbound cyclists to provide cyclists with a clearly marked location to wait.
- DDOT should consider a cyclist education and enforcement campaign to encourage compliance with traffic signals.

Section 7
References

REFERENCES

1. R.O. Phillips, T Bjornskau, R. Hagman, and F. Sagberg, "Reduction in car-bicycle conflict at a road-cycle path intersection: Evidence of road user adaptation?", *Transportation Research Part F*, vol. 14 (2011), p. 87-95.

2. *Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14)*
Federal Highway Administration, April 15, 2011

3. *Highway Capacity Manual*
Transportation Research Board of the National Academies, 2010

4. *Pedestrian and Bicycle Level of Service on Roadway Segments*
Søren Underlien Jensen (Trafitec), January 2007

5. *Bicycle Environmental Quality Index Data Collection Manual*
San Francisco Department of Public Health Environmental Health Section
http://www.sfphes.org/publications/BEQI_Manual_Draft.pdf

6. *Bicycle Environmental Quality Index (BEQI) Draft Report 2009*
San Francisco Department of Public Health Environmental Health Section Program on Health, Equity and Sustainability, 2009
http://www.sfphes.org/HIA_Tools/BEQI_Report_2009.pdf

7. *Highway Capacity Manual*
Transportation Research Board of the National Academies, 2000

8. K.L. Manfreda, M. Bosnjak, J. Berzelak, I. Haas and V. Vehovar, "Web surveys versus other survey modes", *International Journal of Market Research* 50, 2008, 79-104.

9. T.H. Shih and X.T. Fan, "Comparing response rates from Web and mail surveys: A meta-analysis", *Field Methods* 20, 2008, 249-271.