EVALUATION OF SHARED LANE MARKINGS IN MIAMI BEACH, FLORIDA

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FDOT Contract BDM10 977-01
Final Report

University of North Carolina
Highway Safety Research Center

March 2012

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of Shared Lane Markings in Miami Beach, Florida		5. Report Date April 2012
		6. Performing Organization Code
7. Author(s) William W. Hunter, Raghavan Srinivasan, and Carol A. Martell		8. Performing Organization Report No.
9. Performing Organization Name and Address Highway Safety Research Center University of North Carolina CB# 3430, 730 MLK Blvd. Chapel Hill, NC 27599-3430		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. BMD10 977-01
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street, MS-30 Tallahassee, FL 32399		13. Type of Report and Period Covered Draft Final Report 11/24/09-5/24/12
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report is a before-after evaluation of shared lane markings on Washington Avenue in Miami Beach, FL, which requested and received permission from the Federal Highway Administration (FHWA) to conduct a pilot study of shared lane markings. The markings were placed in the center of the outside lane to encourage bicyclists to take control of the lane. The experimental design was to collect videotape data of bicyclists interacting with motorists before and after the installation of the markings. After the markings were placed, approximately 20 percent of the bicyclists rode over the shared lane marking, and another 10 percent avoided the marking when they approached. Thus, 30 percent tracked over or very near the shared lane marking. Some 44 percent were positioned near the center of the lane when interacting with a motor vehicle after the markings were placed on the street. From an analysis of the spatial data, there was an increase of about 10.5 inches between bicycles and parked motor vehicles after the introduction of the shared lane markings. In addition, more bicyclists were riding out of the door zone. The spacing increased about 4.5 inches between motor vehicles in the travel lane and parked motor vehicles. All of these findings were statistically significant. Approximately 2 to 3 percent of bicyclists were riding in the wrong direction in the street, and there was no change after the shared lane marking. However, the percentage of bicycles using the sidewalk decreased from about 55 to 45 percent, and this reduction was statistically significant. Whereas about 10 percent of bicyclists weaved between motor vehicles in the traffic lane and parked motor vehicles in the before period, some 14 percent did so in the after period. This maneuver greatly increases the risk of a dooring crash.

17. Key Word	18. Distribution Statement
Shared lane markings, bicycle dooring crashes	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	63	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

The research was funded by the Florida Department of Transportation (Contract BDM10 977-01), and the contract manager was Dennis Scott. The original project idea came from David Henderson of the Miami-Dade Metropolitan Planning Organization. From the City of Miami Beach, Xavier Falconi, Christine Bettin, and Josiel Ferrer were extremely helpful in all stages of the project. Dan Levitt from the Highway Safety Research Center provided valuable assistance in obtaining spacing data from images.

EXECUTIVE SUMMARY

BACKGROUND

A prior Miami-Dade Metropolitan Planning Organization examination of bicycle-motor vehicle traffic crashes showed a large number of bicycle "dooring" crashes along Washington Avenue in Miami Beach. A "dooring" crash is one in which the door of a parked car is opened suddenly into the path of a bicyclist that is riding too close to the parking lane. The bicyclist can be injured by striking the door or by swerving further into the travel lane and being struck by a passing vehicle. Between 2000 and 2009 (latest data available from Miami-Dade MPO), 52 bicycle crashes were reported along Washington Avenue between 12th St and Dade Blvd (approximately 1.0 mile). Of those, at least 11 (21 percent) involved a bicyclist striking the open car door of a parked vehicle.

As a proposed solution to this problem, the City of Miami Beach requested and received permission from the Federal Highway Administration (FHWA) to conduct a pilot study on Washington Avenue to evaluate shared lane markings. Shared lane markings, specifically the "bike and chevron" marking, were placed in the center of the outside lane on Washington Avenue. Washington Avenue is a main arterial traffic corridor for both motorists and bicyclists and runs north and south on the east side of Miami Beach. A residential neighborhood is located to the east and a commercial and mixed-use entertainment district is located to the west. These areas are popular tourist destinations and attract a large amount of traffic. The average daily traffic is approximately 18,000 vehicles per day at the northbound traffic data collection site and approximately 9,000 vehicles per day at the southbound traffic data collection site. Washington Avenue has recently been renovated with a comprehensive construction and traffic flow plan: upgrades included streetscapes, drainage, and water-mains; replacement of sidewalks; and new curbs and gutters. The street has two travel lanes in each direction, left turn lanes at many of the intersections, and parking on both sides of the street. The typical cross-section is an 8-foot parking lane, two 11-foot travel lanes, an 11-foot median, two 11-foot travel lanes, and an 8-foot parking lane. The entire length of the Washington Avenue study area, from South Pointe Drive to Dade Boulevard, is about 2 miles long.

The Washington Avenue speed limit is 30 miles per hour, and the street is a main transit corridor. In addition, many taxis operate on the street, and double parking and parked vehicle turnover is frequent. The situation can be somewhat chaotic for bicyclists when traffic is heavy, and bicyclists frequently ride between vehicles in the travel lane and parked vehicles. There are bicyclist interactions with pedestrians crossing the street at mid-block and intersections. The mix of bicyclists is extremely variable and includes a considerable number of tourists. The cyclist skill level is also variable, and it would appear that the vast majority of bicyclists are recreational.

The City decided that the most appropriate placement for the shared lane markings was in the middle of the lane near parked vehicles, which would place the center of the marking approximately 13.5 feet from the curb. The City felt that normal spacing of 11 feet from curb next to parked vehicles would not allow enough room for motor vehicles to pass bicycles in the lane next to parking. Middle-of-the-lane placement would allow bicyclists tracking over the markings to be out of the door zone and also to take control of the lane. Figure S1 shows a view of a symbol just past an intersection with a bulb-out and no parking. The block lengths were such that shared lane markings were typically placed near an intersection crosswalk, at mid-block, and near the end of the block. Spacing was approximately 200-250 feet in such a situation.

Figure S1. View of sharrow in middle of lane.

The decision was made to use thermoplastic for the markings. Unfortunately, the contractor who was hired to install the shared lane markings decided to use a thick application, and the result was a symbol that was rough or bumpy in appearance (Figure S2).

Figure S2. View of bumpy sharrow.

The appearance was pointed out to City officials relatively soon after installation, and the decision was made to proceed with data collection to see if the roughness would have an effect on where the bicyclists rode in the vicinity of the marking. As will be shown in the results section of the report, many bicyclists chose to avoid riding over the marking. Several months after completion of the first set of "after" data, the City was able to get the contractor to attempt to smooth the roughness, and a second set of "after" data was collected to see if the smoothing had an effect on riding position, but the results were about the same.

The City conducted several types of educational messaging to notify the public about the placement of the shared lane markings and their intent. These included: door-to-door outreach for businesses along Washington Avenue using an informational flyer; articles in the MB Magazine; information on the City's website; in an electronic newsletter to City residents; and through social media outlets. The Project was presented to the Washington Avenue Neighborhoods Association (WANA) at their August 11, 2010, meeting. The informational flyer was also distributed via WANA and any other impacted neighborhood and homeowners associations. A shared bike program started about the same time, and information about the shared lane markings was provided in the safety tips brochure in the basket that accompanied the bike rental.

METHODS

The experimental design was to collect videotape data of bicycles and motor vehicles traveling along Washington Avenue before and after the installation of the shared lane markings. While it would have been advantageous to have used an experimental design with comparison data, no adequate comparison sites were available. This is often the case in bicycle safety studies because slight differences in the traffic flow, grade, pavement surface, or some other variable can greatly influence outcomes related to the bicyclist. One way to possibly obtain a comparison site is to install a treatment on part of a route and to use the remainder as a comparison. However, when a community is installing a treatment, almost invariably, the desire is to install along the entire route where the cross-section is continuous, and this was the case for Washington Avenue.

The videotaping was done by local videographers during several time periods before and after installation. A camera was set up on a tripod at an intersection bulb-out location in line with the outside edge of a parked motor vehicle to provide a clear view of oncoming bicycles and motor vehicles. Zooming was used to follow the bicycles for several hundred feet, typically from the beginning of the block until the end. Videotape was collected from both directions of travel. The setup was at 16th Street for southbound bicyclists and at 10th Street for northbound bicyclists. The vast majority of "before" data were collected from April through July of 2010. The shared lane markings were placed on the street in January 2011, and the first set of "after" data were collected in March of 2011. A second set of "after" data was collected in January 2012. Data were collected at various times of the day on both weekdays and weekends, when it was not raining.

Images were obtained from videotape for both the northbound and southbound directions for the following two before and after conditions: (1) bicycle to parked motor vehicle (about 450 images in each direction) and (2) motor vehicle in the travel lane to parked motor vehicle with no bicycles present (about 200 images in each direction). SigmaScan® was used to obtain the necessary spacing measures from these images. For the bicycle to parked motor vehicle, the spatial measures were from the hip of the bicyclist to the outside edge of the driver's side-view mirror of the parked motor vehicle. For the motor vehicle in the travel lane to parked motor vehicle, the spatial measures were from the approximate midpoints of the motor vehicles. In addition, the distances from the curb for both the front and rear tires of parked motor vehicles were measured by local data collectors to determine if the shared lane markings had an effect on how the vehicles parked. The videographers also used logs to record both wrong-way and sidewalk riding by bicyclists.

In addition to obtaining spacing data from the images described above, coding of the videotapes was performed to collect information about the bicyclist (i.e., approximate age, gender, and placement within the lane) and to examine the operations of bicycles and motor vehicles when a motor vehicle was following or passing a bicycle in the presence of parked motor vehicles, as well as interactions between bicycles and parked motor vehicles (e.g., near-dooring events, motorists pulling in or out of parking spaces, etc.). The bicycle was the basic unit of analysis. Researchers systematically selected a pro rata share from each before and after videotape to accumulate the desired number of bicyclists and events, amounting to approximately 600 bicyclists in both the before and after periods and balanced by northbound versus southbound direction.

Chi-square tests were performed to examine the distributions of variables before and after placement of the shared lane markings. Analysis of variance (ANOVA) models were used to study the effect on spacing and other performance measures.

SUMMARY AND DISCUSSION

The installation of the shared lane markings on Washington Avenue was associated with a variety of results. The chaotic nature of the street in times of busy traffic and the speed of some of the motor vehicles are likely to be factors in producing these results.

Approximately 20 percent of the bicyclists rode over the shared lane marking and another 10 percent avoided the marking when they approached. It is certainly plausible that the bicyclists avoiding the marking were bothered by the rough appearance mentioned earlier. Thus, 30 percent tracked over or very near the shared lane marking. Some 44 percent were positioned near the center of the lane when interacting with a motor vehicle after the markings were placed on the street. Such placement would locate these bicyclists out of the door zone.

Some 20 percent of female bicyclists rode over the marking and 8 percent avoided, and comparable values for male bicyclists were 18 and 9 percent. Some 7 percent of bicyclists avoided the marking in the northbound direction compared to 11 percent in the southbound direction.

From an analysis of the videotape data, the following operational results were statistically significant:

- Almost 30 percent of bicyclists were first observed near the center of the lane in the after period, as opposed to 10 percent in the before period. The percentage positioned nearer to parked vehicles than the center of the lane decreased from 71 to 55 percent.
- The opportunity was often present for bicyclists to weave between motor vehicles in the travel lane and parked motor vehicles, either in busy traffic or with a motor vehicle double parked. Whereas about 10 percent weaved in the before period, some 14 percent did so in the after period.
- The parking spaces tended to be almost fully occupied most of the time data were collected. About 29 percent of bicyclists rode in empty parking spaces before the shared lane markings compared to 21 percent after. Female bicyclists were less likely to ride in empty parking spaces – 25 percent before and 15 percent after – as compared to male bicyclists – 30 percent before and 23 percent after. There was also a considerable difference by direction of travel. In the northbound direction, 39 percent of bicyclists rode in empty parking spaces before the markings and 29 percent after. For the southbound direction, the values were 20 percent before and 13 percent after. This is possibly a function of the street layout, as there is a mid-block bulb-out in the southbound direction at a bus stop. The bulb-out does not exist mid-block for the northbound direction.
- In regard to the bicycle interactions with parked motor vehicles, there were some positive results. In the after period, the existence of open parked vehicle doors was halved, and there were half as many motor vehicles pulling into or out of a parking space. Near-doorings, or the opening of a door as a bicyclist approached, were few in number but also reduced. The percentage of double-parked vehicles stayed about the same. However, it is not clear whether these changes were more related to street conditions (exposure) than to the existence of the shared lane markings.
- The definition of yielding, where a party had to *give way* to the other, was rather robust. Bicyclist yielding (i.e., changed direction or speed to give way to a motor vehicle) decreased from 8.5 percent in the before period to 2 percent in the after period. Motorist yielding (i.e., changed direction or speed to give way to a bicycle) increased from 4 percent in the before period to 5 percent in the after period. The statistically significant differences were mostly attributable to less bicyclist yielding in the after period. When gender was examined, female bicyclists yielded in 9.3 percent of the interactions before and 1.5 percent after. Male bicyclists yielded in 8.5 percent of the interactions before and 2.7 percent after. Controlling for direction of travel showed little differences.
- When a bicyclist had an interaction with a motor vehicle, pedestrian, or another bicycle, 44 percent of bicyclists were positioned near the center of the lane (as opposed to being nearer to parked vehicles) in the after period compared to 25 percent in the before period. Conversely, the percentage near parked vehicles

decreased. The statistically significant differences were mostly attributable to the increase in bicyclists near the center of the lane. For female bicyclists, 24 percent were positioned near the center of the lane before and 51 percent after. In the northbound direction, 21 percent of bicyclists were positioned near the center of the lane before and 41 percent after. In the southbound direction, 28 percent of bicyclists were positioned near the center of the lane before and 48 percent after.

- In examining the bicyclist responses during their interaction with motorists, pedestrians, and other bicyclists, bicyclists were able to keep moving safely (i.e., no change in speed or direction) about 28 percent of the time overall, with not much change by period. Lane changing decreased from 14.5 percent before to 9 percent after. Full stops decreased from 0.9 percent before to 0.2 percent after. Major direction changes decreased from 3 percent before to 0.5 percent after. However, bicyclists moving unsafely increased from 6 percent in the before period to more than 11 percent in the after period. This primarily refers to bicyclists riding very close to parked motor vehicles and may represent more exposure to double-parked vehicles or vehicles in the traffic queue in the after period.
- Motorists following bicyclists increased from 16.5 percent before to 22 percent after, while motorists passing bicyclists decreased from 34 percent before to 28 percent after. This could indicate a more smoothly flowing traffic stream.
- In examining the motorist responses when there was an interaction with a bicyclist, slowing by motorists increased from 19 percent before to 39 percent after. Moving partway into the adjacent lane decreased from 34 percent before to 30 percent after. Changing lanes decreased from 24 percent before to 17 percent after. Braking decreased from 12 percent before to 4 percent after. Full stops or major direction changes also decreased, but the frequencies were small. Taken together, these changes would represent a safer traffic stream.

From all of the operational results, of most concern would be the bicyclists who continue: (1) riding close to parked vehicles, and (2) weaving between motor vehicles in the travel lane and parked vehicles. These maneuvers represent prime opportunities for a dooring crash. Perhaps more local education can help deter this maneuver.

From the spatial data and other count data, there was an increase of about 10.5 inches (both directions combined) between bicycles and parked motor vehicles after the introduction of the shared lane markings. The increase was larger in the southbound direction (about 12 inches), compared to northbound (about 8.5 inches). ANOVA indicated that all the increases were statistically significant at the 0.05 significance level. Looking at the percentage of spacing values within 20, 30, and 40 inches, it is clear that the percentages decreased substantially after the introduction of shared lane markings. About 10 percent of the spacing values in the before period were within 20 inches, and this decreased to about 2 percent in the after period. Similarly, about 30 percent of the spacing values in the before period were within 30 inches, and this decreased to between 10 and 20 percent in the after period, depending on the direction. Thus, more bicyclists were riding out of the door zone.

For both northbound and southbound directions combined, the spacing increased about 4.5 inches (from 62.0 to 66.5 inches) between motor vehicles in the travel lane and parked motor vehicles. The increase was similar in the two directions. ANOVA indicated that the increases were statistically significant at the 0.05 significance level. The percentage of spacing values within 60, 70, and 80 inches also decreased following the introduction of the shared lane markings, indicating a shift in the distribution of the spacing values away from the parked vehicles. This shift gives bicyclists more operating space and may be coincident with the increase in the distance bicyclists were riding from parked motor vehicles after the shared lane markings.

Approximately 2 to 3 percent of bicyclists were riding in the wrong direction in the street, and there was no change after the shared lane markings. However, the percentage of bicycles using the sidewalk decreased from about 55 to 45 percent, and this reduction was statistically significant.

This is the second evaluation of shared lane markings placed in the center of the lane that we have performed. The first was in Seattle, WA, and approximately 15 percent of the bicyclists rode over the markings. These were commuting bicyclists, and it was assumed they would be comfortable riding over the markings in the middle of the road, but this was not the case. However, the positioning of the bicyclists was such that they still were out of the door zone and maintaining control of the lane. In this Miami Beach evaluation, approximately 30 percent of bicyclists rode over or avoided the shared lane makings, but the spacing data showed that the bicyclists were out of the door zone. Thus, it appears that traffic conditions, bicyclist experience, or other factors tend to limit the percentage of bicyclists tracking over the markings. By way of comparison, approximately 90 percent of bicyclists tend to track over the markings when placed 11 feet from the curb next to parked vehicles or 4 feet from the edge of the pavement when parking is not present.

There were safety effects associated with the placement of the shared lane markings. Of most importance would be the increase in the percentage of bicyclists riding near the center of the lane and the increase in spacing between bicycles and parked motor vehicles. It is recommended that the city continue to educate bicyclists in regard to helmet use, riding position on the street, not riding in and out of parking spaces, not riding in the door zone of parked vehicles, and not weaving between motor vehicles in the travel lane and parked vehicles. Some efforts could also be made to see that bus and taxi drivers show more courtesy to bicyclists.

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INTRODUCTION

A prior Miami-Dade Metropolitan Planning Organization (MPO) examination of bicycle-motor vehicle traffic crashes showed a large number of "dooring" bicycle crashes along Washington Avenue on Miami Beach. A "dooring" crash is one in which the door of a parked car is opened suddenly into the path of a bicyclist that is riding too close to the parking lane. The bicyclist can be injured by striking the door or by swerving further into the travel lane and being struck by a passing vehicle.

Between 2000 and 2009 (latest data available from Miami-Dade MPO), 52 bicycle crashes were reported along Washington Avenue between 12th St and Dade Boulevard (approximately 1.0 mile). Of those, at least 11 (21 percent) involved a bicyclist striking the open car door of a parked vehicle. A number of the drivers were cited for violating Florida Statute 316.2005:

> **316.2005 Opening and closing vehicle doors.**--No person shall open any door on a motor vehicle unless and until it is reasonably safe to do so and can be done without interfering with the movement of other traffic, nor shall any person leave a door open on the side of a vehicle available to moving traffic for a period of time longer than necessary to load or unload passengers. A violation of this section is a noncriminal traffic infraction, punishable as a nonmoving violation as provided in chapter 318.

As a proposed solution to this problem, the City of Miami Beach (the City) requested and received permission from the Federal Highway Administration (FHWA) to conduct a pilot study on Washington Avenue to evaluate shared lane markings (also referred to as *sharrows*). The decision was made to add the "bike and chevron" marking in the center of the outside lane. Figure 1 illustrates a generic sharrow as it appears in the 2009 version of the *Manual on Uniform Traffic Control Devices* (*MUTCD*).

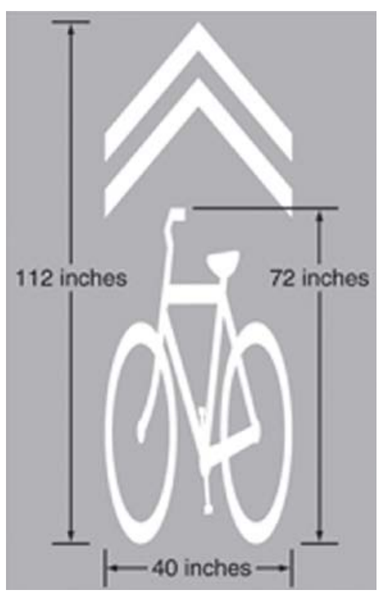

Figure 1. Generic version of a sharrow.

Shared lane markings are intended to convey to motorists and bicyclists that they must share the roads on which they are operating (*Manual on Uniform Traffic Control Devices*, 2009). The purpose of the markings is to create improved conditions for bicyclists by clarifying where they are expected to ride and to remind motorists to expect bicyclists on the road. In the absence of bicycle lanes, motorists often neglect to safely share travel lanes with bicyclists, which can compel bicyclists to ride closer to parked motor vehicles. Such a scenario can result in a dooring crash if someone opens a vehicle door as the bicyclist passes. Also, when bicyclists stay to the far right in narrow travel lanes, passing motorists often track too closely to the bicyclists. This can be unnerving for bicyclists, leaving little margin for error, and sometimes leading to crashes. In addition, shared lane markings have reduced wrong-way and sidewalk riding (Pein, Hunter, and Stewart, 1999; Alta Planning + Design, 2004; Hunter, Thomas, Srinivasan, and Martell, 2010).

To perform the evaluation, video was collected of bicyclists riding on Washington Avenue before and after the placement of the shared lane markings. The video was coded to obtain information about the bicyclist, where the bicyclist was riding on the street, and how bicyclists interacted with motor vehicles. Images were also downloaded from the video to use in calculating the distance bicycles rode from parked vehicles, and the distance motor vehicles in the travel lane drove from parked vehicles, before and after the installation of the markings. By placing the markings in the center of the outside lane, one positive outcome would be indicated with bicyclists riding over or near the markings and thus farther from parked motor vehicles.

This study came about as part of a contract between the University of North Carolina Highway Safety Research Center (HSRC) and the Florida Department of Transportation (FDOT). The contract provides funding to evaluate innovative bicycling and pedestrian improvements in the State of Florida.

LITERATURE REVIEW

Many cities and states have started implementing shared lane markings to encourage the safe coexistence of bicycles and motor vehicles. However, very few localities have formally evaluated the impact of these markings on safety or operations. Pein, Hunter, and Stewart (1999) conducted a before-after study of a variant of the bike-in-house marking implemented on a four-lane high volume (35,000 vehicles per day) roadway with a 30 mi/h speed limit in Gainesville, FL. The roadway had wide outside lanes 15 feet to the curb and no on-street parking. The center of the bike-in-house marking was placed 3.5 feet from the curb face.

In the before period 39 percent of bicyclists were riding in the same direction as traffic. This increased to 45 percent in the after period, and the increase was statistically significant. Bicyclists rode an average of 1.6 feet from the curb (tire to curb) in the before period and 1.8 feet from the curb in the after period—a shift of about 3 inches. This change was statistically significant but not thought to be practically significant. However, examining the distribution of distances showed a larger proportion of bicyclists riding 1.75 to 2.5 feet from the curb, indicating that more riders had additional maneuvering space toward the curb in the event that motor vehicles encroached into their space. This also potentially increased the comfort of bicyclists using the shared lane. Motorists allowed a mean of approximately 1.5 inches additional space when passing bicyclists in the after period (6.1 feet) compared to the before period (6.0 feet); however, this difference was also not thought to be practically significant. The mean and median motor vehicle distance to curb also increased slightly.

Alta Planning + Design and the San Francisco Department of Parking and Traffic (2004) conducted an evaluation of two shared lane marking designs – a bike-in-house design and a bike-and-chevron design (similar to the sharrow) – on streets with parallel parking. The study first conducted assessments to hypothesize an appropriate spacing for bicyclists to be able to avoid the door zone, which is the area where bicyclists risk colliding with an open door of a parked vehicle. By measuring vehicle doors in that locale, they found that the 85th percentile for the door zone extended 9.5 feet from the curb in the study areas. This distance included 7 feet from curb edge to outside of parked vehicle and 2.5 feet occupied by an opened door. From this, they concluded that bicyclists needed to ride at least 2.5 feet, or 30 inches, from parked vehicles to be relatively safe from an opened door. The marking treatments were subsequently implemented with the center of the markings 11 feet from the curb face to suggest a bicycle tracking position. This distance was intended to accommodate the 85th percentile distance of door clearance (9.5 feet plus 0.5 feet of shy distance plus half of the average bicycle width of 2 feet.

The San Francisco evaluation used data that were collected on six street segments before and after markings were introduced. Curb lane widths, including parking, ranged from about 17 to 19 feet on four 4-lane roads, and the curb lane widths, including parking, were 22 feet on two 2-lane roads. Each of the streets had moderate (2,000–4,000 vehicles per lane per day) to heavy (>4,000 vehicles per lane per day) traffic. In each of these locations, the bike-in-house marking was painted along one side of the road and the bike-and-chevron marking on the other side. Both shared lane markings led to the following results:

- 25 to 35 percent fewer sidewalk riders.

- More space (3 to 4 inches) between bicycles and parked vehicles.

- More space (more than 2 feet) between bicycles and passing motor vehicles in travel lanes.

- More space (about 1 foot) between motor vehicles in travel lanes and parked vehicles when no bicycles were present.

There were also reductions in the proportions of wrong-way riders associated with the bike-and-chevron design. Due to the bike-and-chevron marking being more readily understood by bicyclists to indicate a preferred travel path, this marking was the preferred choice and ultimately approved for inclusion in the *California Manual on Traffic Control Devices* (2003).

The Transportation Association of Canada (TAC) has now adopted the sharrow for use in Canada, and a paper by Jacobson, Skene, Davidson, and Rawsthorne (2009) covers side-by-side, single file, and conflict zones applications. Recommendations for stencil placement and spacing are slightly different from that recommended in the 2009 MUTCD. For the conflict zones application, such as a motor vehicle off ramp and straight through bicycle movement, multiple sharrows may be used with a minimum spacing of 1.5 meters. Further research is recommended for stencil elongation as a function of roadway speed, stencil width, minimum sharrow placement from the curb for the full-time parking situation, marking schemes for part-time parking routes, and study of applications and dimensions as related to traffic volume, motor vehicle speed, and vehicle class.

Brady, Loskorn, Mills, Duthie, and Machemehl examined the varying use of sharrows on three different streets in Austin, Texas (2011). Sharrows were installed in the middle of the 11-foot travel lanes on Guadalupe Street, a 4-lane, one-way street with parking on each side. With block lengths of approximately 370 feet, sharrows were installed 40 feet past each intersection, resulting in nominal spacing of 370 feet. Videotape data were collected during peak commuting hours when the parking spaces were rarely filled, thus giving bicyclists the opportunity to ride in the empty parking spaces. After sharrow placement, the average bicyclist lateral position (BLP) from the bicyclist's front wheel to the on-street parking space delineation or the outside of the edge of the parked motor vehicle increased from 3.14 to 3.51 feet, or 4.4 inches. The mode of the BLP observations shifted from 1.1 to 5.5 feet, indicating that an increased number of bicyclists were tracking over the center of the sharrow. The percentage of cyclists riding at a BLP of 4.4 to 6.6 feet, defined as the center of the lane, increased significantly from 31 to 42 percent after sharrow placement. Motorists passing bicyclists also significantly decreased. Bicyclists were significantly less likely to either ride on the sidewalk or in empty parking spaces after sharrows.

In a second evaluation, sharrows were also placed in the center of the lane on E 51st Street, a 2-way, 4-lane arterial in a 2,100 foot section where the bike lanes had been dropped. Sharrow spacing was 250 feet in the center of the outside lanes. After sharrow placement, the average BLP increased from 4.0 to 4.75 feet, an increase of 8 inches, and the mode of the BLP increased from 3 to 5 feet. The percentage of cyclists riding at a BLP of 4 to 6 feet, defined as the center of the lane, increased from 44 to 54 percent after sharrow placement ($p = .069$). Sidewalk bicycle riding significantly deceased from 12 to 4 percent.

A third experiment was conducted on Dean Keeton Street, an arterial where space did not allow bike lane placement throughout. Here sharrows were placed 11 feet from the curb and next to parked vehicles. Parking spaces tended to stay filled. Before sharrows, the BLP was evenly distributed between 1.5 and 4.5 feet when motorists passed cyclists. After sharrows, approximately 70 percent of cyclists rode 3 feet from the parked motor vehicles ($p = 0.363$). During non-passing events the BLP mode was 4.5 feet. The percentage of cyclists riding within the door zone during a passing event significantly decreased from approximately 80 to 36 percent ($p<0.001$). During a non-passing event, the percentage of cyclists riding within the door zone significantly decreased from approximately 82 to 68 percent ($p<0.001$).

Hunter, Thomas, Srinivasan, and Martell (2010) performed three separate evaluations of shared lane markings for the FHWA. In Cambridge, MA, the evaluation compared a “before” condition with no markings to an “after” condition of sharrows placed at 10-foot spacing from the curb. The objective was to determine whether 10 foot spacing would have a positive effect on where cyclists and motorists were positioned compared with no sharrows. Assuming parked vehicles use 7 feet of space, this placement would result in the center of the sharrows being 3 feet from the parked vehicles. The sharrows were placed 10 feet from the curb for about 2,500 feet on Massachusetts Avenue, which is a 4-lane divided street with approximately 29,000 vehicles per day, parallel parking on both sides, and a speed limit of 30 mi/h.

Results pertaining to the interaction of bicycles and motor vehicles included the following changes from before to after:

- The percentage of bicyclists who took control of the lane decreased from 13 to 8 percent.
- The percentage of bicyclists who kept moving safely (were riding safely and did not need to change speed or direction) increased from 73 to 90 percent.
- The percentage of bicyclists who made slight direction changes decreased from 17 to 6 percent.
- The percentage of bicyclists who yielded (changed direction or speed to give way to a motor vehicle) decreased from 23 to 7 percent.
- When a bicyclist was approaching, standing-open vehicle doors decreased from 5 to 2 percent; opening of doors decreased from 4 to 0.3 percent; and motor vehicles pulling in or out of parking spaces decreased from 11 to 4.5 percent. No actual dooring events occurred in either before or after period.
- The percentage of motorists who made no movement to change lanes when overtaking a bicycle increased from 27 to 66 percent.
- The percentage of safe overtaking movements by motorists (approached and passed the cyclist without difficulty) increased from 94 to 98 percent.
- The percentage of motor vehicles making no movement (i.e., continuing to follow) when following bicycles increased from 44 to 65 percent.

- The percentage of motorists who yielded (changed direction or speed to give way to a bicycle) increased from 5 to 10 percent.

- The percentage of motorists who made complete lane changes decreased from 12 to 3 percent.

- The percentage of motorists who made slight direction changes decreased from 38 to 22 percent.

- The percentage of motorists who slowed increased from 5 to 10 percent.

- The percentage of motorists who made no change in speed or direction while following a bicyclist increased from 44 to 65 percent.

- The percentage of avoidance maneuvers (a change in speed or direction) by both bicyclists and motorists decreased from 76 to 37 percent.

There were no statistically significant differences between inbound or outbound directions. Taken together, the results portray a more segregated flow with less lateral movement of bicycles and motor vehicles after sharrow installation.

Results pertaining to the spacing of bicycles and motor vehicles *in the presence of a following motor vehicle* in the after period included the following:

- The distance from a bicyclist riding beside a parked motor vehicle increased from 40.1 to 42.3 inches when both directions were combined and increased from 37.4 to 41.5 inches for the inbound direction.

- Outbound spacing was 42.7 inches in the before period and 43.1 inches in the after period.

- The percentage of bicyclists who rode within 40 inches (i.e., near the door zone) of parked motor vehicles decreased. Most of the effect was in the inbound direction with a decrease from 58 to 41 percent. Comparable outbound values were 44 percent in the before period and 38 percent in the after period.

- The percentage of bicyclists who rode within 30 inches (i.e., within the door zone) remained unchanged at 13 percent.

Results pertaining to the spacing of bicycles and motor vehicles *in the absence of a following motor vehicle* in the after period included the following:

- The change in distance between a bicyclist and a parked motor vehicle was negligible (approximately 45 inches before and after).

- The percentage of bicyclists who rode within 40 inches of parked motor vehicles increased from 37.5 to 45 percent, although this may reflect the high percentage of bicyclists who rode over the sharrows.

- When motorists drove past parked motor vehicles, the spacing increased 16 inches (from 77.4 to 93.6 inches) in the inbound direction, 12 inches (from 84.5 to 96.5 inches) in the outbound direction, and 14 inches (from 80.9 to 95.0) inches combined.

Overall results from Cambridge, MA, indicated the following:

- A total of 94 percent of bicyclists rode over the sharrows.

- There was more operating space for bicycles as motor vehicle spacing from parked motor vehicles increased.

- A number of variables related to the operations of bicycles and motor vehicles showed positive effects.

- Placement of the sharrows 10 ft from the curb (instead of 11 ft) was not a problem.

In a second evaluation in Chapel Hill, NC, the sharrows were placed 43.5 inches from the curb along Martin Luther King, Jr. Boulevard (MLK) for 1.25 miles. MLK is a street with a 5-lane cross section (4 travel lanes and a center two-way left turn lane) with no parking, 27,000 vehicles per day, a speed limit of 35 mi/h, and periodic sunken drain grates next to the curb. There was a 3 to 4 percent grade where the videotape data were collected. The street had previously been resurfaced, and the outside lanes were marked nominally as 15-ft-wide lanes. The spacing of bicycles and motor vehicles from the curb and in situations where motorists passed bicyclists was of primary interest.

Results pertaining to the interaction of bicycles and motor vehicles included the following changes from the before period to the after period:

- A total of 91 percent of the bicyclists rode over the sharrows—97 percent in the downhill direction and 88 percent in the uphill direction. Bicyclists riding uphill traveled slower and tended to ride closer to the curb.

- The percentage of motorists who made no movement to change lanes when overtaking a bicyclist increased from 24 to 32 percent.

- There was no difference in the proportion of bicyclists riding near the curb (approximately 98 percent) or taking the lane (approximately 2 percent).

- The percentage of avoidance maneuvers decreased from 81 to 71 percent.

- The percentage of motorists staying in the lane when following bicyclists increased from 20 to 29 percent.

- There was no change in the percentage of bicyclists or motorists who yielded.

Results pertaining to the spacing of bicycles and motor vehicles included the following:

- In the presence of a following motor vehicle in the after period, bicyclists rode closer to the curb after the sharrows by about 2.5 inches (40.1 to 37.7 inches). The effect was more pronounced downhill (4.6 inches closer) versus uphill (2.9 inches closer). Similar to Cambridge, MA, this was likely a reflection of bicyclists tracking over the sharrows.

- There were slight increases in the percentages of bicyclists who rode within 30 and 40 inches of the curb. The percentage within 30 inches increased from 12.5 to 15 percent downhill and 47.3 to 50.5 percent uphill.

- When motorists passed bicyclists in the after period, there was a small decrease in the passing distance overall from 82 to 79 inches. In the downhill direction, motorists passed 7 inches closer to bicycles (from 84.7 to 77.7 inches). There was no change in the uphill direction (from 80.0 to 81.1 inches).

- The percentage of passing motor vehicles within 50 inches showed only small and insignificant differences (from 2.0 to 2.6 percent).

- When the distance of the right front tires of motor vehicles from the curb in the absence of bicycles was examined in the after period, the spacing increased 8.3 inches in the uphill direction (from 64.4 to 72.7 inches), 4.7 inches in the downhill direction (from 76.6 to 81.3 inches), and 7 inches overall (from 70.5 to 77.0 inches).

- The percentages of motor vehicles within 50 and 60 inches of the curb were also significantly lower in the after period. The effect was most pronounced in the uphill direction (from 16 to 4 percent within 50 inches and from 46 to 17 percent within 60 inches).

- Bicyclist sidewalk riding significantly decreased from 43 percent in the before period to 23 percent in the after period. In the downhill direction, sidewalk riding decreased from 39 to 10 percent, with no significant change in the uphill direction.

- Wrong-way riding by bicyclists was 11 percent in the before period and 8 percent in the after period (nonsignificant change).

Overall results from Chapel Hill, NC, indicated the following:

- A total of 91 percent of bicyclists tracked over the sharrows and rode at a safe distance from the edge of curb with more of an effect in the downhill direction.

- Motorists moved away from the sharrows, providing more operating space for bicyclists.

- A number of variables related to the operations of bicycles and motor vehicles showed positive effects.

- Bicyclist sidewalk riding decreased in the downhill direction.

- There was no change in the percentage of bicyclist wrong-way riding.

In a third evaluation in Seattle, WA, sharrows were placed in the center of the lane 12.25 feet from the curb on a downhill section of Fremont Street, which is a 2-lane street that has a speed limit of 30 mi/h, 10,000 vehicles per day, 3.6 percent grade, and parking on both sides of the street. The placement was meant to encourage bicyclists to take the lane while traveling downhill. Data were collected in two additional periods following the before period. The centerline of the street was repositioned to allow a 5-foot bicycle lane and parking line to be installed on the uphill section of the street (after period 1). Sharrows were then added in the downhill direction (after period 2) since there was not enough width for bicycle lanes on both sides of the streets.

Results pertaining to the interaction of bicycles and motor vehicles included the following changes from the before period to the after period:

- There was no difference in the safety of the manner in which motorists were following and passing bicyclists. Overall, 97 percent of these maneuvers were considered to be performed safely.

- A total of 15 percent of the bicyclists rode over the sharrow during the after period 2.

- A significantly higher percentage (51 versus 28 percent) of bicyclists shifted toward the center of the lane and took the lane during after period 1 when the lane was narrowed to accommodate the addition of the bicycle lane in the uphill direction.

- The percentage of bicyclists who yielded (i.e., changed direction or speed to give way to a motor vehicle) decreased from 3.3 percent in the before period to 2.8 percent in after period 1 and 0.7 percent in after period 2.

- The percentage of motorists who yielded (i.e., changed direction or speed to give way to a bicycle) decreased from 13 percent in the before period to 6.5 percent in after period 1 and 5 percent in after period 2.

Results pertaining to the spacing of bicycles and motor vehicles included the following:

- In the absence of following motor vehicles, the average spacing between bicycles and parked motor vehicles did not significantly change across periods (45.8 inches in the before period, 47.5 inches in after period 1, and 44.5 inches in after period 2).

- The percentage of bicyclist spacing values within 30 inches (i.e., within the door zone) increased from about 6 percent in the before period to about 12 percent in the two after periods.

- The percentage of bicyclist spacing values within 40 inches increased from 36 percent in the before period to 39 percent in after period 1 and 44 percent in after period 2 (nonsignificant change).

- When motorists drove past parked motor vehicles in the absence of bicycles in both after periods, the average spacing decreased about 18 inches due to the change in the roadway configuration (the lane had been narrowed by 2.5 ft).

Overall results from Seattle, WA, indicated the following:

- Sharrow placement alone did not seem to result in an increase in the percentage of bicyclists taking the lane.

- Bicyclists were already riding out of the door zone in the before period and stayed in this location in both after periods. Sharrows had previously been installed 11 ft from the curb next to parked vehicles over a 2,000-ft, four-lane section of Fremont Street leading into the section studied in the current project.

- It is possible that narrowing the travel lanes and adding the uphill bike lane had more of an effect on operations and spacing than the addition of sharrows.

- The bicyclists riding in the street seemed experienced and showed that it was not necessary to ride in the middle of the lane to control the lane.

Similar operational and spacing measures have been used in studies evaluating operational effects of bicycle lanes and wide curb lanes (without shared lane markings). It has generally been found both in comparative studies (Harkey and Stewart, 1997; McHenry and Wallace, 1985) and before-after studies (Hunter, Feaganes, and Srinivasan, 2005) that the presence of a bicycle lane or shoulder stripe reduces motor vehicle encroachment into an adjacent lane and increases tracking consistency for a given roadway width. The studies also report bicyclist shifts away from the roadway edge or parked vehicles with striping in place (Hunter, Feaganes, and Srinivasan, 2005; Van Houten and Seiderman, 2005). The van Houten and Seiderman study examined the effects of sequential bicycle lane markings compared with a baseline of only a roadway center line with no bicycle lane marking. This study found that there was less variability in bicycle tracking with the bike lane markings in place. The study also reported the overwhelming preference of bicyclists for the bike lanes, as well as the motorists' awareness of them.

Furth, Dulaski, Buessing, and Tavakolian (2010) determined that the distance between the curb and a parallel parked car increased as the parking lane width increased from 6 to 9 feet in a study conducted near Boston, Massachusetts. As the width of the parking lane increased from 6 to 7 to 8 to 9 feet, the proportion of vehicles parked more than 12 inches form the curb increased from 1% to 13% to 44% to 60%. Thus, a strategy of narrowing parking lanes can provide more operating space for bicyclists.

THE EXPERIMENT

The overall objective of this project was to evaluate the effectiveness of the bike and chevron shared lane markings along both sides of the Washington Avenue corridor. Washington Avenue is a main arterial traffic corridor for both motorists and bicyclists in the City of Miami Beach and runs north and south on the east side of Miami Beach. In the main study section, a residential neighborhood is located to the east and a commercial and mixed-use entertainment district is located to the west. These areas are popular tourist destinations and attract a large amount of traffic. The average daily traffic is approximately 18,000 vehicles per day at the northbound traffic data collection site and approximately 9,000 vehicles per day at the southbound traffic data collection site. Washington Avenue has recently been renovated with a comprehensive construction and traffic flow plan, which included upgrades of streetscapes, drainage, and water-mains; replacement of sidewalks; and new curbs and gutters. Washington Avenue has two travel lanes in each direction, left turn lanes at many of the intersections, and parking on both sides of the street. The typical cross-section is an 8-foot parking lane, 2 11-foot travel lanes, an 11-foot median, 2 11-foot travel lanes, and an 8-foot parking lane (Figures 2 and 3). The entire length of the Washington Avenue study area, from South Pointe Drive to Dade Boulevard, is about 2 miles long.

Figure 2. Overhead view of Washington Avenue.

Figure 3. Street view of Washington Avenue.

The Washington Avenue speed limit is 30 miles per hour, and the street is a main transit corridor. In addition, many taxis operate on the street, and double parking and parked vehicle turnover is frequent. The situation can be somewhat chaotic for bicyclists when traffic is heavy, and bicyclists frequently ride between vehicles in the travel lane and parked vehicles. There are bicyclist interactions with pedestrians crossing the street at mid-block and intersections. The mix of bicyclists is extremely variable and includes a considerable number of tourists. The cyclist skill level is also variable, and it would appear that the vast majority of bicyclists are recreational. There are many instances of bicyclists using cell phones (Figure 4). On the other hand, there are times when the street is quite calm, and bicycling would be an easy task. The data collection covered a variety of situations as depicted by the various scenes in Figure 5.

Figure 4. Southbound bicyclist using cell phone while carrying passenger and weaving between vehicles in travel lane and parked vehicles.

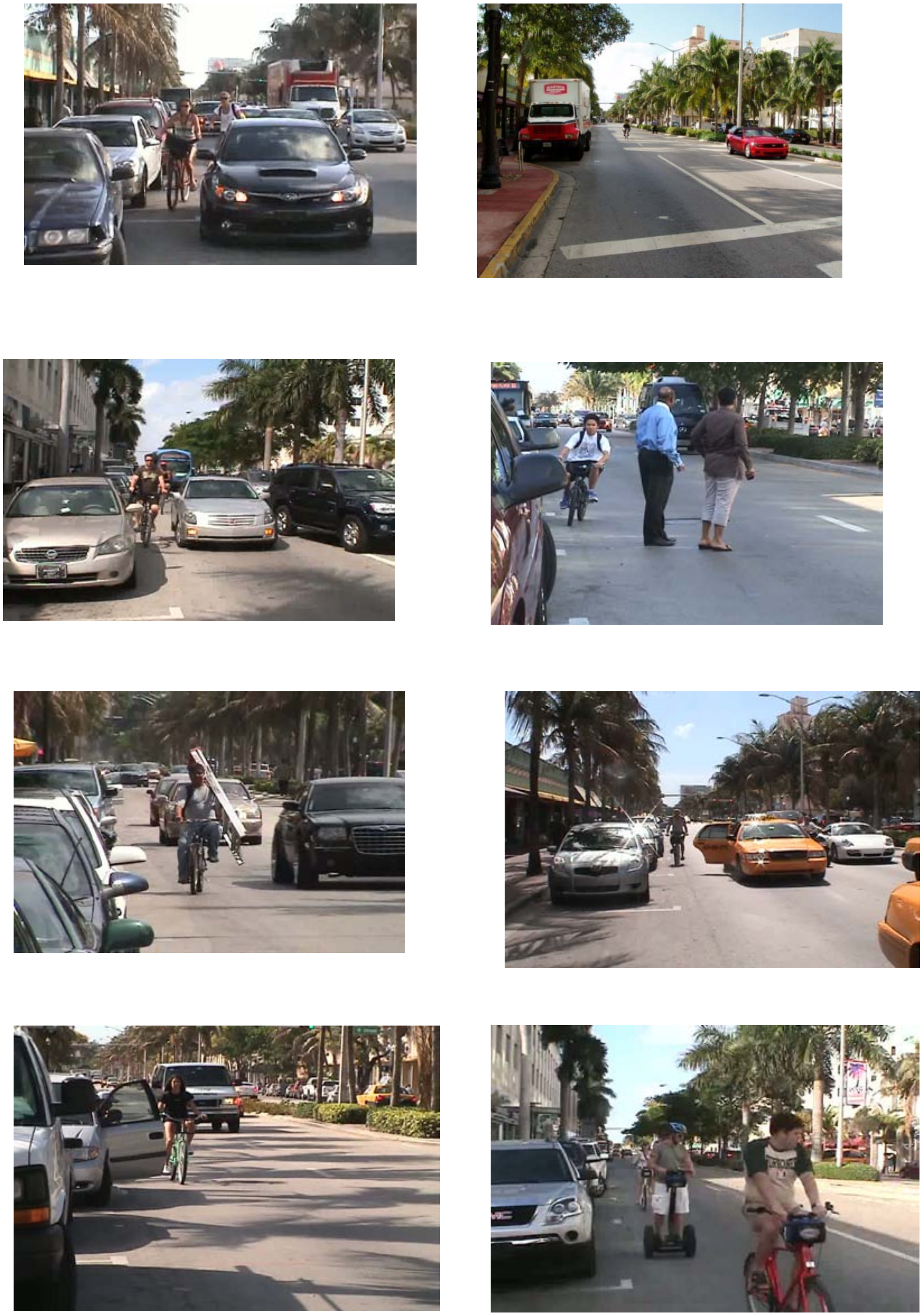

Figure 5. A variety of bicycling scenes on Washington Avenue.

The City decided that the most appropriate placement for the shared lane markings was in the middle of the lane near parked vehicles, which would place the center of the marking approximately 13.5 feet from the curb. The City felt that normal spacing of 11 feet from curb next to parked vehicles would not allow enough room for motor vehicles to pass bicycles in the lane next to parking. Middle of the lane placement would allow bicyclists to be out of the door zone and also to take control of the lane. Figure 6 shows a view of a symbol just past an intersection with a bulb-out and no parking. The block lengths were such that shared lane markings were typically placed near an intersection crosswalk, at mid-block, and near the end of the block. Spacing of markings along the street was approximately 200-250 feet.

Figure 6. View of sharrow in middle of lane.

The decision was made to use thermoplastic for the shared lane markings. Unfortunately, the contractor who was hired to install the markings decided to use a thick application, and the result was a symbol that was rough or bumpy in appearance (Figure 7). The appearance was pointed out to City officials relatively soon after installation, and the decision was made to collect data to see if the roughness would have an effect on where the bicyclists rode in the vicinity of the marking. As will be shown in the results section of the report, many bicyclists chose to avoid riding over the marking. Some time after completion of the first set of “after” data, the City was able to get the contractor to attempt to smooth the roughness, and a second set of “after” data was collected to see if the smoothing had an effect on riding position, but the results were about the same.

Figure 7. View of bumpy sharrow.

The City conducted several types of educational messaging to notify the public about the placement of the shared lane markings and their intent. These included door-to-door outreach for businesses along Washington Avenue using an informational flyer; articles in the MB Magazine; and information on the City's website, in an electronic newsletter to City residents, and through social media outlets. The Project was presented to the Washington Avenue Neighborhoods Association (WANA) at their August 11, 2010 meeting. The informational flyer was also distributed via WANA and any other impacted neighborhood and homeowners associations. A shared bike program started about the same time, and information about the shared lane markings was provided in the safety tips brochure in the basket that accompanied the bike rental.

METHODS

The experimental design was to collect videotape data of bicycles and motor vehicles traveling along Washington Avenue before and after the installation of the shared lane markings. While it would have been advantageous to have used an experimental design with comparison data, no adequate comparison sites were available. This is often the case in bicycle safety studies because slight differences in the traffic flow, grade, pavement surface, or some other variable can greatly influence outcomes related to the bicyclist. One way to possibly obtain a comparison site is to install a treatment on part of a route and to use the remainder as a comparison. However, when a community is installing a treatment, almost invariably the desire is to install along the entire route where the cross section is continuous, and this was the case for Washington Avenue.

The videotaping was done by local videographers during several time periods before and after installation. A camera was set up on a tripod at an intersection bulb-out location in line with the outside edge of a parked motor vehicle to provide a clear view of oncoming bicycles and motor vehicles. Zooming was used to follow the bicycles for several hundred feet, typically from the beginning of the block until the end. Videotape was collected from both directions of travel. The setup was at 16th Street for southbound bicyclists and at 10th Street for northbound bicyclists. The vast majority of “before” data were collected from April through July of 2010. The shared lane markings were placed on the street in January 2011, and the first set of “after” data were collected in March of 2011. A second set of “after” data was collected in January 2012. Data were collected at various times of the day on both weekdays and weekends, when it was not raining.

Images were obtained from videotape for both the northbound and southbound directions for the following 2 before and after conditions: (1) bicycle to parked motor vehicle (about 450 images in each direction), and (2) motor vehicle in the travel lane to parked motor vehicle with no bicycles present (about 200 images in each direction). SigmaScan® was used to obtain the necessary spacing measures from these images. For the bicycle to parked motor vehicle, the spatial measures were from the hip of the bicyclist to the outside edge of the driver’s side-view mirror of the parked motor vehicle. For the motor vehicle in the travel lane to parked motor vehicle, the spatial measures were from the approximate midpoints of the motor vehicles. In addition, the distances from the curb for both the front and rear tires of parked motor vehicles were measured by local data collectors to determine if the shared lane markings had an effect on how the vehicles parked. The videographers also used logs to record both wrong-way and sidewalk riding by bicyclists.

In addition to obtaining spacing data from the images described above, coding of the videotapes was performed to collect information about the bicyclist and to examine the operations of bicycles and motor vehicles when a motor vehicle was following or passing a bicycle in the presence of parked motor vehicles, as well as interactions between bicycles and parked motor vehicles (e.g., near-dooring events, motorists pulling in or out of parking spaces, etc.). The bicycle was the basic unit of analysis. Researchers systematically selected a pro rata share from each before and after videotape to accumulate the desired number of bicyclists and events, amounting to approximately 600 bicyclists in both the before and after periods and balanced by northbound versus southbound direction.

For each bicyclist included in the selected video clips, approximate age, gender, and helmet use were coded along with their direction of travel. Even though the age groups were limited to teen, young adult, middle adult, and older adult, the distinctions were difficult to make with the sun angles, shadows, clothing of the bicyclists, etc. Other bicycle/bicyclist coded items included:

- Whether the bicyclist rode over the sharrow (yes, no, avoided, unsure, n/a).
- Whether the bicyclist was weaving between motor vehicles in the travel lane and parked motor vehicles (yes, no, unsure, n/a).
- Whether the bicyclist was riding at some point in empty parking spaces (yes, no, unsure, n/a).
- Whether there was an interaction with a parked motor vehicle – dooring (actually struck an open door), near-dooring (close encounter with an open door), existing open door (rode past an open door which had already been opened), motor vehicle pulling into or out of a parking space, motor vehicle doubled parked, etc.

We also coded a variety of items whenever there were interactions between bicycles and motor vehicles, bicycles and pedestrians, and bicycles and other bicycles. First we determined whether there was an avoidance maneuver or conflict or none. An avoidance maneuver was defined as a change in speed or direction by either party to avoid the other, while a conflict was defined as a *sudden (abrupt)* change in speed or direction by either party to avoid the other. If a yielding event took place, the party that yielded was coded, such as a bicyclist slowing and *giving way* to a motorist pulling out of a parking space or a motorist slowing and *giving way* to a bicyclist moving to the center of the lane.

Given an interaction, coding for bicycles was performed for:

- Bicycle position—near a parked car, center of the lane, parking curb, or median curb.
- Whether the bicyclist took control of the lane to prevent a motor vehicle from passing.
- Bicycle avoidance maneuver – kept moving safely (i.e., were riding safely and did not need to change speed or direction), kept moving recklessly (e.g., riding close to parked vehicles), no change, slows or stops pedaling, slight direction change, changes lanes, brakes, major direction change/swerve, full stop, etc.

Given an interaction, coding for motor vehicles was performed for:

- Motor vehicle action—following, passing, other, etc.
- Motor vehicle position – curb lane, outside lane, other (e.g., double parked or waiting in traffic).
- Whether the motor vehicle moved to the adjacent lane—part way, all the way, or stayed in lane.

- Whether the motor vehicle overtaking maneuver (following and passing, if applicable) was done safely (i.e., no dangerous slowing or abrupt movements).

- Motor vehicle avoidance maneuver – no change, slows, slight direction change, changes lanes, brakes, major direction change/swerve, full stop, etc.

Up to 2 sets of the above variables (i.e., a bicyclist having more than one interaction) were coded for an interaction event.

Chi-square tests were performed to examine the distributions of variables before and after placement of the shared lane markings. Analysis of variance (ANOVA) models were used to study the effect on spacing and other performance measures.

RESULTS – VIDEOTAPE CODING

The following results pertain to a number of variables and are derived from the coding of the bicycle and motor vehicle interactions from the videotapes. Researchers observed 620 bicycles in the before period and 605 in the after period. With multiple interactions between a bicycle and motor vehicle possible, there were 690 interactions in the before period and 680 in the after period. Totals in the subsequent tables deviating from these numbers represent missing values. Chi-square tests were used to compare the distributions.

Direction of Travel

Table 1 shows the direction of travel for the bicyclists. This will be the typical table pattern in the text with frequencies in the table cells and row or column percentages underneath in parentheses. Overall, 47.4 percent of bicyclists traveled in the northbound and 52.7 in the southbound direction. The chi-square test showed that the before-after differences were not statistically significant.

Table 1. Bicyclist direction of travel.

Bicyclist Direction of Travel	Before Period	After Period	Total
Northbound	277 (44.7)[1]	303 (50.1)	580 (**47.4**)
Southbound	343 (55.3)	302 (49.9)	645 (**52.7**)
Total	620 (50.6)[2]	605 (49.4)	1225 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Bicyclist Data

Table 2 shows the gender of bicyclist in before and after periods. Overall, males accounted for 78.5 percent of the bicyclists, and females accounted for 21.5 percent. The chi-square test indicated that the before-after differences were statistically significant (p=.048), primarily due to the increase in female bicyclists. It is not known why the percentage of males decreased from 80.8 percent in the before period to 78.5 in the after period while the percentage of females increased from 19.2 percent in the before period to 23.8 percent in the after period. It is believed that these differences were not related to the experiment. There may be an association with the time of the year. The after data were collected in the month of March, and the temperature was generally seasonal (i.e., warm but not hot). Subsequent analysis of variables will control for bicyclist gender.

Table 2. Gender of bicyclists.

Gender	Before Period	After Period	Total
Male	498 (**80.8**)[1]	461 (**76.2**)	959 (**78.5**)
Female	118 (**19.2**)	144 (**23.8**)	262 (**21.5**)
Total	616 (50.5)[2]	605 (49.5)	1221 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 3 shows the approximate ages of the bicyclists. Even with broad categories, the coding was difficult to do because of sun angles, shadows, clothing of the bicyclists, etc. Overall, 1.7 percent was considered to be teens, 69.1 percent young adults, 25.4 percent middle adults, and 3.9 percent older adults. Thus, almost 95 percent of the bicyclists were young or middle adults. The differences were statistically significant (p=.0225), primarily due to the increase in middle adults in the after period. This may reflect more tourists in the month of March, when the after data were collected. Given the difficulty of coding, along with the fact that 95 percent of the bicyclists were either young or middle age adults, bicyclist age will not be controlled for in subsequent presentation of results.

Table 3. Bicyclist ages.

Bicyclist Age	Before Period	After Period	Total
Teen	13 (2.1)[1]	7 (1.2)	20 (1.7)
Young adult	442 (72.1)	397 (66.0)	839 (**69.1**)
Middle adult	134 (21.9)	175 (29.1)	309 (**25.4**)
Older adult	24 (3.9)	23 (3.8)	47 (3.9)
Total	613 (50.5)[2]	359 (50.6)	1215 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Only 3 percent of bicyclists wore a helmet, and there was no difference in before versus after period (no table shown).

Table 4 pertains to the bicycle position on the street when first observed and shows significant differences from before to after shared lane marking (p<.0001). Some 29.6 percent of bicyclists were first observed near the center of the lane in the after period, as opposed to 9.6 percent in the before period. The percentage positioned near parked vehicles decreased from 70.7 to 55.4 percent. “Unsure” was coded when the bicyclist came from behind a bus or double-parked vehicle. When controlling for gender, 8 percent of female bicyclists were first observed near the center of lane in the before period, and this increased to 33 percent in the after period. For males, the percentages were 10 percent before and 28 percent after. Examining direction, there was a larger shift to near the center of the lane for bicyclists riding in the southbound direction.

Table 4. Bicyclist position on the street when first observed.

Bicyclist Street Position	Before Period	After Period	Total
Near center of lane	58 (**9.6**)[1]	179 (**29.6**)	237 (19.2)
Near parked vehicle	426 (**70.7**)	335 (**55.4**)	761 (63.0)
Near parking curb	20 (3.3)	1 (0.2)	21 (1.7)
Unsure	99 (16.4)	90 (14.9)	189 (15.7)
Total	603 (49.9)[2]	605 (50.1)	1208 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

The beginning position of the bicyclist was further examined for the instances where there were no interactions with a motorist, pedestrian, or other bicyclist (no table shown). In other words, the bicyclist could choose where to ride with relative ease. The results were similar to the above except for being near a parked vehicle, which decreased from 61.5 percent before to 46.7 percent after, and unsure, which decreased from 25.5 percent before to 21.4 percent after.

Table 5 examines whether the bicyclist rode over the shared lane marking in the after period. Interestingly, 18.4 percent actually rode over any part of the marking, while another 8.9 percent avoided the marking. “Avoided” was coded if the bicyclist approach path would have clearly resulted in riding over the marking, but then a shift in direction was made to avoid the marking (Figure 8). The sum of the “Yes” and “Avoided” rows equals 27.3 percent and approaches the percentage (29.6 percent) first observed near the center of the lane in the after period in Table 4. “Unable to Ride Over” was coded when a vehicle was blocking the ability to ride over the marking, and “Unsure” was used when the view was such that the decision could not be made with certainty. Removal of these last 2 rows would change the “Yes” value to 19.9 percent and the “Avoided” value to 9.7 percent. The sum of these values is 29.6 percent and can be said to represent the percent riding over or very near the shared lane marking. It is certainly plausible that the bicyclists avoiding the marking were bothered by the rough appearance mentioned earlier.

Some 20 percent of female bicyclists rode over the marking and 8 percent avoided, and comparable values for male bicyclists were 18 and 9 percent. Some 7 percent of bicyclists avoided the marking in the northbound direction compared to 11 percent in the southbound direction.

Table 5. Bicyclist rode over the shared lane marking.

Bicyclist Over Marking	**After Period**
No	392 (64.8)[1]
Yes	111 (**18.4**)
Avoided	54 (**8.9**)
Unable To Ride Over	46 (7.6)
Unsure	2 (0.3)
Total	605 (100.0)[2]

[1] Column percent.
Note: Frequencies are shown with percentages in parentheses.

Whether the bicyclist rode over the shared lane marking was also examined for the instances where there were no interactions with a motorist, pedestrian, or other bicyclist, such that bicyclists could choose a path with relative ease. The results were somewhat different from Table 5 above:

- No = 57.3 percent
- Yes = 21.8 percent
- Avoided = 9.9 percent
- Unable to ride over = 10.6 percent
- Unsure = 0.5 percent

The total of “Yes” and “Avoided” equals 31.7 percent.

Figure 8. Southbound bicyclist riding over shared lane marking and away from an opening door (left) and bicyclist avoiding the marking (right).

A second set of after video data were collected 9 months later (January 2012). The contractor had attempted to smooth the thermoplastic, and the additional data were used only to examine the position of the bicyclist at the shared lane marking. Approximately 300 video clips were obtained at both the southbound and northbound data collection locations. Results for whether the bicyclist rode over the marking were the following:

- No = 81.4 percent
- Yes = 15.5 percent
- Avoided = 3.0 percent

The sum of the "Yes" and "Avoided" percentages was 18.5 percent, as compared to 29.6 percent for the comparable rows from Table 5 with "Unable to Ride Over" and "Unsure" removed. Thus, the attempt at smoothing was not successful at increasing the percentage of bicyclists riding directly over the marking. However, when the second set of data were coded, we tallied the number of bicyclists riding within a few inches of the marking, and the percentage was 27.7 percent. (Table 4 previously showed 29.6 percent of bicyclists near the center of the lane when first observed for the first set of after data.) Combining the percent riding near the marking with the "Yes" and "Avoided" amounts to 46.2 percent of bicyclists near the center of the lane. (Table 12 below shows that 44.4 percent of bicyclists were positioned near the center of the lane in the after period during an interaction with a motor vehicle).

Table 6 examines whether the bicyclist chose to weave between vehicles in the travel lane and parked vehicles. The opportunity to weave was often present, either in busy traffic or with a motor vehicle double parked. Whereas 9.8 percent weaved in the before period, 13.7 percent did so in the after period, and the differences in the table were statistically significant (p=.0350). Females increased their weaving from 12 percent in the before period to 15 percent in the after period. Comparable values for males were 9 percent before and 13 percent after. There was little difference by direction of travel.

Table 6. Bicyclist weaving between vehicles in the travel lane and parked vehicles.

Bicyclist Weaving	Before Period	After Period	Total
No	559 (90.2)[1]	522 (86.3)	1081 (88.2)
Yes	61 (**9.8**)	83 (**13.7**)	144 (11.8)
Total	620 (50.6)[2]	605 (49.4)	1225 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Figure 9 shows a bicyclist weaving between motor vehicles in traffic and parked vehicles. The opening of the parked vehicle door shows the danger of this maneuver.

Figure 9. Southbound bicyclist weaving between vehicles in travel lane and parked vehicles.

Table 7 pertains to whether bicyclists were riding in empty parking spaces in the before and after periods. The parking spaces tended to be almost fully occupied most of the time data were collected. Some 28.6 percent of bicyclists rode in empty parking spaces before the shared lane markings compared to 20.8 percent after, and the differences were statistically significant (p=.0016). Female bicyclists were less likely to ride in empty parking spaces – 25 percent before and 15 percent after – as compared to male bicyclists – 30 percent before and 23 percent after. There was also a considerable difference by direction of travel. In the northbound direction, 39 percent of bicyclists rode in parking spaces before the markings and 29 percent after. For the southbound direction, the values were 20 percent before and 13 percent after. This is possibly a function of the street layout, as there is a mid-block bulb-out in the southbound direction at a bus stop. There are no mid-block bulb-outs between 9th and 10th Street in the northbound direction.

Table 7. Bicyclist riding in empty parking spaces.

Bicyclist In Parking Spaces	Before Period	After Period	Total
No	441 (71.4)[1]	479 (79.2)	920 (75.2)
Yes	177 (**28.6**)	126 (**20.8**)	303 (24.8)
Total	618 (50.5)[2]	605 (49.5)	1223 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Figure 10 shows a bicyclist riding out of a parking space and into the travel lane. Note the waving of the hand to indicate his maneuver.

Figure 10. Northbound bicyclist riding out from parking space into travel lane.

Table 8 examines the bicycle interactions with parked motor vehicles. The before-after differences were statistically significant ($p<.0001$) and were a function of several of the categories. The "N/A" row means the event was not related to a parked vehicle, and the percentage was much higher in the after period. This represents a conscious decision made for the coding of the after data, in that attention was paid to whether the bicyclist rode over the shared lane marking. Thus, more video clips where there was no interaction with a motor vehicle were coded. Existing open doors were halved in the after period. There were half as many motor vehicles pulling into or out of a parking space. Near-doorings were few in number but also reduced. The percentage of double- parked vehicles stayed about the same. Controlling for bicyclist gender and direction of travel yielded similar results. It is felt that these changes may be more related to street conditions (exposure) than to the existence of the shared lane markings.

Table 8. Bicyclist interactions with parked motor vehicles.

Parked Motor Vehicle Event	Before Period	After Period	Total
Existing Open Door	41 (**6.6**)[1]	20 (**3.3**)	61 (5.0)
Double Parked	178 (28.8)	152 (25.1)	330 (27.0)
Pulling In or Out	50 (**8.1**)	24 (**4.0**)	74 (6.1)
Near-Dooring	5 (0.8)	2 (0.3)	7 (0.6)
N/A	344 (**55.7**)	407 (**67.3**)	751 (61.4)
Total	618 (50.5)[2]	605 (50.1)	1208 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Interactions between Bicycles and Motor Vehicles

The tables that follow examine the interactions between bicycles and motor vehicles. Table 9 shows the types of interactions that took place on Washington Avenue between bicycles, motor vehicles, and pedestrians. Note that the percentages for “None” (or no interaction) increased dramatically in the after period. These differences again reflect the decision to pay more attention to whether the bicyclist rode over the shared lane marking in the after period. Thus, more video clips where there was no interaction with a motor vehicle were coded. Removing the “None” row showed no statistically significant differences between the periods. Thus, when there was an interaction, 95 percent involved a bicycle and motor vehicle, and about 4 to 5 percent a bicycle and pedestrian. Controlling for bicyclist gender showed no difference by period, while controlling for direction of travel showed more bicycle-pedestrian, and conversely, a few less bicycle-motor vehicle interactions, in the southbound direction.

Table 9. Types of interactions.

Interaction	Before Period	After Period	Total
Bicycle-Motor Vehicle	600 (87.0)[1]	513 (75.4)	1113 (81.2)
Bicycle-Bicycle	4 (0.6)	1 (0.2)	5 (0.4)
Bicycle-Pedestrian	23 (3.3)	29 (4.3)	52 (3.8)
None	63 (**9.1**)	137 (**20.2**)	200 (14.6)
Total	690 (50.4)[2]	680 (49.6)	1370 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 10 shows the distributions of avoidance maneuvers and conflicts by period. In the before period, 89.6 percent of the bicycle-motor vehicle interactions resulted in avoidance maneuvers (change in speed or direction to avoid the other party), and 0.7 percent resulted in conflicts (*sudden* change in speed or direction to avoid the other party). Conversely, 78.8 percent of the interactions resulted in avoidance maneuvers, and 0.3 percent resulted in conflicts in the after period. Having neither an avoidance maneuver nor conflict (the "None" category) increased from 9.7 percent in the before period to 20.9 percent in the after period. Again, this table shows the effect of more video clips where there was no interaction with a motor vehicle being coded. Removing the "None" row showed no statistically significant differences between the periods. In essence, virtually all interactions between a bicycle and motor vehicle produced some change in speed or direction to avoid the other. Controlling for bicyclist gender and direction of travel showed no differences by period.

Table 10. Avoidance maneuvers and conflicts.

Interaction	Before Period	After Period	Total
Avoidance Maneuver	618 (**89.6**)[1]	536 (**78.8**)	1154 (84.2)
Conflict	5 (0.7)	2 (0.3)	7 (0.5)
None	67 (**9.7**)	142 (**20.9**)	209 (15.3)
Total	690 (50.4)[2]	680 (49.6)	1370 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

A conflict between a bicyclist and a parked vehicle pulling out of a parking space is shown in Figure 11.

Figure 11. Bicycle-motor vehicle conflict in southbound direction.

Table 11 shows the number of times bicyclists and motorists yielded in the before and after periods while interacting with each other. Bicyclist yielding (i.e., changed direction or speed to give way to a motor vehicle) decreased from 8.5 percent in the before period to 2.4 percent in the after period. Motorist yielding (i.e., changed direction or speed to give way to a bicycle) increased from 3.6 percent in the before period to 5.2 percent in the after period. The differences were statistically significant ($p < 0.0001$), with most of the contribution attributable to less bicyclist yielding in the after period. It should be noted that the definition of yielding used, where a party had to *give way* to the other, was rather robust. When gender was examined, female bicyclists yielded in 9 percent of the interactions before and 1.5 percent after. Male bicyclists yielded in 8.5 percent of the interactions before and 3 percent after. Controlling for direction of travel showed little differences.

Table 11. Bicyclist and motorist yielding behavior.

Yielding Behavior	Before Period	After Period	Total
Bicyclist Yielded	54 (**8.5**)[1]	13 (**2.4**)	67 (5.7)
Motorist Yielded	23 (**3.6**)	28 (**5.2**)	51 (4.3)
Yielding Not Required	555 (87.8)	502 (92.5)	1057 (90.0)
Total	632 (53.8)[2]	543 (46.2)	1175 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

The next few tables will cover the actions of the bicyclist when an interaction with a motor vehicle or pedestrian occurred. Table 12 examines the bicyclist street position, and shows that 44.4 percent of bicyclists were positioned near the center of the lane in the after period compared to 25.2 percent in the before period. Conversely, the percentage near parked vehicles decreased. The differences were statistically significant ($p<.0001$), with most of the contribution related to the increase near the center of the lane. For female bicyclists, 24 percent were positioned near the center of the lane before and 51 percent after. In the northbound direction, 21 percent of bicyclists were positioned near the center of the lane before and 41 percent after. In the southbound direction, 28 percent of bicyclists were positioned near the center of the lane before and 48 percent after. Further analysis indicated that motorists yielded in 30 percent of the interactions in the before period and 50 percent in the after period when the bicyclist was near the center of the lane (no table shown).

Table 12. Bicyclist street position when an interaction occurred.

Bicyclist Street Position	Before Period	After Period	Total
Near center of lane	169 (**25.2**)[1]	302 (**44.4**)	471 (34.8)
Near parked vehicle	487 (**72.5**)	378 (**55.6**)	865 (64.0)
Near parking curb	16 (2.3)	0 (0.0)	16 (1.2)
Total	672 (49.7)[2]	680 (50.3)	1352 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 13 examines the distributions for whether the bicyclist took control of the lane in the interaction. Bicyclists were taking control of the lane about half the time in the interactions in both periods, and the differences were not statistically significant. A factor in this result is the interaction involving bicyclists riding around double parked motor vehicles or buses. In these instances, bicyclists would have to control the lane to make the maneuver, and there were many of these maneuvers in both periods for which the shared lane marking would have little effect. Nevertheless, further analysis showed that when the bicyclist tool control of the lane the motorist yielded in 48 percent of the interactions before and 57 percent after the placement of the markings (no table shown).

Table 13. Bicyclist took control of lane when an interaction occurred.

Bicyclist Took Control of Lane	Before Period	After Period	Total
No	354 (51.3)[1]	340 (50.0)	694 (50.7)
Yes	336 (**48.7**)	340 (**50.0**)	676 (**49.3**)
Total	690 (50.4)[2]	680 (49.6)	1370 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 14 shows the full distribution of bicyclist responses during their interaction with motorists, pedestrians, and other bicyclists by period. The "No change" code is again an artifact of observing more video clips where there was no interaction with a motor vehicle in the after period. Bicyclists were able to keep moving safely (i.e., no change in speed or direction) 28.0 percent of the time overall, with not much change by period. "Kept moving unsafely" increased from 6.3 percent in the before period to more than 11.6 percent in the after period. This primarily refers to bicyclists riding very close to parked motor vehicles and in danger of being doored. Lane changing decreased from 14.6 percent before to 9.2 percent after. Full stops decreased from 0.9 percent before to 0.2 percent after. Major direction changes decreased from 2.7 percent before to 0.5 percent after. Combining "brakes" and "full stop" into an "other" category resulted in a valid chi-square test, and the before-after distributions were statistically significant ($p < 0.0001$).

Controlling for gender, male bicyclists (7 percent before versus 12 percent after) were involved in a higher percentage of unsafe riding than female bicyclists (4 percent before versus 10 percent after). Lane changing was the reverse, with a higher percentage of female bicyclists (17 percent before versus 12 percent after) than males (14 percent before versus 8 percent after) involved in this activity. Male bicyclists (3 percent before versus 0.7 percent after) were more involved in major direction changes than female bicyclists (0.8 percent before versus 0 percent after).

Controlling for direction, riding unsafely was more associated with the northbound direction (7 percent before versus 15.5 percent after). On the other hand, more of the major direction changes were associated with the southbound direction.

Table 14. Bicyclist responses during interactions with motor vehicles, pedestrians, and other bicyclists.

Bicyclist Response	Before Period	After Period	Total
Kept moving safely	191 (29.9)[1]	146 (25.9)	337 (**28.0**)
Kept moving unsafely	40 (**6.3**)	65 (**11.6**)	105 (8.7)
Slowed, stops pedaling	23 (3.6)	16 (2.8)	39 (3.2)
Slight direction change	264 (41.3)	199 (35.4)	463 (38.5)
Major direction change	17 (**2.7**)	3 (**0.5**)	20 (1.7)
Changes lanes	93 (**14.6**)	52 (**9.2**)	145 (12.1)
Brakes	3 (0.5)	5 (0.9)	8 (0.7)
Full stop	6 (**0.9**)	1 (**0.2**)	7 (0.6)
No change	2 (0.3)	76 (13.5)	78 (6.5)
Total	639 (53.2)[2]	563 (46.8)	1202 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

The next few tables will cover the actions of the motorist when an interaction with a bicyclist occurred. Table 15 examines the action of the motor vehicle in the event. The “Other action” pertains to parked motor vehicle events or vehicles waiting in traffic. Motorists following increased from 16.5 percent before to 21.6 percent after, while passing decreased from 33.7 percent before to 28.0 percent after. This could indicate a more smoothly flowing traffic stream. The differences in this distribution were significant. There were little differences by gender of bicyclist or direction of travel.

Table 15. Motorist action during interactions with bicyclists.

Motorist Action	Before Period	After Period	Total
Following	99 (**16.5**)[1]	111 (**21.6**)	210 (18.9)
Passing	202 (**33.7**)	144 (**28.0**)	346 (31.1)
Other action	299 (49.8)	259 (50.4)	558 (50.1)
Total	600 (53.9)[2]	514 (46.1)	1114 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

The lane position of the motorist is presented in Table 16. The parked vehicle events have been removed from this comparison. Overall, 94.0 percent of the interacting motorists were operating from the curb lane, and there were no differences by period. Controlling for gender of bicyclist and direction of travel showed little differences.

Table 16. Motorist lane position during interactions with bicyclists.

Motorist Lane Position	Before Period	After Period	Total
Curb lane	496 (**93.4**)[1]	460 (**94.7**)	956 (**94.0**)
Outside lane	35 (6.6)	26 (5.4)	61 (6.0)
Total	531 (52.2)[2]	486 (47.8)	1017 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 17 examines whether motorists changed lanes all the way or partway when overtaking a bicyclist. Some 39.4 percent of motorists changed lanes all the way, and there were no differences by period. Controlling for gender of bicyclist and direction of travel showed little differences.

Table 17. Motorist lane changing during interactions with bicyclists.

Motorist Lane Changing	Before Period	After Period	Total
All the way	79 (40.5)[1]	49 (37.7)	128 (**39.4**)
Part way	116 (59.5)	81 (62.3)	197 (60.6)
Total	195 (60.0)[2]	130 (40.0)	325 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 18 compares the distributions of whether the overtaking by the motorist was safe. Even though there would usually need to be a change in motorist speed or direction, 94.2 percent of the motorist overtaking maneuvers were considered to be safe. Even though the proportion of safe overtakings increased in the after period, the differences in the before-after distributions were only marginally significant (p=.0811). Safe overtakings for female bicyclists increased from 88 percent before to 98 percent after. There were no differences by direction of travel.

Table 18. Safety of the overtaking motor vehicle during interactions with bicyclists.

Motorist Overtaking Safe	Before Period	After Period	Total
No	22 (7.5)	10 (4.0)	32 (5.8)
Yes	273 (92.5)	243 (96.0)	516 (**94.2**)
Total	295 (53.8)[2]	253 (46.2)	548 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

Table 19 shows the distribution of motorist responses when there was an interaction with a bicyclist. Parked motor vehicle events or vehicles waiting in traffic have been removed. Slowing by motorists vehicles increased from 19.5 percent before to 38.6 percent after. "Slight direction changes" increased by a small amount. Moving part way into the adjacent lane decreased from 34.4 percent before to 30.3 percent after. Changing lanes decreased from 24.4 percent before to 17.3 percent after. Braking decreased from 12.0 percent before to 3.9 percent after. Full stops or major direction changes also decreased, but the frequencies were small. The changes were statistically significant (p<.0001). Taken together, these changes would represent a safer traffic stream.

The distribution for male bicyclists was similar to the above; however, for female bicyclists, there were distinct differences. Slowing by motorists increased from 24 percent before to 49 percent after. "Slight direction change" decreased from 16 percent before to 3 percent after. Moving partway into the adjacent lanes decreased from 31 percent before to 20 percent after. Changing lanes increased from 18 percent before to 23 percent after. Braking decreased from 12 percent before to 5 percent after. There were no full stops or major direction changes associated with female bicyclists.

Controlling for direction of travel showed only slight differences from the distributions in Table 19.

Table 19. Motorist responses during interactions with bicyclists.

Bicyclist Response	Before Period	After Period	Total
Slows	60 (**19.5**)[1]	98 (**38.6**)	158 (28.1)
Slight direction change	24 (7.8)	23 (9.1)	47 (8.4)
Moved partway into adjacent lane	106 (34.4)	77 (30.3)	183 (32.6)
Changed lanes	75 (**24.4**)	44 (**17.3**)	119 (21.2)
Brakes	37 (**12.0**)	10 (**3.9**)	47 (8.4)
Full stop/major direction change	6 (2.0)	2 (0.8)	8 (1.4)
Total	308 (54.8)[2]	254 (45.2)	562 (100.0)

[1] Column percent.
[2] Row percent.
Note: Frequencies are shown with percentages in parentheses.

RESULTS – SPATIAL DATA

Bicycle to Parked Motor Vehicle

Table 20 shows the average spacing between bicycles in the travel lane and parked motor vehicles along with the results of ANOVA that tested the differences in the average spacing. The measure is the distance from the hip of the bicyclist to the outside edge of the driver's side view mirror. Researchers also looked at the percentage of spacing values within 20, 30, and 40 inches to consider the effect of shared lane markings on the number of bicycles within or near the 30-inch door zone. Results are provided for northbound, southbound, and northbound and southbound directions combined.

Overall, the spacing between bicycles and parked vehicles increased by about 10.5 inches (both directions combined) after the introduction of the shared lane markings. The increase was larger in the southbound direction (about 12 inches), compared to northbound (about 9 inches). ANOVA indicated that all the increases were statistically significant at the 0.05 significance level. Looking at the percentage of spacing values within 20, 30, and 40 inches, it is clear that the percentages decreased substantially after the introduction of shared lane markings (Table 21). About 10 percent of the spacing values in the before period were within 20 inches, and this decreased to about 2 percent in the after period. Similarly, about 35 percent of the spacing values in the before period were within 30 inches, and this decreased to between 10 and 20 percent in the after period, depending on the direction.

Figure 12 shows the histograms of the spacing values in the before and after periods. It is clear that there is a shift in the distribution towards higher values in the after period.

Motor Vehicle in Travel Lane to Parked Motor Vehicle

Table 22 shows the results from the analysis of the spacing between motor vehicles in the travel lane and parked motor vehicles. This measure is the distance between the bodies at the approximate midpoint of the vehicle. The introduction of the shared lane markings seems to have been associated with a significant increase in this spacing.

For both northbound and southbound directions combined, the spacing increased about 4.5 inches (from 62.0 to 66.5 inches). The increase was similar in the two directions. ANOVA indicated that the increases were statistically significant at the 0.05 significance level. The percentage of spacing values within 60, 70, and 80 inches also decreased following the introduction of the shared lane markings, indicating a shift in the distribution of the spacing values away from the parked vehicles (Table 23). This was also confirmed by the histograms of the spacing values before and after the introduction of shared lane markings (Figure 13).

Table 20. Analysis of the spacing between bicycles and parked vehicles.

Direction	Number of Observations		Analysis of Average Spacing			
			Average Spacing (inches)		Results of ANOVA test	
	Before	After	Before	After	F (df1,df2)	p-value
North & South	458	489	37.0	47.6	88.914 (1,945)	<0.001
North	209	222	37.2	46.0	28.443 (1,429)	<0.001
South	249	267	36.8	49.0	62.136 (1,514)	<0.001

Table 21. Analysis of the percentage of bicycles within 20, 30, and 40 inches of parked vehicles.

Direction	Number of Observations		Analysis of the Percentage Within 20 inches				Analysis of the Percentage Within 30 inches				Analysis of the Percentage Within 40 inches			
			% within 20 inches		Results of Chi-square test		% within 30 inches		Results of Chi-square test		% within 40 inches		Results of Chi-square test	
	Before	After	Before	After	Chi-square	p-value	Before	After	Chi-square	p-value	Before	After	Chi-square	p-value
North & South	458	489	10.0%	2.2%	25.398	<0.001	35.8%	14.9%	54.948	<0.001	63.5%	39.9%	52.992	<0.001
North	209	222	9.1%	2.7%	8.040	0.005	35.9%	21.6%	10.739	0.001	63.6%	42.3%	19.581	<0.001
South	249	267	10.8%	1.9%	17.825	<0.001	35.7%	9.4%	52.092	<0.001	63.5%	37.8%	33.845	<0.001

Table 22. Analysis of the spacing between motor vehicles in the travel lane and parked vehicles.

Direction	Number of Observations		Analysis of Average Spacing			
			Average Spacing (inches)		Results of ANOVA test	
	Before	After	Before	After	F (df1,df2)	p-value
North & South	176	225	62.0	66.5	15.599 (1,399)	<0.001
North	75	125	61.7	66.1	6.706 (1, 198)	0.010
South	101	100	62.2	66.9	9.327 (1, 199)	0.003

Table 23. Analysis of the percentage of motor vehicles in the travel lane within 60, 70, and 80 inches of parked vehicles.

Direction	Number of Observations		Analysis of the Percentage Within 60 inches				Analysis of the Percentage Within 70 inches				Analysis of the Percentage Within 80 inches			
			% within 60 inches		Results of Chi-square test		% within 70 inches		Results of Chi-square test		% within 80 inches		Results of Chi-square test	
	Before	After	Before	After	Chi-square	p-value	Before	After	Chi-square	p-value	Before	After	Chi-square	p-value
North & South	176	225	47.7%	31.1%	11.526	0.001	79.5%	60.8%	16.092	<0.001	95.5%	87.1%	8.208	0.004
North	75	125	49.3%	35.2%	3.886	0.049	78.7%	58.4%	8.580	0.003	97.3%	86.4%	6.517	0.011
South	101	100	46.5%	26.0%	9.161	0.002	80.2%	64.0%	6.560	0.010	94.1%	88.0%	2.263	0.133

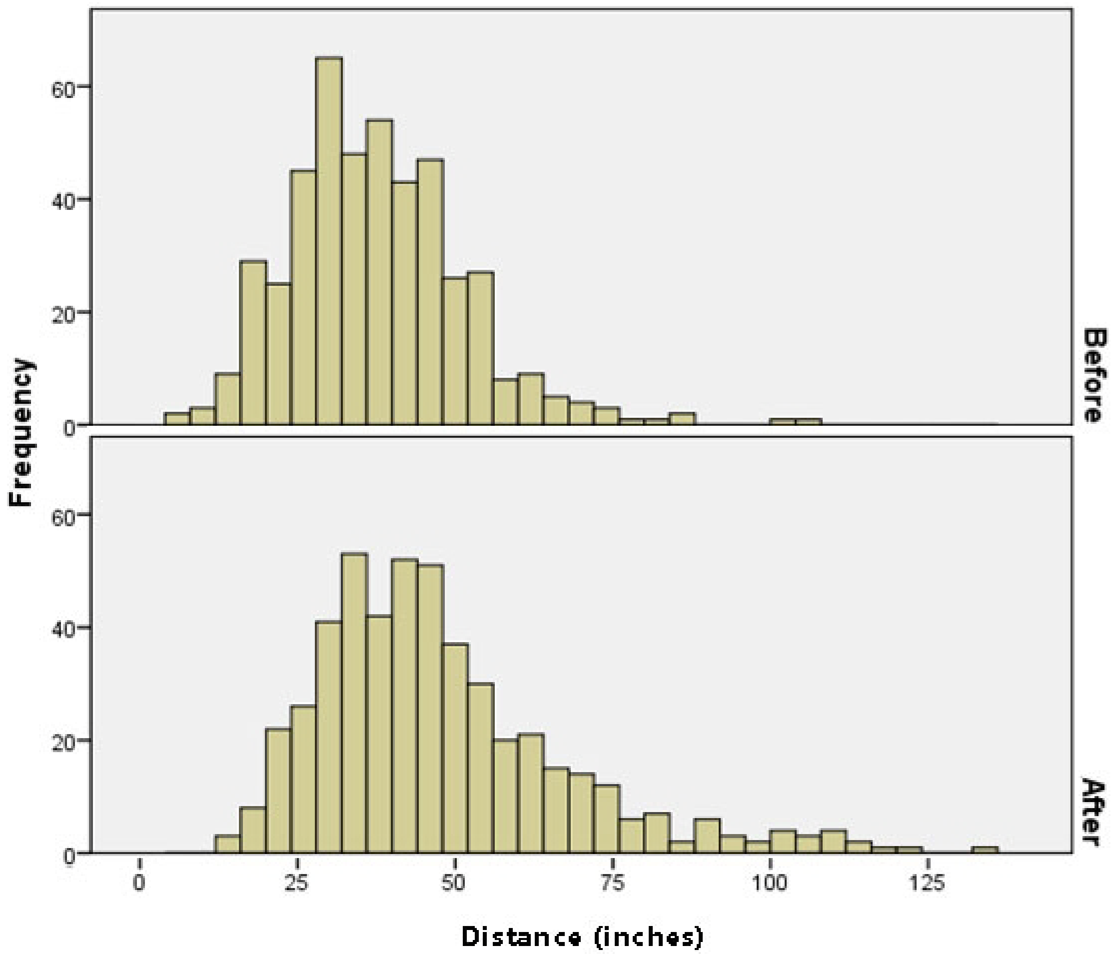

Figure 12. Histograms for distance between hip of bicyclist to outside edge of driver's side view mirror of parked vehicles.

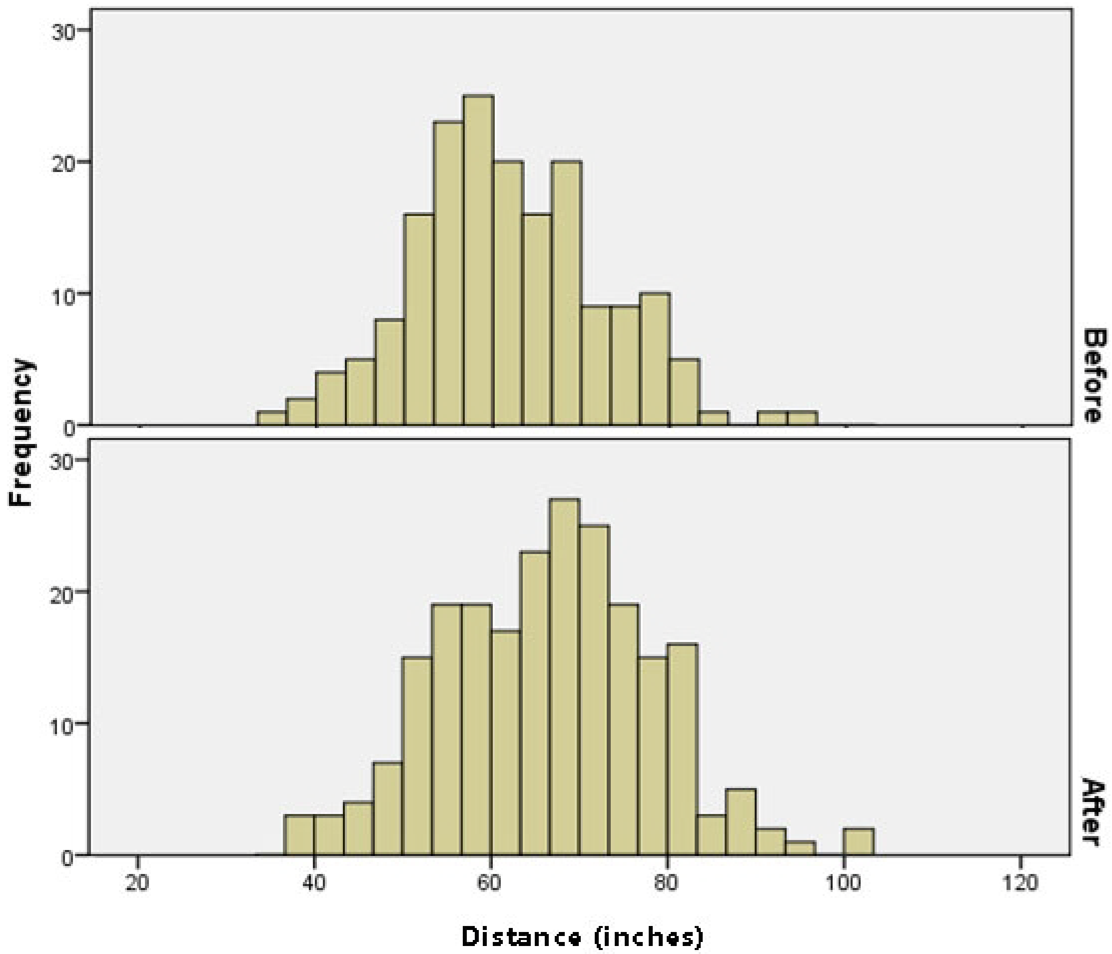

Figure 13. Histograms for distance between motor vehicles in travel lanes and parked vehicles.

Distance between Tires of Parked Motor Vehicles and the Curb

Table 24 shows the results from the analysis of the distance between the back and front tires of parked motor vehicles and the curb. When both directions were combined, there was little change in the distance between the tires and the curb after the introduction of the shared lane markings. None of the changes were statistically significant at 0.05 level.

Table 24. Analysis of the distance between tires of parked motor vehicles and the curb.

Direction	Number of Observations		Front or Rear Tire	Analysis of Average Spacing			
				Average Spacing (inches)		Results of ANOVA test	
	Before	After		Before	After	F (df1,df2)	p-value
North & South	122	156	Front	9.7	10.7	1.739 (1,276)	0.188
			Rear	9.6	10.4	0.867 (1,276)	0.353
North	42	78	Front	11.3	10.6	0.310 (1,118)	0.579
			Rear	10.2	10.7	0.151 (1,118)	0.698
South	80	78	Front	8.9	10.8	3.539 (1,156)	0.062
			Rear	9.3	10.1	0.475 (1,156)	0.492

Note: df indicates degrees of freedom

Counts of Bicycles Traveling on the Sidewalk and the Traffic Lane

Table 25 shows the results from the analysis of the counts of bicycles traveling on the sidewalk and in the wrong direction in the traffic lane. There was very little change in the percentage of bicycles traveling in the wrong direction in the traffic lane. On the other hand, there was a significant reduction in the percentage of bicycles on the sidewalk. When both directions were combined, the percentage of bicycles using the sidewalk decreased from about 55 to 45 percent. As shown in the table, these reductions were statistically significant at the 0.05 level.

Table 25. Analysis of the number of bicycles traveling on the sidewalk and in the traffic lane.

Direction	Analysis of the Percentage In-Street Wrong Way						Analysis of the Percentage in Sidewalk					
	Number of Observations		% in-street wrong way		Results of Chi- square test		Number of Observations		% in sidewalk		Results of Chi-square test	
	Before	After	Before	After	Chi-square	p-value	Before	After	Before	After	Chi-square	p-value
North & South	983	1859	3.0%	2.3%	1.057	0.304	2199	3381	55.3%	45.0%	56.360	<0.0001
North	444	823	2.3%	1.5%	1.066	0.302	865	1346	48.7%	38.9%	20.732	<0.0001
South	539	1036	3.5%	3.0%	0.327	0.567	1334	2035	59.6%	49.1%	35.715	<0.0001

SUMMARY AND DISCUSSION

The installation of the shared lane markings on Washington Avenue was associated with a variety of results. The chaotic nature of the street in times of busy traffic and the speed of some of the motor vehicles are likely to be factors in producing these results.

Approximately 20 percent of the bicyclists rode over the shared lane marking, and another 10 percent avoided the marking when they approached. It is certainly plausible that the bicyclists avoiding the marking were bothered by the rough appearance mentioned earlier. Thus, 30 percent tracked over or very near the shared lane marking. Some 44 percent were positioned near the center of the lane when interacting with a motor vehicle after the markings were placed on the street. Such placement would locate these bicyclists out of the door zone.

Some 20 percent of female bicyclists rode over the marking, and 8 percent avoided. Comparable values for male bicyclists were 18 and 9 percent. Some 7 percent of bicyclists avoided the marking in the northbound direction compared to 11 percent in the southbound direction.

From an analysis of the videotape data, the following operational results were statistically significant:

- Almost 30 percent of bicyclists were first observed near the center of the lane in the after period, as opposed to 10 percent in the before period. The percentage positioned near parked vehicles decreased from 71 to 55 percent.
- The opportunity was often present for bicyclists to weave between motor vehicles in the travel lane and parked motor vehicles, either in busy traffic or with a motor vehicle double parked. Whereas about 10 percent weaved in the before period, some 14 percent did so in the after period.
- The parking spaces tended to be almost fully occupied most of the time data were collected. About 29 percent of bicyclists rode in empty parking spaces before the shared lane markings, compared to 21 percent after. Female bicyclists were less likely to ride in empty parking spaces – 25 percent before and 15 percent after – as compared to male bicyclists – 30 percent before and 23 percent after. There was also a considerable difference by direction of travel. In the northbound direction, 39 percent of bicyclists rode in empty parking spaces before the markings, and 29 percent after. For the southbound direction, the values were 20 percent before, and 13 percent after. This is possibly a function of the street layout, as there is a mid-block bulb-out in the southbound direction at a bus stop. The bulb-out does not exist mid-block for the northbound direction.
- In regard to the bicycle interactions with parked motor vehicles, there were some positive results. In the after period, the existence of open parked vehicle doors was halved, and there were half as many motor vehicles pulling into or out of a parking space. Near-doorings, or the opening of a door as a bicyclist approached, were few in number but also reduced. The percentage of double-parked vehicles

stayed about the same. However, it is not clear whether these changes are more related to street conditions (exposure) than to the existence of the shared lane markings.

- The definition of yielding, where a party had to *give way* to the other, was rather robust. Bicyclist yielding (i.e., changed direction or speed to give way to a motor vehicle) decreased from 8.5 percent in the before period to 2 percent in the after period. Motorist yielding (i.e., changed direction or speed to give way to a bicycle) increased from 4 percent in the before period to 5 percent in the after period. The statistically significant differences were mostly attributable to less bicyclist yielding in the after period. When gender was examined, female bicyclists yielded in 9.3 percent of the interactions before and 1.5 percent after. Male bicyclists yielded in 8.5 percent of the interactions before and 2.7 percent after. Controlling for direction of travel showed few differences.

- When a bicyclist had an interaction with a motor vehicle, pedestrian, or another bicycle, 44 percent of bicyclists were positioned near the center of the lane in the after period compared to 25 percent in the before period. Conversely, the percentage near parked vehicles decreased. The statistically significant differences were mostly attributable to the increase in bicyclists near the center of the lane. For female bicyclists, 24 percent were positioned near the center of the lane before, and 51 percent after. In the northbound direction, 21 percent of bicyclists were positioned near the center of the lane before, and 41 percent after. In the southbound direction, 28 percent of bicyclists were positioned near the center of the lane before, and 48 percent after.

- In examining the bicyclist responses during their interaction with motorists, pedestrians, and other bicyclists, bicyclists were able to keep moving safely (i.e., were riding safely and no need to change speed or direction) about 28 percent of the time overall with not much change by period. Lane changing decreased from 14.5 percent before to 9 percent after. Full stops decreased from 0.9 percent before to 0.2 percent after. Major direction changes decreased from 3 percent before to 0.5 percent after. However, kept moving unsafely increased from 6 percent in the before period to more than 11 percent in the after period. This primarily refers to bicyclists riding very close to parked motor vehicles.

- Motorists following bicyclists increased from 16.5 percent before to 22 percent after, while motorists passing bicyclists decreased from 34 percent before to 28 percent after. This could indicate a more smoothly flowing traffic stream.

- In examining the motorist responses when there was an interaction with a bicyclist, slowing by motorists increased from 19 percent before to 39 percent after. Moving partway into the adjacent lane decreased from 34 percent before to 30 percent after. Changing lanes decreased from 24 percent before to 17 percent after. Braking decreased from 12 percent before to 4 percent after. Full stops or major direction changes also decreased, but the frequencies were small. Taken together, these changes would represent a safer traffic stream.

From all of the operational results, of most concern would be the bicyclists who continue: (1) riding close to parked vehicles, and (2) weaving between motor vehicles in the travel lane and parked vehicles. These maneuvers represent prime opportunities for a dooring crash. Perhaps more local education can help deter this maneuver.

From the spatial data, there was an increase of about 10.5 inches (both directions combined) between bicycles and parked motor vehicles after the introduction of the shared lane markings. The increase was larger in the southbound direction (about 12 inches), compared to northbound (about 8.5 inches). ANOVA indicated that all the increases were statistically significant at the 0.05 significance level. Looking at the percentage of spacing values within 20, 30, and 40 inches, it is clear that the percentages decreased substantially after the introduction of shared lane markings. About 10 percent of the spacing values in the before period were within 20 inches, and this decreased to about 2% in the after period. Similarly, about 35 percent of the spacing values in the before period were within 30 inches, and this decreased to between 10 and 20 percent in the after period, depending on the direction. Thus, more bicyclists were riding out of the door zone.

For both northbound and southbound directions combined, the spacing increased about 4.5 inches (from 62.0 to 66.5 inches) between motor vehicles in the travel lane and parked motor vehicles. The increase was similar in the two directions. ANOVA indicated that the increases were statistically significant at the 0.05 significance level. The percentage of spacing values within 60, 70, and 80 inches also decreased following the introduction of the shared lane markings, indicating a shift in the distribution of the spacing values away from the parked vehicles. This shift gives bicyclists more operating space and may be coincident with the increase in the distance bicyclists were riding from parked motor vehicles after the shared lane markings.

Approximately 2 to 3 percent of bicyclists were riding in the wrong direction in the street, and there was no change after the shared lane markings. However, the percentage of bicycles using the sidewalk decreased from about 55 to 45 percent, and this reduction was statistically significant.

This is the second evaluation of shared lane markings placed in the center of the lane that we have performed. The first was in Seattle, WA, and approximately 15 percent of the bicyclists rode over the markings. These were commuting bicyclists, and it was assumed they would be comfortable riding over the markings in the middle of the road, but this was not the case. However, the positioning of the bicyclists was such that they still were out of the door zone and maintaining control of the lane. In this Miami Beach evaluation, approximately 30 percent of bicyclists rode over or avoided the shared lane markings, but the spacing data showed that the bicyclists were out of the door zone. Thus, it appears that traffic conditions, bicyclist experience, or other factors tend to limit the percentage of bicyclists tracking over the markings. By way of comparison, approximately 90 percent of bicyclists tend to track over the markings when placed in the typical position next to parked vehicles or from the edge of the pavement when there are no parked vehicles.

There were safety effects associated with the placement of the shared lane markings. Of most importance would be the increase in the percentage of bicyclists riding near the center of the lane and the increase in spacing between bicycles and parked motor vehicles. It is recommended that the city continue to educate bicyclists in regard to helmet use, riding position on the street, not riding in and out of parking spaces, not riding in the door zone of parked vehicles, and not weaving between motor vehicles in the travel lane and parked vehicles. Some efforts could also be made to see that bus and taxi drivers show more courtesy to bicyclists.

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