OPERATIONAL ANALYSIS OF SHARED LANE MARKINGS AND GREEN BIKE LANES ON ROADWAYS WITH SPEEDS GREATER THAN 35 MPH

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DISCLAIMER

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.

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
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
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
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
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				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
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")
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
FORCE and PRESSURE or STRESS				
lbf	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa

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16. Abstract

This study analyzed the effectiveness of shared lane markings (sharrows), wide curb lanes, standard and buffered bike lanes, and green bike lanes on improving operations of bicycle facilities. Three measures of effectiveness were used in this study: lateral separation between the motor vehicle and bicyclist, the distance of bicyclists to the curb or edge of pavement, and the yielding behavior of drivers and cyclists at merge points. Also, motor vehicle speeds before, while, and after passing bicyclists were analyzed. Except for the Bridge of Lions site, the before-and-after data indicate that installation of sharrows led to an increase in lateral separation between motor vehicles and bicyclists. At Riverside Drive, the separation increased by 0.67 feet, while at the North 56th Street site, an increase of 2.55 feet was observed after installing sharrows and increasing the outside lane width. Data also suggested a significant improvement in lateral separation of 0.86 feet at Sunset Drive, which was widened to create a wider outside lane (but had no shared lane markings), and Bailey Road, where a marked buffer between the travel lane and bike lane resulted in an increase in separation between motor vehicles and bicyclists of 0.72 feet. It was also observed that bicyclists rode further from the curb/edge of pavement for the after-period compared to the before-period for Riverside Drive, Bridge of Lions, North 56th Street, and Sunset Drive. P-values less than 0.05 were observed for these five sites suggesting that the treatments were effective in moving bicyclists further from the curb/edge of pavement. Data also indicates that drivers slow down as they pass bicyclists on non-limited access roadways (before speed of 32.02 mph to 29.97 mph while-passing) and then increase their speeds after overtaking the bicyclists (30.80 mph while-passing to 32.82 mph after-passing). The difference between the speeds before-passing and while-passing, and while-passing and after-passing, were both significant with a p-value less than 0.000. However, when the before-passing (32.02 mph) and after-passing (32.54 mph), excluding while-passing speeds, were analyzed, no significant difference was found (p-value = 0.110). For limited access facilities, the difference between the overtaking driver's speed before-passing (37.35 mph) and while-passing (34.93 mph) the bicyclists was significant with a p-value of 0.000. However, the difference between motor vehicle speeds while-passing bicyclists (34.94 mph) and after-passing (35.48 mph) was not significant (p-value = 0.150). Contrary to the non-limited access streets, the difference between vehicle speeds before- (37.33 mph) and after-passing (35.48 mph) was significant for the limited access facilities (p-value =0.017).

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EXECUTIVE SUMMARY

The main objective of this study was to examine the effectiveness of shared lane markings (sharrows) and bike lanes on higher speed roadways and operational impacts of bicyclists on limited access bridges. Thus, this study collected before-and-after data on selected roadways that were retrofitted by installing sharrows or bike lanes. In addition to studying the performance of the shared lane markings, the effects of green bike lanes in improving awareness and yielding at complex intersections and limited access ramps was evaluated. One site, Sunset Drive in Miami, was retrofitted by widening the outside lane, and was included in the study. A reconstruction of Bailey Road in Ft. Lauderdale provided an opportunity to compare a bike lane section configured with an adjacent buffer zone, and a bike lane without a buffer.

Three main measures of effectiveness were used in this study: lateral separation between the motor vehicle and bicyclist, the distance of bicyclists to the curb or edge of pavement, and the yielding behavior of drivers and cyclists at merge points. Also, motor vehicle speeds before, while, and after passing bicyclists were analyzed.

Due to variability in site characteristics, a separate statistical analysis was conducted for each site. Statistical analyses consisted of determining descriptive statistics and performing an Analysis of Variance (ANOVA).

The analysis of the before-and-after data at Riverside Drive in Jacksonville and North 56th Street in Temple Terrace indicate a significant increase in lateral separation between motor vehicles and bicyclists after installation of sharrows. Only one site, the Bridge of Lions in St Augustine, did not show improvement in lateral space between vehicles and bicyclists, and was not significant. This might be attributed to the type of roadway section. This is a two-lane undivided bridge, and the only site with a single lane in each direction.

This study also compared operational characteristics between sharrows and bike lanes at the North 56th Street site in Tampa. The difference in lateral separation between the sharrows and the bike lane segments was not significant (p-value = 0.216). However, the results suggest a significant difference for the distance from the bicyclists to the curb or edge of pavement. It was also observed that vehicles did not slow down on the bike lane section as much as they did at the sharrows site. However, this was an anecdotal observation.

Retrofitting Sunset Drive to include a wider outside lane improved the separation between vehicles and bicyclists. The improvement in the lateral clearance was also observed when comparing the buffer and no-buffer bike lane sections at the Bailey Road site. For all sites except Bailey Road, the distance between the bicyclists and the curb or edge of pavement significantly increased in the after-periods.

For limited access facilities, it was observed that bicyclists prefer crossing straight paths rather than less conventional (skewed) crossings, and used the shortest path to cross on- and off-ramps. It was also observed that bicyclists preferred to keep some momentum rather than stopping when crossing the ramps.

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1 INTRODUCTION

Across the United States, a great deal of attention is being focused on promoting energy efficient and environmentally friendly modes of transportation. Bicycling is an integral part of a sustainable transportation system as it is one of the most energy-efficient, cost effective, and environment-friendly modes of transportation. Transportation agencies are looking for ways to better support the growing use of bicycles for transportation and leisure activities in the existing built environment.

In the past, urban design criteria in Florida allowed for the construction of wide outside lanes rather than bike lanes when the corridor was constrained. Wide outside lanes are typically 14 feet wide to allow a shared use by motor vehicles and bicycles. Environmental and historical constraints led to the reconstruction of the Bridge of Lions in St. Augustine with narrow (11”) lanes and no bike lanes. Shared lane markings, also known as “*sharrows*” are a strategy for mitigating the lack of a bike lane. Their intent is to encourage appropriate placement of cyclists in the roadway and sharing of the lane by motorists. According to the Manual on Uniform Traffic Control Devices (MUTCD, 2009) (*12*), *sharrows* are known to offer the following benefits:

A. Assist bicyclists with lateral positioning in a shared lane with on-street parallel parking in order to reduce the chance of a bicyclist hitting an open door of a parked vehicle,

B. Assist bicyclists with lateral positioning in lanes that are too narrow for a motor vehicle and a bicycle to travel side by side within the same traffic lane,

C. Alert road users of the lateral location bicyclists are likely to occupy within the traveled way,

D. Encourage safe passing of bicyclists by motorists, and

E. Reduce the incidence of wrong-way bicycling.

2 RESEARCH OBJECTIVES

This research is a follow-up study that builds on a previous FDOT research study on the evaluation of restriping roadways to create wider outside lanes for bicyclists. The earlier study, titled *Operational and Safety Impacts of Restriping Inside Lanes or Urban Multi Lane Curbed Roadways to 11 Feet or Less to Create Wider Outside Curb Lanes for Bicyclists* (BDK82-877-01) , and can be found on the web page for FDOT's Research Office.

The main objective of this study was to examine the effectiveness of bike lanes and shared lane markings (sharrows) on higher speed roadways, and included FDOT's three pilot projects that allow bicycle travel on limited access highways. Thus, a before-and-after study was conducted on selected roadways that were retrofitted by installing bike lanes and/or *sharrows*. The study evaluated the effects of green bike lanes in improving awareness and yielding at complex intersections and limited access ramps. In addition to the state highways included in the study, Broward County, Florida participated by constructing a new roadway with two styles of bike lanes (buffered and traditional) that we were able to compare.

The study will be used by transportation officials in Florida to collect data on the operational performance of the bicycle pilot projects on limited access roadways and refine guidelines on the design of bicycle facilities, including the use of *sharrows.* Also, this study will provide guidance on suitability of different methodologies used for videotape data collection and reduction.

3 LITERATURE REVIEW

Many cities and states have started implementing shared lane markings on roadways 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. In the late 1990s, Pein, Hunter, and Stewart 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 (48 km/h) speed limit in Gainesville, FL *(1)*. 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.

The San Francisco Department of Parking and Traffic 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 *(2)*. 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 (3)*.

The Transportation Association of Canada (TAC) has now adopted the sharrow for use in Canada, and a paper by Jacobson, Skene, Davidson, and Rawsthorne (*4*) 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 (*12*). 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 (*5*). 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 decreased from 12 to 4 percent.

A third experiment was conducted on Dean Keeton Street, an arterial roadway where space did not allow bike lane placement throughout. Here, sharrows were placed 11 feet from the curb and next to parked vehicles. The width from center of sharrow to center of the outside lane line was 11 feet. 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 performed three separate evaluations of shared lane markings for the FHWA (*6*). 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 the before-period to the after-period:

- The percentage of bicyclists who were taking 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, existing 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 door events occurred in either the before-period 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 while following a bicyclist increased from 44 to 65 percent.
- The percentage of avoidance maneuvers decreased from 76 to 37 percent.

All of these differences were independent of inbound or outbound direction. 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, indicate 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 (non-significant change).

Overall results from Chapel Hill, NC, indicate 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 (non-significant 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, indicate 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 cars 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 *(7,8)* and before-after studies *(9)* that the presence of a bicycle lane or shoulder stripe reduces lateral shifting by motor vehicles 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 *(9, 10)*. 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 *(10)*. The study also reported the overwhelming preference of bicyclists for the bike lanes, as well as the motorists' awareness of them.

Furth, Pulaski, Bussing, and Tavakolian 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 (*11*). 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 from 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.

4 STUDY SITES

Locations for data collection were determined by the Florida Department of Transportation (FDOT) with District and local government cooperation, based on the availability of roadway segments of varying characteristics, where higher volumes of bicyclists and pedestrians were known to occur, and where existing shared lane pavement markings (sharrows) for bicycle traffic were not already in place. Sites for the green bike lanes were selected based on pilot projects where the installation of green bike lanes at on-ramps of limited access facilities was underway.

Based on prior experience, it was determined that evaluating existing bicycle traffic would not produce sufficient data for the intended analysis. The FDOT districts were contacted to solicit volunteer riders. For liability reasons, riders had to be employees of participating institutions conducting the research (Florida State University and University of North Florida), the FDOT, or supportive local governments and transportation planning organizations. Research assistants were used only for operating cameras and collecting speed data.

As shown in Figure 4.1, study sites were distributed across the state. Table 4.1 details the roadway characteristics of all study sites. Three sites involved installation of sharrows while one site in Miami, Sunset Drive, was a retrofit from a symmetric multilane to asymmetric section with a wide outside lane. Another site in Fort Lauderdale (Bailey Road) had two different configurations, a conventional bike lane with no buffer and a bike lane with a buffer between motor traffic and bicycles. Three corridors were evaluated for travel by bicyclists on limited access bridges (Pineda, William Lehman, and Julia Tuttle Causeways) and included the installation of standard and green bike lanes. More information about characteristics of the limited access sites can be found in Appendices A to F.

FIGURE 4.1 Locations of Study Sites

TABLE 4.1 Roadway Characteristics of Study Sites

City	Road Name	State Route No.	From	To	No. of Lanes	Lanes Each Direction	Median Type	Posted Speed	Lane Width (feet)						Type of Lane Treatment
									Lane Treatment Before			Lane Treatment After			
									Inner	Middle	Outer	Inner	Middle	Outer	
Jacksonville	Riverside Ave	SR 211	Post St	Rosselle St	3	2-NB/ 1-SB	Undivided	30	10	10	10	10	10	10	Sharrows added
St. Augustine	Bridge of Lions	A1A	Avenida Menendez	N St. Augustine Blvd	2	1	Undivided	30	11	--	11	11	--	11	Sharrows added
Temple Terrace	N 56th St	SR 583	Serena Dr	Mission Hills Ave	5	2	TWLT	45 Before/ 35 After	12	--	12	11	--	13	Lane restriping for 11 ft. inner lane, 13 ft. outer lane with Sharrows
												12	--	12	4 ft. Bike lane added upstream of Sharrows section
Ft Lauderdale	Bailey Rd	Broward County	Woodlands Blvd	NW 64th Ave	5	2	TWLT	35	11	--	10.5				Two Sites: a) 4 ft. bike lane with 2 ft. buffer zone, b) 5 ft. bike lane added
Miami	Sunset Dr	SR 986	SW 72nd Ave	SW 68th Ct	4	2	Divided	40	12	--	12	11	--	14	Widened pavement and restriped for 11 ft. inner lane, 14 ft. outer lane (no curb)
*Melbourne	Pineda Cswy	SR 404	US 1	S Patrick Dr	4	2	Divided	55	12		12				Pilot Study: Included bike lanes, raised barriers, and green bike lane
*Miami	Lehman Cswy	SR 856	Sullivan Dr	Edward Dr	4	2	Divided	25	12	--	12	12	--	12	10 ft. Existing shoulder marked as bike lane
*Miami	Julia Tuttle Cswy	SR 112	Alton Rd	Bridge section	6	3	Divided	55	12	12	12	12	12	12	Added green bike lane

Notes: * Limited access facilities that are part of a pilot study; Riverside and Bridge of Lions, no gutter pan; Number of lanes equals total through lane width plus any continuous turn lanes.

5 METHODOLOGY

5.1 Data Collection

The data was collected at various times during the day, often in peak hour durations. In addition to the local cyclists who were traveling through the corridor, volunteer cyclists from FDOT, City, County, and Metropolitan Planning Organization (MPO) staff, as well as FDOT's design consultant were used to provide as many samples as possible of interactions of vehicles sharing the outside lane with bicyclists both before and after bike lanes or sharrow markings were added to the roadway segments. Members of the public who traveled the corridor by bicycle while data was being collected were also included in the analysis.

At each location, cyclists rode along the selected road segment while researchers videotaped their paths and interactions with motor vehicles. Video cameras were strategically located to capture the behavior of motor vehicles as they approached and passed a bicyclist. Efforts were made to conceal the camera and operator from passing traffic as to not influence driver behavior. A plastic pipe, one foot in length, was attached to the front and back of each bicycle as a control measure for determining distances from the video images. Figure 5.1 illustrates the pipe attached to the bicycle.

The lateral separation between the bicyclists and vehicles was measured as the distance from the left shoulder of the bicyclist to the right front passenger door of the vehicle. The distance between the bicyclist and the face of curb or edge of pavement was measured from the bicycle tire (center).

FIGURE 5.1 Pipe Attachment

5.2 Data Reduction

The field videos were converted to MPEG-4 video format in the laboratory. Using Adobe Photoshop CS3 software, the videos were analyzed for lateral distances between the curb and the cyclist and the cyclist and the vehicle body. The one-foot plastic pipe served as a control parameter to establish a custom measurement scale using the ruler tool within the software to determine the lateral distances. Measurements included the lateral distance from the bicycle tire center to the face of curb or edge of pavement and from the cyclist's left shoulder to the passing vehicle's passenger door. The percent of lateral shift by vehicles into the inner lane while passing the bicyclist was determined visually and estimated to within the closest quartile of the adjacent lane width. Figure 5.2 shows examples of quartile assessment during data collection.

FIGURE 5.2 Vehicle Lateral Shift into Adjacent Lane Quartiles

Apart from lateral separation between motor vehicles and bicyclists and vehicle lateral shift into the adjacent lane, other variables were recorded, including vehicle type and speed, and gender, and type of dress of the bicyclist. Restrictions such as the presence of vehicles in the inside lane that may limit lateral shift and lane changing maneuvers for the driver were also recorded. The vehicles were classified into six types: passenger cars, sport utility vehicles (SUVs), pickup trucks, medium trucks, large trucks, and buses. Medium trucks were defined as being larger than a pickup truck but smaller than a tractor-trailer truck. Tractor-trailers were categorized as large trucks. Medium trucks, large trucks, or buses did not appear in the videos often enough to allow for statistical analysis.

Not all videos contributed usable data and some allowed for only certain measurements to be obtained. All the data were entered into a Microsoft Access database and then exported to MINITAB for statistical analysis.

5.3 Data Analysis

Due to variability in site characteristics, a separate statistical analysis was conducted for each site. Statistical analyses consisted of determining descriptive statistics and performing an

Analysis of Variance (ANOVA) which use the sum of squares for treatments and sum of squares for error to test the significance of the difference in treatments.

The mean square for treatments is the measure of variability among the treatment means, while the mean square for error measures the sampling variability within the treatments. The F-statistic is calculated as the ratio of the mean square for treatments (MST) and the mean square for error (MSE) as shown in the equation below.

$$F = \frac{\text{MST}}{\text{MSE}}$$

Values of the F-statistic near one indicate that the two sources of variation, between treatment means and within treatments, are approximately equal. In this case, the difference between the treatment means may well be attributable to sampling error, which provides little support for the significance of the difference between the two treatments. To determine whether the value of F-statistic exceeds the value of one, enough to suggest a significant difference between the two treatments, a computed F-statistic is compared to the F-value taken from statistical tables and is based on the degrees of freedom and the confidence level. If the obtained p-value is less than the considered level of significance, typically 95% in traffic studies (i.e., $\alpha = 0.05$), there would be sufficient evidence to conclude that the two treatment means differ.

6 ANALYSIS AND RESULTS

Due to differences in site characteristics and the before-and-after configurations, separate analyses were conducted for each study site. This section discusses the analyses and results for each site.

6.1 Riverside Drive (Jacksonville)

The site at Riverside Drive consists of three lanes, two northbound and one southbound, with lane widths of approximately 10 feet. Figures 6.1 and 6.2 display the study segment, located between Post and Rosselle Streets. Sharrows were installed in both directions along the segment as shown in Figure 6.2.

FIGURE 6.1 Riverside Drive Northbound

FIGURE 6.2 Shared Lane Markings: Riverside Drive

Descriptive statistics of the lateral clearance between motor vehicles and bicycles and distance from bicycle to the curb are summarized in Tables 6.1 and 6.2. The lateral vehicle clearance, the lateral separation between the vehicle and the body of the bicyclist, increased from 5.18 feet in the before condition to 5.85 feet after sharrows were installed; a gain of 0.67 feet. The distribution of lateral separation between vehicles and bicyclists, shown in Figure 6.3, indicates the tendency of drivers to shift to the inside lane, and leaving more space for the bicyclist to ride, with the presence of sharrows.

TABLE 6.1 Lateral Clearance between Bicyclist and Vehicle: Riverside Drive

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
Jacksonville	Riverside Dr.	38	30	5.18	5.85	1.82	1.72	1.59	1.70	8.69	8.34

TABLE 6.2 Lateral Clearance between Bicyclist and Curb: Riverside Drive

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
Jacksonville	Riverside Dr.	38	30	2.94	4.32	0.69	2.92	2.07	1.83	4.64	12.83

The mean lateral distance between the bicycle tire center and face of curb, the lateral bicycle clearance, increased by 1.38 feet from the before-period to the after-period (after sharrows were installed) as listed in Table 6.2. These findings are similar to those found by Brady *et al. (5)* in relation to the lateral bicycle position to the on-street parking delineation line. The standard location for the shared lane markings was 5.5 feet from the face of curb; however the location of the sharrows varied within the lane as the designers were trying to avoid some rough pavement or utilities. After the sharrows were installed, bicyclists tended to ride further away from the curb, and northbound drivers tended to use the inside lane more frequently. The distribution of the distance from the bicyclist to the curb is depicted in Figure 6.4.

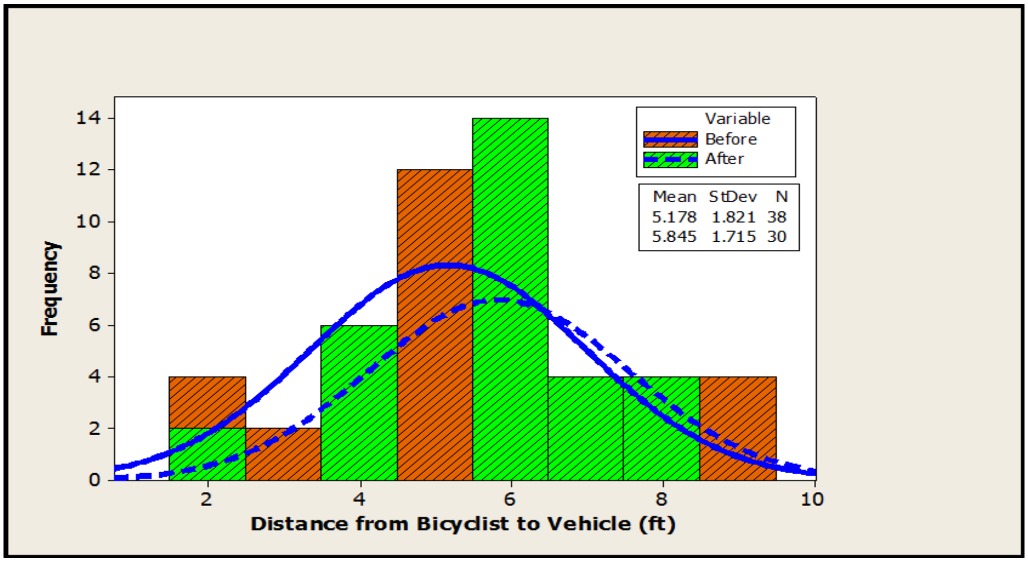

FIGURE 6.3 Distribution of Bicyclist to Vehicle Separation: Riverside Drive

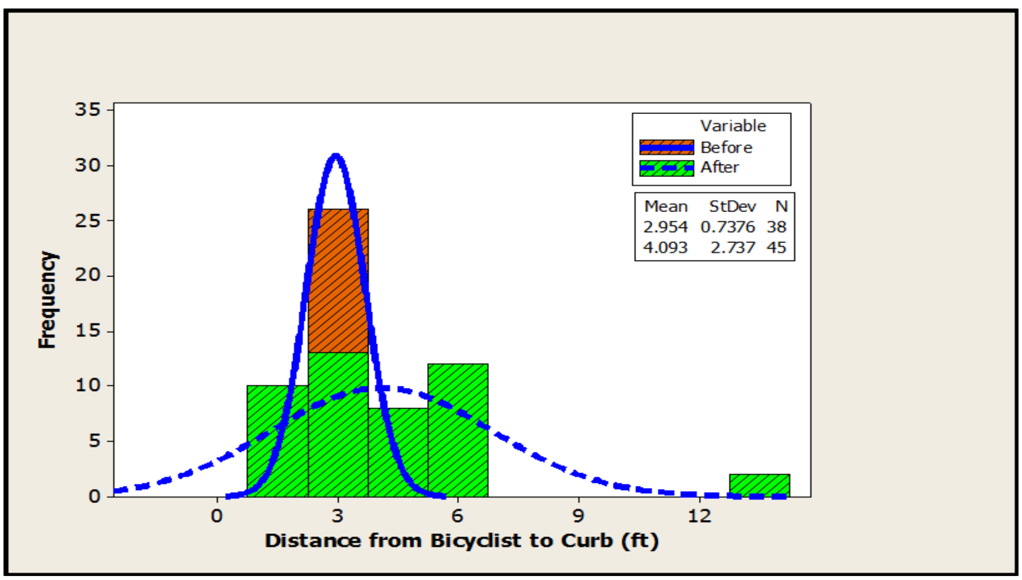

FIGURE 6.2 Distribution of Bicyclist to Curb Distance: Riverside Drive

6.1.1 Analysis of Variance

Tables 6.3 and 6.4 show the ANOVA results for the Riverside Drive study segment. The Analysis of Variance indicates a significant difference between the vehicle and bicycle separation from the before-period to the after-period with sharrows by the p-value of 0.039. Also, the results suggest that there is a significant difference in the way bicyclists ride in relation to the curb after sharrows were installed. A p-value of 0.015, obtained from the ANOVA, for the distance between bicyclists and the curb for the before- and after-scenario reflects the significance in the difference.

TABLE 6.3 ANOVA Results for Sharrows Effect (Cyclist to Vehicle): Riverside Drive

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	7.45	7.45	2.36	0.039
Error	77	208.07	3.15		
Total	67	215.52			

TABLE 6.4 ANOVA Results for Sharrows Effect (Cyclist to Curb): Riverside Drive

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	26.74	26.74	6.19	0.015
Error	66	349.80	4.32		
Total	67	376.54			

6.2 Bridge of Lions (St. Augustine)

The study segment at this location is across the Bridge of Lions, a two lane undivided roadway with lane widths of 11 feet, one in each direction. Sharrow placement at this site is illustrated in Appendix G. Descriptive statistics of the lateral clearance between motor vehicles and bicycles and the distance from bicycle to the curb are summarized in Tables 6.5 and 6.6. The lateral vehicle clearance did not improve significantly at this site. Before sharrows, an average clearance of 3.58 feet was observed. After sharrows were installed, the average clearance improved by only 0.04 feet for an average to of 3.62 feet. Sharrows were placed 5.5 feet of the face of curb due to the narrow lanes. The Bridge of Lions study segment after sharrows were installed is shown in Figure 6.5.

FIGURE 6.5 Shared Lane Markings: Bridge of Lions

These findings may be attributed to high traffic volumes and the crown of the bridge limiting forward sight distance, thus providing little opportunity to overtake bicyclists. Without an adjacent lane in the same direction, oncoming traffic severely limits a driver's ability to shift left and pass a bicyclist. The bridge is also marked as a no passing zone. The distribution of lateral clearance distances shown in Figure 6.6 also depicts the same phenomenon, little difference between the two distributions.

TABLE 6.5 Lateral Clearance between Bicyclist and Vehicle: Bridge of Lions

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
St. Augustine	Bridge of Lions	77	60	3.58	3.62	1.34	1.43	0.82	1.29	6.86	7.82

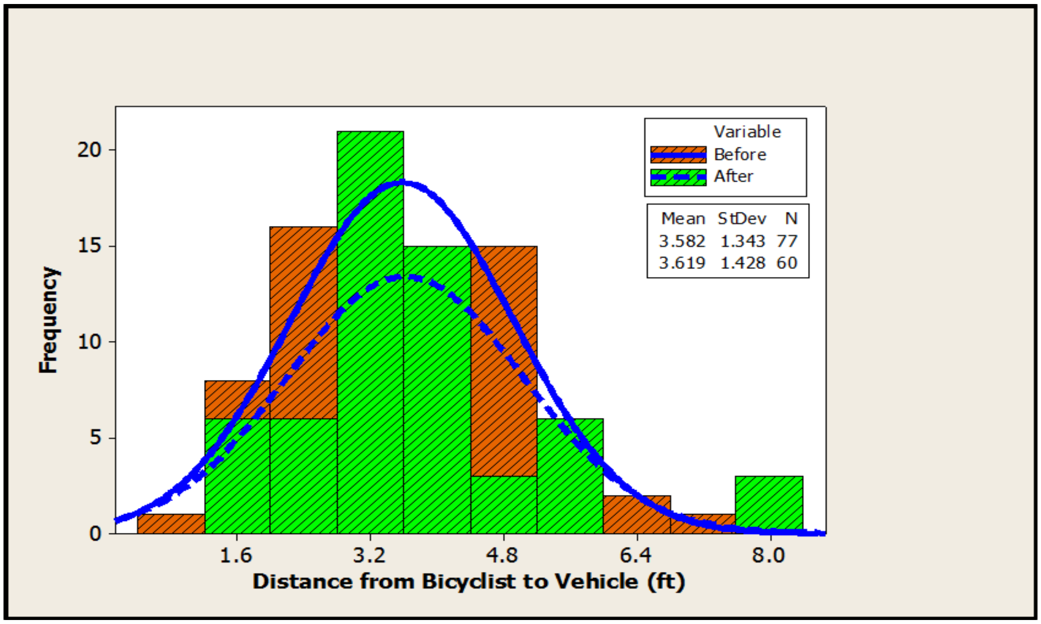

FIGURE 6.6 Distribution of Bicyclist to Vehicle Separation: Bridge of Lions

Although not much improvement was observed on the lateral clearance between vehicles and bicyclists at the Bridge of Lions site, the lateral distance between the bicyclist and the raised curb increased notably. Before sharrows, the distance from the bicyclist to the raised curb was observed to be 2.74 feet, and 4.24 feet after sharrows; an increase of 1.50 feet (Table 6.6). These findings are further supported by the distribution plots shown in Figure 6.7. This observation suggests that as bicyclists moved further away from the curb after sharrows were installed on the Bridge of Lions, motor vehicles also shifted to the left to maintain the same relative separation. The frequency of aggressive behavior from drivers seemed to decrease, although this is based upon the personal observations of cyclists in the study.

TABLE 6.6 Lateral Clearance between Bicyclist and Curb: Bridge of Lions

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
St. Augustine	Bridge of Lions	77	60	2.74	4.24	0.78	0.68	2.17	3.24	6.09	6.10

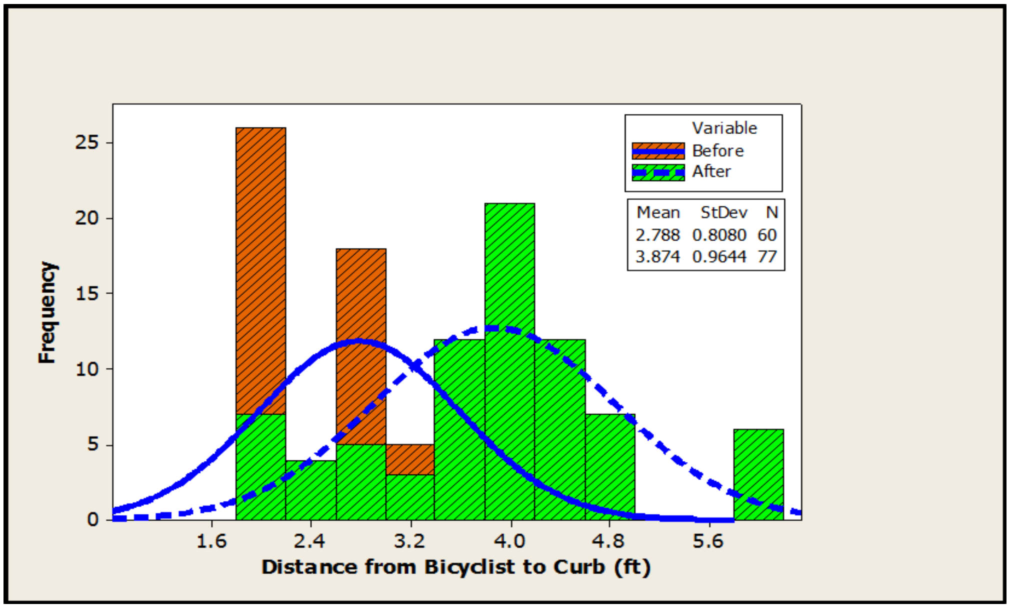

FIGURE 6.7 Distribution of Bicyclist to Curb Distance: Bridge of Lions

6.2.1 Analysis of Variance

Tables 6.7 and 6.8 show the ANOVA results for the Bridge of Lions study segment. The Analysis of Variance indicates that there is no significant difference between the vehicle and bicycle separation before and after sharrows were installed, denoted by a p-value of 0.585. However, the results suggest a significant difference in the distance between bicyclists and the raised curb with a p-value of 0.000.

TABLE 6.7 ANOVA Results for Sharrows Effect (Cyclist to Vehicle): Bridge of Lions

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	0.57	0.57	0.30	0.585
Error	135	256.77	1.90		
Total	136	257.34			

TABLE 6.8 ANOVA Results for Sharrows Effect (Cyclist to Barrier): Bridge of Lions

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	39.75	39.75	49.14	0.000
Error	135	109.21	0.81		
Total	136	148.96			

6.3 North 56th Street (Temple Terrace)

The site at N 56th Street in Temple Terrace included two 4-lane typical sections, one with curb and gutter, a narrow median separator and left turn lane (Site A), and a second with flush shoulders and a grass median (Site B). Through a resurfacing project, lane widths were adjusted in both sections. South of Serena Drive to Mission Hills Avenue (Site A), the four travel lanes were adjusted to 11 feet for the inner lanes, and 13 feet for the outer lanes with sharrows installed 4.0 feet from the face of the curb. Four-foot bike lanes were added in the flush shoulder section North of Serena Drive to Whiteway Drive (Site B), and the four travel lanes transitioned from 12 feet to 11 feet in width. The effects of sharrows and bike lanes were analyzed separately.

Initially at Site A, when the "before" data was collected the study location had a posted speed of 45 mph. As part of the design review, it was determined that the speed limit should be reduced to 35 mph due to the constrained curb and gutter section in Temple Terrace. Figure 6.8 displays the retrofitted design and sharrow placement on N 56th Street from Serena Drive to Mission Hills Avenue.

FIGURE 6.8 Wider Outside Lanes with Shared Lane Markings: N 56th Street (Site A)

6.3.1 Sharrows (Site A)

Descriptive statistics of the lateral clearance between motor vehicles and bicycles and the distance from bicycle tire to the curb for Site A are summarized in Tables 6.9 and 6.10. A significant improvement in the separation between bicycles and motor vehicles was observed after adjusting the lane widths, reducing the speed and installing sharrows at this site. The average lateral separation increased from 3.96 feet (before sharrows) to 6.51 feet (after sharrows), an increase of 2.55 feet as shown in Table 6.9 and Figure 6.9.

When a bicyclist was present, most motorists shifted to the inside lane while passing the bicyclist if there was an opportunity to do so and then returned to the outside lane after passing the bicyclist. Before sharrows, there was a tendency of drivers to remain in the outside lane, essentially squeezing between the bicyclist and inner lane, leaving less separation between. Vehicle lateral shift into the adjacent lane is discussed further in Section 6.8.

TABLE 6.9 Lateral Clearance between Motor Vehicle and Bicyclist: N 56th Street (Site A) Wider Outside Lane with Shared Lane Markings

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
Tampa	N 56th St.	365	171	3.96	6.51	1.36	3.17	1.40	1.42	9.71	14.3

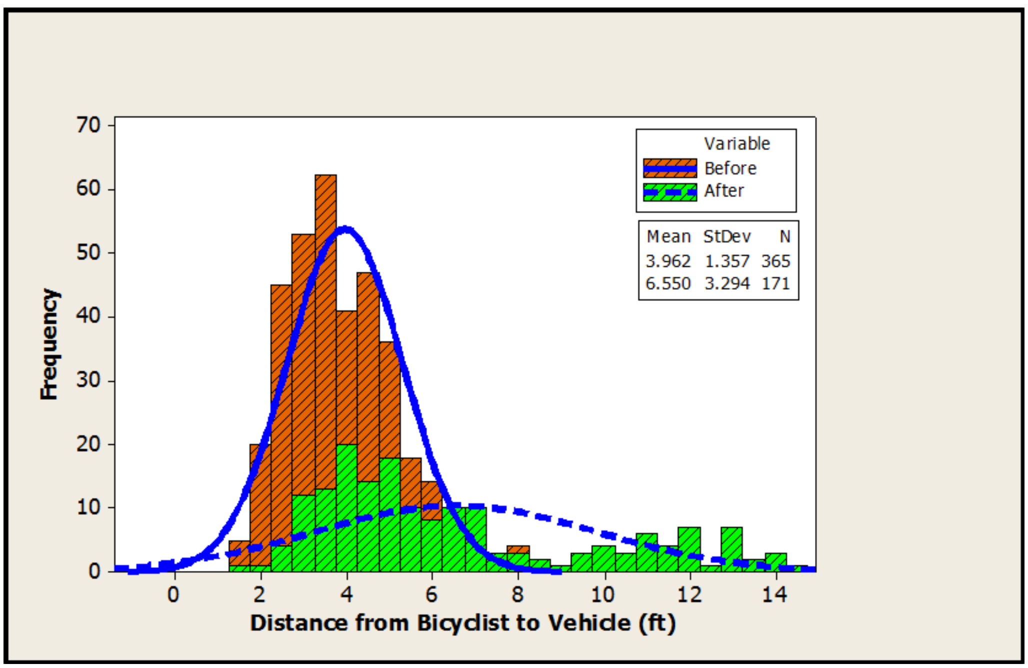

FIGURE 6.9 Distribution of Bicyclist to Vehicle Separation: N 56th Street (Site A) Wider Outside Lane with Shared Lane Markings

It was observed that bicyclists rode further from the curb after the lane width was widened, speed reduced and sharrows installed at Site A of the N 56th Street study location (Table 6.10 and Figure 6.10). An average distance from bicyclist to curb of 2.32 feet was observed with sharrows present compared to 1.92 feet before sharrows were installed. The majority of cyclists rode from 2.0 to 2.5 feet from the face of curb in the after-period as illustrated in Figure 6.10.

TABLE 6.10 Lateral Clearance between Bicyclist and Curb: N 56th Street (Site A) Wider Outside Lane with Shared Lane Markings

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
Tampa	N 56th St.	365	171	1.92	2.32	0.43	0.62	0.64	1.00	3.43	6.01

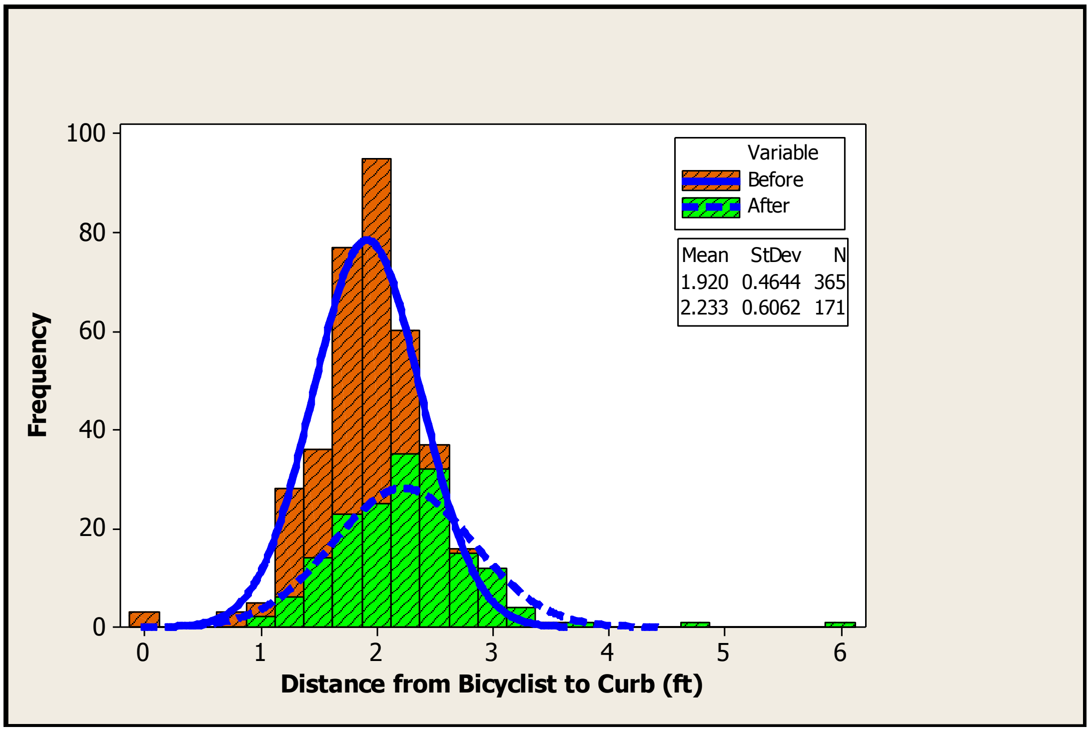

FIGURE 6.10 Distribution of Bicyclist to Curb Distance: N 56th Street (Site A) Wider Outside Lane with Shared Lane Markings

6.3.2 Analysis of Variance for Wider Outside Lane and Sharrows (Site A)

As shown in the previous section, descriptive statistics indicate that there was more lateral separation after the outside lane was widened, sharrows installed, and speed reduced. The purpose of conducting an Analysis of Variance (ANOVA) was to determine whether the difference was significant. From the results listed in Tables 6.11 and 6.12, the p-value of 0.000 shows a significant difference, indicating that the improvements appear to have an influence on increasing the separation between bicyclists and motor traffic. Likewise, the distance from the bicyclist to the curb shows a significant difference, signifying that bicyclists ride further from the curb in the presence of sharrows.

TABLE 6.11 ANOVA Results for Wider Outside Lane with Shared Lane Markings (Cyclist to Vehicle): N 56th Street (Site A)

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	779.82	779.82	165.58	0.000
Error	534	2514.87	4.71		
Total	535	3294.69			

TABLE 6.12 ANOVA Results for Wider Outside Lanes with Shared Lane Markings (Cyclist to Curb): N 56th Street (Site A)

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	11.389	11.389	43.14	0.000
Error	534	140.982	0.264		
Total	535	152.371			

6.3.3 Bike Lane (Site B)

The N 56th Street (Site B) study location consisted of added bike lanes with adjusted lane widths as shown in Figure 6.11. Descriptive statistics of lateral separation between motor vehicles and bicyclists are listed in Table 6.13. An average of 6.15 feet of separation between vehicles and bicyclists was observed on this segment compared to 6.51 feet observed on the sharrows segment (Site A), a difference of 0.36 feet. As shown in Figure 6.12, the wider distribution curve also indicates that the separation between motorists and bicyclists varied considerably more at Site A than distances observed with bike lanes (Site B). This suggests more willingness by motorists to provide extra space to a bicyclist in the absence of a dedicated bike lane when sharrows are present. In Florida, a minimum separation of 3 feet is required by law.

The distance between bicyclists and edge of pavement noted in Table 6.14, depict that bicyclists rode only slightly farther away from the edge of pavement (2.51 feet) compared to the sharrows site (2.23 feet). The distribution curves in Figure 6.13 illustrate the minor variation between the two treatments.

FIGURE 6.11 Bike Lanes: N 56th Street (Site B)

TABLE 6.13 Lateral Clearance between Motor Vehicle and Bicyclist-Comparing Bike Lane and Sharrows: N 56th Street

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Sharrows	Bike Lane	Sharrows	Bike Lane	Sharrows	Bike Lane	Sharrows	Bike Lane	Sharrows	Bike Lane
Temple Terrace	N 56th St.	365	86	6.51	6.15	3.17	2.06	1.42	3.06	14.3	13.13

TABLE 6.14 Lateral Clearance between Bicyclist and Curb/Edge of Pavement-Comparing Bike Lane and Sharrows: N 56th Street

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Sharrows	Bike Lane	Sharrows	Bike Lane	Sharrows	Bike Lane	Sharrows	Bike Lane	Sharrows	Bike Lane
Temple Terrace	N 56th St.	171	86	2.23	2.51	0.61	0.76	1.00	0.92	6.01	5.00

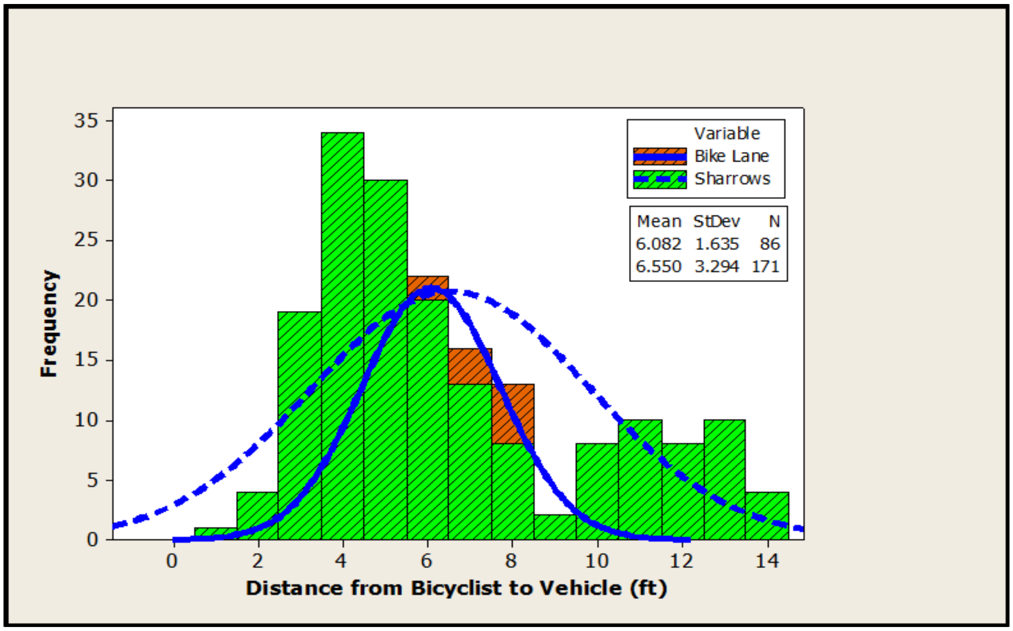

FIGURE 6.12 Distribution of Bicyclist to Vehicle Separation-Comparing Bike Lane and Sharrows: N 56th Street

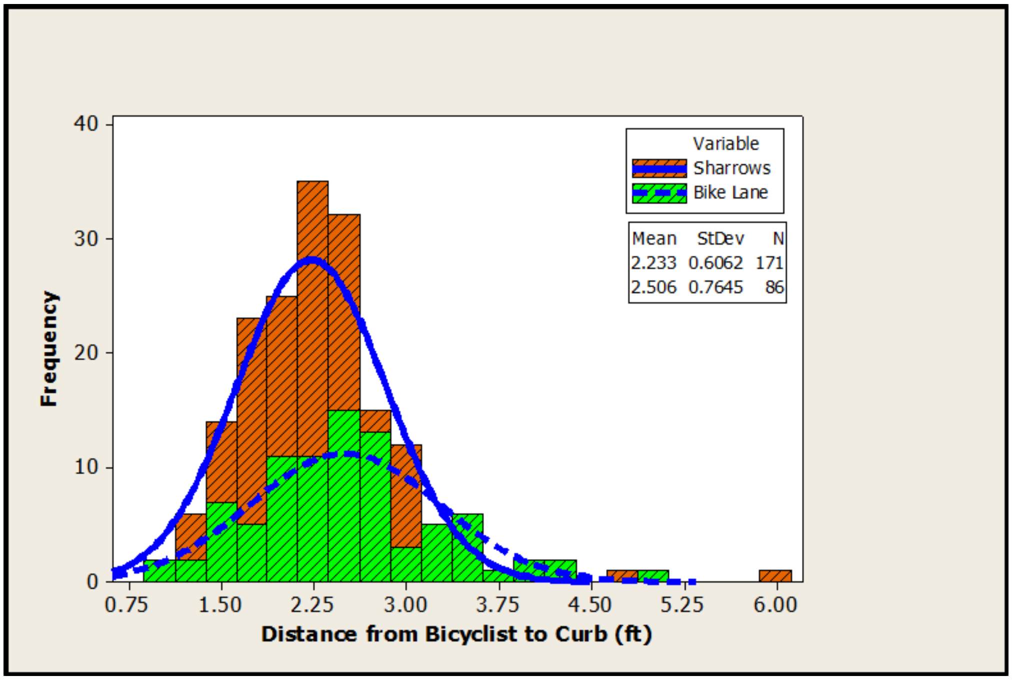

FIGURE 6.13 Distribution of Bicyclist to Curb Distance-Comparing Bike Lane and Sharrows: N 56th Street

6.3.4 Analysis of Variance for Bike Lane (Site B)

ANOVA results from the comparison between bicycle treatments (sharrows and bike lane) on North 56th Street are summarized in Tables 6.15 and 6.16. The results indicate that there is no significant difference (p-value of 0.216) between the two treatments in lateral separation between vehicles and bicyclists. However, the results suggest a significant difference (p-value of 0.02) in the distance from the bicyclists to the curb or edge of pavement. It was also observed that drivers did not slow down in the bike lane section as much as they did at the sharrows site. However, this was an anecdotal observation.

TABLE 6.15 ANOVA Results for Sharrows vs. Bike Lane (Cyclist to Vehicle): N 56th Street

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	12.53	12.53	1.54	0.216
Error	255	2072.13	8.13		
Total	256	2084.65			

TABLE 6.16 ANOVA Results for Sharrows vs. Bike Lane (Cyclist to Curb/Edge of Pavement): N 56th Street

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	4.27	4.27	9.70	0.02
Error	255	112.15	0.44		
Total	256	116.42			

6.4 Sunset Drive (Miami)

The Sunset Drive study site involved comparing operational characteristics of a four-lane (two lanes in each direction) divided roadway with a curbed median and flush grass shoulders. The pavement width was increased by reducing the median and applying the additional width to the outside lanes. The result was wider outside lanes (14 feet lane) and narrower inside lanes (11 feet). No sharrows were installed on this facility, shown in Figures 6.14 and 6.15.

FIGURE 6.14 Sunset Drive (before scenario)

FIGURE 6.15 Sunset Drive (after scenario)

6.4.1 Descriptive Analysis

The descriptive statistics for the lateral clearance between vehicles and bicyclists are shown in Table 6.17. Data analysis revealed that more separation between the bicyclists and vehicles was attained after retrofitting the site to include a wider outside lane. An average lateral separation of 5.11 feet was observed after retrofitting compared to an average separation of 4.25 feet that was observed before the widening, illustrated in Figure 6.16.

TABLE 6.17 Lateral Clearance between Motor Vehicle and Bicyclist: Sunset Drive

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
Miami	Sunset Blvd.	65	84	4.25	5.11	1.69	1.44	1.75	3.12	10.32	13.02

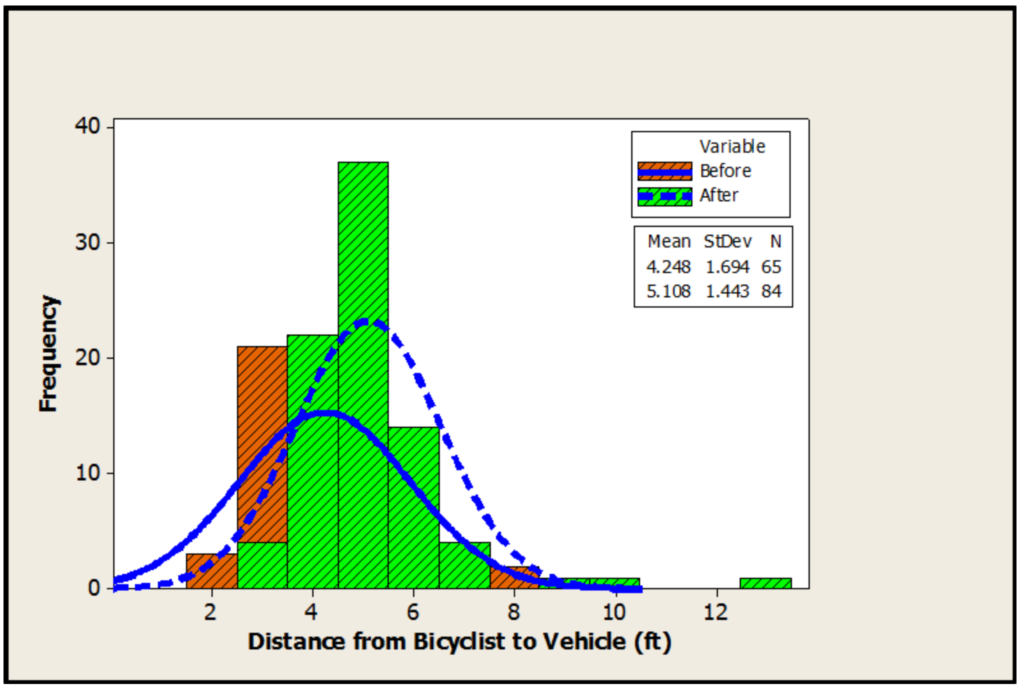

FIGURE 6.16 Distribution of Bicyclist to Vehicle Separation: Sunset Drive

On Sunset Drive, bicyclists tended to ride closer to the edge of pavement after the outside lane was widened (1.92 feet) than before widening (2.17 feet), a reduction of .25 feet. These findings are listed in Table 6.18 and illustrated in Figure 6.17.

TABLE 6.18 Lateral Clearance between Bicyclist and Edge of Pavement: Sunset Drive

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		Before	After	Before	After	Before	After	Before	After	Before	After
Miami	Sunset Blvd.	65	84	2.17	1.92	0.65	0.55	1.30	0.62	3.71	3.34

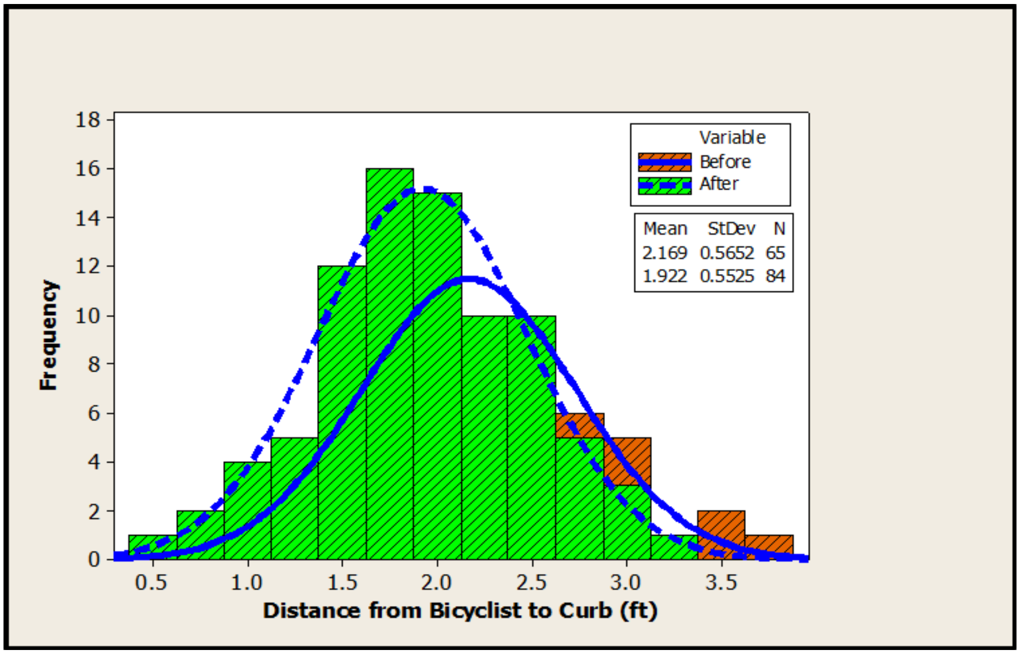

FIGURE 6.17 Distribution of Bicyclist to Edge of Pavement Distance: Sunset Drive

6.4.2 Analysis of Variance

The ANOVA results for Sunset Drive are summarized in Tables 6.19 and 6.20. The results reveal a significant difference in both the separation between motor vehicles and bicyclists (p-value of 0.001) and the lateral distance between bicyclists and the edge of pavement (p-value of 0.008). These findings are in agreement with the first phase of this study that solely analyzed the influence of a wide outside lane on bicycle and motor vehicle interactions.

TABLE 6.19 ANOVA Results for Wider Outside Lane Effect (Cyclist to Vehicle): Sunset Drive

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	27.11	27.11	11.17	0.001
Error	147	356.62	2.43		
Total	148	383.73			

TABLE 6.20 ANOVA Results for Wider Outside Lane Effect (Cyclist to Edge of Pavement): Sunset Drive

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	2.231	2.231	7.16	0.008
Error	147	45.781	0.311		
Total	148	48.011			

6.5 Bailey Road (Fort Lauderdale)

6.5.1 Site Description

The analysis of the Bailey Road site in Broward County involved comparing two cross-sections, one with a 5-foot wide bike lane separated from traffic by a 6 inch lane line (Figure 6.18), and the other with a 4-foot wide bike lane, separated from adjacent traffic by a 2-foot striped buffer zone (Figure 6.19). Both sections consist of 11-foot wide outer lanes and 10.5-foot wide inner lanes.

FIGURE 6.18 Section with 5-foot Bike Lane: Bailey Rd.

FIGURE 6.19 Section with 4-foot Bike Lane and 2-foot Buffer: Bailey Rd.

6.5.2 Descriptive Statistics

Tables 6.21 and 6.22 present the descriptive statistics of the buffer and no-buffer segments studied on Bailey Road. Data analysis indicates a significant improvement in the lateral vehicle clearance with the presence of the buffer between the bike lane and adjacent travel lane (Figure 6.20). On average, the lateral separation for the buffered bike lane segment was 5.72 feet, while the separation in the segment with the traditional bike lane was 5.00 feet, a difference of 0.72 feet. The buffered bike lane used six feet of pavement, versus the five feet of width used for the traditional bike lane, but the net gain in separation was only 0.72 feet.

As shown in Figure 6.21, the distance from the bicyclist to the curb also increased from 2.16 feet (with buffer) to 2.31 feet (without buffer). It is interesting to note that while bicyclists rode further from the curb at the site with a buffer, the lateral separation between bicycles and vehicles increased, an indication that a buffered lane plays a role in providing additional separation between motor and bicycle traffic.

TABLE 6.21 Lateral Clearance between Motor Vehicle and Bicycle: Bailey Rd.

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		No Buffer	Buffer	No Buffer	Buffer	No Buffer	Buffer	No Buffer	Buffer	No Buffer	Buffer
Ft. Lauderdale	Bailey Rd.	66	61	5.00	5.72	1.01	1.10	2.24	2.03	7.30	8.54

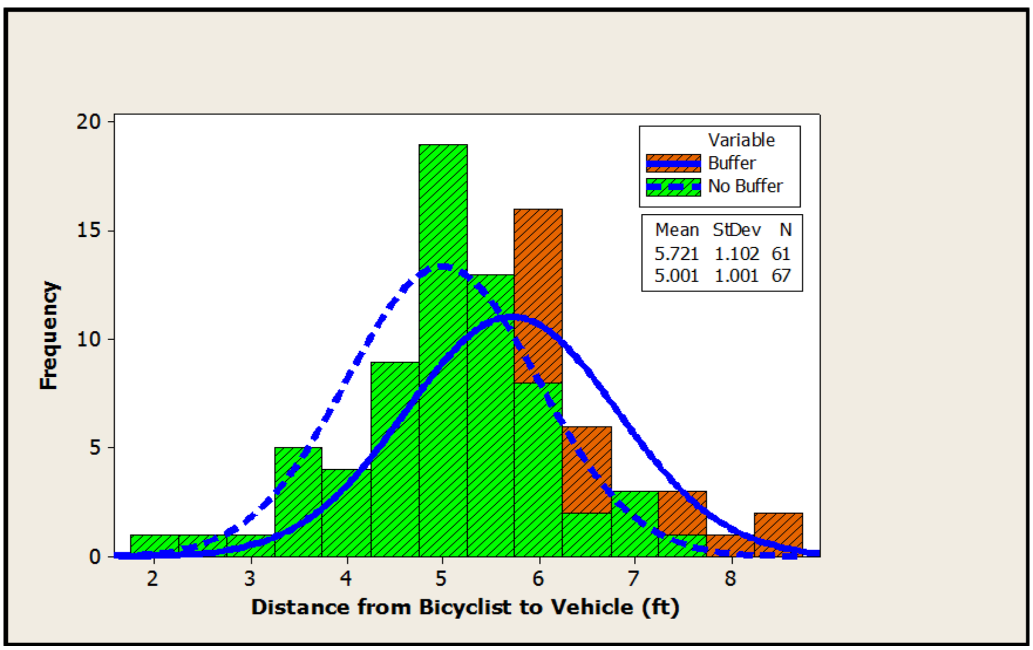

FIGURE 6.20 Distribution of Bicyclist to Vehicle Distance: Bailey Road

TABLE 6.22 Lateral Clearance from Bicyclist to Curb: Bailey Rd.

City	Road	Sample Size		Mean (ft.)		Std. Dev. (ft.)		Minimum (ft.)		Maximum (ft.)	
		No Buffer	Buffer	No Buffer	Buffer	No Buffer	Buffer	No Buffer	Buffer	No Buffer	Buffer
Ft. Lauderdale	Bailey Rd.	66	61	2.31	2.16	0.59	0.53	0.74	0.61	4.93	3.38

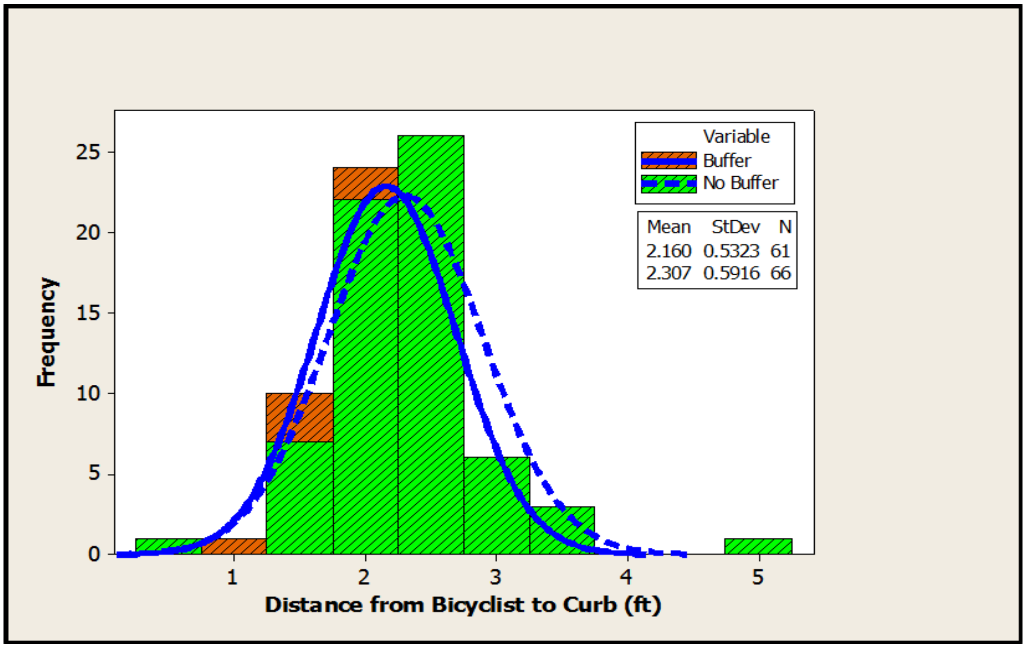

FIGURE 6.21 Distribution of Bicyclist to Curb Distance: Bailey Road

6.5.3 Analysis of Variance

Tables 6.23 and 6.24 show the ANOVA results for the Bailey Road sites. The analysis indicates a significant difference in the vehicle to bicycle separation between the two configurations (buffer and no-buffer) with a p-value of 0.000. However, the results suggest that there is no significant difference in the way bicyclists ride relative to the curb (p-value = 0.144).

TABLE 6.23 ANOVA Results for Buffer vs. no Buffer (Cyclist to Vehicle): Bailey Road

Source	DF what does this mean?	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	16.35	16.35	14.71	0.000
Error	125	138.98	1.11		
Total	126	155.33			

TABLE 6.24 ANOVA Results for Buffer vs. no Buffer (Cyclist to Curb): Bailey Road

Source	DF	Sum of Squares	Mean Square	*F*-Value	*p*-value
Model	1	0.689	0.689	2.17	0.144
Error	125	39.752	0.318		
Total	126	40.441			

6.6 Limited Access Facility Pilot Projects

6.6.1 Limited Access Sites

The limited access sites included three locations on Florida's Atlantic Coast that are part of FDOT's Bicycles on Limited Access Pilot Project. One site, Pineda Causeway (SR 404), is located in Melbourne, Brevard County, while the other two sites, Julia Turtle Causeway (I 195/SR 112) and William Lehman Causeway (SR 856/192nd Street) are located in Miami-Dade County. Figures 6.22 to 6.26 show the crossing locations at these limited access facilities. Refer to Table 4.1 for a description of each site.

FIGURE 6.22 William Lehman Cswy Westbound Off-ramp

FIGURE 6.23 William Lehman Cswy Westbound On-ramp

FIGURE 6.24 William Lehman Cswy Eastbound Off-ramp

FIGURE 6.25 William Lehman Cswy Eastbound On-ramp

FIGURE 6.26 Julia Tuttle Cswy Westbound (Mt. Sinai) On-ramp

6.6.2 Analysis of Driver Characteristics at Crossing Locations

It was observed that overtaking drivers slowed down as they approached a bicyclist at a crossing location. When watching the video clips, brake lights indicated the drivers slowing down. In some instances, a reduction in speed was observed without the brake lights illuminated suggesting the driver may have simply released the acceleration pedal to slow the vehicle. On sites with two lanes at the crossing locations, drivers who intended to overtake bicyclists before crossing shifted to the inside lane to provide more room for the bicyclist when passing.

TABLE 6.25 Operational Characteristics at Crossing Locations

Location	Road Name	Bicyclist reduced speed?		Bicyclist visibly checked for overtaking traffic before crossing?		Driver reduced speed?		Bicyclist used marked crossing location?	
		Y	N	Y	N	Y	N	Y	N
Miami	Lehman West Off-Ramp (Figure 6.22)	50.0%	50.0%	87.5%	12.5%	100.0%	0%	25.0%	75.0%
Miami	Lehman West On-Ramp (Figure 6.23)	95.7%	4.3%	100.0%	0%	100.0%	0%	8.7%	91.3%
Miami	Lehman East Off-Ramp (Figure 6.24)	90.0%	10.0%	100.0%	0%	100.0%	0%	10.0%	90.0%
Miami	Lehman East On-Ramp (Figure 6.25)	76.9%	23.1%	100.0%	0%	100.0%	0%	38.5%	61.5%
Miami	Julia Tuttle West (On-Ramp) (Figure 6.26)	81.0%	19.0%	100.0%	0%	100.0%	0%	100.0%	0%

6.6.3 Analysis of Bicyclist Characteristics at Crossing Locations

As shown in Table 6.25, bicyclists slowed down when crossing ramp lanes most of the time except at the William Lehman Causeway Eastbound Off-ramp site. At this location, bicyclists did not see the need to slow down as they could ride on the chevron pavement markings as they waited for an acceptable gap to cross. Bicyclists consistently turned their heads to search for overtaking traffic before crossing to ensure a safe crossing maneuver. Examples of bicyclist and driver interactions are shown in Appendix H.

6.6.4 Analysis of Pineda Causeway Data

The data collection for the effectiveness of green bike lanes in the ramp areas on the Pineda Causeway used local bicyclists. Most of the bicyclists that were observed rode in groups of about 15 cyclists as shown in Figure 6.27. Due to the low number of local cyclists using the Causeway and some riding in groups during the data collection periods, it was difficult to obtain statistically significant sample sizes. This shows the importance of using FDOT teams and volunteers from other agencies to gather sufficient data to allow for inferential statistical analysis. For this section, general observations are discussed with the use of photos for illustration.

FIGURE 6.27 Bicyclist Group Riding from US 1 to Pineda Cswy Eastbound After Green Bike Lane Installation

FIGURE 6.28 Bicyclist Crossing from US 1 to Pineda Cswy Eastbound Before Green Bike Lane Installation

FIGURE 6.29 Bicyclist Crossing from US 1 to Pineda Cswy Eastbound Before Green Bike Lane Installation

Data collected for the before-scenario, before green bike lane installation, indicates that most bicyclists prefer to use the shortest distance to cross the ramp. Figures 6.28 and 6.29 illustrate this phenomenon. After installation of green bike lanes, the same trend was observed. Most bicyclists continued to prefer using a straighter alignment to cross the ramp (Figure 6.30). Cyclists preferred to continue riding in the same alignment they had used on the paved shoulder adjacent to the outside lane as they come down the bridge, as shown in Figure 6.30.

FIGURE 6.30 Bicyclist Crossing Ramp from US 1 to Pineda Cswy Eastbound After Green Bike Lane Installation

6.7 Speed Analysis

Vehicle speed data was collected at three stages during passing events: just before passing, while passing, and after passing the bicyclist. All passing events with missing data from one or more of the three data stages were removed from the sample set. Table 6.26 shows the combined average spot speeds observed for each of the three scenarios for non-limited access study sites. In general, the data reflects a tendency of drivers to reduce speeds while-passing the bicyclist (Figure 6.31). Table 6.27 and Figure 6.32 is similar representation of the observed before, during, and passing average speeds but for the limited access sites.

TABLE 6.26 Average Speed in Terms of Vehicle Types (Non-Limited Access Sites)

Non-Limited Access				
Type of Vehicle	No. of Observations	Average Speed (mph)		
		Before	Passing	After
Passenger	64	32.1	28.6	33.2
SUV	53	32.9	30.2	34.8
Truck	22	32.5	28.9	34.5
Van	13	36.0	31.1	35.2
Bus	2	23.0	19.0	20.0
Overall	154	32.6	29.3	34.0

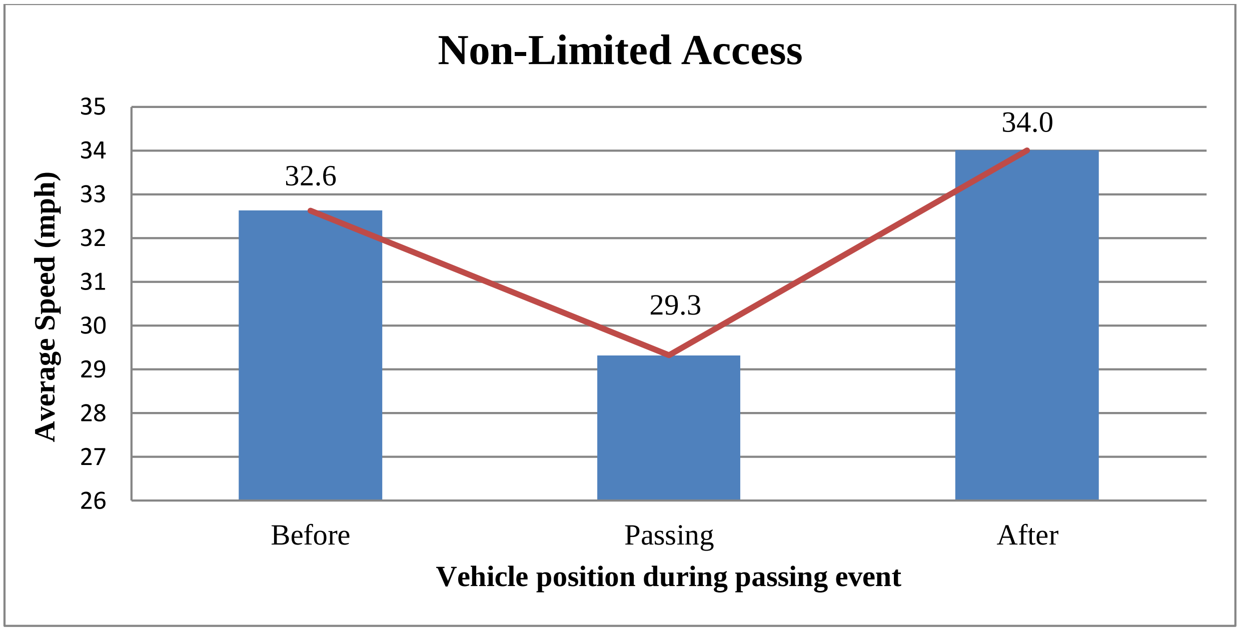

FIGURE 6.31 Average Vehicle Speed during Passing Events (Non-Limited Access Sites)

TABLE 6.27 Average Speed in Terms of Vehicle Types (Limited Access Sites)

Limited Access				
Type of Vehicle	No. of Observations	Average Speed (mph)		
		Before	Passing	After
Passenger	44	38.2	37.1	37.9
SUV	29	35.6	32.6	34.0
Truck	23	37.0	34.2	34.2
Van	9	36.8	32.0	32.6
Bus	4	36.3	39.0	37.8
Overall	109	37.1	34.9	35.6

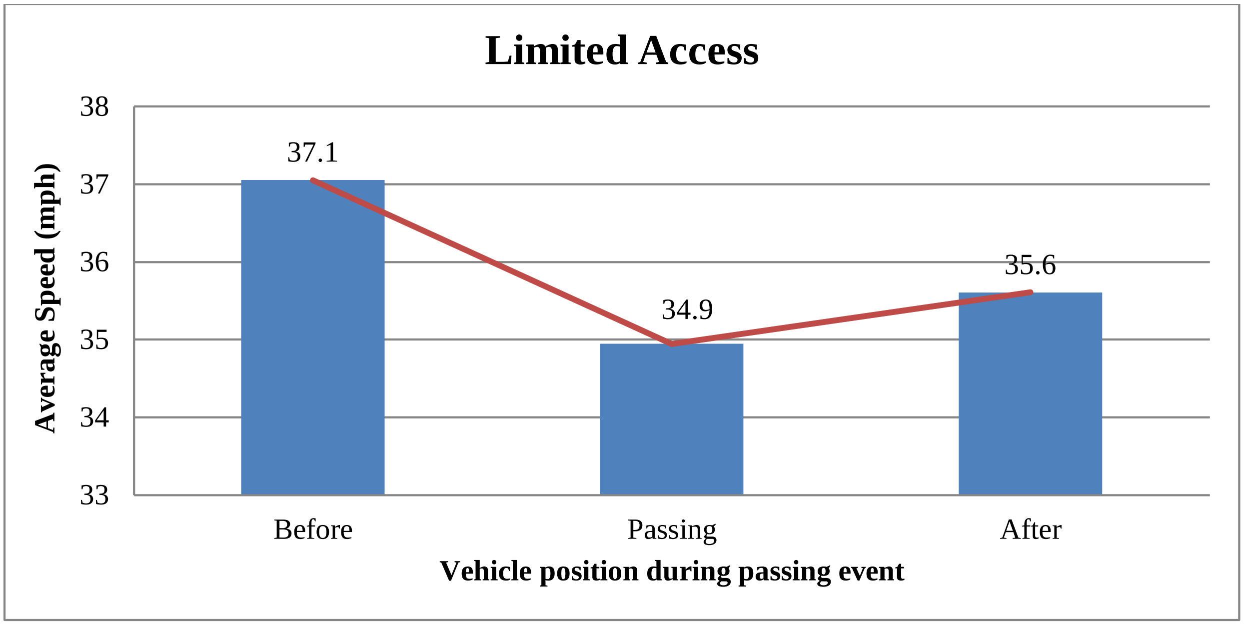

FIGURE 6.32 Average Vehicle Speed during Passing Events (Limited Access Sites)

Speeds for the three scenarios were therefore compared using a paired *t*-test. This test is appropriate for analyzing samples that have two different treatments, i.e., paired treatments. In this case, paired treatments include before- and while-passing, and while- and after-passing scenarios. The paired *t*-test provides the statistic, which is used to determine if there is a significant difference between the speeds of each motor vehicle for the paired scenarios. The null hypothesis for this test represented the proposition that the spot speeds of the above mentioned scenarios are equal while the alternative hypothesis is that the speeds are not equal. The alternative hypothesis is accepted only when the data suggest sufficient evidence to support it, hence rejecting the null hypothesis. All paired scenarios were tested at the 95% confidence level.

The MINITAB statistical software results of the paired *t*-test are shown in Tables 6.28 and 6.29. Table 6.28 summarizes the results for the non-limited access roads studied: Riverside Avenue, Bridge of Lions, N 56th Street, Bailey Road, and Sunset Drive. At a 95% confidence level, data shows sufficient evidence to indicate that drivers slow down as they approach bicyclists (before speed of 32.02 mph to 29.97 mph while-passing) and then increase their speeds after overtaking the bicyclists (30.80 mph while-passing and after speed of 32.82 mph). The difference between the speeds before-passing and while-passing and while-passing and after-passing were significant with a p-value less than 0.000. When the before-passing (32.02 mph) and after-passing (32.54 mph), excluding while-passing data, was analyzed, no significant difference was found (p-value = 0.110). It should be noted that the speed values, e.g., the after-passing speed shown in the comparison to while-passing (32.82 mph) differ from the average after-passing speed of 32.54 mph indicated when comparing before-passing and after-passing because not every pass had all three events (before-, while-, and after-passing) collected.

For limited access facilities (Table 6.29), the difference between the overtaking driver's speed before-passing (37.35 mph) and while-passing (34.93 mph) the bicyclists was significant with a p-value of 0.000, while the difference between motor vehicle speeds while-passing bicyclists

(34.94 mph) and after-passing (35.48 mph) was not significant (p-value = 0.150). Contrary to the non-limited access streets, the difference between vehicle speeds before- (37.33 mph) and after-passing (35.48 mph) was significant for the limited access facilities (p-value =0.017).

Table 6.28 Paired T-Test Results for Motor Vehicle Speeds (Non-Limited Access Streets)

Paired T-Test and Confidence Interval for Before & While-Passing

Paired T for Before – While-Passing

	N	Mean	StDev	SE Mean
Before	228	32.022	6.850	0.454
While-Passing	228	29.969	8.207	0.544
Difference	228	2.053	5.164	0.342

95% CI for mean difference: (1.379, 2.727)
T-Test of mean difference = 0 (vs not = 0): T-Value = 6.00 P-Value = 0.000

Paired T-Test and Confidence Interval for While-Passing & After

Paired T for While-Passing_1 – After

	N	Mean	StDev	SE Mean
While-Passing_1	226	30.801	8.148	0.542
After	226	32.819	7.312	0.486
Difference	226	-2.018	3.556	0.237

95% CI for mean difference: (-2.484, -1.552)
T-Test of mean difference = 0 (vs not = 0): T-Value = -8.53 P-Value = 0.000

Paired T-Test and Confidence Interval for Before & After-Passing

Paired T for Before_1 - After_1

	N	Mean	StDev	SE Mean
Before_1	209	32.024	6.878	0.476
After_1	209	32.545	7.242	0.501
Difference	209	-0.522	4.699	0.325

95% CI for mean difference: (-1.162, 0.119)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.60 P-Value = 0.110

Table 6.29 Paired T-Test Results for Motor Vehicle Speeds (Limited Access Causeways)

Paired T-Test and Confidence Interval for Before & While-Passing

Paired T for Before – While-Passing

	N	Mean	StDev	SE Mean
Before	94	37.351	7.587	0.783
While-Passing	94	34.926	7.508	0.774
Difference	94	2.426	6.217	0.641

95% CI for mean difference: (1.152, 3.699)
T-Test of mean difference = 0 (vs not = 0): T-Value = 3.78 P-Value = 0.000

Paired T-Test and Confidence Interval for While-Passing & After

Paired T for While-Passing_1 - After

	N	Mean	StDev	SE Mean
While-Passing_1	93	34.935	7.548	0.783
After	93	35.484	7.203	0.747
Difference	93	-0.548	3.646	0.378

95% CI for mean difference: (-1.299, 0.203)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.45 P-Value = 0.150

Paired T-Test and Confidence Interval for Before & After-Passing

Paired T for Before_1 - After_1

	N	Mean	StDev	SE Mean
Before_1	93	37.333	7.626	0.791
After_1	93	35.484	7.203	0.747
Difference	93	1.849	7.337	0.761

95% CI for mean difference: (0.339, 3.360)
T-Test of mean difference = 0 (vs not = 0): T-Value = 2.43 P-Value = 0.017

6.8 Vehicle Lateral Shift

Table 6.30 shows the percent of the vehicle lateral shift at each site. Except for the Bridge of Lions and Riverside Drive sites, about 50% or more of vehicles passed bicyclists without shifting into the adjacent lane. This may be attributed by the fact that Riverside and Bridge of Lions sites have the narrowest lane widths of all the sites (10 feet for Riverside Drive and 11 feet for Bridge of Lions). At Riverside, all vehicles shifted to the inside lane when passing bicyclists. When examining the 76% to 100% lateral shift quartile, data shows a high level of lateral shift for Riverside (82.33% and 53.33% before- and after-sharrows, respectively) and a lower level of lateral shift for Bridge of Lions (3.71% and 0.00% before- and after-sharrows, respectively). This may be attributed to the fact that the Bridge of Lions is a two lane undivided narrow bridge with a no passing zone.

Table 6.30 Lateral Shift Data for Study Sites

Site		Vehicle Lateral Shift into Adjacent Lane				
		No Lateral Shift	1%-25%	26%-50%	51%-75%	76%-100%
Riverside Dr., Jacksonville	Before	0.00	12.50	4.17	0.00	83.33
	After	0.00	6.67	13.33	26.67	53.33
Bridge of Lions, St. Augustine	Before	33.33	33.33	16.67	12.96	3.71
	After	26.09	52.17	17.39	4.35	0.00
N 56th St., Temple Terrace	Before	49.86	28.22	14.52	8.84	3.56
	After	52.92	14.40	10.89	3.50	18.29
Bailey Rd., Ft. Lauderdale	No Buffer	84.84	12.12	0.00	1.52	1.52
	Buffer	95.08	3.28	1.64	0.00	0.00
Sunset Dr., Miami	Before	53.85	29.23	6.15	4.62	6.15
	After	84.52	11.91	0.00	1.19	2.38
Pineda Cswy., Melbourne	Before	73.33	13.33	6.67	6.67	0.00
	After	60.00	20.00	0.00	0.00	20.00
Lehman Cswy., Miami	After	69.72	10.56	5.63	3.53	10.56
Julia Tuttle Cswy., Miami	After	48.28	20.69	10.34	13.79	6.90

7 CONCLUSIONS

This study was conducted to examine the influence of several bicycle facilities on the interaction between motor vehicles and bicyclists. The effectiveness of sharrows, bike lanes, buffers, wide curb lanes, and bicycle crossing pavement markings, were evaluated, including green bike crossings on limited access facilities. Several measures of effectiveness were investigated, including the lateral separation between motor vehicles and bicyclists, the distance from the bicycle tire to the curb, and motor vehicle speeds before-passing, while-passing, and after-passing a bicyclist. The following sections discuss the results produced from this study.

7.1 Lateral Spacing between Vehicles and Bicyclists

The lateral separation between motor vehicles and bicyclists was greater with sharrows compared to without sharrows for all three sites that were evaluated for shared lane markings. For the two sites with narrow outside lanes (Bridge of Lions and Riverside Drive), the lateral separation improved, with the greatest increase at Riverside Drive from an average of 5.18 feet before sharrows to 5.85 feet after sharrows were installed. Increased lateral separation of 2.55 feet also was observed at Site A in Temple Terrace (North 56th Street) after sharrows were installed with an average separation of 3.96 feet and 6.51 feet observed before- and after-sharrows were installed, respectively.

This study also compared operational characteristics between sharrows and bike lanes at North 56th Street (Site B) in Temple Terrace. The separation between motor vehicles and bicyclists in the bike lane segment was of 6.15 feet, compared to the 6.51 feet for the sharrows section. The range of lateral spacing varied from 1.42 feet to 14.30 feet for the sharrows segment, while bike lanes had a narrower range of 3.06 feet to 13.13 feet. Site observations indicated that there were less shifting to the inside lane at the bike lane site compared to the sharrows site. The difference in lateral separation between the sharrows section and the bike lane segment was not significant (p-value = 0.216).

At the Sunset Drive site in Miami, where the effect of a wide curb lane was examined, lateral vehicle to cyclist separation of 5.11 feet was observed after retrofitting compared to the separation of 4.25 feet before widening the roadway and restriping the lanes to include a wide curb lane, a significant increase (p-value = 0.001).

The influence of a buffer between the vehicle travel lane and bike lane was also evaluated at the Bailey Road site in Broward County. On average, a lateral separation of 5.00 feet was observed for the section without a buffer zone, while the lateral separation between bicyclist and vehicles for the section with a striped buffer was 5.72 feet, a difference of nearly three quarters of a foot.

In general, there was improvement in the amount of lateral spacing drivers provided to bicyclists at all of the study sites. The analyses of variance showed that the difference was significant.

7.2 Lateral Spacing between Bicyclists and Curb

While consistent results were obtained for lateral spacing between vehicles and bicycles, mixed results were observed for lateral spacing between bicyclists and the curb or edge of pavement. Distances observed for the Riverside and Bridge of Lions sites showed increases of 1.38 feet and

1.50 feet, respectively, while the spacing at North 56th Street (Site A) in Temple Terrace improved from 1.92 feet to 2.32 feet. The lateral spacing between bicyclists and the edge of pavement on the bike lane section on North 56th Street (Site B) was observed to be greater (2.51 feet) than observed at the sharrows segment (2.23 feet) and the difference was statistically significant, indicated by a p-value of 0.02. The results suggested no significant difference in the way bicyclists ride relative to the curb after reconstructing Sunset Drive to a wide curb lane, and when comparing a no-buffer to buffer zone at the Bailey Road site in Fort Lauderdale.

7.3 Limited Access Crossing

It was observed that overtaking drivers regularly reduced speeds when approaching a bicyclist at a crossing location. Simultaneously, bicyclists typically slowed down when passing a motorist at a crossing location except at the eastbound off-ramp study site on William Lehman Causeway. At this location, bicyclists did not see the need to slow down as they could ride across the striped chevron pavement markings alongside the ramp lane until an acceptable crossing gap was presented. It is interesting to note that bicyclists consistently turned their heads to watch for approaching traffic before crossing to ensure a safe crossing maneuver.

7.4 Speed Analysis

Vehicle speeds were analyzed separately for limited access and non-limited access facilities. Data indicates that drivers slow down as they pass bicyclists on non-limited access roadways (before speed of 32.02 mph to 29.97 mph while-passing) and then increase their speeds after overtaking the bicyclists (30.80 mph while-passing to 32.82 mph after-passing). The difference between the speeds before-passing and while-passing, and while-passing and after-passing, were both significant with p-values less than 0.000. However, when the before-passing (32.02 mph) and after-passing (32.54 mph), excluding while-passing speeds, were analyzed, no significant difference was found (p-value = 0.110).

For limited access facilities, the difference between the overtaking driver's speed before-passing (37.35 mph) and while-passing (34.93 mph) the bicyclists was significant with a p-value of 0.000. However, the difference between motor vehicle speeds while-passing bicyclists (34.94 mph) and after-passing (35.48 mph) was not significant (p-value = 0.150). Contrary to the non-limited access streets, the difference between vehicle speeds before- (37.33 mph) and after-passing (35.48 mph) was significant for the limited access facilities (p-value =0.017).

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APPENDIX A

I-195/Julia Tuttle Causeway Fact Sheets

Bicycles on
Limited Access Facilities
PILOT PROGRAM

I-195/Julia Tuttle Causeway
FROM US1/BISCAYNE BOULEVARD TO SR 907/ALTON ROAD

- Program established by State Legislature under House Bill 599 in 2012.
- Permits bicyclists (not pedestrians) to travel on selected limited access facilities.
- Two (2) sites selected in Miami-Dade County: I-195/Julia Tuttle Causeway and SR 856/William Lehman Causeway.
- Improvements include signing and pavement markings, new crossings, bridge railing, and minor roadway widening.
- Facilities proposed to be open to bicycle traffic by March 2013.
- Study examining safety, operations, and demand will be conducted throughout the two (2) year period with a final report due in September 2015.
- Signing and pavement marking scheme will include shared lane markings (sharrows) from Biscayne Boulevard to the Julia Tuttle Causeway along NE 36th Street (Eastbound) and NE 38th Street (Westbound) and at the SR 907/Alton Road interchange, a marked crossings at the SR 907/Alton Road off-ramp, a green colored bicycle lane at the Mt. Sinai Hospital exit ramp, and designated bicycle lanes along the Causeway.

Example of marked bicycle lane on a causeway.

Example of shared lane markings (sharrow) with "bikes may used full lane" signage.

- Initially, eastbound cyclists will be encourged to utilize the existing shared use path along the south side of the Causeway near the SR 907/Alton Road eastbound off-ramp to access SR 907/Alton Road southbound. Once the widening of the eastbound off-ramp is complete, cyclists will be encouraged to utilize the bicycle lane on the new paved shoulder.
- Cyclists traveling from points south and east of the SR 907/Alton Road interchange will be encouraged to travel north on Alton Road (E) to Sullivan Drive, left (southbound) onto Alton Road (W) to the westbound I-195 on-ramp. See the attached map for more information.
- Cyclists will be directed to enter/exit the Causeway via US 1/Biscayne Boulevard. Bicyclists will not be permitted to travel on I-195 west of US 1/Biscayne Boulevard ramps.
- For additional information, please contact Ken Jeffries, the District 6 Bicycle/Pedestrian Coordinator, at 305-470-5445 or at ken.jeffries@dot.state.fl.us.

FIGURE A.1 Julia Tuttle Cswy Bicycle Improvement Details

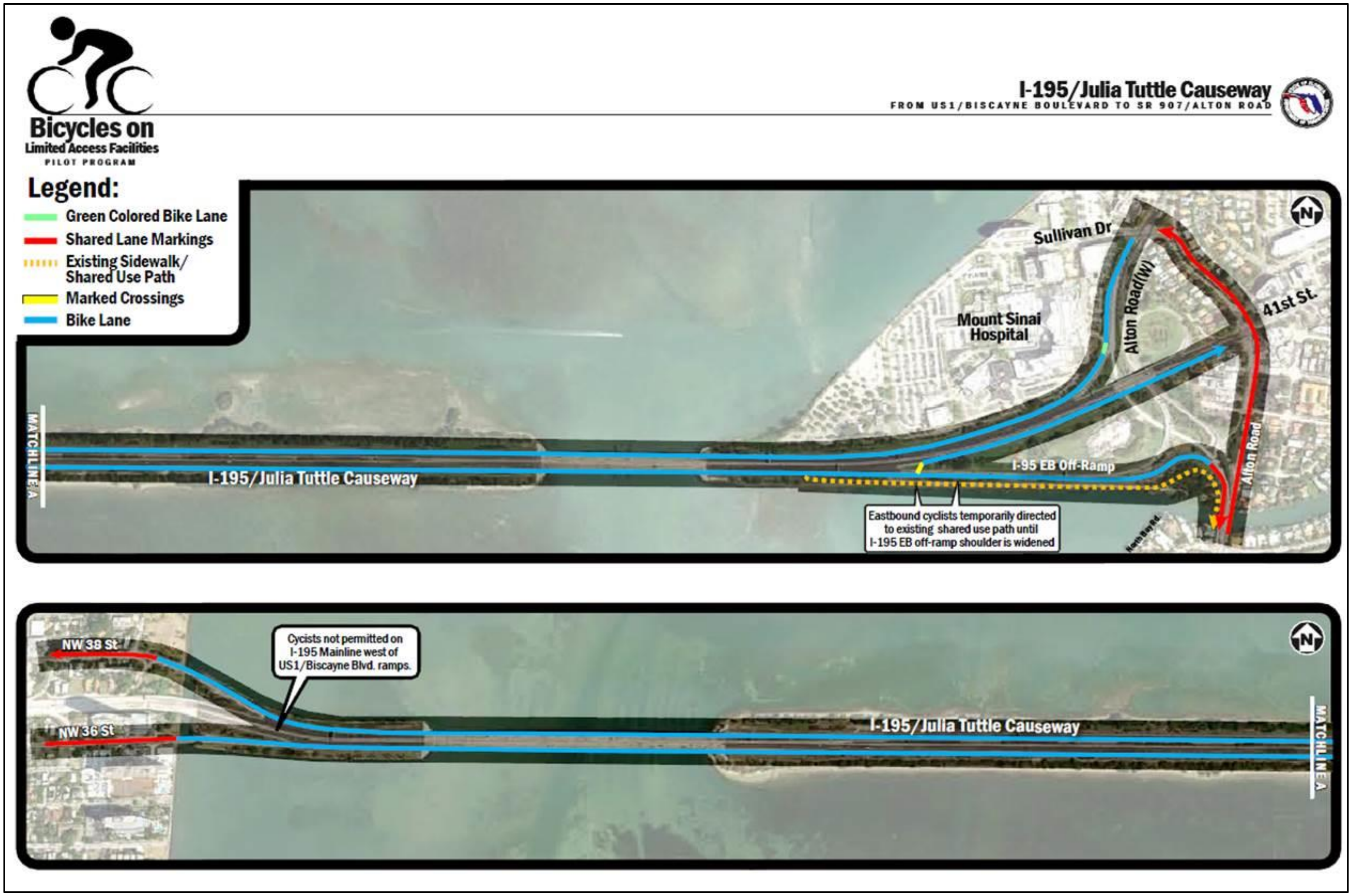


FIGURE A.2 Julia Tuttle Cswy Bicycle Improvement Plan

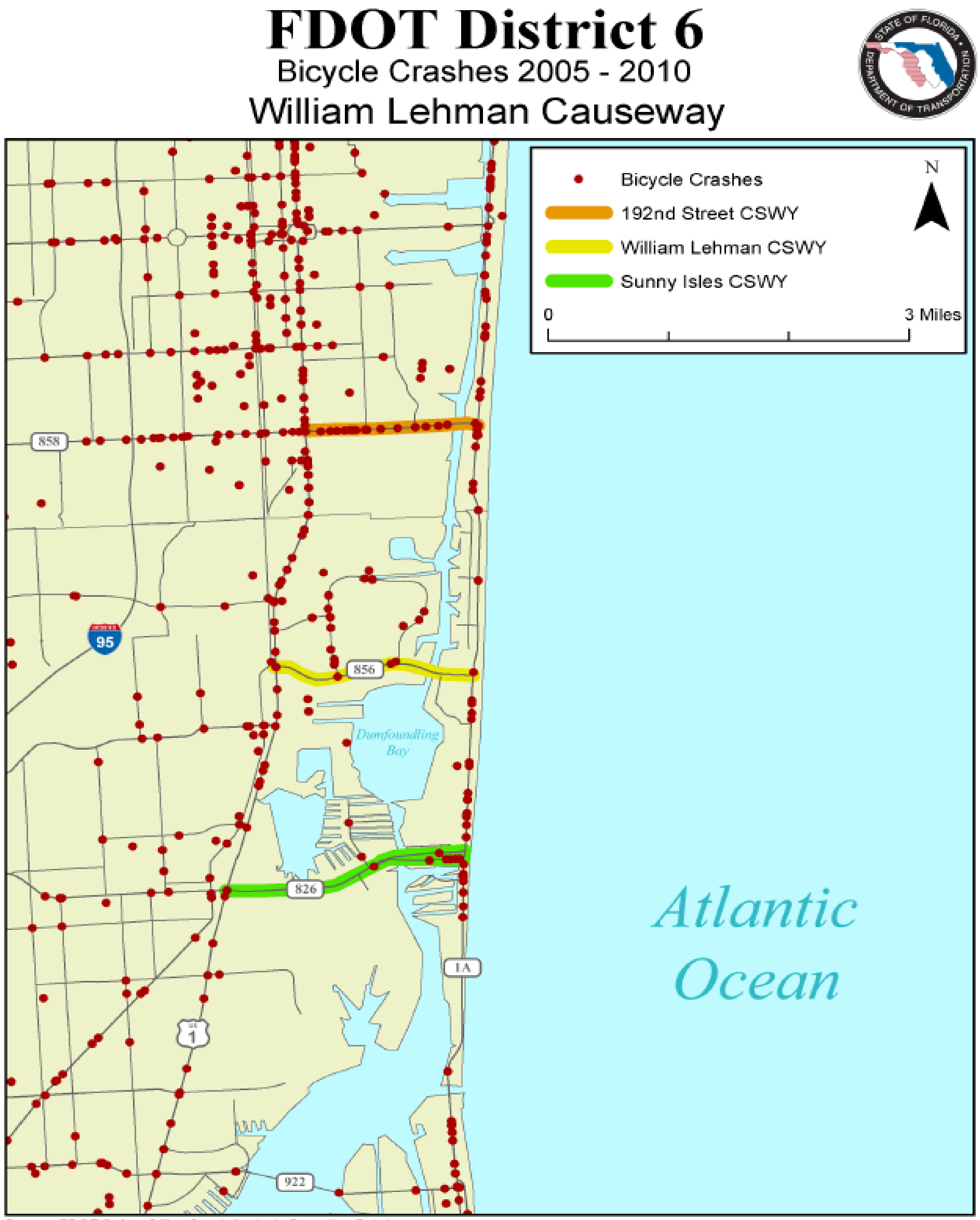
APPENDIX B

Bicycle Crash Maps for Limited Access Pilot Studies

Source: FDOT Safety Office Crash Analysis Reporting Database

FIGURE B.1 Pineda Cswy Bicycle Crash Map 2005-2010

FIGURE B.2 Julia Tuttle Cswy Bicycle Crash Map 2005-2010



Source: FDOT Safety Office Crash Analysis Reporting Database

FIGURE B.3 William Lehman Cswy Bicycle Crash Map 2005-2010

APPENDIX C

Bicycles on Limited Access Bridges

TABLE C.1 Pilot Projects of Bicycles on Limited Access Bridges

Bicycles on Limited Access Bridges			
Pilot Projects			
Location	Brevard Co.	Aventura	Miami Beach/Miami
Name	Pineda Causeway	Wm Lehman Causeway	Julia Tuttle Causeway
Google Map Link	http://goo.gl/maps	http://goo.gl/maps	http://goo.gl/maps
Limited Access Route	SR 404	SR 856	I -195
Waterbody Crossing	Indian & Banana Rivers	ICWW	Biscayne Bay
Interchange 1	US 1	W. Country Club	NE 36th / NE 37th
Interchange 2	SR A1A	A1A (Collins Ave)	Alton Road
Alt. Crossing Route	SR 518	SR 826	Venetian Causeway
Distance to Alt. Crossing	> 2 miles	1.7-2.0 miles	> 2 miles
Population within 5 miles of Bridge Ends	96,000	311,000	?
Bike Lane at Interchange 1?	Paved shoulders on Mainline, not on connecting ramp	No, Curb & Gutter.	Sidewalk. No Paved Shoulder / Bike Lane
Bike Lane at Interchange 2?	Paved Shoulders (4'?)	No, Curb & Gutter.	Sidewalk. No Paved Shoulder / Bike Lane
AADT	33500 to 37500	33,500	109,000
AADT/Lane	8375 to 9375	5,583	18,167
% Trucks	4	3	2.3
Number of Lanes	4	6	6
Shoulder Width 1 (FT)	7 to 8	10'	10
Max. Grade (%)	?	6	?
Posted Speed (MPH)	55	45	55
Potential Primary Usage	Transportation	Transportation	Both
Local Support	YES	YES	Yes
Potential Use	Significant	Great	Significant
Supports Regional Trails System	Access to Cape Canaveral National Seashore	Don Soffer Trail	Alternate route for East Coast Greenway instead of Venetian Causeway

x-Bikes-on-LA-Bridges Council.xlsx, 9/19/2012

APPENDIX D

Pineda Causeway Fact Sheet

NOTICE OF
FDOT BIKE LANES PILOT PROJECT

For Pineda Causeway/State Road (S.R.) 404

From US-1 to SR A1A

Pineda Causeway
State Road (S.R.) 404 Bicycle Lanes
From US-1 to SR A1A
<u>Pilot Project</u>: Bikes on
Limited Access Facilities
Financial Project ID: 432300-1-52-01

Changes are coming soon to the Pineda Causeway/State Road 404. The Florida Department of Transportation (FDOT) is conducting pilot projects, statewide, to allow bicyclists to use specific sections of select, limited access facilities. Pineda Causeway is one of the sites selected.

As part of the pilot project, the guard railing on the Pineda Causeway is being retrofitted—making it higher, the roadway restriped, and drainage inlets replaced. Green stripes (above) are being used on the roadway to alert bicyclists and motorists that cyclists are crossing through areas of vehicular traffic. Grated inlets are being replaced with those that have smaller openings, to lower the risk of bike tires slipping in.

The addition of bicycle lanes will not affect the lane width or access for vehicular users on the roadway, nor is any road widening anticipated at this time. No additional right of way is needed. The speed limit will remain the same.

Bicycle lanes are planned for use in March of 2013. The project cost is estimated at $862,000 and is covered by state transportation funds.

Table 1: *Project Schedule*

Design Begin	May-2012
Design Complete	June-2012
Project Awarded to Contractor	September-2012
Facility Open to Bike Traffic	March-2013

For additional information concerning the project, please contact Jeremy Dilmore, the FDOT Project Manager at (386) 943-5544 or via email at: Jeremy.Dilmore@dot.myflorida.com, or log onto www.cflroads.com.

FIGURE D.1 Pineda Cswy Bicycle Improvement Details

APPENDIX E

William Lehman Causeway Bike Lane Concept

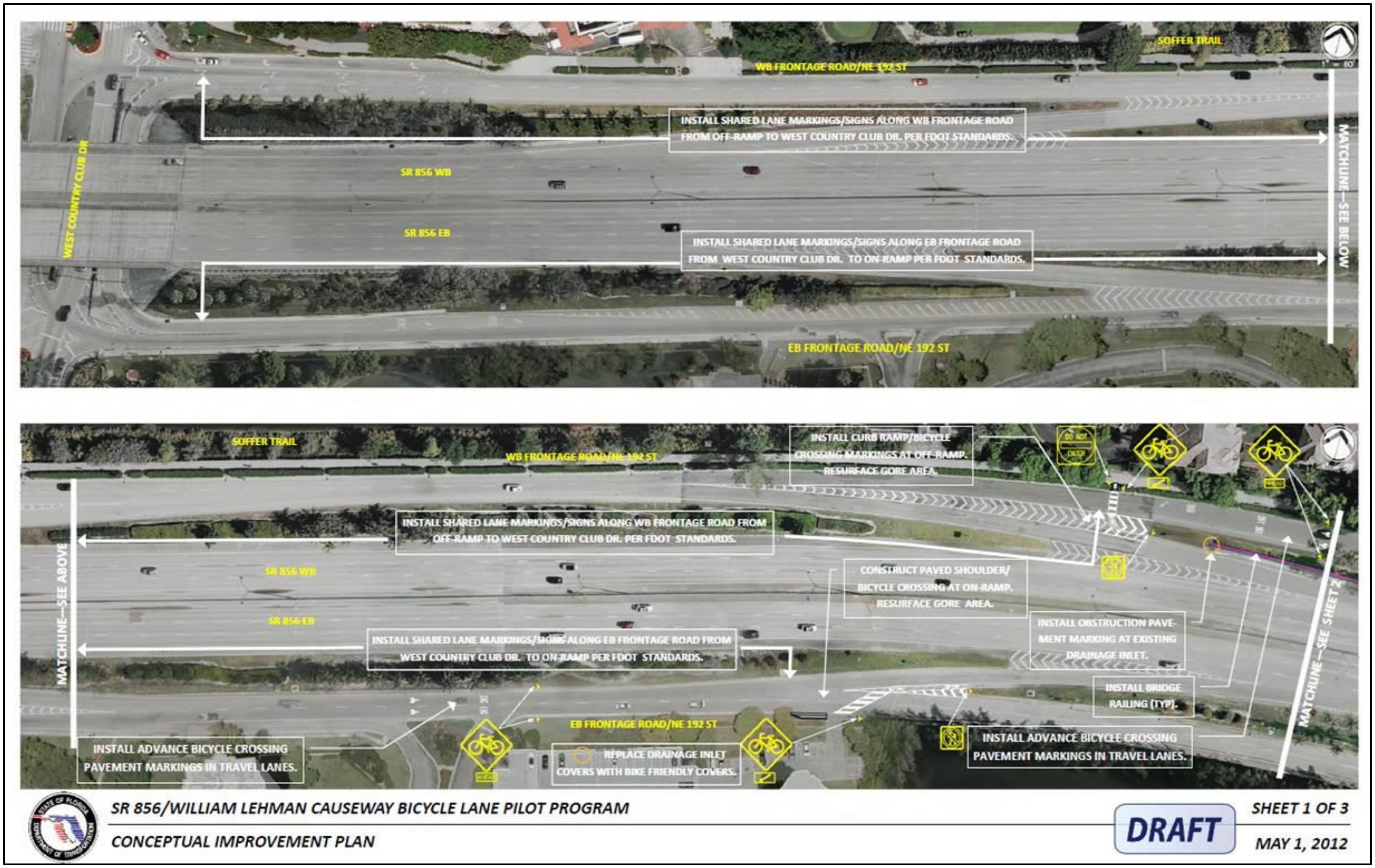


FIGURE E.1 William Lehman Cswy Bike Lane Plan Sheet 1 of 3

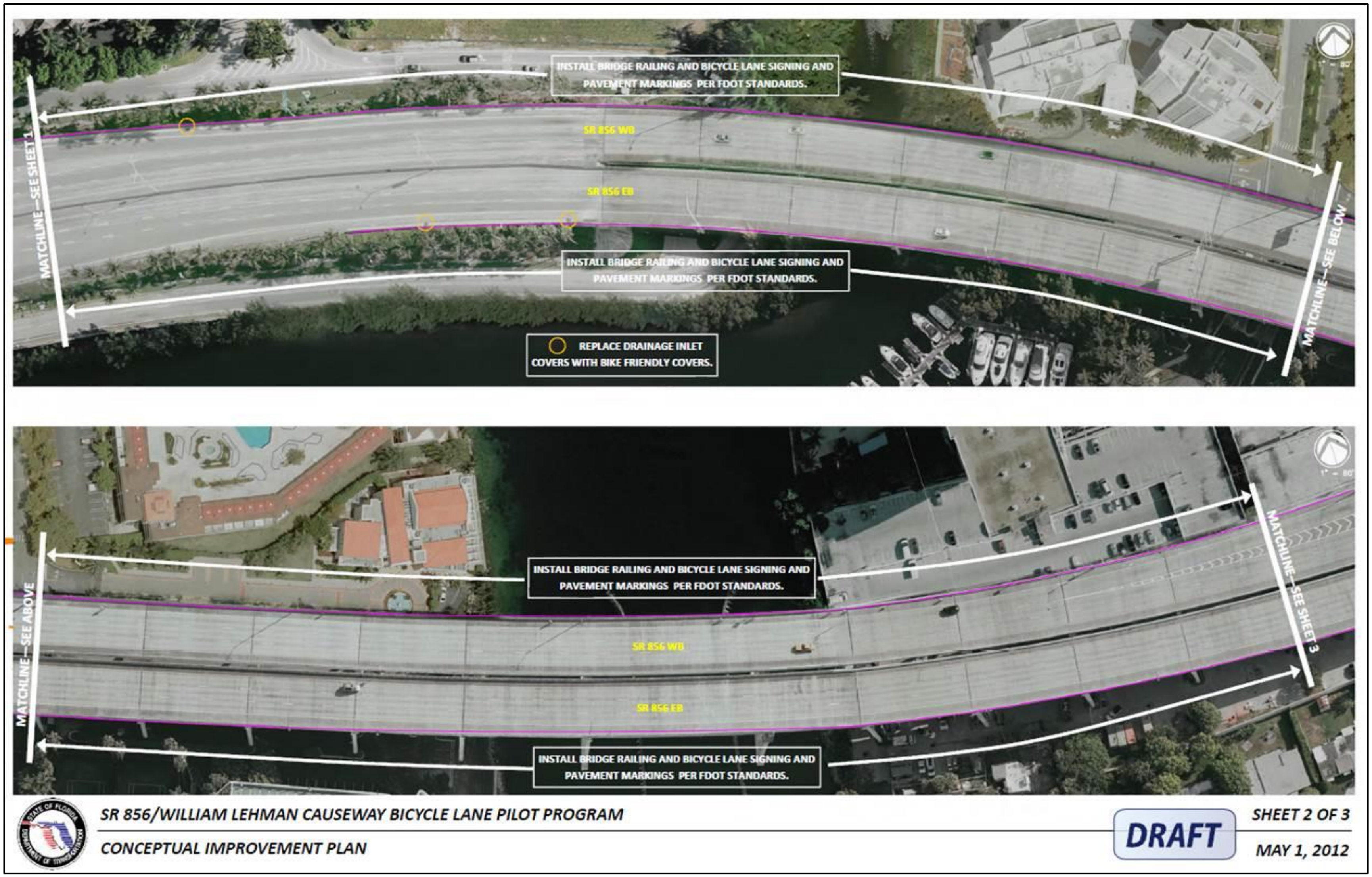


FIGURE E.2 William Lehman Cswy Bike Lane Plan Sheet 2 of 3

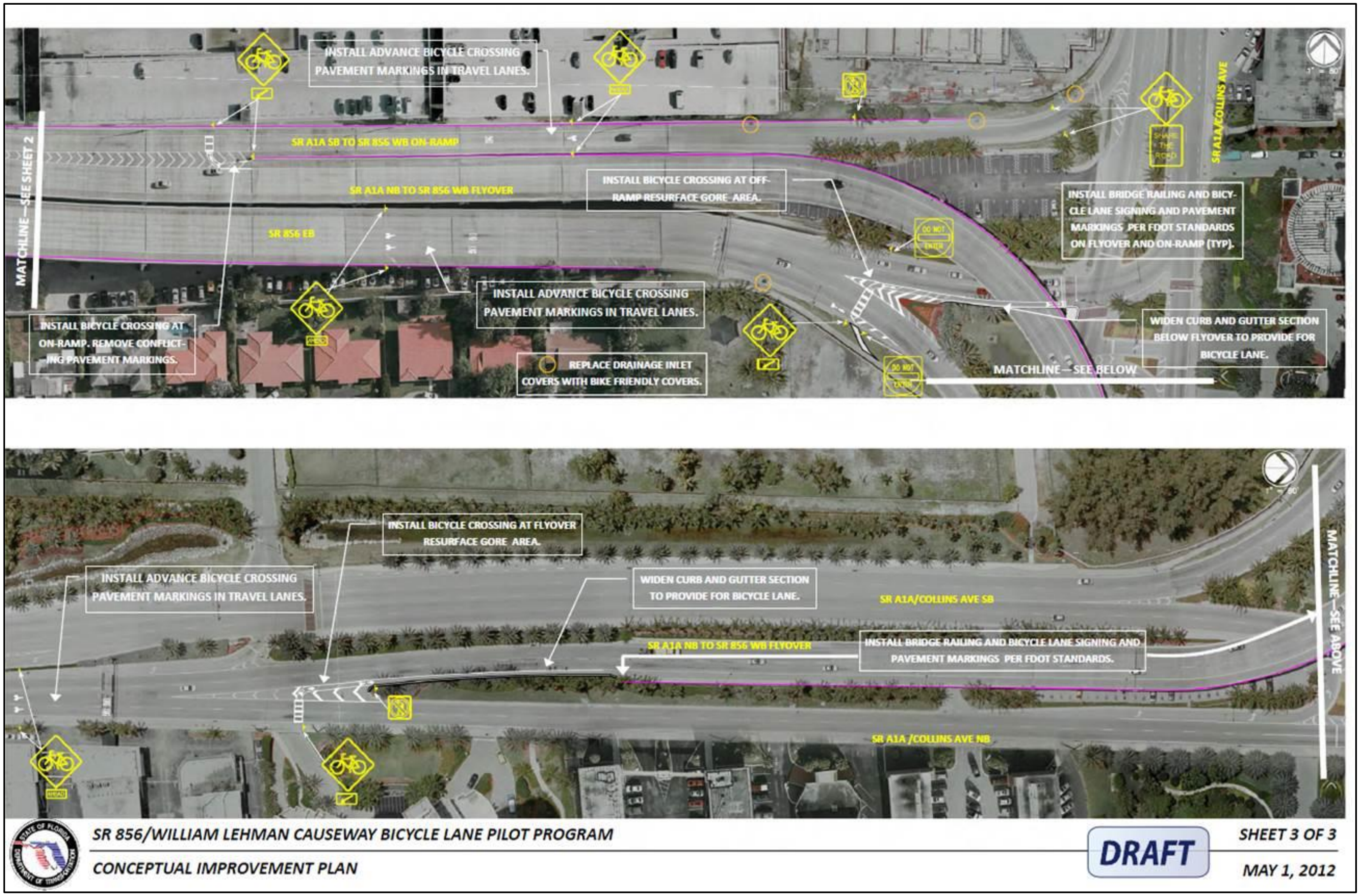


FIGURE E.3 William Lehman Cswy Bike Lane Plan Sheet 3 of 3

APPENDIX F

William Lehman Causeway Fact Sheets

Bicycles on
Limited Access Facilities
PILOT PROGRAM

SR 856/William Lehman Causeway
FROM WEST COUNTY CLUB DRIVE TO SR A1A/ COLLINS AVENUE

- Program established by State Legislature under House Bill 599 in 2012.
- Permits bicyclists (not pedestrians) to travel on selected limited access facilities.
- Two (2) sites selected in Miami-Dade County: SR 856/William Lehman Causeway and I-195/Julia Tuttle Causeway.
- Improvements include signing and pavement markings, new crossings, bridge railing, and minor roadway widening.
- Facilities proposed to be open to bicycle traffic by March 2013.
- Study examining safety, operations, and demand will be conducted throughout the two (2) year period with a final report due in September 2015.
- Signing and pavement marking scheme will include shared lane markings (sharrows) along the SR 856 Frontage Roads, marked crossings at the on-/off-ramps, and marked bicycle lanes on the Causeway.
- Cyclists will be encouraged to utilize the Frontage Roads to enter/exit the Causeway in the City of Aventura. Cyclists will not be permitted to travel on the Causeway between the Frontage Road exit/entrance ramps and US 1/Biscayne Boulevard.

Example of marked bicycle lane on a causeway.

Example of shared lane markings (sharrow) with "bikes may used full lane" signage.

- Eastbound Cyclists will be encouraged to transfer to the sidewalk as they travel south-bound on SR A1A/Ocean Boulevard in Sunny Isles Beach to NE 189th Street.
- For additional information, please contact Ken Jeffries, the District 6 Bicycle/Pedestrian Coordinator, at 305-470-5445 or at ken.jeffries@dot.state.fl.us.

FIGURE F.1 William Lehman Cswy Bicycle Improvement Details

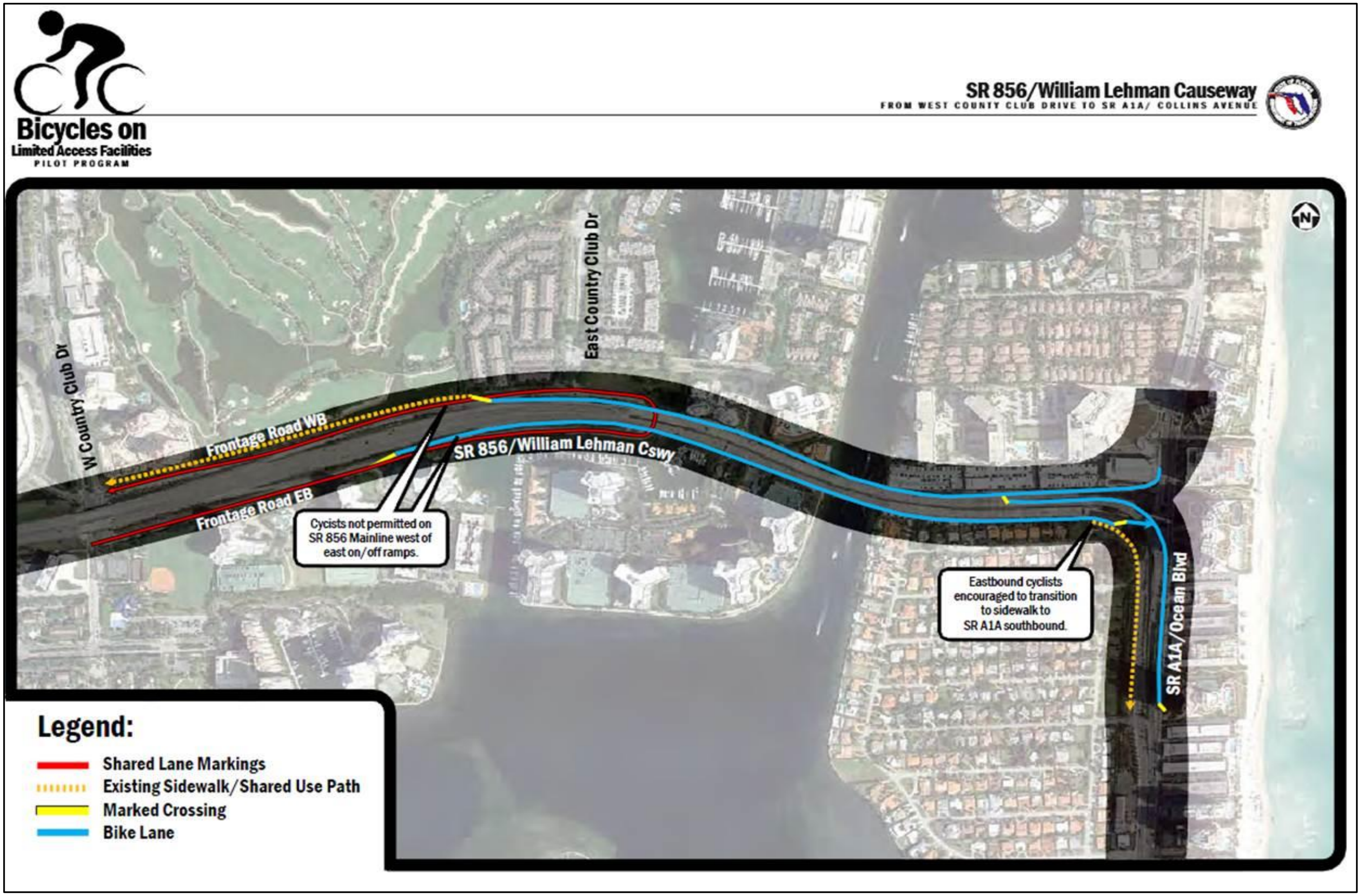


FIGURE F.2 William Lehman Cswy Bicycle Improvement Plan

APPENDIX G

Bridge of Lions Sharrows Plan

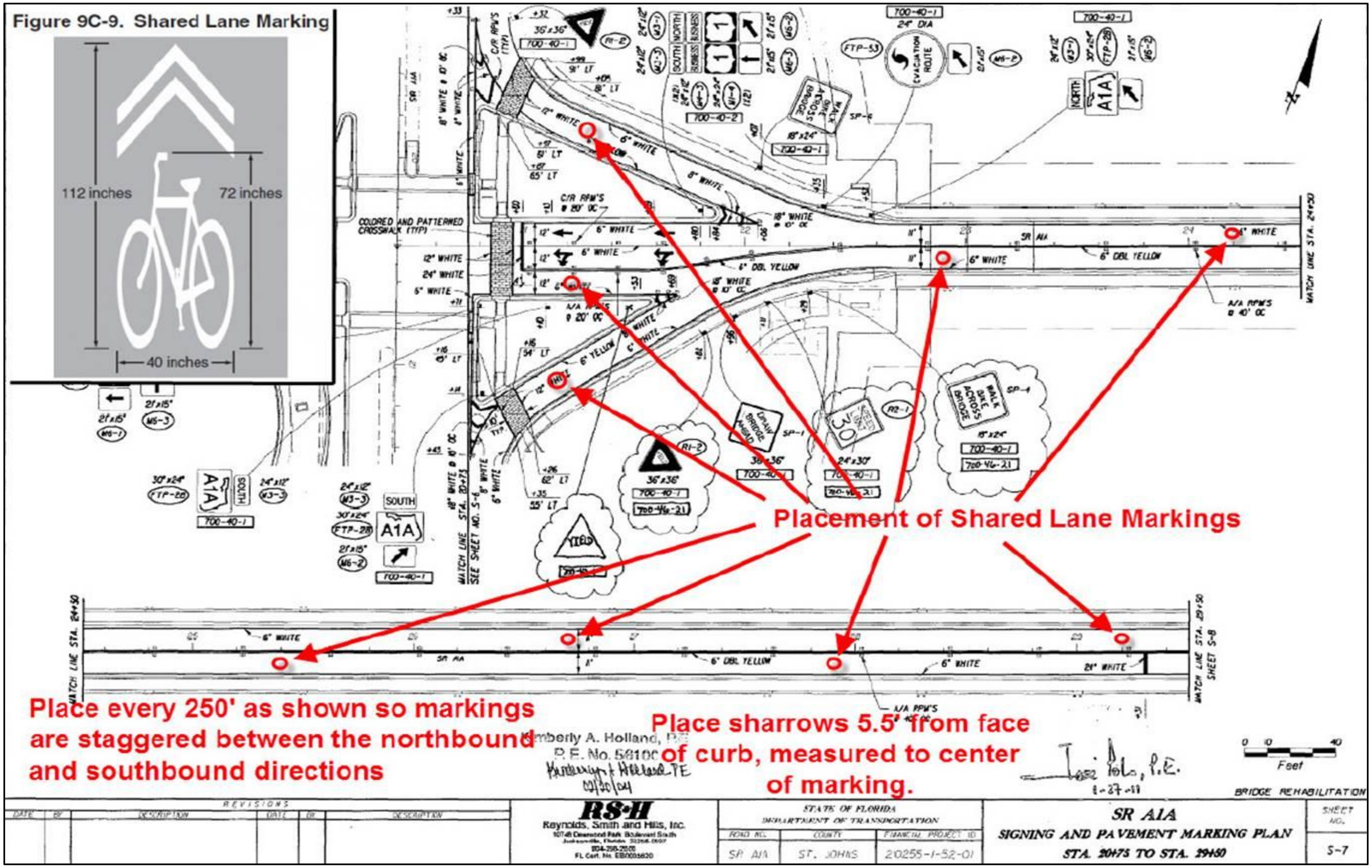


FIGURE G.1 Bridge of Lions Sharrows Placement Plan

APPENDIX H

Additional Photographs

FIGURE H.1 Driver Yielding Right-of-Way to Bicyclist at Ramp Crossing on Julia Tuttle Cswy

FIGURE H.2 Bicyclist Crossing Ramp Using Green Bike Lane on Julia Tuttle Cswy

FIGURE H.3 Cyclist Group Using Wide Shoulder on Julia Tuttle Cswy

FIGURE H.4 Sharrows on Lehman Cswy On-Ramp

FIGURE H.5 Bicyclist using Bike Lane Approaching Lehman Cswy On-Ramp

FIGURE H.6 Cyclist Checking Traffic before Crossing Lehman Cswy On-Ramp

FIGURE H.7 Bicyclist Yielding to Traffic before Crossing Lehman Cswy On-Ramp

FIGURE H.8 Bicyclist Negotiating with Driver before Crossing Lehman Cswy On-Ramp

FIGURE H.9 Bicyclist Crossing Ramp After Yielding to Driver (Fig. H.8)

FIGURE H.10 Bicyclist Crossing Ramp Using Bike Lane at Lehman Cswy On-Ramp