AN EVALUATION OF BIKE LANES ADJACENT TO MOTOR VEHICLE PARKING

William W. Hunter
J. Richard Stewart
University of North Carolina
Highway Safety Research Center

Study Prepared for the Florida Department of Transportation
Pedestrian/Bicycle Safety Section

December 1999

AN EVALUATION OF BIKE LANES ADJACENT TO MOTOR VEHICLE PARKING

William W. Hunter
J. Richard Stewart
University of North Carolina
Highway Safety Research Center

Study Prepared for the Florida Department of Transportation
Pedestrian/Bicycle Safety Section

December 1999

TABLE OF CONTENTS

Page

List of Tables and Figures

Introduction

Bike lanes (BLs) have become increasingly popular in recent years and sometimes are retrofitted to existing roadways. This often requires re-striping of the existing traffic lanes, particularly if the roadway has on-street parking. The Pedestrian/Bicycle Safety section of the Florida Department of Transportation (FLDOT) has received inquiries from local pedestrian/bicycle coordinators about how well a BL next to on-street motor vehicle parking operates when the adjacent motor vehicle traffic lane is narrowed. These inquiries prompted this study by the University of North Carolina Highway Safety Research Center (HSRC) for the FLDOT.

This evaluation compares roadways in Ft. Lauderdale and Hollywood, FL that have bicycle lanes (BLs) next to motor vehicle parking. The BLs are nominally 5 feet in width. The primary difference in the locations is the width of the motor vehicle traffic lane next to the BL. In order to retrofit the BL on route A1A in Ft. Lauderdale, the traffic lane next to the BL was striped to be 10.5 feet wide. In contrast, Hollywood Boulevard in Hollywood, FL has a standard 12-foot traffic lane next to the BL.

Site Descriptions

Route A1A - Ft. Lauderdale, FL

Route A1A is a busy urban street that parallels the coastline. In the study area, the street has four lanes and an AADT of 28,000 vehicles per day. The BL (see Figure 1) is 4.5 feet inside the striped area and has a considerable amount of bicycle traffic, as well as joggers, walkers, and in-line skaters. The majority of the bicyclists are recreational riders. The ocean is within several hundred feet of the street, so that motor vehicles seeking parking spaces on the street are numerous. The parking turnover (i.e., the number of motor vehicles entering or exiting available parking spaces along the study route) was approximately 111 per hour. Prior to retrofitting the BL, the motor vehicle parking was angled, and conflicts and/or crashes with bicycles were frequent.

Figure 1. View of the Route A1A study site in Ft. Lauderdale, FL.

Figure 2. View of the Hollywood Boulevard study site in Hollywood, FL.

Hollywood Boulevard - Hollywood, FL

Hollywood Boulevard is a four-lane urban street with a two-way, center left-turn lane. The AADT is approximately 12,700 vehicles per day in the study area. The BL here is 5 feet inside the striped area (see Figure 2) and is also quite busy as it provides a direct route to the beach. Again, most of the bicyclists are recreational riders. The eastbound BL terminates at a bridge crossing the Intracoastal Waterway; thus, in-line skaters are rarely seen in the BL. Joggers and walkers are also infrequent. The study area is about 1/4 mile from the beach, so that motorists seeking parking are not as numerous as in the Ft. Lauderdale location. The parking turnover was 11 vehicles per hour.

Methods

The study methodology was to compare the operations of bicyclists and motorists at the two study sections. Videotape data were collected at both locations during the spring of 1999. The data collector worked for 2 hours at each site, varying between weekday and weekend time periods. Videotaping was normally done between the hours of 8 a.m. and 5 p.m. on days with good weather. The camera was always facing the oncoming cyclist so that estimates of cyclist age and gender could be made. Although the camera was visible, a zoom lens was used to record cyclist behavior over a distance of 400-500 feet. Based on observations made before videotaping began, there was no evidence that the camera presence affected either cyclist or motorist behavior.

In regard to data reduction, the bicycle was the basic unit of analysis. For each bicyclist passing through the study sections, age, gender, helmet use, and passenger presence were coded, as well as whether they were riding in the BL or in the motor vehicle traffic lane. Information was also gathered on conflicts between bicyclists and motorists, pedestrians, and other bicyclists. A conflict was defined as one of the parties having to *suddenly* change speed or direction to avoid a collision. Data were coded for 321 cyclists on Route A1A and 317 cyclists on Hollywood Boulevard.

The other major measures of effectiveness pertained to lateral positioning by bicyclists using the BLs, particularly distance from the edge of the BL (or distance to the motor vehicle traffic lane) and separation distance between bicycles and passing motor vehicles. Image analysis software (SigmaScan Pro 4.0) was used to derive the positioning and spacing data, using the width of the BL as the calibration measure.

Analysis Results

Bicyclist Characteristics

Slightly more than 70 percent of the bicyclists were male, as is typically the case in studies of observed bicyclists. Chi-square testing was performed to compare differences in the distributions between the Ft. Lauderdale and Hollywood locations. There were no gender differences between the two study sections.

Age of the bicyclists was estimated from observing the videotapes and categorized into the following groups: <16, 16-24, 25-64, and >64 years. The age distributions were significantly different ($p<.05$, or due to chance alone less than 5 times out of 100), primarily due to greater numbers of <16 and 16-24 year old cyclists at the Ft. Lauderdale location (Table 1).

Table 1. Age of bicyclists at the Ft. Lauderdale and Hollywood locations.

Age*	Ft. Lauderdale	Hollywood	Total
< 16	10 (3.1)[1]	1 (0.3)	11 (1.7)
16-24	39 (12.2)	26 (8.2)	65 (10.2)
25-64	254 (79.1)	272 (85.8)	526 (82.5)
> 64	18 (5.6)	18 (5.7)	36 (5.6)
Total	321 (50.3)[2]	317 (49.7)	638 (100.0)

[1] Column percent
[2] Row percent
* p < .05

Helmet use was 25 percent in Ft. Lauderdale and 15 percent in Hollywood (Table 2). The difference was significantly different (p<.001).

Table 2. Helmet use of bicyclists at the Lauderdale and Hollywood locations.

Helmet Use***	Ft. Lauderdale	Hollywood	Total
Yes	81 (25.2)	47 (14.8)	128 (20.1)
No	240 (74.8)	270 (85.2)	510 (80.0)
Total	321 (50.3)	317 (49.7)	638 (100.0)

*** p < .001

None of the cyclists were carrying passengers at either location, and all but one cyclist was using the BL. This occurred in Ft. Lauderdale, where two cyclists were riding side-by-side, and one was in the traffic lane.

Conflicts

As mentioned previously, information was also gathered on conflicts between bicyclists and motorists, pedestrians, and other bicyclists. A conflict was defined as one of the parties having to *suddenly* change speed or direction to avoid a collision, a rather stringent definition. Conflicts were infrequent, with 8 occurring in Ft. Lauderdale and 5 in Hollywood. All were minor and took place in the BL. These convert to rates of 2.5 and 1.6 conflicts per 100 bicycles on the Ft. Lauderdale and Hollywood study sections, respectively.

In Ft. Lauderdale 6 of the 8 conflicts were related to motor vehicles involved in parking maneuvers, 1 with a passenger disembarking from a vehicle, and 1 with an in-line skater going the wrong-way in the BL. Figure 3 shows an example of a parking maneuver conflict. Given the turnover in parking spaces mentioned earlier, it is not surprising that the majority of conflicts relate to parking vehicles. Motorists frequently wait in the BL for a space to open, and sometimes perform u-turns in the street to move into an available space (Figure 4).

Figure 3. Parking maneuver conflict on Route A1A in Ft. Lauderdale.

Figure 4. Motor vehicle making a u-turn to park.

The situation was somewhat different in Hollywood. Parking turnover was much less, but there were several intersecting neighborhood streets that crossed the BL. Four of the 5 conflicts involved motor vehicles either crossing the BL from a side street or turning from Hollywood Boulevard across the BL to enter a side street. The other conflict involved a city bus pulling into and out of the BL.

The bicyclist level of avoidance was also coded for conflict. The level of avoidance has been used in past research and ranges from "no change in riding" up to "collision or near crash." In Ft. Lauderdale 5 of the cyclists made a slight change of direction and 3 applied the brakes. In Hollywood 4 cyclists made a slight change in direction and 1 applied the brakes.

Lateral Positioning of Bicyclists

It was felt that a comparison of the lateral positioning of bicyclists in these two study areas might reveal any problems associated with the narrow traffic lane next to the BL in Ft. Lauderdale, and this was done in two ways. First, approximately 100 videotape images were captured of cyclists riding next to parked motor vehicles in each of the study areas. For these images, the position of the parked motor vehicle was noted as: (1) touching or across the BL edge line (i.e., "crowding" the BL), (2) within 6 inches of the BL edge line, and (3) more than 6 inches away from the BL edge line.

In addition to the images mentioned above, another 100 images were extracted from the videotape in each of the two study areas that showed bicyclists being passed by motor vehicles while also riding next to parked vehicles. The position of the parked motor vehicle was noted as before.

Bicyclist position in BL - Figure 5 shows the mean distance of bicyclists from the outside edge (motor vehicle travel lane side) of the BL stripe in the presence of a parked motor vehicle and indicates that, on average, cyclists preferred to center themselves in the middle of the BL at both study locations. Recall that Route A1A in Ft. Lauderdale has a slightly narrower BL width, as well as a narrower traffic lane adjacent to the BL. A t-test showed the means to be significantly different ($p<.01$), although the actual difference in the mean distances amounted to only 2.5 inches, a value that is less than the 6-inch difference in the width of the BLs at the two study sites.

Figure 6 shows the same information but includes the three positions of the parked motor vehicles. At both sites, there seems to be a slight tendency for the bicyclists to ride a bit farther away from the edge of the BL stripe, and perhaps passing traffic, when the parked motor vehicle is closer to the curb.

Bicyclist position in BL and separation from a passing motor vehicle - Figure 7 shows both mean positioning within the BL and mean separation distance from a passing motor vehicle for the study sites. Bicyclists on Hollywood Boulevard tended, on average, to ride farther from the outside edge of the BL stripe (3.02 versus 2.59 feet on Route A1A) when being passed by a motor vehicle. These means were significantly different ($p<. 01$), and the actual difference amounted to 5.2 inches, or slightly less than the difference in the width of the two BLs. At both locations the mean distance of the bicycle from the outside of the BL stripe was greater when a passing vehicle was present. The difference was about 3 inches on Route A1A and 5.5 inches on Hollywood Boulevard.

Mean separation from passing motor vehicles was 5.77 feet on Route A1A and 7.52 feet on Hollywood Boulevard, and this difference of 1.8 feet was significantly different ($p<.001$). This amount is very close to the 1.5-foot difference in the motor vehicle travel lanes at the 2 sites

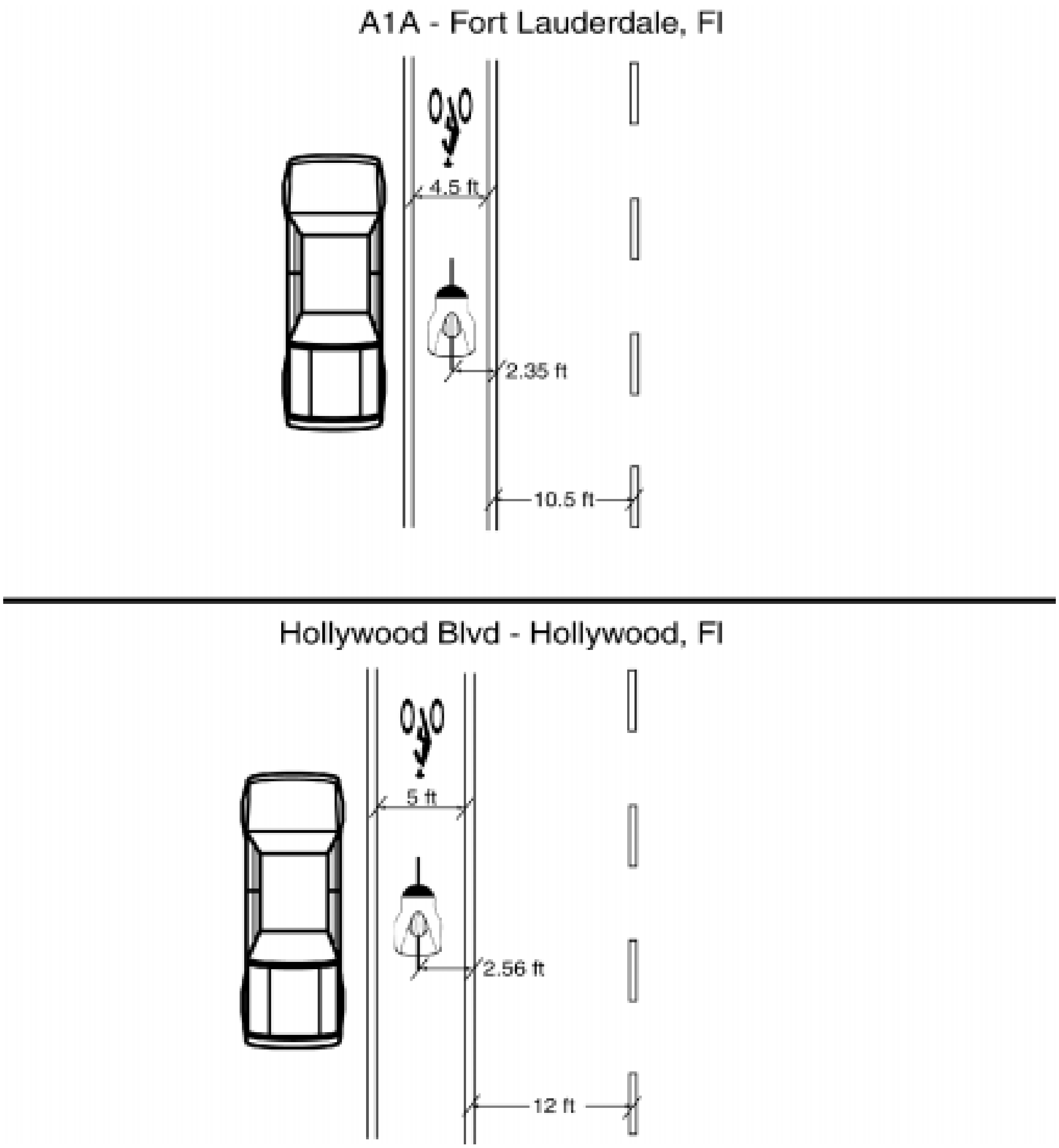

Figure 5. Mean distance from bicycle tire to outside of BL stripe at the two study locations.

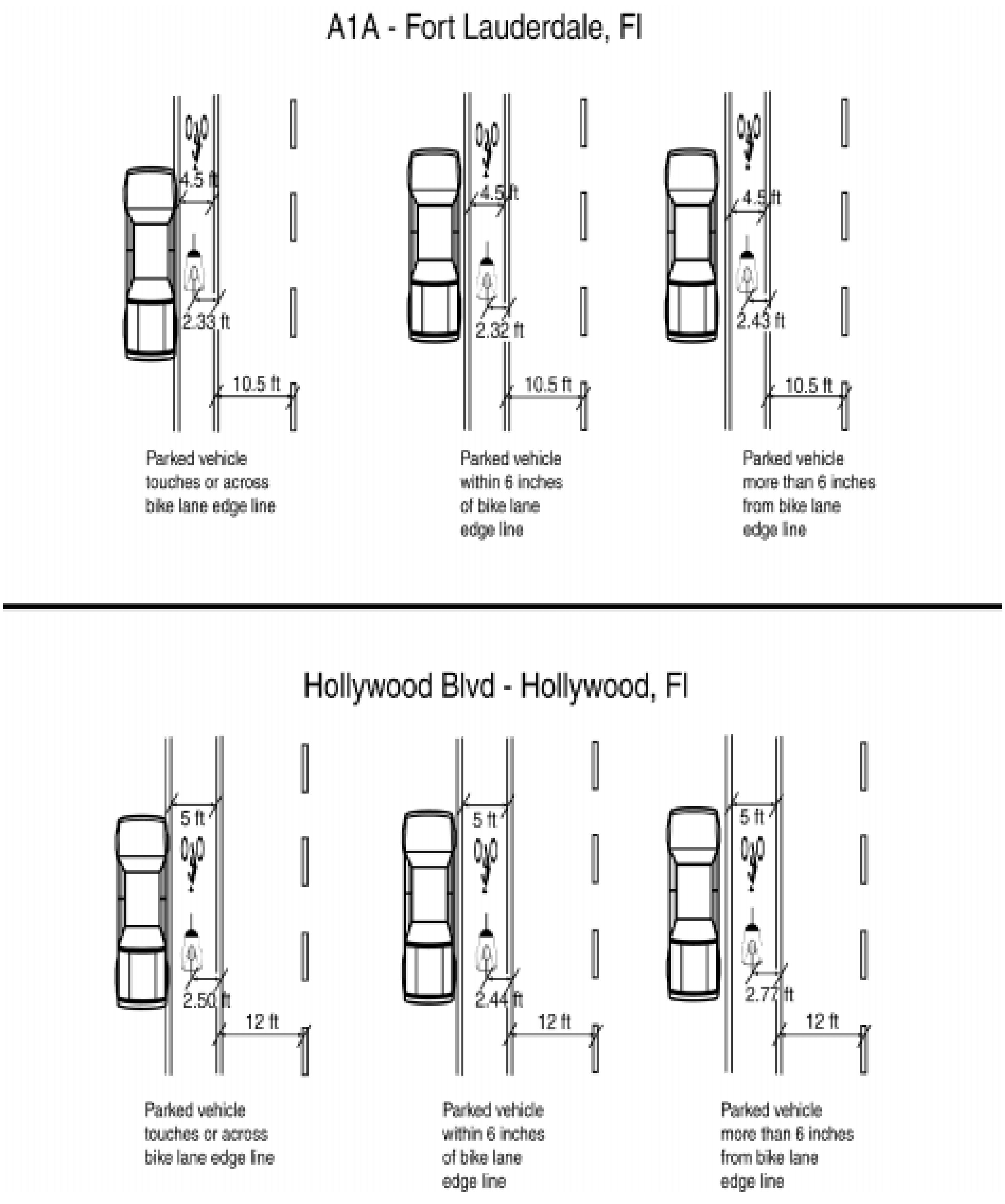

Figure 6. Mean distances from bicycle tire to outside of BL stripe for three different motor vehicle parking positions.

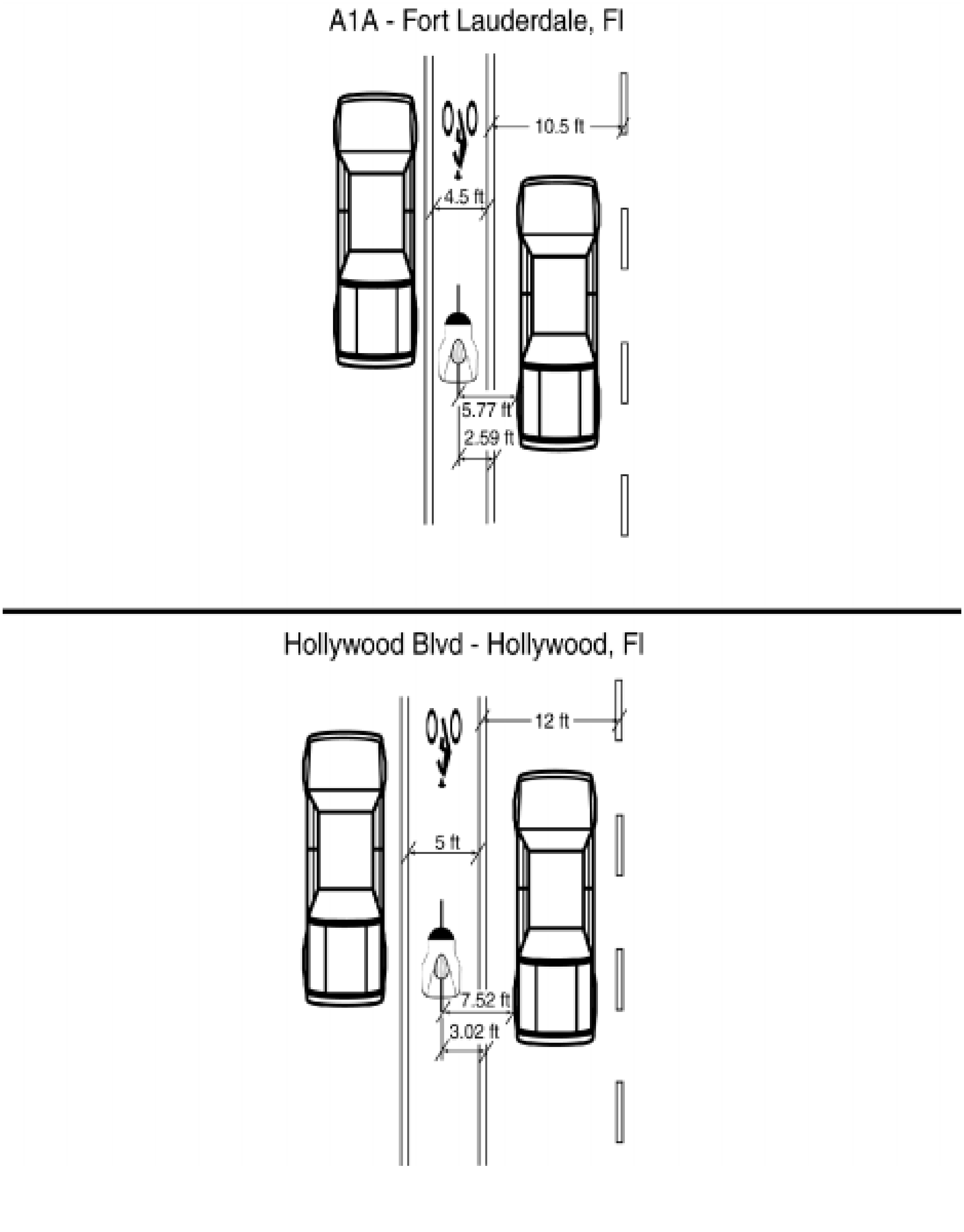

Figure 7. Mean distance from bicycle tire to outside of BL stripe and mean separation distance between bicycle tire and motor vehicle tire at the two study locations.

(12 feet at Hollywood Boulevard versus 10.5 feet at Route A1A). Considerably fewer entering and exiting parked vehicles on Hollywood Boulevard may also have had an effect.

As before, Figure 8 adds the position of the parked motor vehicle to the information. Mean distance from outside edge of the BL stripe is greater on Hollywood Boulevard in the presence of a passing motor vehicle for each parking condition. There is a slight tendency for cyclists to ride farther from the edge stripe as parked motor vehicles are closer to the curb. Comparing with Figure 6, it is also clear that bicyclists in both locations tend to ride farther away from the outside BL edge stripe in the presence of a passing motor vehicle, regardless of the position of the parked vehicle. The mean distances are greater on Hollywood Boulevard, not only due to the wider BL but also likely associated with less parking turnover, less opening of doors, etc.

For the three parking conditions, the mean spacings of bicyclists from passing motor vehicles are greater on Hollywood Boulevard by 1.4-1.9 feet. This difference basically amounts to the difference in the width of the BL and adjacent traffic lane between the 2 locations. Examining both sites, it is not clear that bicyclists tend to ride farther from passing motor vehicles when motor vehicles are parked closer to the curb.

Reference should be made to an earlier study done by HSRC for the FLDOT involving shared-use facilities. [1] This study also examined the lateral positioning of bicycles and motor vehicles on roadways with BLs, wide curb lanes, and paved shoulders. All of the roadways in this study had 11-foot or greater travel lanes. The separation distance between bicycles and passing motor vehicles was typically in the 6 to 6.5 foot range, very similar to that found in the current study. It would thus appear that this distance represents a comfortable separation for passing motor vehicles, whether the travel lane is standard width or narrower.

Analysis of variance of bicycle lateral positioning- Analyses of variance (ANOVA) were performed to further examine statistically the lateral positioning data. One analysis was conducted for the bicycle position within the BL. For this analysis of the mean distance of

---

[1]Harkey, D.L. and Stewart, J.R. "Evaluation of Shared-Use Facilities for Bicycles and Motor Vehicles." *Transportation Research Record 1578, pp. 111-118, 1997.*

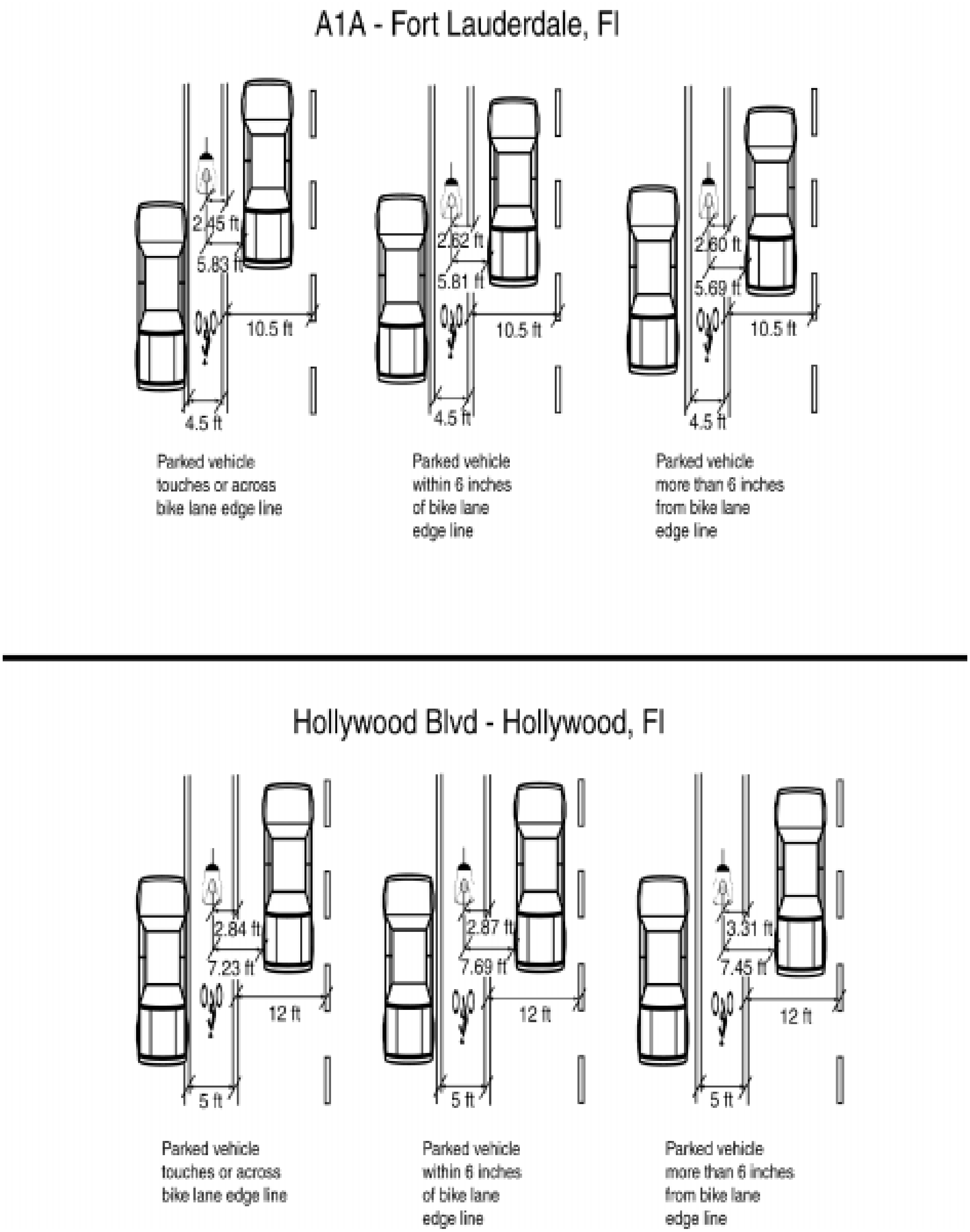

Figure 8. Mean distance from bicycle tire to outside of BL stripe and mean separation distance between bicycle tire and passing motor vehicle tire for three different parking positions.

bicyclists within the BL to the outside edge of the BL stripe (hereafter called Bike to Lane Line), the Bike-to-Lane-Line measurement was considered to depend on three factors:

Study location - with level 1 for Ft. Lauderdale or level 2 for Hollywood;

Motor vehicle parking position - with levels 1 = NEAR (touching or across BL edge line), 2 = MID (within 6 inches of BL edge line), and 3 = FAR (more than 6 inches from BL edge line) as defined previously; and

Park/pass - with level 1 indicating that the bicycle was simply riding beside a parked vehicle, and level 2 indicating that the bicycle was being passed by a motor vehicle while riding beside a parked vehicle

In the ANOVA model, no interactions involving the above three factors were significant. All three main effects, however, were significant with p-values .0001, .0189, and .0001 respectively. Since the factors for study location and Park/pass each contained only two levels, the Bike-to-Lane-Line mean distances corresponding to the two levels differed from each other. For the factor pertaining to the motor vehicle parking position, the level 3 (FAR) mean of 2.81 feet differed significantly from the level 1 (NEAR) mean of 2.52 feet and the level 2 (MID) mean of 2.55 feet, while levels 1 and 2 did not differ from each other as determined by Duncan's Multiple Range Test. Table 3 shows the mean Bike-to-Lane-Line distances by factor level. These mean distances differ from those presented earlier in Figures 5 and 6 which show mean distances *within* levels of study location and park/pass condition.

Table 3. Mean Bike-to-Lane-Line distances.

Factor	Level	Mean	N
Study Location	1 2	2.47 2.79	214 209
MV Parking Position	1 2 3	2.52 2.55 2.81	81 206 136
Park/pass	1 2	2.45 2.81	213 210

Examining the separation distance when the bicycle was being passed by a motor vehicle (hereafter called Bike-to-Passing-Vehicle distance) meant that Park/pass could only be = 2 for these observations. A 2-way ANOVA was run to determine how these mean separation distances depended on the other 2 factors of study location and motor vehicle parking position. As before, the interaction was not significant. For this model only the study location main effect was significant, p = .0001, (i.e., the Ft. Lauderdale mean separation distance of 5.77 feet was significantly different from the Hollywood mean separation distance of 7.52 feet). Table 4 shows the mean Bike-to-Passing-Vehicle Distances by factor level.

Table 4. Mean Bike-to-Passing-Vehicle distances.

Factor	Level	Mean	N
Study Location	1	5.77	104
	2	7.52	106
MV Parking Position	1	6.65	34
	2	6.70	101
	3	6.58	75

Distance measurement distributions - While the above analyses address differences in the mean or average values of the distance measurements, Figures 9 and 10 depict the entire distributions of the distance measurements of Bike-to-Lane Line and Bike-to-Passing-Vehicle in the form of box and whisker plots. In these plots, the solid box includes observations from the 25^{th} to the 75^{th} percentiles; thus, the height of the box is the interquartile distance (IQD). The horizontal band through the box indicates the median of the distribution while the mean is marked with an X. The whiskers (dotted lines) extend from the top and bottom of the box to either the extreme values or to a distance that is 1.5 × (IQD) from the median, whichever is less. Extreme values lying beyond the extent of the whiskers are marked with horizontal lines.

These figures clearly show the differences in means described earlier, but also show how the overall distributions tend to shift from one condition to another. For example, consider

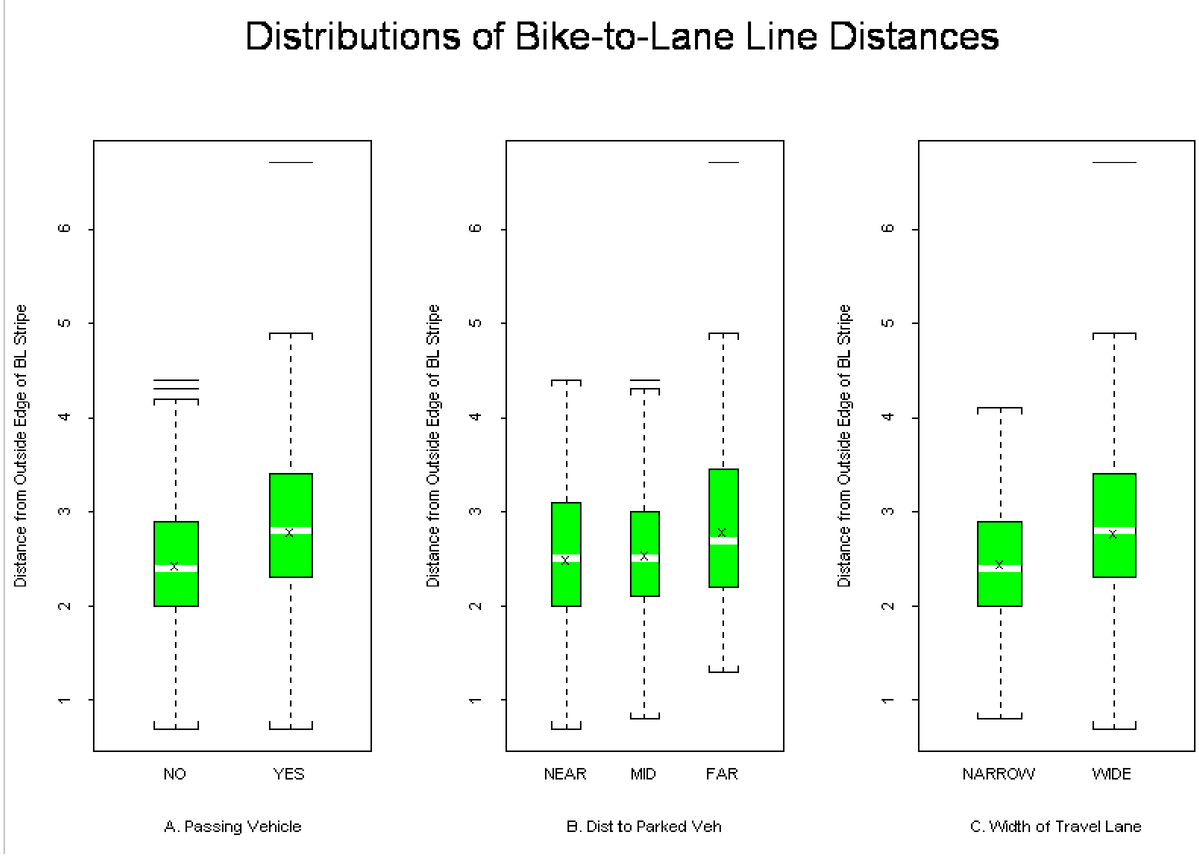

Figure 9. Distributions of Bike-to-Lane-Line distances.

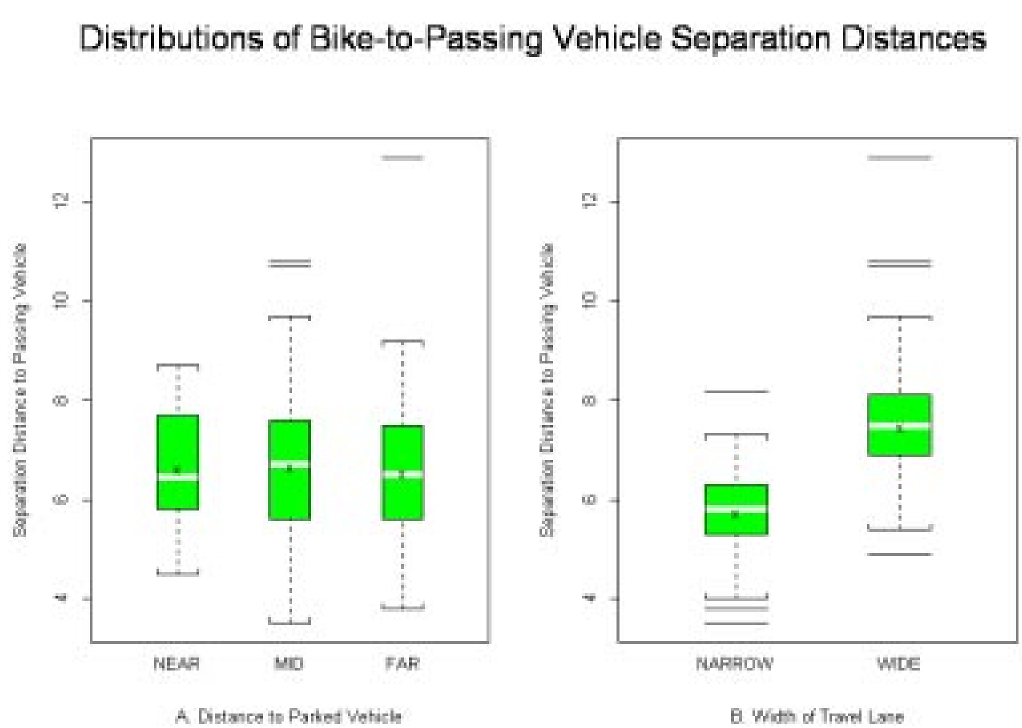

Figure 10. Distributions of Bike-to-Passing-Vehicle separation distances.

Figure 9.C, which shows the distributions of Bike-to-Lane-Line distances. Although the mean and median are larger for the Hollywood situation ("NARROW" for Ft. Lauderdale and "WIDE" for Hollywood), *minimum* distances are nearly equal. See also Figure 10.B, which shows the distributions of Bike-to-Passing-Vehicle distances. The ANOVA results indicated a significant difference in the separation distance means for these two distributions. Figure 10.B shows that this is clearly the case. Moreover, the overall distribution of separation distance measurements for the wider lane situation is greater than that corresponding to the narrower lane situation. Figure 10.B also shows that even for the NARROW traffic lane case only two observations indicate separation distances from passing motor vehicles of less than 4 feet, and these appear to be greater than 3 feet. More than 75 percent of the separation distances in this NARROW traffic lane case are greater than 5 feet. So while these distributions differ significantly, the separation distances from passing vehicles seem to indicate a very safe bicycling environment, even for Route A1A in Ft. Lauderdale with the 10.5-foot adjacent motor vehicle traffic lane.

Discussion

Main findings from the comparison of the two study sections are the following:

- The bicyclists at the Ft. Lauderdale site tended to be younger and more inclined to wear helmets. It is not clear how this difference affects the remaining results, but the effect is considered to be minimal.
- There were few conflicts between bicyclists and motorists, pedestrians, and other bicyclists at either site, and all were minor. Conflicts per 100 bicyclists were 2.5 and 1.6 at the Ft. Lauderdale and Hollywood sites, respectively.
- Bicyclists tended to center themselves in the middle of the BL in the presence of a parked motor vehicle in both locations. There was a slight tendency for the bicyclists to ride a bit farther away from the edge of the BL stripe when the parked motor vehicle was closer to the curb.
- Bicyclists in both locations tended to ride farther away from the outside BL edge stripe in the presence of a passing motor vehicle, regardless of the position of the parked vehicle. The mean distances were greater on Hollywood Boulevard, most likely due to less parking turnover, less opening of doors, etc..

- For the three parking conditions, the mean spacings of bicyclists from passing motor vehicles were greater on Hollywood Boulevard by 1.4-1.9 feet. This difference basically amounts to the difference in the width of the BL and adjacent traffic lane on Hollywood Boulevard.
- An ANOVA model showed all 3 main effects of study location, motor vehicle parking position, and whether the bicycle was riding beside a parked vehicle or being passed in the presence of a parked vehicle to be significant. The Bike-to-Lane-Line mean distance was significantly greater at the Hollywood location.
- A 2-way ANOVA showed the mean separation distance to be significantly greater at the Hollywood location.
- An examination of the distributions of the Bike-to-Lane-Line measurements showed only slight differences in the Ft. Lauderdale and Hollywood sites. Although the mean and median were larger at Hollywood, the minimum distances to the edge of the BL were quite similar.
- An examination of the distributions of the Bike-to-Passing-Vehicle measurements showed a larger separation at the Hollywood site. However, at the Ft. Lauderdale narrow-traffic-lane site there were only two measurements of separation distances less than 4 feet, and both of these were greater than 3 feet. In addition, 75 percent of the separation distances at Ft. Lauderdale were greater than 5 feet.

While there were lateral positioning and other differences between the locations studied, conflicts were very infrequent and all were minor in nature. The Ft. Lauderdale site was certainly far busier, with twice as much traffic and 10 times the parking turnover, but the cyclists using the BL seemed to accommodate to the situation quite easily. Their position in the BL and awareness of parking turnover was such that encounters with opening motor vehicle doors were almost non-existent. Perhaps the most important outcome was that spacing from motor vehicles was never less than 3 feet at the narrow-traffic-lane site, an amount generally deemed to be quite acceptable by cyclists. The overall conclusion is that the narrowing of the traffic lane to retrofit the BL and parallel parking has been successful.

Acknowledgments

Special thanks to Mark Horowitz, the Bicycle Coordinator for Broward County, who helped with many local needs, and to Tom Dezern, who collected the videotape data.