EFFECT OF WIDE CURB LANE CONVERSIONS ON BICYCLE AND MOTOR VEHICLE INTERACTIONS

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16. Abstract

The main objective of this project was to examine the operational effects of converting 14-foot WCLs to an 11-foot travel lane with a 3-foot undesignated lane at various locations in Broward County, Florida. Six midblock and four intersection sites were selected for study. The selected study sites were a mix of configurations to provide comparisons. One of the midblock sites where the stripe was newly added did not have curb and gutter. Two of the midblock sites had been previously striped with the 3-foot undesignated lane. The study design was before-after in which data were collected prior to and after the stripe designating the 3-foot lane was deployed. The ideal would have been before-after with comparison sites, but obtaining matching comparison sites would have been very difficult. Videotapes were taken of bicyclists riding through the midblock and intersection locations before and after placement of the 3-foot undesignated lane striping. In the locations where the 3-foot stripe was already in place, the videotaping was done to examine whether changes were occurring over time. To an extent, these previously-striped roadways served as control or comparison sites. Once the videotaping was complete, software was used to extract images at all midblock locations so that before-after lateral spacing measurements could be obtained. After the new striping: (1) bicycles were ridden, on average, 7 to 9 inches farther away from the gutter pan seam, (2) motor vehicles were driven, on average, 6 to 12 inches farther away from the gutter pan seam, (3) passing motor vehicles were driven, on average, 3 to 5 inches closer to bicycles at curb and gutter sites; conversely, passing motor vehicles were driven, on average, 4 to 6 inches farther away from bicycles at the sites where the stripe was already in place, (4) the addition of the stripe at new locations had the effect of reducing the amount of motor vehicle encroachment into the adjacent lane on these multi-lane roadways.

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Introduction

The Highway Safety Research Center (HSRC) has evaluated a number of innovative bicycling countermeasures within the State of Florida for the Florida DOT. Examples include a study of red shoulders as a pedestrian and bicycle facility (Hunter, 1998), an evaluation of bike lanes next to parking (Hunter and Stewart, 1999), and an examination of the shared-use arrow in a wide curb lane corridor (Hunter, Pein, and Stewart, 1999). Harkey, Stewart and Rodgman (1996) also performed a study of lateral spacing of bicycles and motor vehicles on various types of roadways, and this study served as a model for the current effort.

Background

This report is an evaluation of a bicycle facility retrofit in Broward County, Florida. The retrofit involved the conversion of a 14-foot wide curb lane (WCL) to an 11-foot travel lane with a 3-foot undesignated lane on several roadways within the county. Figure 1 shows an example of the original 14-foot WCL and Figure 2 the conversion.

Figure 1. Before condition with 14-foot wide curb lane.

Figure 2. After condition with 11-foot travel lane and 3-foot undesignated lane.

The conversion of these WCLs grew out of a similar conversion that took place about 10 years ago on SR A1A, the famous Fort Lauderdale route beside the ocean. Mark Horowitz, the Broward County Bicycle Coordinator, describes the SR A1A conversion in the following way[1]:

> In the early 1990's the City of Fort Lauderdale redesigned SR A1A, the famous Fort Lauderdale "strip." It went from a three-lane cross-section with head-in parking on the ocean side with a narrow sidewalk on the commercial side to a four-lane divided roadway with a 14-foot wide outside lane, 8-foot wide sidewalks on both sides. Shortly after the completion of the initial redesign, the city began receiving complaints about bicyclist/pedestrian conflicts on the beach-side sidewalk. While the typical section included a "bicycle facility," only the proficient bicyclist was comfortable riding in the same direction as motor vehicle

[1] Text taken from a case study prepared by Mark Horowitz for a bicycle countermeasure selection system being prepared by the UNC Highway Safety Research Center for the Federal Highway Administration.

traffic in the 14-foot wide outside lane. As the complaints continued to rise, the City began requesting the Florida Department of Transportation (FDOT) to add 4-foot bicycle lanes. After considerable discussion between the City of Fort Lauderdale, the FDOT, and the Broward County Bicycling Advisory Committee about reducing the outside travel lanes to 10 feet and putting in 4-foot bicycle lanes, it was decided to try 3-foot marked bicycle lanes (Figure 3) next to 11-foot travel lanes. During these discussions concerns were raised that there might be increases in wrong-way riding and turning conflicts at hotel driveways.

Figure 3. SR A1A, the 'Strip' after the conversion to 11- and 3- foot lanes

A 3-foot bike lane was incorporated into the wide outside lane (Figure 4). Because this was a pilot project, the existing edge stripe was left in place. Standard bicycle lane pavement markings and signs were added to identify the lane as a bicycle facility.

Figure 4. SR A1A with three-foot marked bike lanes.

The project was evaluated by several means. The local bicycle coordinator tested the facility by bicycle. Members of the County's Bicycling Advisory Committee and FDOT staff conducted observations of the bicyclists on the sidewalk and in the undesignated lane, and surveyed bicyclists using the undesignated lane. In addition, the complaints regarding bicycle/pedestrian conflicts received by the city decreased.

Overall, the evaluation of the facility was positive. The on-bike test by the bicycle coordinator found that while the stripe did provide an additional measure of traffic control and bicyclist comfort level increased, it was the minimum width that should be striped. The observations of bicyclists showed a decrease in sidewalk riding and conversely an increase in bicyclists riding in the street. The bicyclist surveys revealed that the majority of bicyclists were glad the lane was present but felt it was too narrow. Prior to the installation of the lane, the club cyclist typified the bicyclist in the street. After installation, a wider variety of experience levels were observed using the 3-foot lane. In this instance the concerns about an increase in wrong-way riding were not validated. However, this is most likely because the major attraction to this area is the beach, and there was a significant amount of wrong-way riding on the beach side prior to the installation. The installation did not, however, increase wrong way riding. Additionally, wrong-way riding did not increase on the opposite side of the street nor was there an increase in turning conflicts at the numerous hotel driveways.

Because this type of facility provides better direction for the motoring and bicycling public but does not meet any current standards, bicycle signage and pavement markings are not used. Additionally, this facility type has been referred to as an undesignated lane or urban shoulder. It should be noted that referring to this facility as an urban paved shoulder has created some confusion during the striping process and has resulted in the lane being placed to the right of a dedicated right-turn lane instead of the left. This facility will thus be referred to as an undesignated lane.

Site Selection

Undesignated lanes were in place or planned for use throughout Broward County on major arterials as well as collector streets with ADTs ranging from 25,000 to 45,000 vehicles per day. Candidate study sites with the existing 14-foot outside lane were examined with the County bicycle coordinator. Six midblock and four intersection sites were selected for study. Study sites are shown in Table 1.

The selected study sites were a mix of configurations to provide comparisons. Some had 4 lanes and others 6 lanes. Speed limits varied between 40 and 45 miles per hour. All 6 midblock sites had a curb and gutter except for Pine Island between Griffin and Stirling. This site had more of a rural cross-section appearance. Sites M-6 and M-7 had been previously striped with the 3-foot undesignated lane. All 4 intersection sites contained an auxiliary right-turn lane, as there was interest in examining the weaving between bicycles and motor vehicles in these locations. Sites I-4 and I-5 had also been previously striped with the 3-foot undesignated lane. At all intersection sites the undesignated lane was striped to the left of the auxiliary right-turn lane.

Table 1. Study sites.

Midblock Locations	**Traffic Volume (vehicles per day)**	**Speed Limit (miles per hr)**	**Midblock Cross-Section Information (both directions)**
M-1 Andrews north of McNab	19,600	40	4 through lanes with 2-way center turn lane
M-2 Rock Island north of McNab	34,800	40	4 through lanes with grass median
M-3 Broward at Central Park Place shopping center	28,000	45	6 through lanes with grass median
M-4 Pine Island between Griffin and Stirling	9,700	45	4 through lanes with grass median – no curbing
M-6 McNab between Andrews and Powerline	19,500	45	4 through lanes with previous 3' undesignated striping
M-7 US1 near NE 48th Street	45,000	45	6 through lanes with grass median and previous 3' undesignated striping
Intersection Locations			**Intersection Cross-Section Information (1 direction only)**
I-1 Rock Island @ Margate	28,200	40	2 through lanes with 1 auxiliary left and 1 auxiliary right turn lane
I-2 Broward @ Jacaranda	28,000	45	3 through lanes with 1 auxiliary left and 1 auxiliary right turn lane – grass median
I-4 McNab @ Powerline	22,000	45	3 through lanes with 2 auxiliary left and 1 auxiliary right turn lanes - previous 3' undesignated striping
I-5 US1 @ NE 43rd	47,500	45	3 through lanes with 2 auxiliary left and 1 auxiliary right turn lanes - previous 3' undesignated striping

Methodology

The study design was before-after in which data were collected prior to and after the stripe designating the 3-foot lane was deployed. The ideal would have been before-after with comparison sites, but obtaining matching comparison sites would have been very difficult. Videotapes were taken of bicyclists riding through the midblock and intersection locations before and after placement of the 3-foot undesignated lane striping. In the locations where the 3-foot stripe was already in place, the videotaping was done to examine whether changes were occurring over time. To an extent, these previously-striped roadways served as control or comparison sites.

Videotaping and placement of the striping was done on the following schedule:

- Before data collection started in the fall of 2000 and was completed in the spring of 2001
- Striping started in the fall of 2002 and was completed in early winter of 2003
- After data started in spring of 2003 and was completed in summer of 2003

As indicated above, there was a long delay in getting the stripe on the selected roadways. The city was trying to get a contractor that could install long sections of thermoplastic, but none was available. Eventually the striping was simply painted.

Once the videotaping was complete, software was used to extract images at all midblock locations so that lateral spacing measurements could be obtained. SigmaScan software was used for the measurements. Similar to the methodology used in the Harkey, Stewart and Rodgman (1996) study, lateral spacing measurements were obtained for 3 conditions:

- Distance of bicycle from gutter pan seam or edge of roadway
- Distance of motor vehicle from the gutter pan seam or edge of roadway
- Distance between bicycle and passing motor vehicle

Because of low numbers of bicyclists at these relatively high-speed, high-volume locations, subject riders were used for the videotapings. These were members of the Sheriff's Department who served as School Resource Officers. The composition of the group varied between the before and after periods, and the individual riders exhibited varying levels of riding skill in both time periods. For the first taping at Site M-4, on Pine Island, the School Resource Officers were unavailable and members of a bicycle club were the subjects. Again, the individual riders exhibited varying levels of riding skill. Occasionally a local bicyclist would be traveling the route when videotaping was taking place. These cyclists were videotaped as well and included in the analysis where possible.

At midblock locations, subjects were instructed to ride as they would normally along a distance of approximately 500 feet. They would then leave the roadway at a convenient spot such as a driveway. We attempted to obtain 50 individual circuits of the study location (i.e., if 10 subject riders were available, each would make five trips over the circuit. The same method was employed at intersections, except that riders rode completely through the intersection before leaving the roadway. The intent was to examine any conflicts that might occur between bicycles and motor vehicles at these intersections with auxiliary right-turn lanes.

Table 2 shows the number of images available for SigmaScan analysis by time period. No bicycles were present when videotaping was done for the "vehicle only" condition. Occasionally multiple images of a single bicyclist were obtained to develop adequate numbers for analysis. This could happen, for example, when motor vehicle traffic was low and opportunities to videotape a motor vehicle passing a bicycle were limited.

Table 2. Number of videotaped images available for lateral spacing analysis by time period.

Site	Number of Before Images			Number of After Images		
	Bike Only	Vehicle Only	Bike & Vehicle	Bike Only	Vehicle Only	Bike & Vehicle
M-1	51	53	40	51	58	52
M-2	47	51	57	53	52	56
M-3	19	55	36	51	64	51
M-4	39	64	40	51	60	54
M-6	57	57	50	53	62	53
M-7	52	55	55	52	57	54

Analysis and Results

Lateral Spacing

We examined three separate hypotheses involving the before-after lateral spacing of bicycles only, motor vehicles only, and bicycles and motor vehicles in combination (when a motor vehicle was passing a bicyclist). We were interested in determining the impact of the stripe:

- On the positioning of bicycles on the roadway
- On the positioning of motor vehicles on the roadway
- On the positioning of each mode as a bicycle was being passed by a motor vehicle

Table 3 shows the differences in mean lateral spacing from before to after by site. Positive values indicate a shift to the left, away from the gutter pan seam (or edge of the roadway at Site M-4). Negative values indicate a shift to the right, or closer to the gutter pan seam (or edge of roadway at Site M-4).

Table 3. Change in lateral spacing, relative to before period, by site.

Site	Traffic Volume (vpd)	Curb Presence	Bicycle (only) Lateral Change (inches)	Motor Vehicle (only) Lateral Change (inches)	Bicycle-Motor Vehicle Separation Change (inches)
M-1	19,600	Curb	9	12	-4
M-2	34,800	Curb	9	10	-3
M-3	28,100	Curb	7	6	-5
M-4	9,700	No curb	-2	5	6
M-6	19,500	Curb	-1	3	5
M-7	45,000	Curb	0	-4	4

There were differential effects by site. For the bike only examination, Sites M-1, M-2, and M-3 showed an increase in distance of approximately 7 to 9 inches of the bicycle from the gutter pan seam after placement of the 3-foot undesignated lane. At Site M-4, the bicyclists rode, on average, about 2 inches closer to the pavement edge (no curb and gutter at this site). There was little change at Sites M-6 and M-7, where the conversion to the 3-foot undesignated lane had been done previously.

For the vehicle only examination, all sites except M-7 showed motor vehicles spaced farther from the curb by amounts varying between approximately 3 to12 inches after placement of the 3-foot undesignated lane. Sites M-1, M-2, and M-3 showed the largest increases in distance, as the effect of the undesignated lane should naturally ‘force” motor vehicles to shift away from the gutter pan seam. Site M-4 showed motor vehicles driving 5 inches farther away from the pavement edge. Site M-6 showed motor vehicles about 3 inches farther away from the gutter pan seam, while Site M-7 showed motor vehicles about four inches closer to the gutter pan seam.

For the bike and motor vehicle effect (or where a motor vehicle was passing a bicycle), Sites M-1, M-2, and M-3 showed motor vehicles tracking closer to bicycles when passing by amounts varying, on average, between 3 to 5 inches. This is likely related to the shifts to the left by both bicycles and motor vehicles noted above. At sites M-4, M-6, and M-7, the opposite was the case, with motor vehicles tracking farther away from bicycles when passing by amounts, on average, between 4 to 6 inches.

Statistical analysis was used to examine these effects more closely. Three null hypotheses were formulated and tested.

- **Null hypothesis 1 - There is no difference in the lateral spacing of bicycles from the gutter pan seam or edge of road before and after the placement of the striping creating the 3-foot undesignated lane.**

This hypothesis was tested using Analysis of Variance, ANOVA (see Table 4). The table includes added-in order tests (Type 1). For the bike only effects presented in ANOVA Table 4, the Type I SS (Type one sum of squares) are commonly called sequential sums of squares or added-in order tests. They represent a partitioning of the MODEL SS into components sums of squares due to each variable as it is added sequentially to the model in the order prescribed in the table.

The Type I SS for the ANOVA includes simply an intercept $n\bar{Y}^2$, which is commonly called the correction for the mean. The Type I SS for site (40.86) is the Model SS for a regression equation that contains only site as an explanatory variable. The Type I SS for time (10.30) is the increase in MODEL SS due to adding time to the model that already contains site. Continuing the pattern, the Type I SS for site*time (24.39) is the increase in MODEL SS due to adding site*time to a model that already contains site and time. Note that the MODEL SS is 75.54 from the top part of the table, and that it is the sum of Type I SS for the explanatory variables, site, time, and site*time.

Restating this as an equation:

$$\text{MODEL SS} = 75.54 = 40.86 + 10.30 + 24.39.$$

This illustrates the sequential partitioning of the MODEL SS into the Type I components that correspond to the explanatory variables in the ANOVA.

The test examined the difference in the average change in lateral spacing for bicycles only at Sites M-6 and M-7, where the stripe was already in place, versus the average change in lateral spacing for Sites M-1, M-2, M-3, and M-4, where the stripe was added. The conclusion of the test is that, on average, the lateral spacing of bicycles from the gutter pan seam or edge of road was wider with the stripe as compared to without the stripe, and the difference was statistically significant. The analysis further concludes that the addition of a stripe affected lateral spacing differently for different sites, as shown above in Table 3. Figure 5 presents these differences graphically. The largest shift away from the gutter pan seam after the addition of the stripe occurred at Sites M-1, M-2, and M-3. Sites M-6 and M-7, where the stripe was already in place, show little change.

Because the treatment effect was different by site, we attempted to explore the question, "Are there characteristics of a given site that result in the operational differences found?" We plotted the change in lateral spacing (effect size) versus traffic volume, and there appeared to be no visible relation between the two. A correlation of 0.33 between effect size and traffic volume was not statistically significant.

Table 4. Results from analysis of variance for bike only effects.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**PR > F**
Model	11	75.5414969	6.8674088	43.87	<.0001
Error	564	88.2935391	0.1565488		
Corrected Total	575	163.8350359			
Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**PR > F**
Site	5	40.85771586	8.17154317	52.20	<.0001
Time	1	10.29757989	10.29757989	65.78	<.0001
Site*Time	5	24.38620112	4.87724022	31.15	<.0001

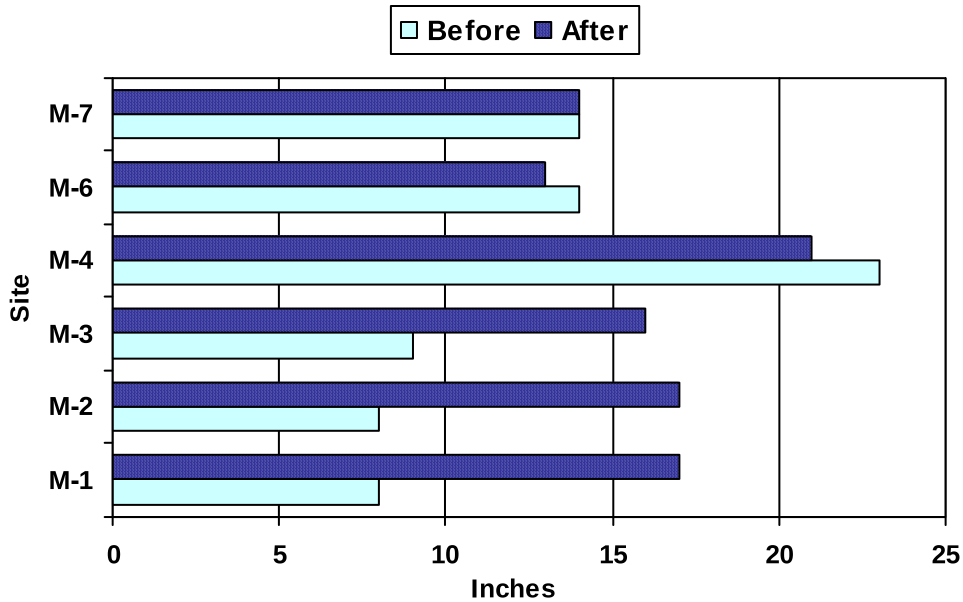

Figure 5. Comparison of average distance of bike to gutter pan seam or edge of road before and after the addition of the 3-foot stripe.

- **Null hypothesis 2 - There is no difference in the lateral spacing of motor vehicles from the gutter pan seam or edge of road before and after the placement of the striping creating the 3-foot undesignated lane.**

This hypothesis was tested using ANOVA (see Table 5). As before, the table includes added-in order tests (Type 1). The test examined the difference in the average change in lateral spacing for motor vehicles only at Sites M-6 and M-7, where the stripe was already in place, versus the average change in lateral spacing for Sites M-1, M-2, M-3, and M-4, where the stripe was added. The conclusion of the test is that, on average, the lateral spacing of motor vehicles from the gutter pan seam or edge of road was wider with the stripe as compared to without the stripe, and the difference was statistically significant. This would be expected, since motor vehicles had been “forced to” shift away from the gutter pan seam or edge of road by virtue of the striping. The analysis further concludes that the addition of a stripe affected lateral spacing differently for different sites, as shown above in Table 3. Figure 6 presents these differences graphically. Once again, the largest shift away from the gutter pan seam or edge of road after the addition of the stripe occurred at Sites M-1, M-2, M-3, and M-4. Sites M-6 and M-7, where the stripe was already in place, showed the least change.

Table 5. Results from analysis of variance for vehicle only effects.

Source	DF	Squares	Mean Square	F Value	PR > F
Model	11	167.9840758	15.2712796	15.28	<.0001
Error	676	675.6597916	0.9994967		
Corrected Total	687	843.6438674			
Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**PR > F**
Site	5	103.3106873	20.6621375	20.67	<.0001
Time	1	33.0043824	33.0043824	33.02	<.0001
Site*Time	5	31.6690061	6.3338012	6.34	<.0001

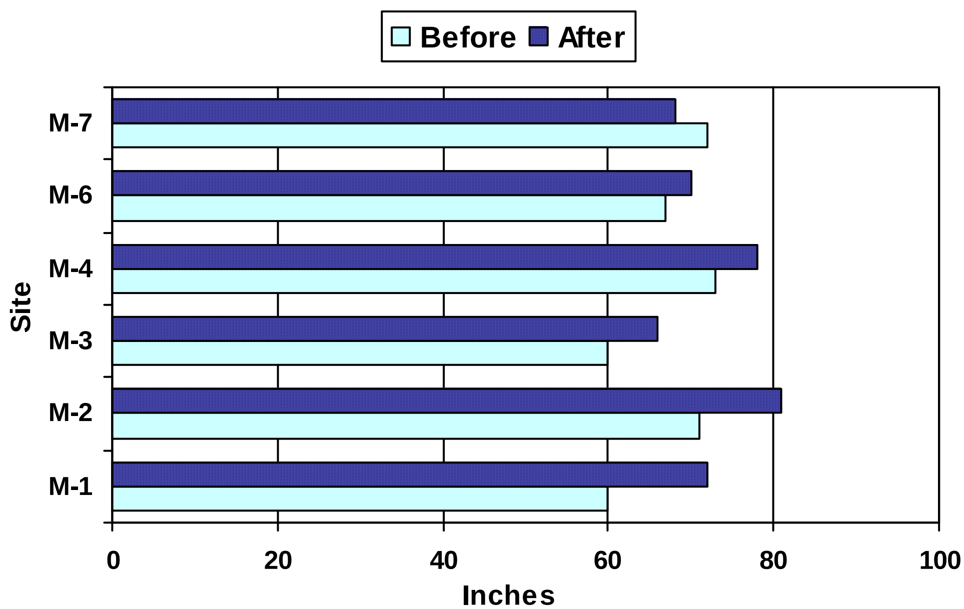

Figure 6. Comparison of average distance of motor vehicle to gutter pan seam or edge of road before and after the addition of the 3-foot stripe.

As before, we plotted the change in lateral spacing (effect size) versus traffic volume, and there appeared to be no visible relation between the two. A correlation of -0.08 between effect size and traffic volume was not statistically significant.

- **Null Hypothesis 3 - There is no difference in the lateral separation between bicycles and passing motor vehicles before and after the placement of the striping creating the 3-foot undesignated lane.**

This hypothesis was tested using ANOVA (see Table 6). Again, the table includes added-in order tests (Type 1). The test examined the difference in the average change in lateral spacing for motor vehicles passing bicycles at Sites M-6 and M-7, where the stripe was already in place, versus the average change in lateral spacing for Sites M-1, M-2, M-3, and M-4, where the stripe was added. The conclusion of the overall test is that, on average, the lateral spacing between motor vehicles and bikes was statistically wider with the stripe as compared to without the stripe. The analysis further concludes that the addition of a stripe affected lateral spacing differently for different sites, as shown above in Table 3. Figure 7 presents these differences graphically. At Sites M-1, M-2, and M-3, where the stripe was added, passing motor vehicles were slightly closer to bicycles. This could be indicative of increased comfort level for both modes, where motor vehicle drivers believe bicyclists will ride within the striped area, and bicyclists believe motor vehicle drivers will not cross into their space in the striped area. At Sites M-6 and M-7, where the stripe was already in place, passing motor vehicles were slightly farther away from bicyclists. The same was true at Site M-4, where the stripe was added to a section of roadway with no curb and gutter. The lateral separation between passing motor vehicles and bicycles is related to the outcomes found earlier, where bicycles have shifted farther away from the gutter pan seam (Hypothesis 1), and where motor vehicles have also shifter farther away from the gutter pan seam (Hypothesis 2), following the addition of the stripe.

Table 6. Results from analysis of variance for motor vehicles passing bicycles effects.

Source	**DF**	**Squares**	**Mean Square**	**F Value**	**PR > F**
Model	11	64.3250968	5.8477361	3.78	<.0001
Error	586	905.5584356	1.5453216		
Corrected Total	597	969.8835324			
Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**PR > F**
Site	5	41.87202165	8.37440433	5.42	<.0001
Time	1	0.22613258	0.22613258	0.15	0.7022
Site*Time	5	22.22694258	4.44538852	2.88	0.0141

Once again, we plotted the lateral separation (effect size) versus traffic volume, and there appeared to be no visible relation between the two. A correlation of 0.33 between effect size and traffic volume was not statistically significant.

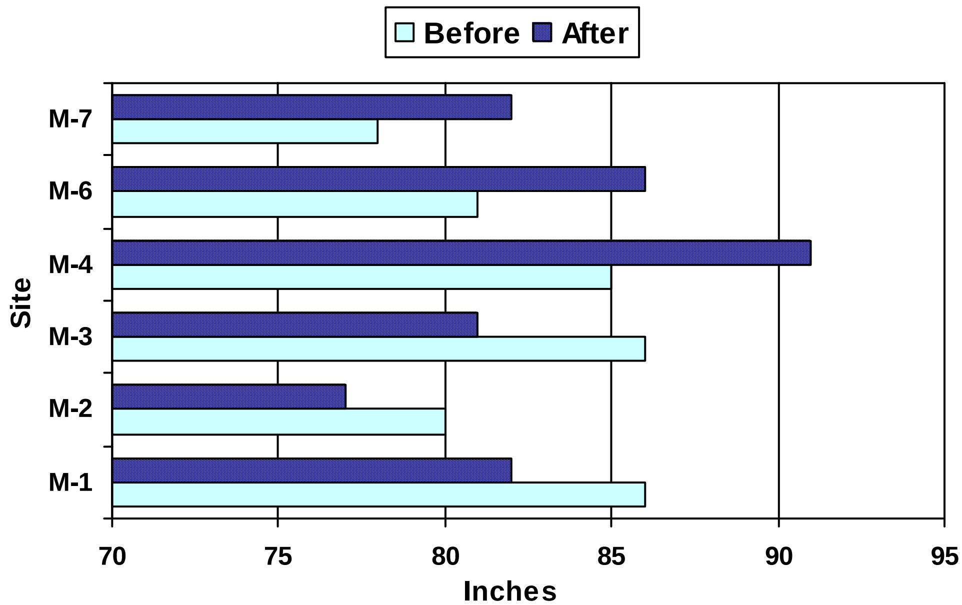

Figure 7. Comparison of average distance between a bicycle and a passing motor vehicle after the addition of the 3-foot stripe.

Motor Vehicle Encroachments into the Adjacent Lane

Another outcome variable worthy of study is whether motor vehicles passing bicyclists encroach into the adjacent motor vehicle travel lane on multi-lane roadways. Such encroachments could produce motor-vehicle-to-motor-vehicle conflicts. A prior study for the Florida DOT (Harkey, Stewart and Rodgman (1997)) showed that more encroachment takes place in shared lane situations, such as a regular travel lane or a wide curb lane, as opposed to a roadway with a bike lane or paved shoulder. For this study of the undesignated lane, it was possible to examine encroachments in the before period and two after periods. The first after period, or After 1, took place over April and May of 2003, or relatively soon after the stripe had been placed on the roadways, and videotapes were collected by the local data collector. It was necessary to collect more data in July 2003 to fill in gaps in the number of images available for the lateral spacing analyses. This opportunity enabled a second examination of encroachment activity and will be referred to as the After 2 period.

The After 1 and After 2 videotapes provided enough situations to examine encroachments during these two separate time periods. An encroachment took place when the tires of a free-flowing motor vehicle (or the first vehicle in a queue of vehicles) passing a bicycle touched the lane line stripe separating the curb lane from the adjacent motor vehicle travel lane. Table 7 shows the number of encroachments for the three time periods. The row percentages are shown in parentheses, and the percentages of interest are bolded. Thus, for example, at Site M-1 the percentages of motor vehicles encroaching into the adjacent lane was 78.0 percent in the Before period, 45.8 percent in After 1 and 46.9

percent in After 2. Encroachments also were less at Sites M-2, M-3, and M-4. Sites M-6 and M-7, where the stripe had been in existence, also showed somewhat lesser encroachments, but the percent change was smaller.

Table 7. Encroachment data for the before and after time periods.

	Before			After 1			After 2		
	No	Yes	Total	No	Yes	Total	No	Yes	Total
M-1	11 (22.0)	39 **(78.0)**	50	58 (54.2)	49 **(45.8)**	107	26 (53.1)	23 **(46.9)**	49
M-2	112 (69.6)	49 **(30.4)**	161	45 (88.2)	6 **(11.8)**	51	50 (76.9)	15 **(23.1)**	65
M-3	13 (36.1)	23 **(63.9)**	36	37 (44.1)	47 **(56.0)**	84	27 (49.1)	28 **(50.9)**	55
M-4	16 (40.0)	24 **(60.0)**	40	54 (54.0)	46 **(46.0)**	100	20 (45.4)	24 **(54.6)**	44
M-6	26 (51.0)	25 **(49.0)**	51	58 (53.2)	51 **(46.8)**	109	23 (57.5)	17 **(42.5)**	40
M-7	110 (79.7)	28 **(20.3)**	138	63 (63.0)	37 **(37.0)**	100	77 (81.9)	17 **(18.1)**	94

Statistical analysis was used to examine these data more closely. The following null hypotheses was formulated and tested.

- **<u>Null hypothesis 4</u> - There is no difference in the proportion of motor vehicles which encroach into the adjoining motor vehicle travel lane in the Before period as compared to After the placement of the striping creating the 3-foot undesignated lane in either the After 1 period or the After 2 period.**

This hypothesis was tested using a logistic regression model. The conclusion of this modeling effort was that adding the stripe reduces the odds of motor vehicle encroachment into the adjoining lane. When comparing the Before period to After 1, the odds ratio is estimated as 0.729 [Chi-square (1 df) = 4.9491, p-value = 0.0261] Adding the stripe also reduces the odds of motor vehicle encroachment into the adjoining lane when comparing the Before period to the After 2 period. The odds ratio is estimated as 0.654. [Chi-square (1 df) = 7.3707, p-value = 0.0066]. A test of homogeneity of effect, or testing that the effect of the stripe is the same for each site, was rejected [Chi-square (10 df) = 30.1536, p-value=0.0008]. Thus, the effect of the stripe is different for different sites. We also conclude that the effect of the pre-existing stripe, or comparing sites M6 and M7 to M1, M2, M3, and M4, was statistically significant for the Before period compared to the After 1 period {Chi-square(1 df) = 16.7798), p-value = <.0001] However, in comparing the Before period to the After 2 period, the null hypothesis is not rejected [Chi-square (1 df) = 1.5485, p-value = 0.2134].

In a more detailed examination of the sites, a Mantel-Haenszel test of association was performed on a contingency table for each site. The test examines, on average, whether the proportion of motor vehicles that encroach into the adjoining lane decreases from the Before period to After 1 or After 2 period, or both. The 6 tests are summarized in Table 8. Sites M1 and M2 experienced a statistically significant decrease in the proportion of vehicles that encroached into the adjoining lane. Sites M3, M4, and M6 each have non-significant effects. For Site M7 the hypothesis of homogeneity is rejected, and the proportion of motor vehicles encroaching was greater in the After 1 period and less in the After 2 period.

Table 8. Summary of Mantel-Haenszel tests for each site.

Site	Chi-Square	P-value
M-1	15.4713	0.0004
M-2	7.3654	0.0252
M-3	1.4879	0.4752
M-4	2.5179	0.2840
M-6	0.3911	0.8224
M-7	11.7892	0.0028

The *overall* conclusion of this analysis is that the addition of the stripe had the effect of reducing the amount of motor vehicle encroachment into the adjacent lane on these multi-lane roadways. The effect varied by site. The differences by site are most likely due to variation in traffic volume for the periods of data collection, even though care was taken to collect data at the same time of day for all periods. When traffic volume is less, it is apparent from videotape review that passing motor vehicles have a tendency to give bicycles greater clearance.

Intersection Conflicts between Bicycles and Motor Vehicles

A final step taken in the analysis was to examine conflicts between bicycles and motor vehicles before and after placement of the stripe. Bicycle and motor vehicle interactions were examined at the four intersection locations with auxiliary right-turn lanes. These locations typically produce weaving between straight-through bicyclists and right-turning motor vehicles. A conflict was defined as a *sudden* change in speed or direction by either party to avoid the other. Before and after tapes were examined at each intersection, and no conflicts were observed in either period. There were numerous avoidance maneuvers, such as a right-turning vehicle braking while changing from the through lane to the auxiliary right-turn lane to yield to a straight-through bicycle. However, no conflicts were observed.

Summary

This study of the conversion of a 14-foot wide curb lane to an 11-foot travel lane with an undesignated 3-foot lane produced the following results:

- The **lateral spacing of bicyclists** from the gutter pan seam was greater with the stripe as compared to without the stripe. The addition of the stripe affected lateral spacing differently for different sites. On average, bicycles were ridden 7 to 9 inches farther away from the gutter pan seam at Sites M-1, M-2 and M-3 where the stripe was newly added. This would provide a greater margin of safety for bicyclists.

- The **lateral spacing of motor vehicles** from the gutter pan seam was greater with the stripe as compared to without the stripe. This would be expected with the shift of the travel lane to the left by 3 feet with the addition of the stripe. As above, the addition of the stripe affected lateral spacing differently for different sites. On average, motor vehicles were driven 6 to 12 inches farther away from the gutter pan seam at Sites M-1, M-2 and M-3 where the stripe was newly added.
- Overall, the **lateral spacing between bicycles and motor vehicles** was greater with the stripe as compared to without the stripe, but the effect was not as clear cut as for the other lateral spacing measures above. Once again, the addition of the stripe affected lateral spacing differently for different sites. On average, passing motor vehicles were driven 3 to 5 inches closer to bicycles at newly-striped Sites M-1, M-2 and M-3. This could be indicative of increased comfort level for both modes, where motor vehicle drivers believe bicyclists will ride within the striped area, and bicyclists believe motor vehicle drivers will not cross into their space in the striped area. Conversely, passing motor vehicles were driven 4 to 6 inches farther away from bicycles at the comparison sites where the stripe had already been in place.
- The addition of the stripe had the effect of **reducing the amount of motor vehicle encroachment** into the adjacent lane on these multi-lane roadways. The effect varied by site. On average, encroachments were reduced by approximately 15 to 40 percent at the sites where a stripe was newly added.
- At intersections, there were numerous avoidance maneuvers during the before and after periods, such as a right-turning vehicle braking while changing from the through lane to the auxiliary right-turn lane to yield to a straight-through bicycle. However, no conflicts were observed.

These findings are similar to those obtained in the earlier Harkey, Stewart and Rodgman study (1996), which found that the distance between the bicyclist and the edge of the roadway was considerably greater on bike lane and paved shoulder facilities than on wide curb lanes. The earlier study also found that motor vehicle encroachment into the adjacent lane when passing a bicycle was much greater on wide curb lanes than on bike lane and paved shoulder facilities. In essence, the striping in either a standard bike lane or an undesignated lane tends to produce bicycle tracking in the approximate middle of the bike lane or undesignated lane and thus farther away from the gutter pan seam or edge of road, giving a larger safety margin. Less encroachment by motor vehicles into the adjacent traffic lane should also result in improved motor vehicle safety. As indicated in the development of the Bicycle Compatibility Index, a tool that can “be used by practitioners to evaluate the capability of specific roadways to accommodate both motorists and bicyclists,” the placement of a stripe designating a space for bicyclists likely tends to produce an increased comfort level for both bicyclists and motorists, with each feeling that the boundary of the stripe will not be crossed by either party (Harkey, Reinfurt, Knuiman, Stewart, and Sorton, 1998).

This study represents a data point in regard to the utility of this striping technique, and the results should be contemplated within the limitations that were present. The roadways that were striped tended to be relatively high-speed and high-volume, especially as pertains to bicycling routes. As a result, few local bicyclists currently use the routes, and subject riders had to be employed to gather the lateral spacing data in an efficient manner. Instead of thermoplastic, the striping was painted and faded to less brightness over time. It is recommended that additional evaluations of striping an undesignated lane be conducted. If possible, the next study of the striping should involve routes where local bicyclists are a natural part of the traffic stream.

Overall, this pilot study has indicated that this type of roadway striping has the potential to improve both bicycle and motor vehicle safety, even given the limitations of the study design, and the technique certainly seems deserving of further study.

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APPENDIX A

BEFORE-AFTER IMAGES OF THE MIDBLOCK SITES

SITE M-1

Before Stripe

After Stripe

SITE M-2

Before Stripe

After Stripe

SITE M-3

Before Stripe

After Stripe

SITE M-4

Before Stripe

After Stripe

SITE M-6

Before

After

SITE M-7

Before

After