EVALUATION OF A GREEN BIKE LANE WEAVING AREA IN ST. PETERSBURG, FLORIDA

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16. Abstract

This report focuses on colored (green) pavement and accompanying signing used in St. Petersburg, Florida in a bike lane weaving area, where motor vehicles cross the bike lane, near an intersection. The objective was to determine if the painting and signing highlighting these areas changed the behavior of bicyclists and motorists traveling through this section. The study methodology was to compare the operations of bicyclists and motorists at the selected location using videotapes made before and after the green pavement and signing treatments were installed. A significantly higher percentage of motorists yielded to bicycles in the after period. The percentage of motorists that signaled their intention to turn right increased significantly from the before to the after period. A significantly higher percentage of bicycle riders scanned for proximate vehicles in the after period. While the percentage of conflicts (sudden changes in speed or direction) was lower in the after period, the differences were not statistically significant. Most of the conflicts were between motorists maneuvering near the bicyclists. It was not surprising to see a large number of motorists in a queue maneuvering to get into the right-turn lane. In times of busy motor vehicle traffic, this location was a severe test of the green bike lane weaving area. The significant increase in yielding behavior by motor vehicles is an important finding and matches what was found in the earlier evaluation of the blue bike lane weaving areas in Portland, Oregon.

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EXECUTIVE SUMMARY

This report focuses on colored (green) pavement and accompanying signing used in St. Petersburg, Florida in a bike lane weaving area, where motor vehicles cross the bike lane, near an intersection. The objective was to determine if the painting and signing highlighting these areas changed the behavior of bicyclists and motorists traveling through this section. The study methodology was to compare the operations of bicyclists and motorists at the selected location using videotapes made before and after the green pavement and signing treatments were installed. A significantly higher percentage of motorists yielded to bicycles in the after period. The percentage of motorists that signaled their intention to turn right increased significantly from the before to the after period. A significantly higher percentage of bicycle riders scanned for proximate vehicles in the after period. While the percentage of conflicts (sudden changes in speed or direction) was lower in the after period, the differences were not statistically significant. Most of the conflicts were between motorists maneuvering near the bicyclists. It was not surprising to see a large number of motorists in a queue maneuvering to get into the right-turn lane. In times of busy motor vehicle traffic, this location was a severe test of the green bike lane weaving area. The significant increase in yielding behavior by motor vehicles is an important finding and matches what was found in the earlier evaluation of the blue bike lane weaving areas in Portland, Oregon.

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INTRODUCTION

This report focuses on colored (green) pavement and accompanying signing used in St. Petersburg, Florida in a bike lane weaving area, where motor vehicles can cross the bike lane, near an intersection. The objective was to determine if the painting and signing highlighting these areas changed the behavior of bicyclists and motorists traveling through this section. This study came about as part of a contract between the University of North Carolina Highway Safety Research Center (HSRC) and the Florida Department of Transportation (FDOT). The contract provides funding to evaluate innovative bicycling improvements in the State of Florida.

LITERATURE

Intersections and intersection-related locations account for 50 to 70% of reported bicycle-motor vehicle crashes (*1*). Colored pavement is a countermeasure that has the potential to reduce conflicts and crashes at or near intersections.

Many European cities use colored markings at bicycle-motor vehicle crossings to reduce conflicts. In Denmark, the marking of bicycle travel paths (raised overpasses) at signalized junctions resulted in 36% fewer crashes with motor vehicles and 57% fewer bicyclists who were killed or severely injured (*2*).

Colored bicycle crossings were installed at five intersections in Montreal, with the pavement painted blue at bicycle-path crossing points. After the markings were painted, bicyclists were more likely to obey stop signs and to stay on designated bicycle-path crossings. Improved bicyclist behavior led to a decline in the level of conflict between bicyclists and motorists (*3*).

As an innovative treatment, the community of Tavares, Florida decided to add one mile of shoulders to a scenic roadway and paint the shoulders red to provide visual narrowing and to emphasize their use as a bicycle facility. Hunter (*4*) evaluated the red shoulders and found: 1) no increase in motor vehicle speeds after the addition of the red shoulders, 2) full-time use of the red shoulder by 80% of bicyclists (and another 6% partial use), 3) slightly increased spacing between bicyclists being passed by motor vehicles at the site without red shoulders, and, 4) due to the increased spacing, more vehicular encroachment into the opposing lane of travel and more vehicle-to-vehicle conflicts at the site without red shoulders. The overall conclusion was that the red shoulders had produced operational benefits for both bicyclists and motorists.

Hunter, Harkey, Stewart, and Birk (*5*) studied the use of blue pavement markings and a novel signage system to delineate selected bicycle-motor vehicle conflict areas in the city of Portland, Oregon. From 1997 to 1999, Portland marked 10 conflict areas with paint, blue thermoplastic, and an accompanying "Yield to Cyclist" sign. All of the sites had a high level of cyclist and motorist interaction, as well as a history of complaints. The crossings were all at locations where the cyclist travels straight and the motorist crosses the bicycle lane in order to exit a roadway (such as an off-ramp situation), enter a right-turn lane, or merge onto a street from a ramp. The study used videotape analysis and found most behavior changes to be positive. Significantly higher numbers of motorists yielded to cyclists and slowed or stopped before entering the blue pavement areas, and more cyclists followed the colored bike lane path. However, the blue pavement also resulted in fewer cyclists turning their heads to scan for traffic or using hand signals, perhaps signifying an increased comfort level. The overwhelming majority of cyclists and close to a majority of motorists surveyed felt the blue areas enhanced safety.

Policy guidance pertaining to the use of colored pavement for cycle lanes has been developed for Portsmouth, England (*6*). One recommendation is to use green for the cycle lane and to further provide a red colored buffer zone with white cross hatching to the side of the cycle lane.

Sadek, Dickason, and Kaplan (*7*) examined the effectiveness of a green, high-visibility bike lane and crossing treatment located on a cloverleaf interchange in Vermont. Bicyclists and motorists were observed and videotaped in the vicinity of on- and off-ramps. It was concluded that the green bike lane treatment was associated with a majority of bicyclists using the bike lane instead of the sidewalk or the road. The treatment did not lead to increased yielding by motorists to cyclists at the crossings.

SITE SELECTION AND PHASING

Working with the City of St. Petersburg, a site was selected on 1st Avenue N near the intersection with 34th Street for use of a colored portion of a bike lane. The city requested and was granted permission by the Federal Highway Administration (FHWA) to experiment with the treatment. At this location, 1st Avenue N is a one-way street running east-to-west with five lanes, including a left-turn-only lane, three through lanes, and a right-turn-only lane. A bike lane is positioned between the right-turn-only lane and the next through lane. The bike lane continues for a number of blocks through this area. A recent traffic count showed a total of 16,793 vehicles, including 2,902 right-turning vehicles, or 17% of the total. At this location, the weaving area where the paths of motorists and bicyclists were intended to cross was outlined by dashed striping of 190 feet along both sides of the bicycle lane. The “before” condition, which refers to the period before the green paint and signage were applied to the roadway, is shown in Figure 1.

In the first “after” period (After 1), which refers to the first application of green paint and new signage, the 190 foot dashed striping area was painted green (Figure 2). Solid bike lane stripes approach this area, so that there was no change in the length of the weaving area.

Figure 1. Cross-section and "before" condition.

Figure 2. First "after" condition for green bike lane weaving area.

A sign assembly similar to those used in Portland, Oregon, in their blue bike lane installations (but substituting green for blue on the main sign) was installed at the start of the green bike lane weaving area. The green color was chosen to match the recommendation of FHWA, which recommended that further testing with colored bike lanes use green, since blue is associated with another meaning in pavement marking contexts (Figure 3).

Figure 3. Sign assembly used in the vicinity of the green bike lane weaving area.

The After 1 period began on March 20, 2007. A variable message board was used to send the following message to motorists: “RIGHT TURN YIELD TO BIKES”. The variable message board was installed three parking spaces in advance of the green weaving area. A press release was prepared and distributed to explain the treatment.

After the paint and the sign assembly had been in place for several months, it was felt that some motorists did not understand the intent of yielding to bicyclists and crossing behind them in the green weaving area. Many motorists were crossing either behind or in front of the green weaving area. The city then decided to enhance the treatment by installing black mini-stripes around the border of the dashed area (Figure 4).

Figure 4. Black mini-stripes added to border of green bike lane weaving area.

The variable message board (Figure 5) was used again in the same location, and the following message was displayed in two panels: "YIELD TO BIKES AND CROSS IN GREEN." The sign assembly was moved about 65 feet into the green weaving area, and another sign assembly was located 270 feet in advance of the green weaving area. All upgrades were completed on August 20, 2007, including another press release, and this was the start of the After 2 period, referring to the application of the black mini-stripes and additional signage.

Figure 5. Use of variable message board.

DATA COLLECTION

The study methodology was to compare the operations of bicyclists and motorists at the selected location using videotapes made before and after the green pavement and signing treatments were installed. The data were collected by a technician from HSRC. Before data were collected in February 2006, May 2006, and September/October 2006. After 1 data were collected in May 2007, and After 2 data in October 2007. Videotape data were collected at various hours of the day and on weekdays and weekends. The vast majority of the data were collected from the rear of the passing bicyclist. The data collector generally set up some 400 feet from the intersection and followed the bicyclist through the intersection. Some data were collected of bicyclists riding toward the camera in the before period, but it was felt that the former method provided the best vantage point. The number of bicyclists riding through the site was lower than anticipated. Therefore, a number of bike clubs were contacted to ask if their members would ride through the site. A number of cyclists from the neighborhood also participated.

DATA REDUCTION

From the before and after video data, a number of measures of effectiveness and other attributes were coded. The bicycle was the basic unit of analysis. For each bicyclist passing through the treatment site, gender and helmet use were recorded, along with their approach position (vast majority in the bike lane), direction (vast majority with traffic), whether the bicyclist scanned for proximate motor vehicles, and whether the bicyclist used a hand signal for any maneuvers. Additionally, we coded whether the dashed weaving area was used, the destination of the cyclist, and their method for going straight, left, or right. The vast majority of cyclists approached in the bike lane, went straight through the intersection, and continued in the bike lane on the far side of the intersection.

The interactions between bicyclists and passing motor vehicles were also studied. As many as four interactions were coded for each bicyclist traveling through the section. On many occasions, a bicyclist proceeded through the intersection either without any motorists in proximity or with no motorists moving to the right-turn lane. These were coded as no interaction or “none.” When motorists moved into the right-turn lane, we coded whether an avoidance maneuver or conflict or no interaction occurred. An avoidance maneuver was defined as a change in speed or direction by either the bicyclist or motorist to avoid the other (e.g., minor braking by the motor vehicle). A conflict was defined as a *sudden* change in speed or direction by either the bicyclist or motorist to avoid the other (e.g., major braking by the motor vehicle). Conflicts and avoidance maneuvers have been, and continue to be, used in a variety of HSRC studies (e.g., *8*).

Additional information associated with each interaction was coded. The type of interaction was coded as bicycle-motor vehicle, bicycle-bicycle, or motor vehicle-motor vehicle, depending on the interacting parties. We coded whether the motorist used a right-turn signal if moving into the right-turn lane, whether they actually used the green bike lane weaving area, and whether they passed in front of or behind the bicyclist. The main dependent variable coded was whether the bicyclist or motorist yielded to the other.

Yielding was defined as slowing or stopping to give way to the other party when the weaving maneuver in the green bike lane area occurred. Finally, when an avoidance maneuver or conflict occurred, we coded the responses of the bicyclist and the motorist, or in turn the responses of both motorists if the event was motor vehicle-motor vehicle. There were only three bicycle-bicycle events. Bicyclist response categories were no change, slows or stops pedaling, slight direction change, brakes, major direction change, full stop, or unsure. Motorist response categories were no change, slows, slight direction change, brakes, major direction change, full stop, or unsure.

ANALYSIS AND RESULTS

Bicyclist Characteristics and Behaviors

A total of 1,181 bicycles were examined as part of the data collection (598 in the before period and 583 in the after period). General descriptions include the following:

- 88% were male, 9% female, and for 2% the gender was unsure
- 73% used a helmet, 24% did not, and for 3% helmet use was unsure
- 94% used the bike lane as they approached, 4% a travel lane, 0.3% the sidewalk, and 0.4% some other location
- 99% rode with traffic
- 94% used the dashed weaving area
- 90% went straight through the intersection, 0.7% made a left turn in advance of the intersection, 0.7% made a left turn at the intersection, 4% made a right turn in advance of the intersection, 4% made a right turn at the intersection, and less that 1% made some other maneuver
- for the 1,063 bicyclists going straight through the intersection, 95% went straight through the intersection from bike lane to bike lane, 1% went from the right-turn lane to the bike lane or right-turn lane on the far side of the intersection, 1% moved to the sidewalk and then the crosswalk, 1% stayed in the street but then moved to the crosswalk area, 0.2% went from travel lane to travel lane, less than 1% went from the bike lane to a travel lane, and the remainder performed some other maneuver
- for the 98 bicyclists making a right turn, 30% made the turn from the right-turn lane to the traffic lane, 62% went from the bike lane or traffic lane to the sidewalk, and 8% went from the bike lane or another traffic lane to the intersecting street
- for the 21 bicyclists making a left turn, 29% made an advance crossover, 5% a hybrid bicycle-motor vehicle maneuver, 14% went left from the bike lane, 19% made a motor-vehicle-style left, 29% used the near side crosswalk in a pedestrian-style maneuver, and 5% made a “right hook” (maneuvered to the right to wait for crossing motor vehicles to clear before turning left)

Yielding Behavior

Table 1 shows the number of times motorists and bicycles yielded in the before and after periods while interacting with each other. Only those situations where either the motorist or the bicycle yielded were considered for this analysis.

Table 1. Yielding behavior.

Period	Bicycle Yielded		Motorist Yielded		Total
	Count	Percentage	Count	Percentage	
Before	46	15.3%	300	86.7%	346
After	6	1.5%	407	98.5%	413
Total	52		707		759

It is clear that a higher percentage of motorists yielded to bicycles in the after period; a chi-square test revealed the differences to be statistically significant at the 5% significance level ($p < 0.001$). Further analysis included the comparison of yielding behavior in the two after conditions, (i.e., After 1 and After 2). There was very little difference in the percentage of motorists yielding in the two after periods (99% in After 1 and 98.2% in After 2).

Avoidance Maneuvers and Conflicts

Interactions and maneuvers were defined as either avoidance maneuvers or the more severe conflicts. Table 2 shows the number of events that were defined as avoidance maneuvers and conflicts in the before and after periods. This table includes both bicycle-motor vehicle and motor vehicle-motor vehicle events.

Table 2. All avoidance maneuvers and conflicts.

Period	Avoidance		Conflict		Total
	Count	Percentage	Count	Percentage	
Before	357	96.5%	13	3.5%	370
After	405	97.8%	9	2.2%	414
Total	762		22		784

The percentage of conflicts was slightly lower in the after period compared to the before period (2.2% versus 3.5%). The chi-square test did not indicate this difference to be statistically significant at the 5% significance level ($p = 0.26$). The percentage of conflicts was 3.1% in the After 1 period and 1.4% in the After 2 period; again, differences were not statistically significant at the 5% significance level.

Table 3 shows only the number of bicycle-motor vehicle interactions in the before and after periods that were defined as either avoidance maneuvers or conflicts. The percentage of conflicts is again slightly lower in the after period. However, the since the number of conflicts was low, it was not possible to make definitive conclusions on the effect of the treatment on the severity of the interactions.

Table 3. Bicycle-motor vehicle avoidance maneuvers and conflicts.

Period	Avoidance		Conflict		Total
	Count	Percentage	Count	Percentage	
Before	227	97.8%	5	2.2%	232
After	281	99.3%	2	0.7%	283
Total	508		7		515

Bicycle and Motor Vehicle Responses while Interacting

Tables 4 and 5 show the bicycle and motor vehicle responses during their interaction with each other in the before and after periods. It is clear from Table 4 that bicycles slowed down less often during the after period. In addition there were fewer braking and direction changes in the after period.

Table 4. Bicycle responses during bicycle-motor vehicle interactions.

	Before		After	
Events	Count	Percentage	Count	Percentage
No change	438	90.7%	685	98.7%
Slows/stops pedaling	33	6.8%	7	1.0%
Slight direction change	4	0.8%	1	0.1%
Major direction change	3	0.6%	0	0.0%
Brakes	2	0.4%	1	0.1%
Full stop	0	0.0%	0	0.0%
TOTAL	483		694	

Table 5 indicates that motor vehicles slowed down 2.0% of the time in the after period compared to 5.8% in the before period. On the other hand, motor vehicles braked more often in the after period (34.6% in the before period versus 36.7% in the after period). Regarding change in direction, the number of such events was quite similar in the before and after periods. In summary, the effect of the treatment on motor-vehicle motor vehicle responses is not very clear.

Table 5. Motor vehicle responses during bicycle-motor vehicle interactions.

	Before		After	
Events	Count	Percentage	Count	Percentage
No change	274	56.7%	413	59.5%
Slowed	28	5.8%	14	2.0%
Slight direction change	6	1.2%	4	0.6%
Major direction change	3	0.6%	6	0.9%
Brakes	167	34.6%	255	36.7%
Full stop	2	0.4%	2	0.3%
TOTAL	483		694	

Use of the Green Bike Lane Weaving Area by Motorists

The number of times motorists used the green bike lane weaving area was explored for those situations where the type of interaction was bicycle-motor vehicle. Table 6 shows the results for this comparison.

Table 6. Use of green bike lane weaving area by motorists.

Period	Did not use bike area		Used bike area		Total
	Count	Percentage	Count	Percentage	
Before	65	13.5%	417	86.5%	482
After1	63	19.7%	257	80.3%	320
After2	73	19.6%	300	80.4%	373
Total	201		974		1174

It is clear from Table 6 that a lower percentage of motorists used the green bike lane weaving area during the after periods. The differences were statistically significant at the 5% significance level ($p = 0.02$). Again, there was very little difference between After 1 and After 2.

Motorist Turning Ahead or Behind Bicyclist Using the Green Bike Lane Weaving Area

The number of times the motorist turned ahead or behind the bicyclist using the green bike lane weaving area was examined for situations when the type of interaction was bicycle-motor vehicle. Table 7 shows the results.

Table 7. Turning ahead or behind the bicycle.

Period	Ahead of Bike		Behind Bike		Total
	Count	Percentage	Count	Percentage	
Before	207	43.2%	272	56.8%	479
After1	130	40.6%	190	59.4%	320
After2	167	44.7%	207	55.3%	374
Total	504		669		1173

The results are very similar for the before and the two after periods, although a higher proportion of motorists were turning behind the bicyclist in the After 1 period. The differences were not statistically significant at the 5% significance level ($p = 0.22$).

Motorist Signal for Right Turn

Table 8 shows how often motorists signaled their intention to turn right during the before and after periods. Results indicate the percentage of motorists that did signal their intention to turn right increased from the before period to the after period. Chi-square tests indicated that the differences were statistically significant at the 5% significance level (p = 0.022). Table 9 is a comparison between the two after periods. The percentage of motorists who signaled was higher in the After 2 period; however the difference was not statistically significant at the 5% significance level (p = 0.24).

Table 8. Motorist signal for turning right (comparison of before and after periods).

Period	Motorist did not Signal		Motorist did Signal		Total
	Count	Percentage	Count	Percentage	
Before	91	14.8%	523	85.2%	614
After	89	10.8%	736	89.2%	825
Total	180		1259		1439

Table 9. Motorist signal for turning right (comparison of the two after periods).

Period	Motorist did not Signal		Motorist did Signal		Total
	Count	Percentage	Count	Percentage	
After1	47	12.1%	340	87.9%	387
After2	42	9.6%	396	90.4%	438
Total	89		736		825

Bicycle Head Scan

Table 10 shows the number and percentage of all bicycles that scanned the environment to look for other vehicles and motorists. It is clear that a much higher percentage of bicycle riders scanned for proximate vehicles in the after period. Chi-square results confirm that the differences are indeed statistically significant at the 5% significance level (p < 0.001). There was very little difference between the scanning behavior in the two after periods: 12.3% in After 1 scanned for proximate vehicles versus 11.7% in After 2.

Table 10. Bicycle head scan for all bicycles.

Period	Did not Scan		Did Scan		Total
	Count	Percentage	Count	Percentage	
Before	560	94.0%	36	6.0%	596
After	513	88.0%	70	12.0%	583
Total	1073		106		1179

Table 11 shows these numbers and percentages only for those bicycles that made a right turn at the sites. Since the number of right turns by bicycles was small, it was not possible to make any definitive conclusions regarding the effect of the treatment on the scanning behavior of right turning bicycle riders.

Table 11. Bicycle head scan for right turning bicycles.

Period	Did not Scan		Did Scan		Total
	Count	Percentage	Count	Percentage	
Before	23	88.5%	3	11.5%	26
After	22	95.7%	1	4.3%	23
Total	45		4		49

SUMMARY AND DISCUSSION

This use of colored pavement and signing to identify a bicycle-motor vehicle weaving area on a busy one-way street showed positive results for a number of factors:

- A higher percentage of motorists yielded to bicycles in the after period (86.7% before versus 98.5% after). A chi-square test revealed the differences to be statistically significant at the 5% significance level ($p < 0.001$). There was very little difference in the percentage of motorists yielding in the two after periods
- Examining all interactions, the percentage of conflicts was slightly lower in the after period compared to the before period (2.2% versus 3.5%). The chi-square test did not indicate this difference to be statistically significant at the 5% significance level ($p = 0.26$).
- Examining the number of bicycle-motor vehicle interactions in the before and after periods showed the percentage of conflicts to be slightly lower in the after period (2.2% before versus 0.7% after). However, the number of conflicts was too small to test for statistical significance.
- A lower percentage of motorists used the green bike lane weaving area during the after periods (86.5% before versus 80.3% in After 1 and 80.4% in After 2). The differences were statistically significant at the 5% significance level ($p =0.02$). There was very little difference between After 1 and After 2.
- Examining bicycle-motor vehicle interactions, there was no difference in the percentage of times the motorist turned ahead or behind the bicyclist using the green bike lane weaving area (56.8% turned behind the bike in the before period versus 59.4% in After 1 and 55.3% in After 2).
- The percentage of motorists that signaled their intention to turn right increased from the before period (85.2%) to the after period (89.2%). Chi-square tests indicated that the differences were statistically significant at the 5% significance level ($p = 0.022$). There was no difference between After 1 (87.9%) and After 2 (90.4%).
- A much higher percentage of bicycle riders scanned for proximate vehicles in the after period (6.0% before versus 12.0% after). Chi-square results confirmed that the differences were statistically significant at the 5% significance level ($p < 0.001$). There was very little difference between the scanning behaviors in the two after periods (12.3% in After 1 versus 11.7% in After 2).

In times of busy motor vehicle traffic, this location was a severe test of the green bike lane weaving area. The significant increase in yielding behavior by motor vehicles is an important finding and matches what was found in the earlier evaluation of the blue bike lane weaving areas in Portland, Oregon *(5)*. To some extent, this result in St. Petersburg is a reflection of the skill of the bicyclists riding through this location. These bicyclists seemed quite knowledgeable about how to ride in traffic.

While the percentage of conflicts (sudden changes in speed or direction, Figures 6 and 7) was lower in the after period, the differences were not statistically significant. It should be noted that most of the conflicts were between motorists maneuvering near the bicyclists.

Figure 6. Bicycle-motor vehicle conflict.

Figure 7. Motor vehicle-motor vehicle conflict.

It was not surprising to see a large number of motorists in a queue maneuvering to get into the right-turn lane. A considerable number of late merges to the right-turn lane took place near the intersection. At times a motorist would move from the left-most through lane to the right-turn lane.

Figure 8. Motorist queue to turn right.

That a lower percentage of motorists used the green bike lane weaving area during the after periods is somewhat puzzling. Sometimes a motorist would drive all the way past the weaving area to move into the right-turn lane, even though there was plenty of space ahead of the bicyclist to enable use of the weaving area. At other times a motorist would turn behind the bicyclist before reaching the green bike lane weaving area. In addition, there was no difference in the percentage of times the motorist turned ahead or behind the bicyclist using the green bike lane weaving area, even with the increased yielding. Perhaps some motorists never understood the intent of the weaving area and simply stayed out of it after the coloring was added.

An increase in the number of motorists signaling their intent to move to the right-turn lane is a safety benefit. An increase in scanning by bicyclists in the after period is also important. This was not the case in the earlier Portland, Oregon *(5)* evaluation.

The green bike lane weaving area led to operational benefits for bicyclists on this busy, multi-lane roadway with a high proportion of motor vehicle right turns. It is recommended that additional study of colored bike lane weaving areas should be conducted in different traffic settings.

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