How Pavement Markings Influence Bicycle and Motor Vehicle Positioning: A Case Study in Cambridge, MA

by

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ABSTRACT

The purpose of this study was to determine how pavement markings influence bicyclist and motorist positioning, particularly how far bicyclists travel from parked cars. The research examined the effects of sequentially adding the component markings of a bike lane on a road (Hampshire St.) with on-street parking in the city of Cambridge, MA. Data measured were the distance cars parked from the curb, the distance bicyclists rode from the curb, and the distance traveling motor vehicles drove from the curb. The data on bicyclists and moving motor vehicles were gathered by videotape. The three pavement marking treatments – an edge line demarcating the travel lane, the edge line and bicycle symbols, and a full bike lane – were all effective at influencing bicyclists to ride farther away from parked cars than when no pavement markings were present.

The analysis examined the percentage of cyclists riding 9 and 10 feet out from the curb. These distances were used as benchmarks for how far cyclists should ride so as to be farther from the "door" zone of a parked car. All three treatments significantly increased the percentage of cyclists riding more than 9 and 10 feet from the curb. There was variation at the measurement sites near the signalized intersection vs. measurement sites near uncontrolled intersections, with higher increases near the signalized locations.

"Before" and "after" intercept surveys of cyclists and motorists were administered. Cyclists during baseline most often responded that the best way to improve bicycling on Hampshire St. was to add bike lanes. Cyclists also rated the full bike lane most favorably in the "after" survey. There was no change in comfort level rated on 5-point scale between baseline and the end of the study surveys. When motorists were asked what made them most aware of cyclists on the street, the most common response during the "before" condition was "nothing." In the "after" survey, the most common response was "the bike lane."

INTRODUCTION

In the United States, bicyclists in various surveys have indicated a preference for marked bicycle lanes on streets (Stimson, 2003; Kroll and Sommer, 1976; Rodale, 1992). Some advocates have been concerned that bicycle lanes might increase the risk of cyclists coming in conflict with opening car doors. Although the Uniform Vehicle Code clearly states that the motorist parking the car is responsible for not opening a car door on the side of moving traffic unless it is safe to do so, the reality is that many motorists have not been well educated about this. Bicyclists generally travel on streets between parked cars and moving vehicles whether or not bicycle lanes are present, and the risk of colliding with a car door is always present in these circumstances. The question that arises, therefore, is whether pavement markings – and in particular bicycle lanes – have an impact on bicyclist safety by influencing whether bicyclists ride closer to parked cars and therefore increasing the risk presented by an opening door.

Research on bicycle facilities has often focused on examining bicycle lanes installed on roads without on-street parking (Harkey & Stewart, 1997; Harkey, Stewart, & Stutts, 1999). Several studies have shown that drivers make fewer wide swerves or close passes when passing bicyclists on streets with bicycle lanes (Kroll & Ramey, 1977; McHenry & Wallace, 1985) and have found that bike lanes reduced the percentage of encroachments by motorists into the next lane, and resulted in less variation in wheel path for bicycles and motor vehicles (McHenry & Wallace,1985). McHenry and Wallace (1985) also found that motorist swerved less when passing cyclists when there was a marked bike lane than when there was none.

Harkey and Stewart (1997) found that bicycle lanes as narrow as .92 m (3 feet) provide sufficient space for bicycles and motor vehicles to interact safely and that lanes of 1.22 m (4 feet) worked best. They also found that a stripe separating motor vehicles and bicycles produced fewer erratic maneuvers by motorists. Hunter, Stewart, & Stutts, (1999) found there was more wrong-way cycling, and more sidewalk riding at wide curb lanes sites than at bicycle lane sites and that more cyclists obeyed stop signs at locations with bicycle lane sites. These studies involved comparisons of existing sites and did not involve comparisons of cyclist and driver behavior before and after facilities were installed.

One recent study did look at streets with on-street parking. The San Francisco Department of Parking & Traffic engaged Alta Planning & Design to study the effects of “shared use” markings on cyclists’ and motorists’ road position, cyclists’ riding behavior, and bicycle/motorist conflicts. The report, “San Francisco’s Shared Lane Pavement Markings: Improving Bicycle Safety,” (February, 2004) concluded that the markings increased the distance of cyclists from parked cars as well as the distance between cyclists and passing vehicles. One of the marking types, the “bike and chevron,” significantly reduced the number of wrong-way riders.

The purpose of the present study was to examine the effects of a variety of pavement markings on motorists and bicyclists; in particular, the study’s aim was to determine the impact of the various markings on the distance bicyclist’s rode from parked cars. By sequentially adding a lane line, bicycle lane symbol, and then curbside line of a bicycle lane, the effects could be seen using the same street, thus controlling for other variables that might exist when using different streets.

In order to establish where ideally bicyclists should be riding, it is important to know how far the door zone extends from the curb face. Data gathered in the San Francisco study determined that the 85th percentile of car doors observed opened to 9’6” from the curb (SFDPT data). Giving a 6” clear zone to the bicycle handlebar, the total width of the potential door zone would be 10 feet.

This current study compares where bicyclists rode in the absence of any markings, with a lane line alone, a lane line plus bicycle symbol, and a full bike lane. Data were also collected on vehicle wheel paths to determine whether motorists behaved differently in the presence of these conditions, and on how far motorists parked from the curb under the various conditions. In addition, intercept surveys were administered to cyclists and drivers, before any markings were installed, and after the full bike lane had been installed.

METHOD

Participants and Setting

Participants were bicyclists and motorists traveling on Hampshire Street (Figure 1). Hampshire Street is a 44-foot wide road, with curbside parking on both sides of the street and one traffic lane in each direction. Parking in this section is primarily by residential permit, with some time-limited spots in front of small businesses; parking is full most of the time. ADT is approximately 15,000; peak hour bicycle counts are approximately 150 in the a.m. peak and 120 in the p.m. peak. The section of Hampshire St. that received experimental treatments has a number of “T” intersections and full intersections, some with traffic signals. Hampshire Street is a little over 3/4 mile long, and the study section was just over 1/3 mile long.

General Procedure

To collect data on the bicyclists and moving vehicles, a camera was set up at four points along the study section (Figure 1), at two points eastbound and two points westbound. Two of the points were near a signalized intersection, and two near unsignalized intersections. All data on bicycle and vehicle traffic were collected during morning and afternoon rush hours, with eastbound traffic measured in the morning between approximately 7:30 and 9:30 AM, and westbound traffic measured in the evening between approximately 4:30 and 6:30 PM The rush hour periods were used, as this is when cyclists are primarily present in this corridor; means and resources were not available to do the extensive filming that would have been needed to get enough data points for a valid study during the off-peak hours. Data were collected on approximately 60 bicycles during each rush hour. All data were collected during the spring, summer, and fall of 2003 on days without precipitation. The 100 hours of filming yielded data on approximately 4500 cyclists and 4500 moving vehicles.

Data were collected on the following variables: 1) The distance that vehicles parked from the curb for the entire length of the study section on the north and south side of the street (collected once during each condition); 2) The wheel path of bicycles in the roadway at each of the four camera locations; 3) The near side tire path of motor vehicles in close proximity to bicyclists at the same locations. Bicycle position was measured in all cases at locations between 105 and 148 feet downstream of an intersection. Figure 1 shows the approximate locations of where measurements were taken.

Four-inch squares of marking material were laid down to show the boundaries of a five-foot bike lane that was to be sequentially installed later in the study. A square was also located at the center of the planned location for the bike lane. Figure 1 (bottom) illustrates how the squares were installed at each of the four measurement locations.

Taping Procedure

All tapes were labeled with the date, time, location, and weather conditions. The tripod was set up so that the two legs closest to the centerline was parallel to the street and placed between two parked cars. Care was taken to ensure that the view zoomed in at squares marked in the road and that all vehicles traveling on the approaching half of the roadway cut an imaginary line extending from the two marks in the roadway. All recording was done using a Canon GL 2 digital video tape recorder.

Tape Scoring Procedure

Tapes were played onto a 52-inch screen and all measurements were taken in millimeters off the screen. In order to convert measurements to feet, the scorer measured the distance between outside of both of the square markings (known to be 5 feet) in millimeters.

Experimental Design

Baseline

The only marking in the roadway on Hampshire St. during the baseline condition was the centerline. Hampshire Street had been recently repaved and no other markings were present.

Lane edge line alone

Following the baseline condition, lane edge lines were installed 10 feet from the centerline on either side (12 feet from the curb) and would later form the outside line of the bike lane.

Lane edge line plus bike lane symbols

Next, the bike lane symbols, which consisted of the bike symbol and a direction arrow, were placed in the roadway, with the center of the symbol offset 4 inches to the left of center of the bike lane in the east direction and 14 inches to the left of the center of the bike lane in the west direction. The intent was to determine whether skewing the bike lane symbol farther away from the parked cars and towards the travel lane would influence bicyclists' positioning.

Full bicycle lane

After the effects of the lane edge line plus bike lane symbols had been evaluated the curbside edge of the bicycle lane was installed seven feet from the curb in both directions forming a 5-foot wide bicycle lane in each direction.

Measures

Parking position measurements

Parking position measurements were obtained in the field for the distance between the curb face and the front and rear tire of each vehicle parked along the study section of Hampshire Street once during each condition; data was collected on a total of 500 cars.

Bicycle and motor vehicle lane road position measurements

When a bicycle crossed between the two square markings the scorer paused the tape player, producing a high quality freeze frame. The scorer then measured the distance from the curbside of the curb square, which was 7 feet from the curb, to the portion of the tire in contact with the roadway. Next the scorer took the motor vehicle that was closest in time to the bicycle, paused the tape, and recorded the distance between the left of the curb line marking and the middle portion of the vehicle tire in contact with the roadway.

Intercept survey

An intercept survey of bicyclists and motorists was conducted during the baseline and final treatment condition. All intercept surveys were conducted at traffic signals on Hampshire St. After the signal turned red the research assistant or volunteer approached the stopped cyclist or driver and said “Good morning/afternoon. I am doing a survey for the City of Cambridge and have a few brief questions to ask you. It will take less than a minute. May I proceed?” If the potential respondent refused, the surveyor approached the next person. There were few refusals. Cyclists who agreed to participate were asked to stay against the curb, out of the line of traffic. The baseline bicyclist survey (n = 117) had participants rate their comfort level on a five-point scale; how often they cycled on a five-point scale; and what they would change to improve cycling on Hampshire St. (open ended question). During the after survey (n = 123; 115 were scored for the rankings), cyclists were again asked to rate their comfort level on a five-point scale; how often they cycled on a five-point scale; if they noticed street markings on Hampshire St. over the course of the past few months (yes/no); and to rank each of the four conditions with a “1” being most preferred and a “4” being least preferred. Surveyors also took note of the sex and age of each of the respondents.

The baseline survey was administered to 129 motorists, and 120 received the “after” survey. The motorist survey asked drivers whether they were aware of bicyclists while driving on Hampshire St.; what about the street made them aware of bicyclists (open ended question); and how often they drove on Hampshire St. (five point scale). The surveyors took note of the sex and approximate age of the drivers.

RESULTS

Parked Vehicles

Parking distance from the curb face to the average distance of the front and back tires for the eastbound and westbound direction is shown in Figure 2. After the lane line marking was installed, motorists parked approximately 3 inches farther on average from the curb when facing in the eastbound direction and approximately 2 inches farther from the curb when facing in the westbound direction. Parking distance moved progressively closer to the curb after the bike symbols were put in, and after the curb line was put in.

Statistical analysis of these data is also shown in Figure 2. An analysis of variance (ANOVA) was used along with the Tukey method to test for contrasts. The most important information to draw from the analysis is that with the installation of the lane line (treatment

1), motorists parked significantly farther from the curb in both directions. The motorists moved in with each additional marking and in the end, there was no statistically significant difference between where motorists parked in the baseline condition and the full bike lane condition.

Bicycle Position

When one looks simply at an *average* position, the cyclists did move further away from parked cars in all circumstances, but only by a couple of inches – not as significant as might be hoped. However, the critical evaluation is the effect of the treatments on the *distribution* of where cyclists rode. Figures 3-6 show histograms of bicycle distance from the curb. Under all test markings, the distributions narrowed, so that there were fewer outliers on either side (which is why the average did not change dramatically). Most importantly, cyclists who were riding the closest to parked cars in the baseline condition moved further away, so the percentage of people riding more than 2 or 3 feet from parked cars went up significantly.

The data also needed to be adjusted to account for the placement of the parked cars. At first blush, it looked as though the “line only” marking had the most influence on cyclist position, with the highest percentage of people riding more than 9 or 10 feet out from the curb. However, when the data was adjusted to account for the change in where cars were parked, the three interventions became more equal in their impact of how far cyclists were from the parked cars.

There was also a difference amongst the locations, particularly between the locations near the signalized intersection and those near unsignalized intersections. The influence of the markings was greater on the cyclists near the former, because they started out closer to the parked cars. At the end of the study, the locations were similar as to where cyclists were riding.

Pooled data

An ANOVA for bike-from-curb data adjusted for the curb parking measure indicated that all three treatments were different from baseline and that the three treatments were not significantly different from each other. Cyclists rode 2.8 inches farther from parked cars with the lane line alone, 2 inches farther with the lane line plus bike lane symbol, and 2.4 inches farther with the full bike lane. Logistic regression for the pooled data for the percentage of cyclists more that 9 and 10 feet from the curb adjusted for the curb parking measure indicated that all three treatments significantly increased the percentage of cyclists riding 9 and 10 feet from the curb with increases of 10.5, 9.7, and 11.9% for cyclists riding 9 feet from the curb and 12.5, 10.7, and 8.6% for cyclists riding 10 feet or more from the curb for the curb line alone, curb line plus symbol, and full bike lane treatments respectively. Since the four sites showed variations in the results, they were also evaluated separately.

Westbound at Columbia (signal)

Figure 3 shows the percentage histograms of the bicycle wheel-path-to-curb measures corrected for the change in vehicle parking distance for the westbound vehicles west of Columbia. Wheel paths less than 9 feet from the curb are shaded red/darkest gray in the graph; between 9 and 10 feet from the curb are yellow/lightest gray and 10 feet or more from the curb are green/middle gray. An ANOVA was used to compare the percentage of cyclists riding more than 9 and 10 feet from the curb during each condition. This shows that the percentage of cyclists 9 and 10 feet from the curb was significantly greater than baseline during all treatment conditions and that the treatments were not significantly different from each other. An examination of these distributions shows that the baseline distribution is significantly skewed toward the curb and that all of the treatment conditions are associated with more normally distributed data.

Eastbound at Columbia (signal)

Figure 4 shows the percentage histograms for the eastbound direction east of Columbia. Again the baseline distribution is somewhat more skewed toward the curb than the treatment distributions. Analysis for cyclists 10 or more feet from the curb shows that all treatments are different from baseline but not different from each other. For cyclists 9 feet or more from the curb only the lane line and full bike lane are significantly different from baseline and these conditions are not significantly different from each other.

Westbound at Norfolk (unsignalized)

Figure 5 shows the percentage histograms for the westbound direction west of Norfolk. Baseline data were not skewed toward the curb and were more similar to treatment data at the other measurement sites. Statistical analysis showed that a smaller percentage of cyclists were 10 feet from the curb during the full bike lane condition than during the other three conditions, and that the other three conditions were not different from each other. In addition, cyclists were significantly farther from the curb during the lane line alone and line with bike symbol condition and the baseline and full bike lane condition were not different from each other.

Eastbound at Tremont (unsignalized)

The percentage distributions for eastbound cyclists east of Tremont are shown in Figure 6. The baseline distribution at this site was skewed toward the curb. Statistical analysis showed that all treatments had a higher percentage of cyclists riding more than 10 feet from the curb line, and there was no difference between the three treatment conditions. All treatments had a significantly higher percentage of cyclists riding more than 9 feet from the curb, and the full bike lane was significantly superior to the other two treatments for this measure.

Intersection Comparisons

There were differences between the sites downstream from the intersections with traffic signals and those that had no signal. An ANOVA for bike from parked cars (bike from curb adjusted for the curb parking measure) was done for the pooled data for the sites downstream from a traffic signal and those downstream from uncontrolled intersections. The analysis indicated that at the sites downstream from the traffic signal, all treatments were different from baseline and the treatments were not different from each other. However, at the two sites downstream from the uncontrolled intersections the differences were small and only the curb line alone treatment was statistically different from baseline.

Specifically, cyclists rode 3.4 inches farther from parked cars with the lane line alone, 3.2 inches farther with the lane line plus bike lane symbol, and 4 inches farther with the full bike lane at the sites downstream from the traffic signal. At the two sites downstream from uncontrolled intersections the cyclists rode 1.9 inches from parked cars with the lane line alone, 0.8 inches more from parked cars with the lane line and bike symbol treatment, and 0.7 inches farther from the curb with the full bike lane treatment.

Logistic regression for the data for the percentage of cyclists more that 9 and 10 feet from the curb adjusted for the curb parking measure was done pooling data at signalized intersections vs. unsignalized. All three treatments significantly increased the percentage of cyclists riding 9 and 10 feet from the curb at the sites downstream from the traffic signal with increases of 13.7, 12.1, and 17.6% for cyclists riding 9 feet from the curb and 15.3, 15.8, and 15.4% for cyclists riding 10 feet or more from the curb for the curb line alone, curb line plus symbol, and full bike lane treatments respectively. Smaller changes were noted at the two sites downstream from uncontrolled intersections with changes of 7.6, 7.1, and 6.2% respectively riding 9 feet or more from the curb and 9.8, 5.8, and 2% respectively riding 10 feet or more from the curb.

Figure 7 shows the differences in signalized vs. unsignalized intersections for cyclists riding more than 9 feet (adjusted). It is interesting to note that in the full bike lane condition, there is no difference between them.

Comparison of Baseline Data.

An ANOVA was performed to examine whether baseline data differed between sites downstream from signalized intersections vs. uncontrolled intersections. In the baseline, cyclists at uncontrolled intersections rode farther out than those at signalized intersections. There was more of an effect at controlled intersections because cyclists there were closer to begin with.

Data on cyclist veering at intersections

In observing bicyclist behavior at study intersections, it was noted that bicyclists had a tendency to veer to the right, i.e., away from the road and towards the curb direction, while traveling through intersections. This could be a matter of concern, since it may be that motorists who saw cyclists making this maneuver might assume they were turning right. In general, it is safer for cyclists to maintain as even a course as possible, staying within view of motorists. It was decided to look at this phenomenon more closely.

Cyclists' veering at the traffic signal controlled intersection (Columbia) was significantly greater than at uncontrolled intersections (Norfolk and Tremont) during the baseline condition. Fifty-three percent of the cyclists riding through the intersection at West Columbia and 36% at East Columbia veered toward the curb, while only nine percent at Norfolk and 23% at Tremont veered toward the curb.

Offset bicycle symbol

The study attempted to determine whether having the bicycle symbol to the leftmost edge of the bike lane might further encourage cyclists to ride closer to it. One side of the street had the bicycle symbol placed all the way to the edge, the other closer to the middle. There were no obvious patterns that resulted from this difference.

Moving Motor Vehicles

These data revealed that the treatments had little effect on driver wheel path. The average driver traveled approximately 2 feet from the lane line, leaving a typical vehicle 1.5

feet from the centerline. The treatments likely had little effect on vehicle path because the lane was reasonably narrow (10 feet) and drivers were already 2 feet from the lane line during baseline. Because Hampshire St. is relatively busy at rush hour there may not have always been room for drivers to move into the opposing lane. One other item of note is that drivers were nearly 2/3 foot farther from the curb at the observation site downstream from Norfolk than they were at the observation sites downstream from Columbia.

The data on the mean distance between bicyclists and through vehicles show that the distance between bicyclists and the nearest through vehicle was greatest during baseline and significantly less at three of the four sites during the lane line alone condition. Since bicyclists were moving toward the travel lane with the treatments, this finding is consistent.

SURVEYS

The baseline survey was administered in May, 2003 and the “after” survey was administered in October, 2003.

Survey data: Cyclists

Because this is a commuter route and because data were collected during commuting periods, it is not surprising that the vast majority of riders rode their bikes on Hampshire on a daily basis and virtually all respondents rode at least several times a week. It was therefore reasonable to expect them to be aware of the various interventions.

Riders comfort ratings, on a 5-point scale, averaged 3.4 during baseline survey and 3.3 during the after study survey. This difference was not statistically significant (t=0.87, P-value=0.384). Ratings in this range fall between neutral and fairly comfortable. Figure 8 shows the frequency of responses when respondents were asked (open-ended question) what they would change to improve bicycling on Hampshire St. These data show that by far the most common response was to “add a bike lane.”

During the after study survey 80% of cyclists they had noticed the markings. When asked to rank the various conditions from 1 (most preferred) to 4 (least preferred), cyclists ranked the full bike lane the highest (average rank of 1.25), the lane line plus bike symbol next (average rank 1.97), followed by the lane line alone (average rank of 2.95), then no markings at all (average rank 3.78).

Another way of looking at this is to summarize which of the options were chosen as the first preference (Figure 8, bottom). Eighty-two percent of the respondents chose the full bike lane and eight percent chose the line with bike symbol; since the latter is also a bike lane (by AASHTO guidelines), this means that 90% of the respondents prefer a bicycle lane.

Survey data: Motorists

Most drivers in both surveys drove on Hampshire on a daily basis. A similar percentage of drivers in both surveys responded that they were aware of cyclists on Hampshire (86% of the baseline respondents and 84% of the end of study survey respondents). This difference was not significant (chi square=1.901, P value = 0.387).

Figure 9 shows the frequency of responses to the question “What about this street makes you aware of bicyclists? During baseline the most frequent response was “nothing” (68%). After all of the treatments had been introduced the most frequent response was “bike lanes” (42%) and the second most frequent response was “I see them [the cyclists].”

DISCUSSION

All three pavement marking treatments were effective at influencing bicyclists to ride farther away from parked cars than when no pavement markings were present. There was some variation at each of the four sites. At sites where the cyclists were closer to parked cars during baseline, the treatments all normalized the distribution and were associated with an increase in the percentage of cyclists traveling more than 9 and 10 feet from the curb. At the one location where the cyclists were significantly farther from the curb to begin with, the introduction of the installation of the lane line and lane line with bike symbol increased the percentage of cyclists more than 9 feet but not those more than 10 feet from the curb. The effects at this location can be understood when one considers that the full bike lane provides boundaries within which riding is expected. A close examination of the data shows that the full bike lane is associated with a peak in responding near the center of the bike lane and a reduction in outliers in the vehicle travel lane.

While the lane line alone most consistently increased the percentage of cyclists farther than 9 feet from the curb, since cars parked farther away from the curb with the lane line alone, the distance that cyclists were from parked cars was not significantly different in the end from the other interventions. This intervention doesn’t specifically alert drivers to expect cyclists, and it received a low rating from cyclists in the preference survey.

Another factor possibly influencing the experiment was the limited width of the roadway. For cyclists to travel completely outside the full door zone, the left handle bar would be in the travel lane. Cyclists may not have felt comfortable riding with a portion of their bicycle in a relatively narrow travel lane of 10 feet. It would be informative to see what would happen given other cross sections. For example, where there is room, it would seem that wider parking lanes could help, but it would be important to determine how far motorists park from the curb to determine how far cyclists would be from parked cars. Motorists probably park differently with an 8’ parking lane than the 12’ undesignated space presented in the lane-line study condition, but it would be informative to look at how far vehicles park from the curb with, 9’ or 10’ parking lanes. Where there is metered parking, stalls could be marked to keep the motorists closer to the curb. It might also be worth pursuing the idea of offsetting the bicycle symbol where wider bike lanes and/or travel lanes exist, to see if it makes a difference under those circumstances.

Other ways of addressing the issues should also be pursued. Motorists must be better educated about the importance of looking before opening car doors and of parking as close to the curb as possible; investigators should identify the most effective ways to change behavior. Enforcement of parking regulations and of motorist behavior is also important.

One interesting finding was that cyclists rode significantly closer to parked cars at sites downstream from a signalized intersection than they did at sites downstream from an uncontrolled intersection. The treatments changed cyclist position at the sites downstream from the traffic signals so that it was more similar to the position downstream from the uncontrolled locations; by the time the bicycle lane was installed, bicycle position was virtually the same.

One reason why cyclists rode closer to the curb downstream from the traffic signals may be because they veered away from the centerline more when entering a controlled intersection than a less busy uncontrolled intersection. It is also possible that cyclists traveled further from the curb where motor vehicles traveled significantly further from the curb, such as happened downstream from the uncontrolled intersection at Norfolk.

Intercept survey data yielded several interesting results. Cyclists during baseline most often responded that the best way to improve bicycling on Hampshire St. was to add bike lanes. Cyclists also rated the full bike lanes highest in the post study survey. This did not immediately translate into a change in comfort level; it remained the same before and after the study. When asked what made them most aware of cyclists, motorists' most common response during baseline was "nothing." In the after survey "a bike lane" was the most frequent response. Interestingly, the second most frequent response in the after survey was "I see them [the cyclists]," which was a minute portion of the responses before.

This study shows that all three pavement-marking options encouraged cyclists to ride farther away from parked cars. It also supports using marked bicycle lanes as a facility option on city streets. Given that cyclists prefer marked lanes and have indicated that they make them feel welcome on the street, and that motorists do notice them, bicycle lanes can be seen as a positive way of providing for bicyclists in the transportation network.

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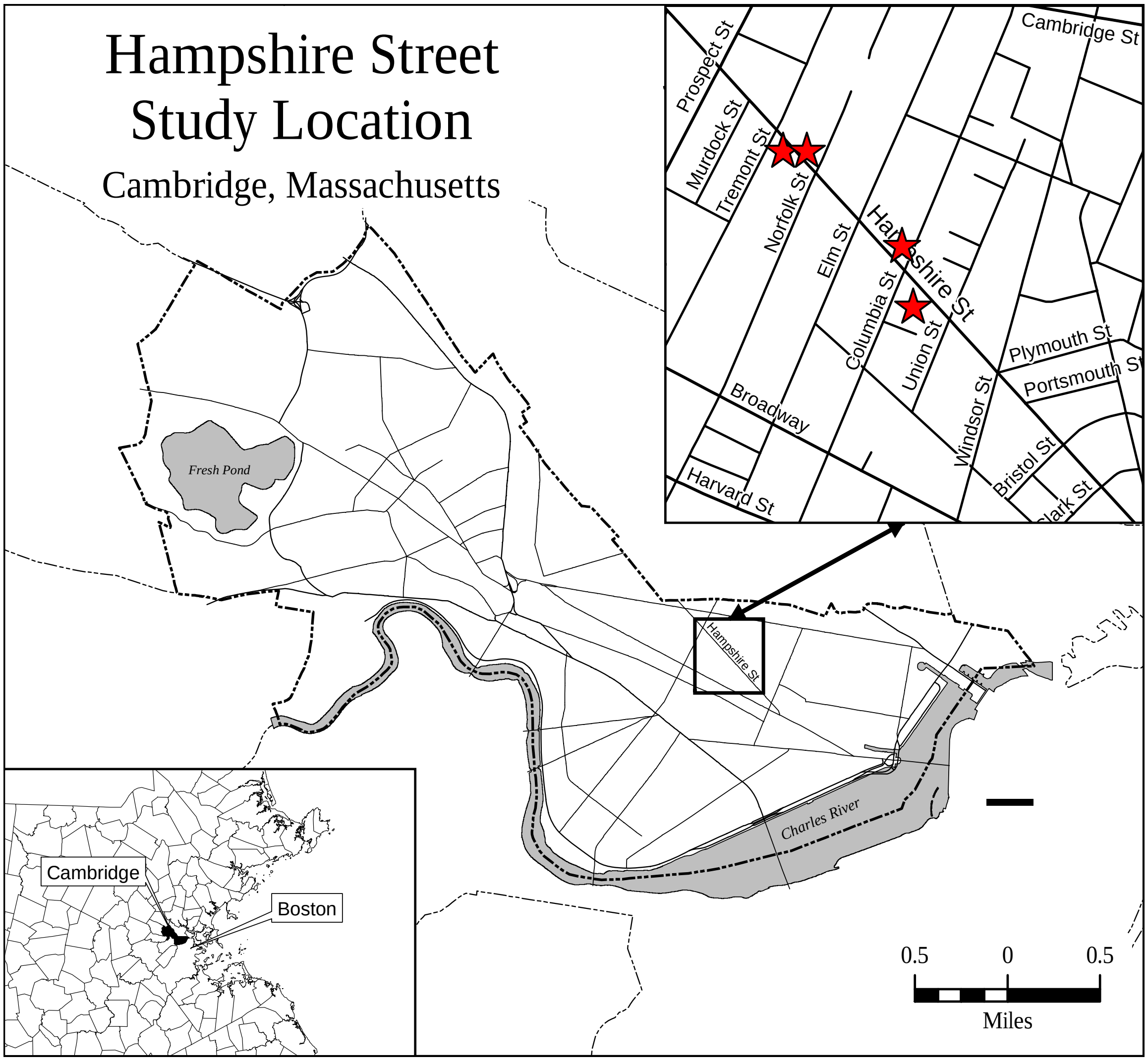
LIST OF TABLES AND FIGURES

FIGURE 1 Study location and marking setup



★ Star = Camera Locations (NTS)

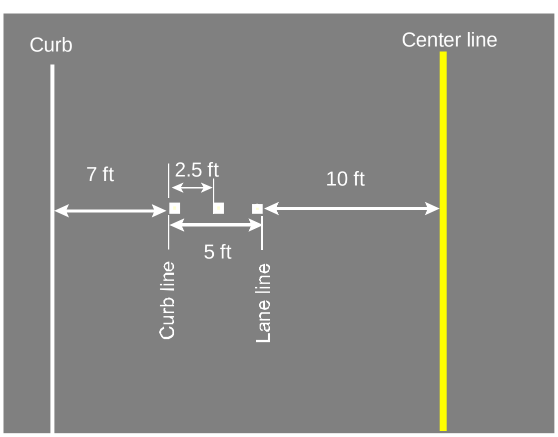
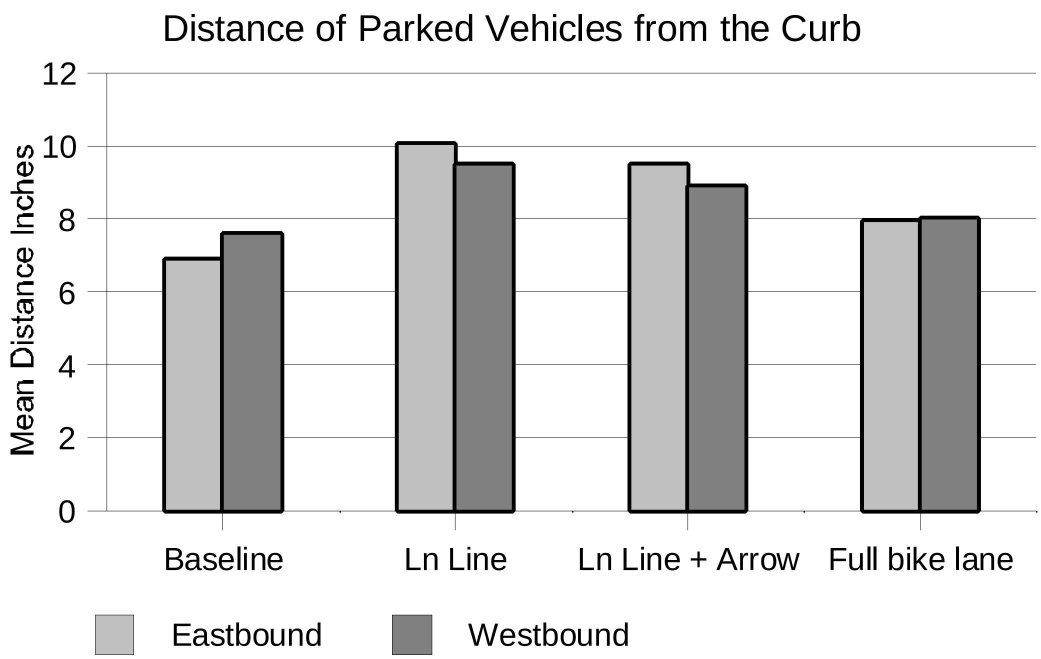


FIGURE 2 Distance of Parked Vehicles From Curb



ANOVA Analyses for Parking Measurements

Direction	Baseline 1	Treatment 2 Lane Line	Treatment 3 Line+Symbol	Treatment 4 Bike Lane	F	P-value	Tukey
South Side/ Eastbound	6.88	10.07	9.50	7.94	14.05	**0.000**	1432*
North Side/ Westbound	7.62	9.48	8.90	8.00	5.01	**0.002**	1432**

*all comparisons significant except 1 vs. 4 and 3 vs. 2
** only 2 vs. 1 and 2 vs. 4 are significant
Significant for both directions: 1 (baseline) vs. 2 (lane line) and 2 (lane line) vs. 4 (bike lane)
Not significant for both directions: 1 (baseline) vs. 4 (bike lane) and 2 (lane line) vs. 3 (line + symbol)

FIGURE 3 West Columbia Bicycle Position

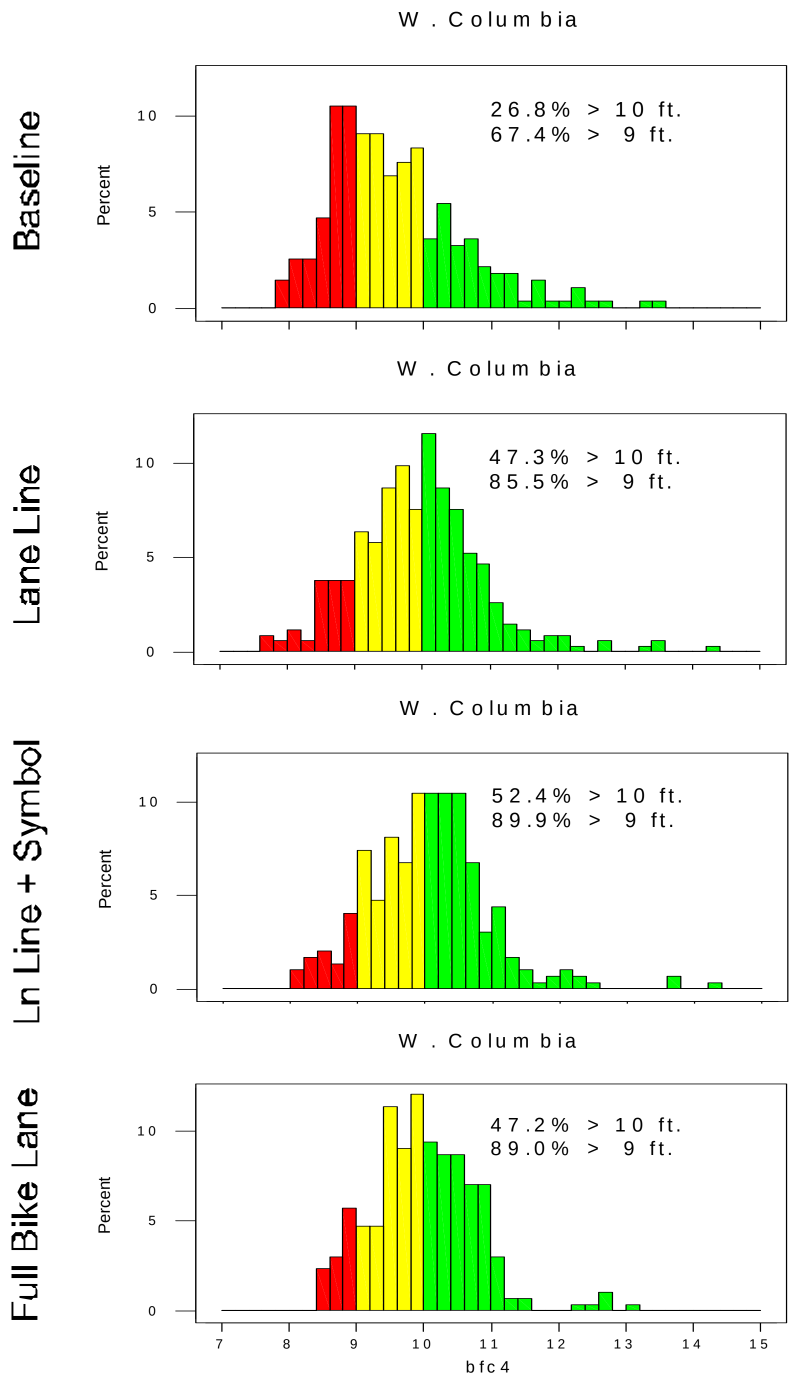


FIGURE 4 East Columbia Bicycle Position

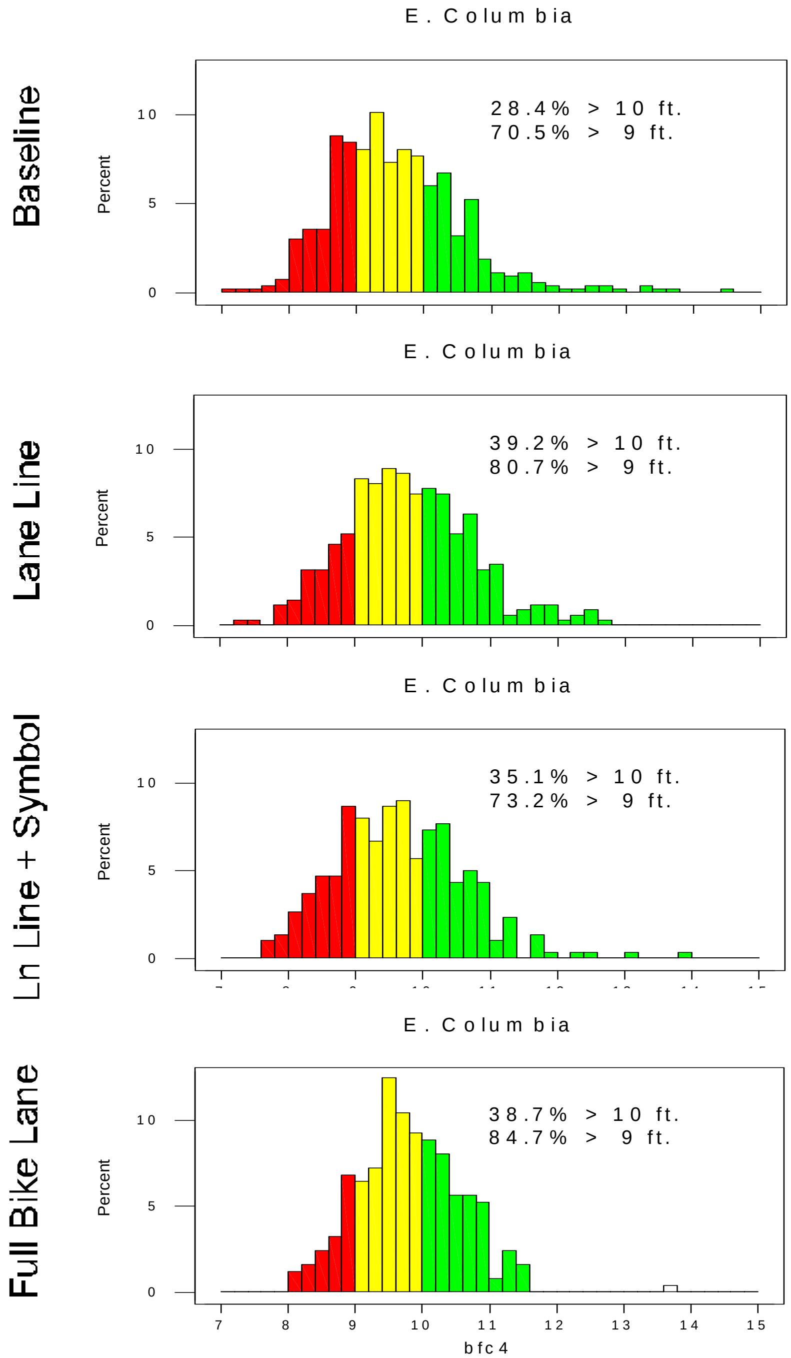


FIGURE 5 West Norfolk Bicycle Position

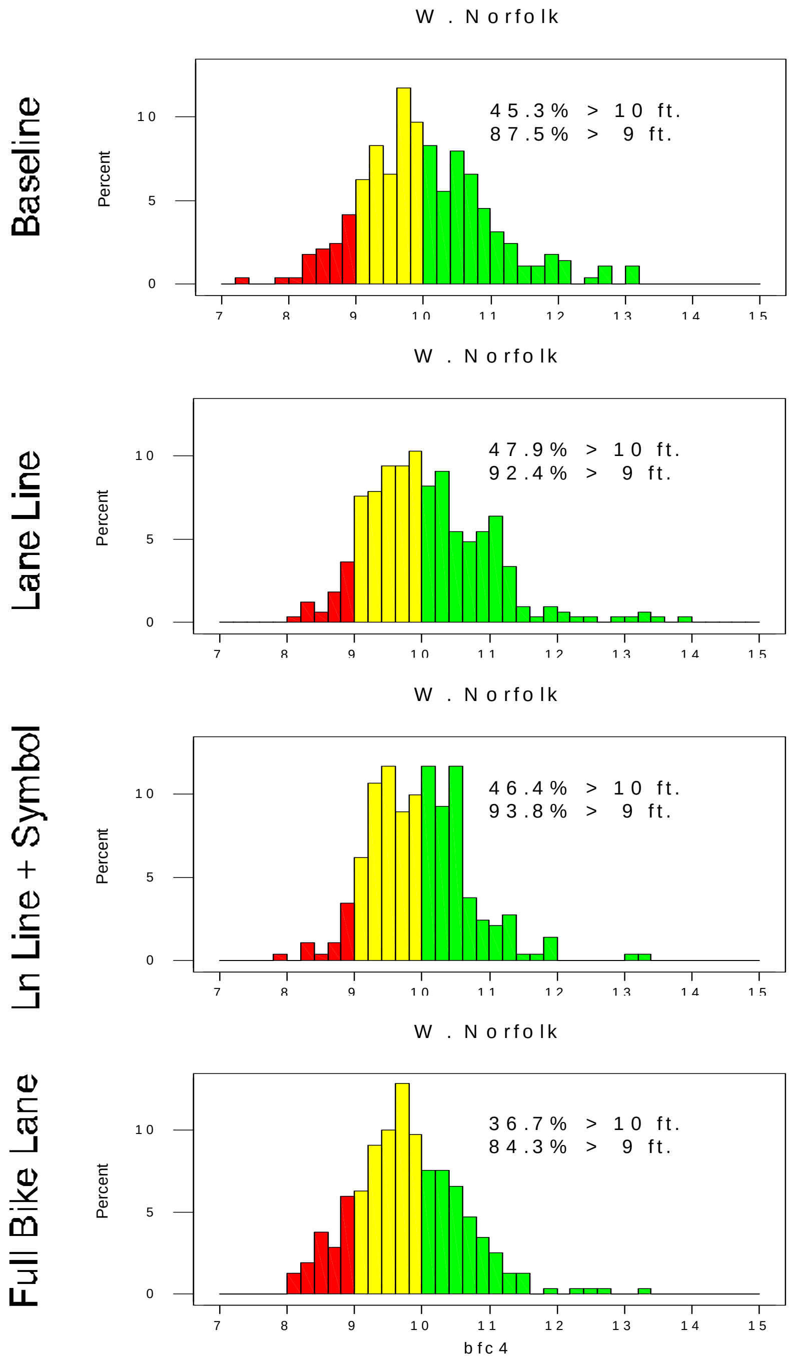


FIGURE 6 East Tremont Bicycle Position

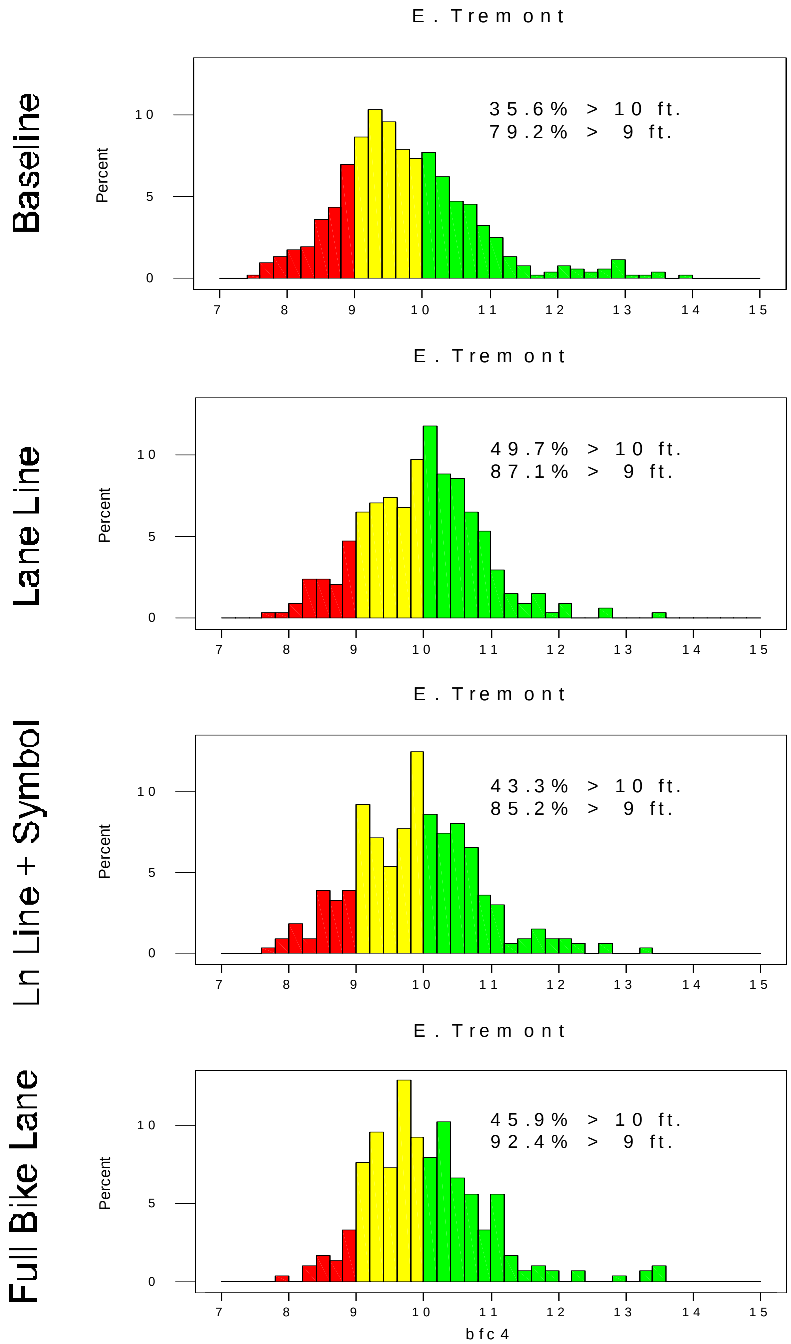


**Figure 7: Signalized vs. Unsignalized Intersections –
Percentage of cyclists riding more than 9 feet from the curb**

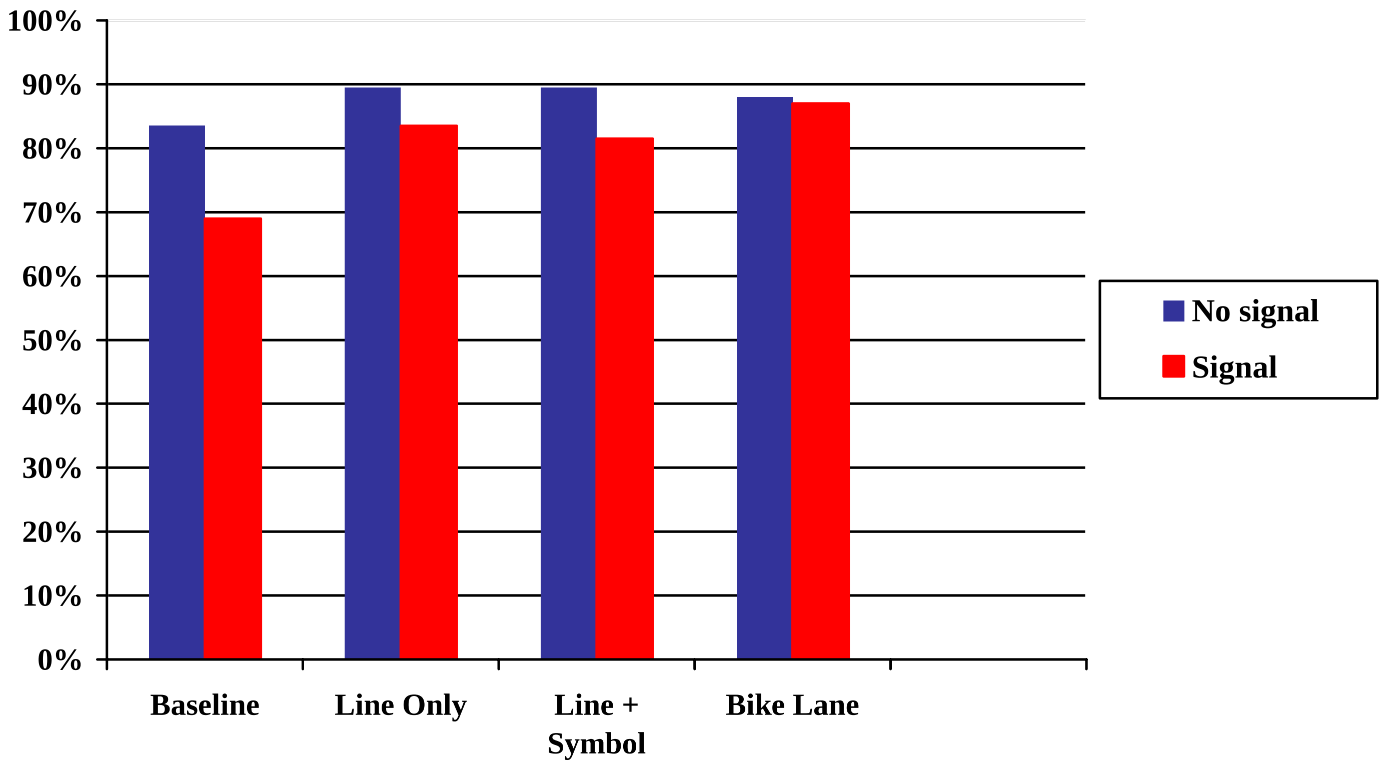
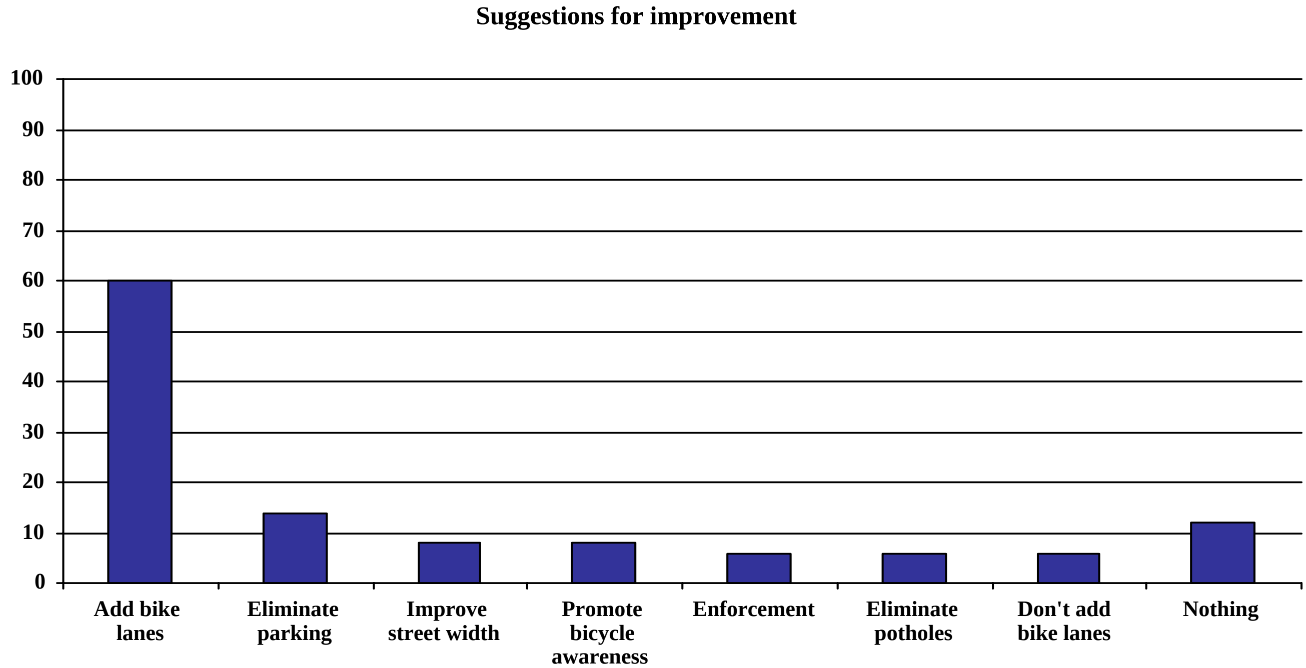


FIGURE 8 Bicyclist Survey Results – Before (top) & After (bottom) Surveys



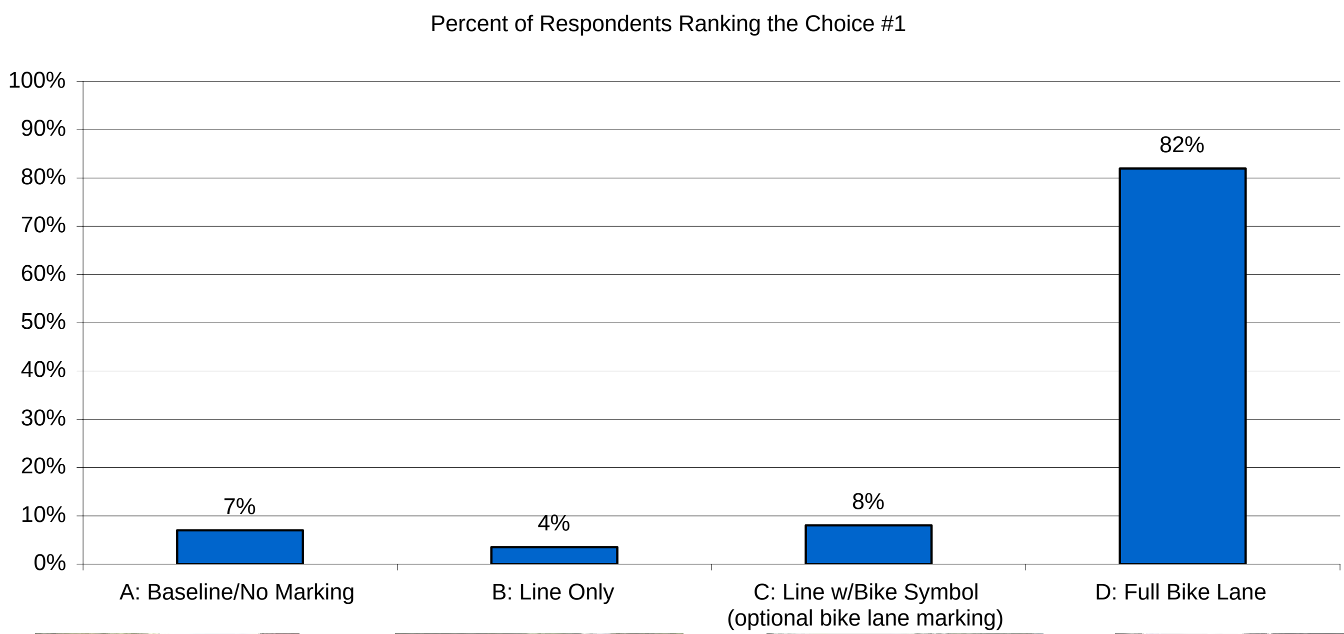


FIGURE 9 Motorists Awareness – Before and After Surveys