



Effects of “Bicycles May Use Full Lane” Signs on Bicyclist and Motorist Behavior along Multi-Lane Facilities

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Executive Summary

Although Austin has a sizeable network of bicycle lanes and wide shoulder lanes, several gaps exist where roadways are too narrow to accommodate bicyclists and motorists side-by-side in the same lane. It is a considerable challenge to expand existing roadways to accommodate bicycles in a separate lane, so a need exists for planning and engineering tools that allow for motorists and bicyclists to share narrow roadways safely. One potential tool to meet this need is the “Bicycles May Use Full Lane” sign, which can be erected alongside narrow streets at little cost.

The sign’s message encourages bicyclists to ride in the center of the motor vehicle lane and alerts motorists to the potential presence of bicyclists. A version of this sign is included in the newly released 2009 Manual of Uniform Traffic Control Devices (MUTCD), the national standard for all regulatory traffic signs, markings, and lights. At the time this research was conducted, the 2009 MUTCD had not yet been released, so a text-only regulatory sign was designed to display the message “Bicycles May Use Full Lane”.

The primary goal of this study was to determine what effect, if any, “Bicycles May Use Full Lane” signs have on bicyclist and motorist safety. Therefore, pre- and post-implementation data for each of two study sites was compared to determine if an improvement in safety occurred. Safe bicyclist behavior was defined as: (1) bicyclists rode in the middle of the lane when on the road and (2) bicyclists did not ride outside of the traffic lane (e.g. on the sidewalk or in off-street driveways). Additionally, safe motorist behavior was defined as: (1) motorists gave adequate space to bicyclists when passing, (2) motorists did not encroach on adjacent lanes when passing, and (3) motorists made complete lane changes when passing.

To test for a change in behavior, signs were installed on Pleasant Valley Road (between Cesar Chavez Street and East 12th Street) and Lamar Boulevard (between Oltorf Street and Barton Springs Road). Neither Lamar Boulevard nor Pleasant Valley Street had any pre-existing bicycle accommodations before the installation of the signs—there were no bicycle lanes, wide shoulders, Shared Lane Markings, or bicycle-related signs in the direction of travel that was studied. Traffic monitoring cameras installed at intersections along the study area recorded the actions of bicyclists and motorists.

The results of this study suggest that “Bicycles May Use Full Lane” signs do improve bicyclist and motorist safety along routes where commuter bicyclists are common users of the facility. After signs were installed along Lamar Boulevard, bicyclists tended to ride closer toward the center of the lane and motorists provided more space when passing bicyclists—additionally, passing motorists were more likely to encroach on the adjacent lane when passing. However, the signs were not proven to be effective at encouraging bicyclists to take the full lane or at encouraging passing motorists to make complete lane changes. The studied location at Pleasant Valley Road and Cesar Chavez Street did not see any increase in safe bicyclist behavior after the installation of the signs. This is perhaps due to the high number of recreational bicyclists and schoolchildren who prefer to ride along the Pleasant Valley Road sidewalks and driveways.

Given these results, there exists a very reasonable expectation that signs can be effective at improving the safety of bicyclists who already ride in the full lane along narrow, multi-lane facilities where the signs can be placed next to the bicyclist lane of travel.

Background

Since Austin's bicycle program was re-established in 1992, the city has seen a significant growth in bicycle facilities. Unlike many other cities, bicycle routes in Austin were selected by identifying routes already used for bicycle commuting. This procedure, along with a focus on network connectivity is at least partially responsible for the increase in the percentage of adults commuting to work by bicycle. Douma and Cleaveland (2008) documented a statistically significant increase in bicycle mode share in Austin from 1990 (0.87%) to 2000 (1.19%) in Census block groups with new bicycle routes developed during that period. During that time period, the journey-to-work bicycle mode share for Austin increased significantly from 0.76% to 0.95%. The University of Texas, the largest trip attractor in Austin with approximately 68,000 students, faculty and staff members, estimates that 5-7% of all trips to campus are made by bicycle (BMA, 2007).

While the proportion of commuting trips made by bicycle appears to be increasing, it remains small. Surveys studying the factors affecting bicycling demand show safety to be a major concern. In a survey of bicyclists in Texas, 69% of respondents stated they feel bicycling is "somewhat dangerous" or "very dangerous" from the standpoint of traffic crashes (Sener et al., 2009). A recent survey in Portland, Oregon showed that positive perceptions of the availability of bicycle facilities are associated with more bicycling and a desire to bicycle more often (Dill and Voros, 2007).

In urban areas, many roadways were not designed to be wide enough to accommodate bicyclists and motorists side-by-side, so bicycle facilities are often disconnected at points where the roadway narrows. The aim of this study is to evaluate the effectiveness of "Bicycles May Use Full Lane" signs in improving bicyclist and motorist behavior in locations where the outside lane is narrow.

Signs Detail

Before this study, no previous research had been conducted regarding the effectiveness of any type of “Bicycles May Use Full Lane” signs as a means of improving road user safety. In 2009, the sign shown in Figure 1 was approved for inclusion in the new version of the Manual on Uniform Traffic Control Devices (MUTCD). The sign was approved because variations of it were being employed by municipalities to act as a reminder of existing law in narrow-lane conditions.



Figure 1. The MUTCD version of a "Bicycles May Use Full Lane" sign known as R4-11

The “Bicycles May Use Full Lane” sign appears in the 2009 version of the Manual on Uniform Traffic Control Devices (MUTCD) as R4-11. According to the MUTCD, the signs are optional on roadways “where no bicycle lanes or adjacent shoulders usable by bicyclists are present and where travel lanes are too narrow for bicyclists and motor vehicles to operate side by side” (MUTCD, Section 9B.06). The National Committee on Uniform Traffic Control Devices (NCUTCD) Bicycle Technical Committee recommended the signs in June 2005 to guide bicyclists to a safe position when the traffic lane is too narrow to be shared, alert motorists to the existence of bicyclists, and encourage safe passing of bicyclists by motorists. According to the Bicycle Technical Committee “[the] proposed sign uses a standard symbol and word legend, and therefore is already acceptable for use under Section 2B.54 of the MUTCD.” The sign ultimately selected for the experiment is a text-only variation of the MUTCD sign R4-11, as shown in Figure 2 below.

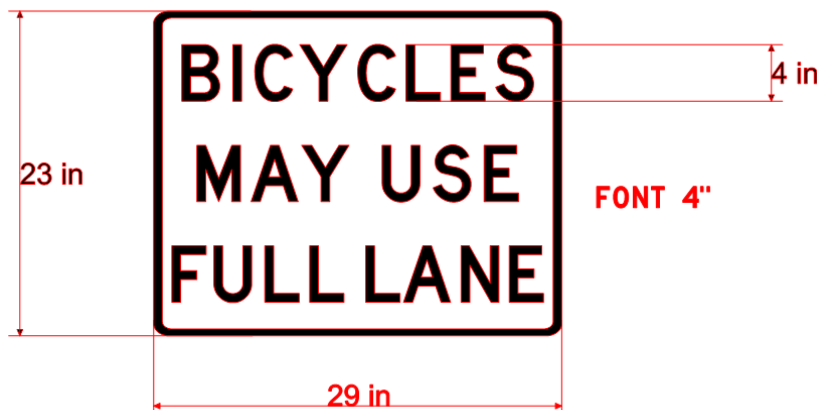


Figure 2. A detail of the sign used during the course of the study

Site Descriptions

Signs that read “Bicycles May Use Full Lane” were installed along two multi-lane arterials within the City of Austin. The sites chosen did not have any pre-existing bicycle facilities and were designated as ‘low ease of use’ on the City of Austin bicycle facility map. Both of the sites used in this study had 11-foot lane widths.

Along Pleasant Valley Road between 7th Street and Lakeshore Boulevard

Pleasant Valley Road is a four lane, two-way arterial that provides north-south connectivity between the neighborhood of Central East Austin and Riverside Drive the major arterial in South East Austin. This facility is frequented by bicyclists who often ride on the sidewalk. A cross-section of the location is shown in Figure 3.

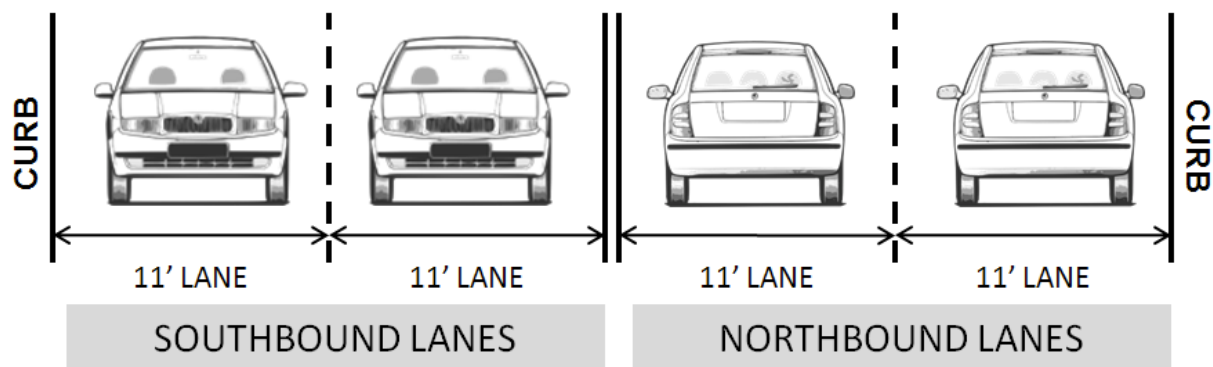


Figure 3. Cross-section of southbound Pleasant Valley Road approaching the intersection with Cesar Chavez Street

For this study, six “Bicycles May Use Full Lane” signs were placed along Pleasant Valley Road between 7th Street and Lakeshore Boulevard in accordance with the MUTCD sign placement standards and guidance described in Section 2A of the 2009 MUTCD. The exact sign placement is shown below in Figure 4. Between 7th Street and Lakeshore Boulevard, the speed limit on Pleasant Valley varies between 30 mph and 45 mph. The posted speed limit at the intersection with Cesar Chavez Street, where the data was collected, is 40 mph.

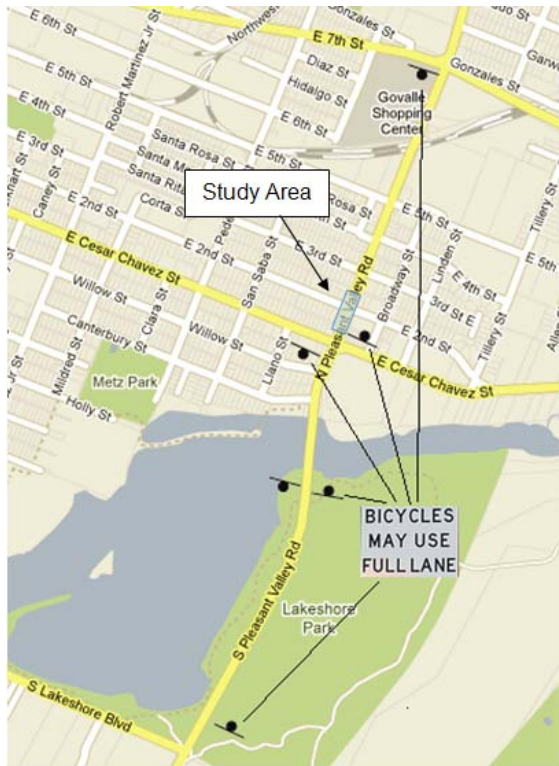


Figure 4. A map of the sign placement along Pleasant Valley Road

A traffic monitoring camera at the intersection of Cesar Chavez Street and Pleasant Valley Road recorded traffic traveling southbound on Pleasant Valley Road as it approached the intersection. Information about bicyclist and motorist behavior was collected from the video footage. Lengthy driveways along both directions of the street (as shown in Figure 5) provided bicyclists with made for easy transitions between street riding and sidewalk riding. Typical vehicle traffic volumes were 300 vehicles per hour (vph) in the AM peak and 700 vph in the PM peak. In this report, the AM peak was defined between 6:00am to 10:00am and the PM peak was defined between 4:00pm and 7:00pm.

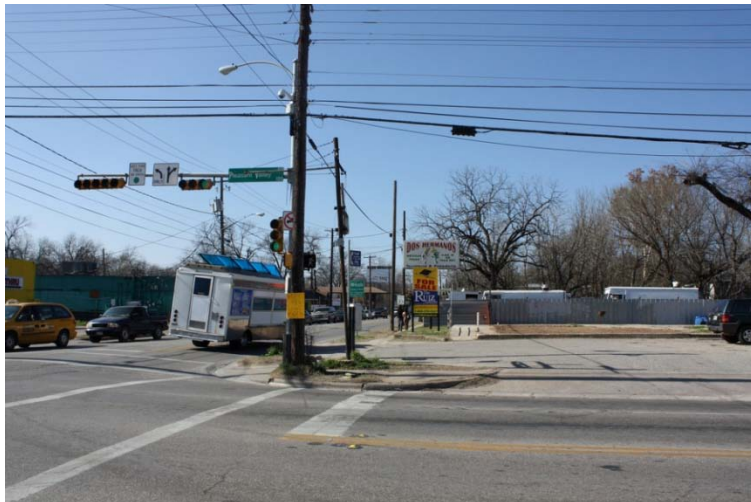


Figure 5. A driveway at the study location, Cesar Chavez and Pleasant Valley

Along Lamar Boulevard between Barton Springs Road and Oltorf Street

Lamar Boulevard is a high volume four-lane, two-way arterial in southwest Austin. In the southbound direction, a bicycle lane is provided to facilitate uphill bicycle traffic but no facilities are provided for bicyclists traveling northbound. A cross-section of the location is shown in Figure 6.

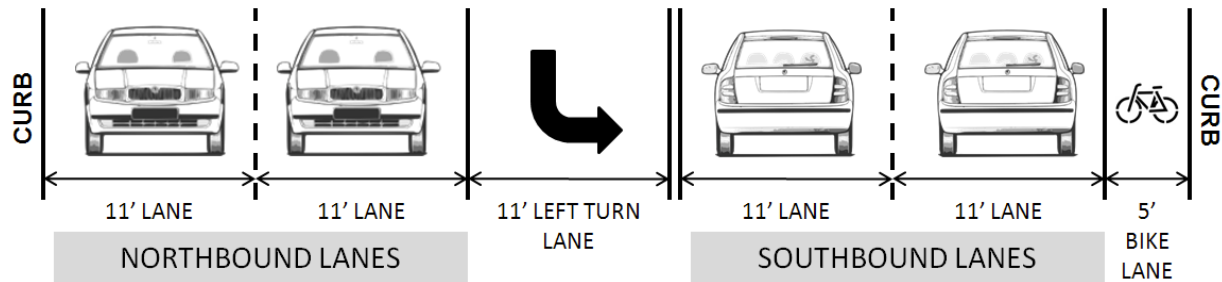


Figure 6. Cross-section of northbound Lamar Boulevard approaching the intersection with Treadwell Street

The signs were placed along the northbound lanes as shown in Figure 7. Typical traffic volumes were around 1300 vph in the AM peak and upwards of 1800 vph in the PM peak. The posted speed limit on Lamar Boulevard at the study area is 35 mph. A traffic camera located at the intersection of Lamar Boulevard and Treadwell Street observed traffic traveling northbound along the southern leg of the intersection. An example of one sign as it was installed on southbound Lamar Boulevard is shown in Figure 8.

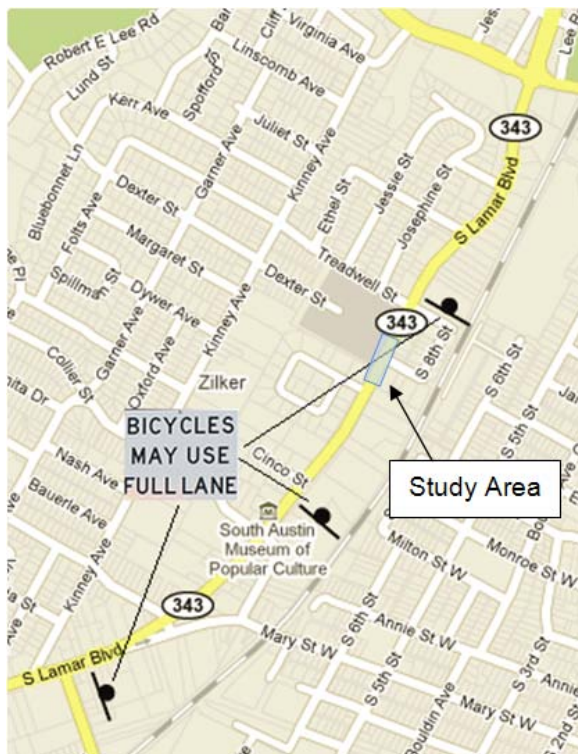


Figure 7. The locations of signs along Lamar Boulevard



Figure 8. A “Bicycles May Use Full Lane” sign installed in the northbound direction of Lamar Boulevard

Experimental Design

To measure and evaluate bicyclist and motorist behavior, video footage of traffic movements at each site was collected by traffic surveillance cameras located at intersections along the study site. Video was collected during the traditional morning and afternoon peak periods when automobile and bicycle traffic appeared to be the highest. Video was played back on flat panel monitors and a transparency placed over the screen allowed measurements of bicyclist and motorist lateral position to be recorded. Measurements taken on both facilities were accurate to within one-tenth of a lane width (13.2 inches).

The goal of this study was to determine what effect, if any, “Bicycles May Use Full Lane” signs have on bicyclist and motorist safety. Therefore, before-sign and after-sign data for each site were compared to determine if safer conditions existed after the installation. Safe bicyclist behavior was defined by two factors: (1) bicyclists rode in the middle of the lane when on the road and (2) bicyclists did not ride outside of the traffic lane (e.g. on the sidewalk or driveways). Additionally, safe motorist behavior was defined by two factors: (1) motorists gave adequate space to bicyclists when passing and (2) motorists did not encroach on adjacent lanes when passing.

To evaluate safety as defined above, several elements of the environment, bicyclist behavior, and bicyclist-motorist interaction were recorded. Although no single measurement can comprehensively measure bicyclist and motorist safety, the improvement of several safety indicators could contribute to the conclusion that safety is indeed improved. Among the measurements taken were the position of motor vehicles and bicycles during passing and non-passing events, the percent of motorists that change lanes to pass, the proportion of motorists who encroach on the adjacent lane when passing, and the percent of bicyclists traveling with traffic (as opposed to against traffic or on sidewalks). Figure 9 illustrates how measurements of the lateral position of bicyclists (LPB) and motorists (LPM) were recorded.



Figure 9. Method for measuring LPB and LPM during passing events

Tests of statistical significance were conducted to determine if there were any notable differences between the before and after data. All proportions and means were compared using a two-sided test of equality, where the null hypothesis was that no change occurred and the alternative hypothesis that behavior changed.

Educational information was not distributed to the public so that the device's impact could be measured without interference. However, Austin citizens were involved in the sign proposal's development. Bicyclists were solicited for their preferences for experimental locations, an opportunity for citizen comment was provided when the Austin City Council voted to fund this project, and a presentation of the proposal has been given to the City's Bicycle Advisory Committee where further comments from citizens were noted.

Terminology

The following terms are used throughout this paper to characterize the actions of bicyclists and motorists at the various study sites.

- **Lateral Position of Bicyclist (LPB)** – LPB is a measurement of the bicyclist's position within the lane. Along both sites, LPB was measured as the lateral distance between the bicyclist's front wheel and the curb face.
- **Lateral Position of Motorist (LPM)** – LPM is defined as the distance between the motorist's curb side wheel and the curb face.
- **Stronger (or weaker) lateral position** – A strong lateral position is one that is far from the curb. A bicyclist riding in the middle of the lane is said to have a stronger lateral position than a bicyclist riding alongside the curb.
- **Avoidance maneuver** – An avoidance maneuver was recorded whenever a bicyclist rode outside of the lane (e.g. rode on the sidewalk or cut through a driveway to turn).
- **Passing event (P)** – A passing event was recorded when a motorist, who was previously in the same lane behind the bicyclist, pulled around the bicyclist in an attempt to pass. The measurements of LPB and LPM were taken simultaneously at the instant the front edge of the bicycle drew even with the front edge of the passing motorist.
- **Non-passing event (NP)** - A non-passing event was recorded when a bicyclist rode past our camera and a passing event did not take place.
- **Incomplete passing event** - An incomplete passing event was recorded when the motorist passed a bicyclist without changing lanes.
- **Encroachment** – Encroachment was recorded when a passing motorist occupied two lanes while passing.

Results

The following section describes the results of the study. Although many pieces of information were collected about bicyclist and motorist behavior, the measured lateral positions of bicyclists and motorists, as well as information about sidewalk riding proved to be the most revealing and are studied in detail below. Figure 1 shows the number of observations gathered from each of the two study sites.

Table 1. Total non-passing and passing events counted at the study sites

Site	Before Signs			After Signs		
	Non-Passing	Passing	Total	Non-Passing	Passing	Total
Lamar Boulevard	218	61	198	305	45	350
Pleasant Valley Road	85	5	90	78	0	78

Lamar Boulevard and Treadwell Street

Figure 10 and Figure 11 show the lateral position of bicyclists riding southbound on Lamar Boulevard during non-passing events and passing events, respectively. The histograms suggest that after the installation of signs, bicyclists tended to take a stronger lateral position in the lane as evidenced by the slight shift in the distributions to the right. These trends are confirmed by the changes in the average LPB. After installation, the LPB during passing events increased substantially from 2.42 to 2.73 feet ($p < 0.001$) and the LPB during non-passing events increased from 2.83 to 3.03 feet ($p = 0.184$). There was no notable change in the proportion of bicyclists riding in the center of the lane (defined between 5.5 and 7.7 feet) during either passing or non-passing events.

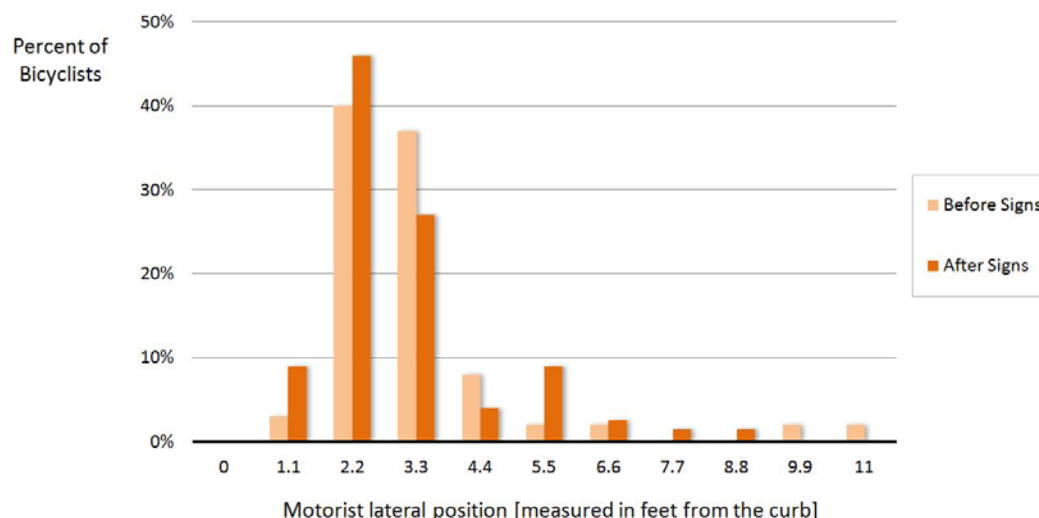


Figure 10. Lateral position of bicyclists on Lamar Boulevard during non-passing events

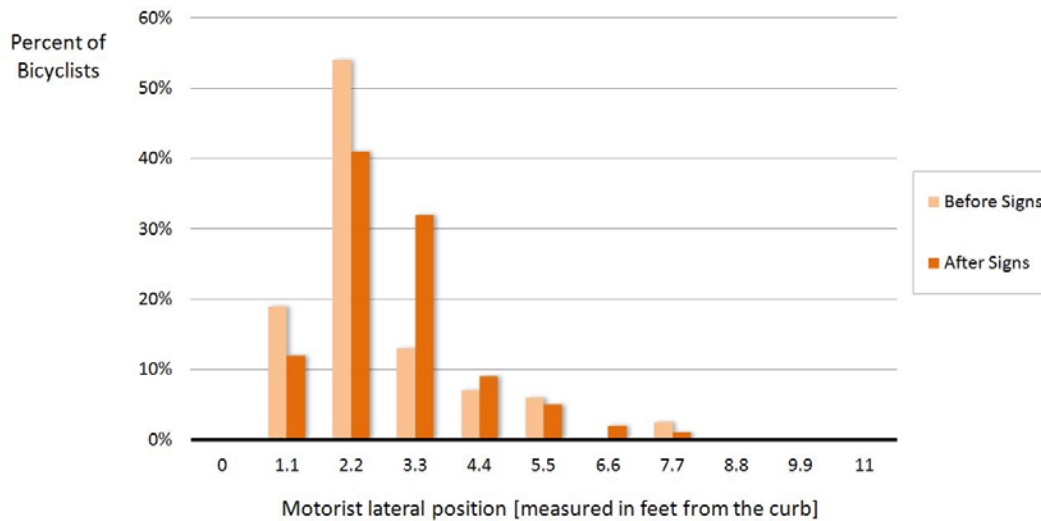


Figure 11. Lateral position of bicyclists on Lamar Boulevard during passing events

In addition to bicyclist lateral position, the LPM during passing events was recorded. Figure 12 shows the lateral position of motorists who did not change lanes to pass. The average LPM increased from 6.23 to 7.93 feet after the sign installation ($p < 0.001$), and the proportion of motorists who encroached while passing increased significantly from 77% to 97% ($p = 0.030$). In October 2009, the City of Austin passed a vulnerable road users ordinance that requires motorists to give at least three feet of space when passing pedestrians, workers, bicyclists, and other vulnerable road users. Figure 13 below shows the space between the bicyclist and passing motorist during passing events. After the sign installation, the proportion of motorists who passed within 3 feet of a bicyclist decreased from 44% to 0%.

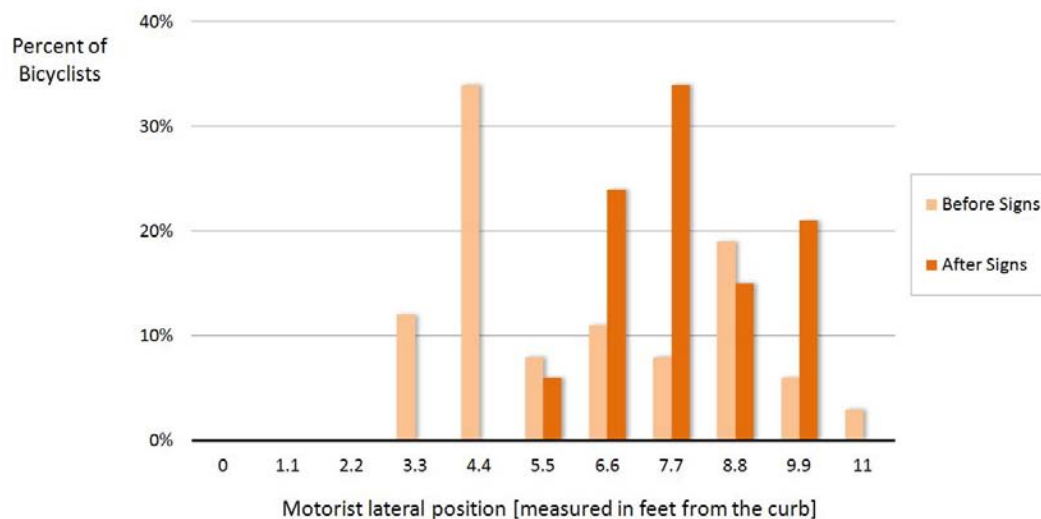


Figure 12. Lateral position distribution of motorists on Lamar Boulevard who did not change lanes to pass

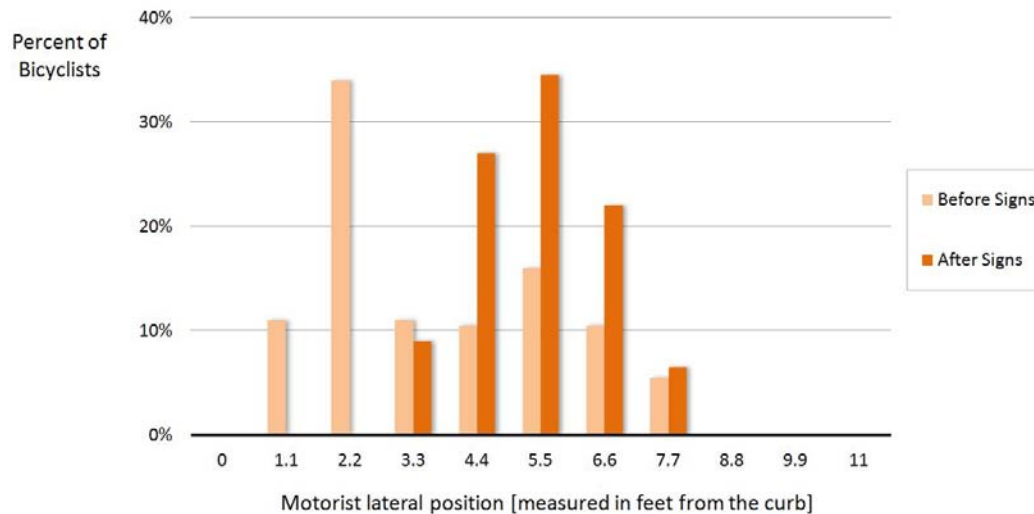


Figure 13. The distance between bicyclists and passing motorists who did not change lanes to pass on Lamar Boulevard

Other changes in bicyclist and motorist behavior were also monitored and are displayed in Figure 14. Regarding motorist behavior, it is interesting to note that the ratio of passing events to non-passing events decreased significantly, while the proportion of passing motorists who encroached while passing increased. These results lend themselves to the hypothesis that as bicyclists took a stronger position in the lane, the motorists who did choose to pass found themselves taking a stronger position in the lane that caused them to encroach on the adjacent lane.

Regarding bicyclist behavior, the implementation of the “Bicycles May Use Full Lane” signs did not discourage sidewalk riding. It is uncertain whether the bicyclists who avoid the motor vehicle lane are regular commuters and recreational bicyclists who prefer to ride outside of the motor vehicle lane or if they are simply neighborhood children or inexperienced bicyclists. Regardless of their experience level, it appears that the addition of signs did not significantly change the proportion of bicyclists who use the motor vehicle lane.

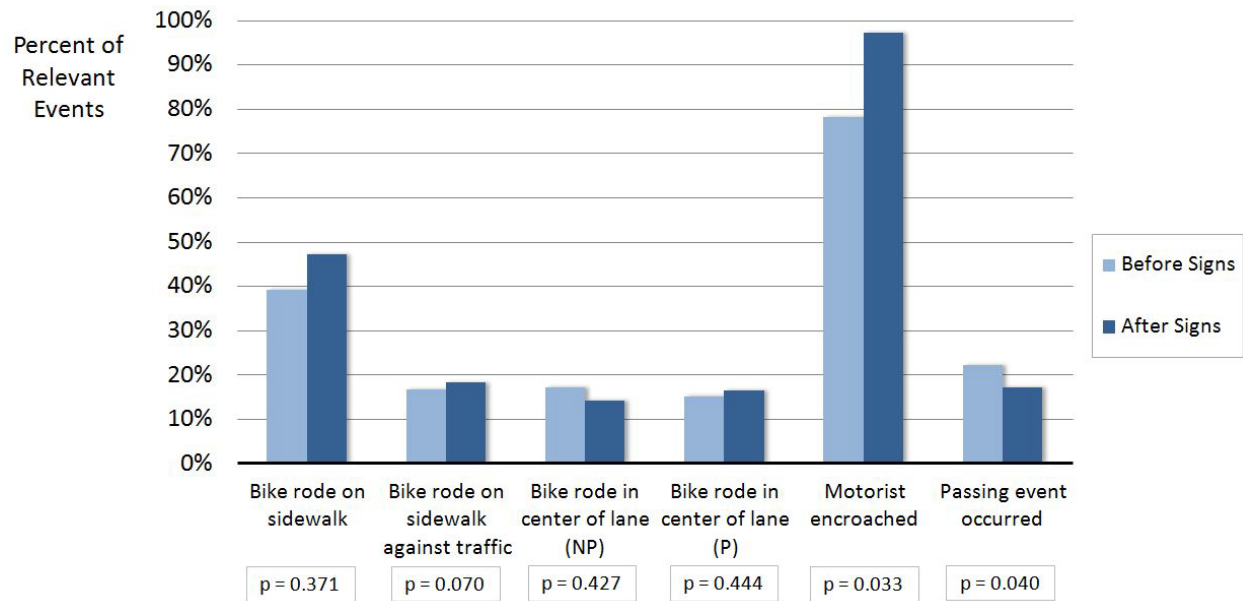


Figure 14. Notable measures of bicyclist and motorist behavior on Lamar Boulevard

Pleasant Valley Road and Cesar Chavez Street

The data collected from Pleasant Valley shows that signs may not be effective at universally improving bicyclist or motorist behavior. The proportion of bicyclists using the full lane decreased substantially after signs were installed near Cesar Chavez Street and Pleasant Valley Road. The proportion of bicyclists who rode on the sidewalk at some point within the study area increased greatly, as did the proportion of bicyclists who made an avoidance maneuver (like cutting across a driveway while turning). These results are opposite to the intended effect of the signs, since the presence of the sign was intended to encourage bicyclists to ride in the full lane and not on the sidewalk or in empty adjacent lots.

It was noted during data collection whether or not a bicyclist rode against traffic when riding on the sidewalk. Before the signs were installed approximately half of bicyclists riding on the sidewalk were riding against traffic and the installation of the signs did not decrease wrong-side sidewalk riding. However, the increase of bicyclists riding against traffic on the sidewalk did not prove to be significant. Figure 15 shows the percent of times these behaviors occurred before and after the signs were installed and the p-value of the difference.

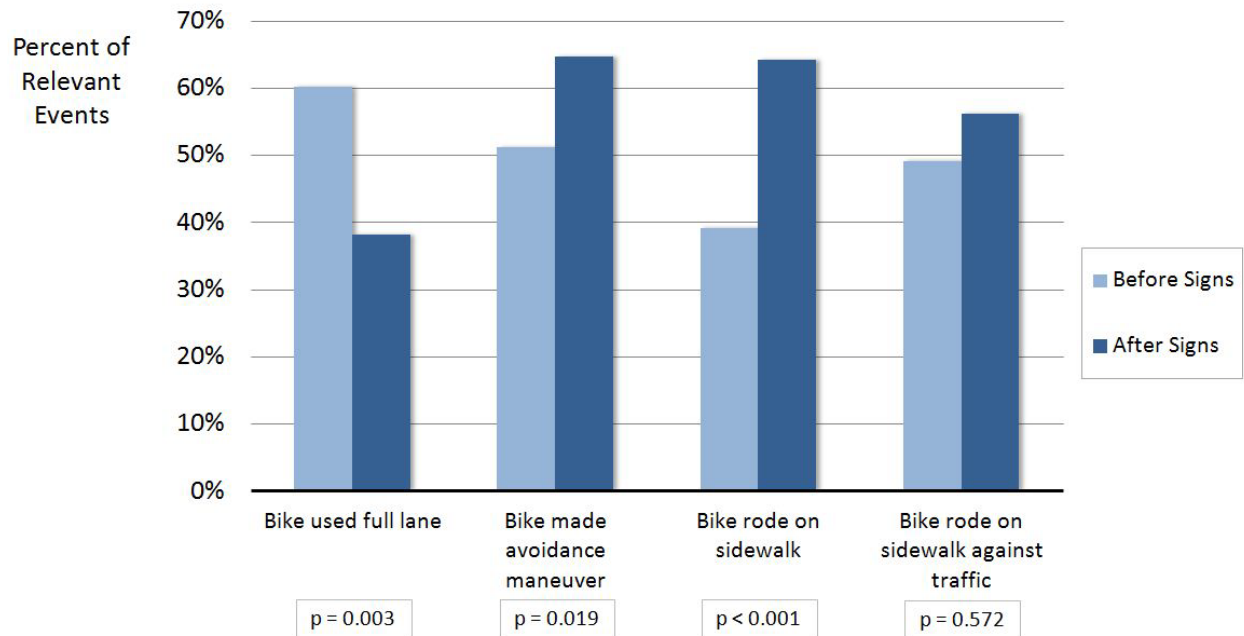


Figure 15. Notable measures of bicyclist and motorist behavior on Pleasant Valley Road

Several issues emerged from site conditions at Cesar Chavez Street and Pleasant Valley Road that may have had an effect on the results of this study. Researchers observed that recreational sidewalk bicycling was a common occurrence at this intersection. This may have resulted in recording the same bicyclist multiple times in an observation period and overestimating the proportion of bicyclist riding on the sidewalk. It is difficult to avoid multiple counts of recreational sidewalk riders, since the resolution of the video camera being used did not allow bicyclists to be individually identified.

The presence of multiple driveways, a sidewalk connecting to an nearby extensive park trail system, long queues of cars at the intersection, and the lack of a shoulder or bicycle lane meant very few bicyclists were observed riding in the vehicle lane. Therefore there was insufficient data to effectively compare before and after bicyclist lateral position. For the same reasons, insufficient data was available to evaluate behavior during passing events. Before signs were installed only 5.5% of all events were passing events, and virtually non-existent after the signs were installed.

Conclusions and Recommendations

The response of bicyclists and motorists to “Bicycles May Use Full Lane” signs was studied along two multi-lane facilities in Austin, Texas. The facilities (Lamar Boulevard and Pleasant Valley Road) were chosen because they did not have any pre-existing bicycle facilities in the direction of travel studied before the installation of the signs. This allowed the effect of the signs to be measured without interference from other bicycle facilities but ultimately presented unique challenges in data collection, particularly at the Pleasant Valley Road site.

The study location on Lamar Boulevard saw a significant shift in bicyclist lateral position toward the center of the lane during both passing and non-passing events. After the installation of the signs, motorists were observed to provide more space when passing and resultantly, motorists were more likely to encroach on the adjacent lane while passing. It should be noted that encroachment is only dangerous when there are vehicles present in the adjacent lane, and this study did not note whether or not this was the case. The signs were not proven effective at encouraging bicyclists to ride in the full lane; rather, this study observed that sidewalk riding increased or remained unchanged after the installation of the signs.

The difference in bicyclist makeup presented some unique data collection challenges. Lamar Boulevard is generally considered a commuter bicyclist route—it connects the businesses south of the Colorado River with downtown Austin via a bicycle/pedestrian bridge. The facility was well-traveled (approximately 10 bicyclists per hour between 4:00 PM and 8:00 PM) and over half of the bicyclists were observed riding in the full lane at the study location. This resulted in a rich data set that allowed the researchers to perform robust statistical analyses. On the other hand, Pleasant Valley Boulevard is generally used by recreational bicyclists and schoolchildren—it connects East Austin neighborhoods to Lakeshore Park. Perhaps due to the presence of wide driveways on Pleasant Valley (which provide an easy transition between the full lane and the sidewalk), bicyclists so rarely used the full lane that any analysis of bicyclist position in the full lane would be inconsequential. The lack of bicyclists using the full lane, coupled with low vehicle volumes resulted in few observed bicyclist-motorist interactions. Therefore, a substantial analysis of bicycle and motorist lateral position during passing events could not be performed given the data collected.

Given the improvement in bicyclist safety observed on Lamar Boulevard, there is a reasonable expectation that signs can be effective at improving the safety of bicyclists who already ride in the full lane along narrow, multi-lane facilities where the signs can be placed next to the bicyclist lane of travel. Further research conducted by the City of Austin or corroborating findings by another institution could clarify the exact effect “Bicycles May Use Full Lane” signs have on bicyclist and motorist safety.

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Appendix A: Bicycle Counts

The charts below illustrate the level of bicycle traffic that Lamar Boulevard and Pleasant Valley Road received before and during the course of this study. Figures 16 and 17 show the number of bicyclists recorded at each site for each hour of the day, expressed in military time (where 15 represents 1500 hours, or 3:00pm). Notice that Lamar Boulevard exhibits a clear rise in observations during the morning hours and a declining number of observations during the afternoon peak. This trend is similar to the bicycle ridership trends seen on Guadalupe Street and Airport Boulevard, which were observed during the shared lane markings study, and indicates that the route is used for commuting. On Pleasant Valley Road, there is a high level of variability among the hourly volumes of bicyclists and no clear pattern emerges.

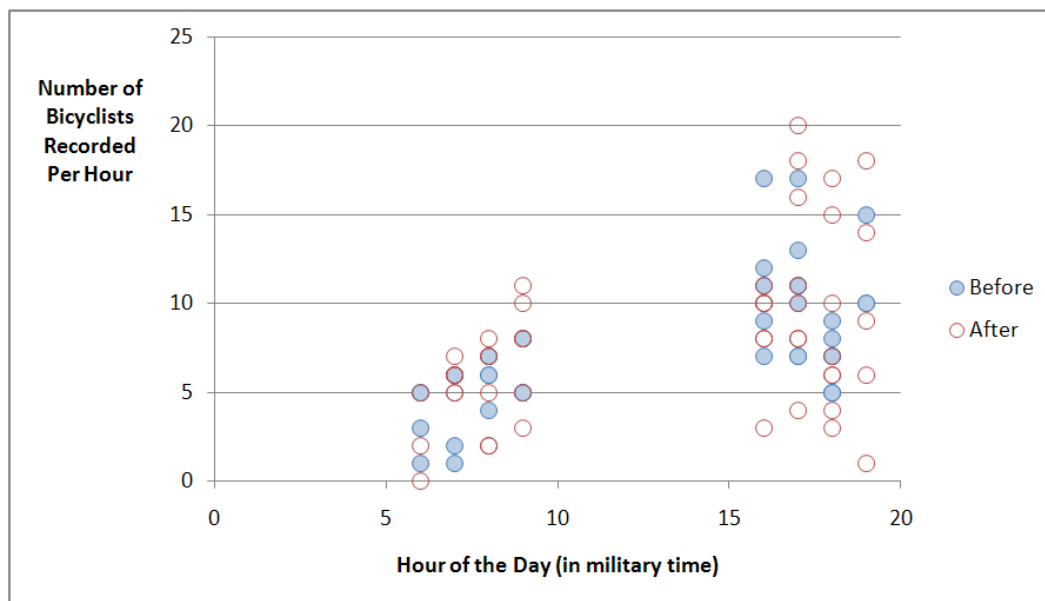


Figure 16. Number of bicycles recorded each hour of the day on Lamar Boulevard

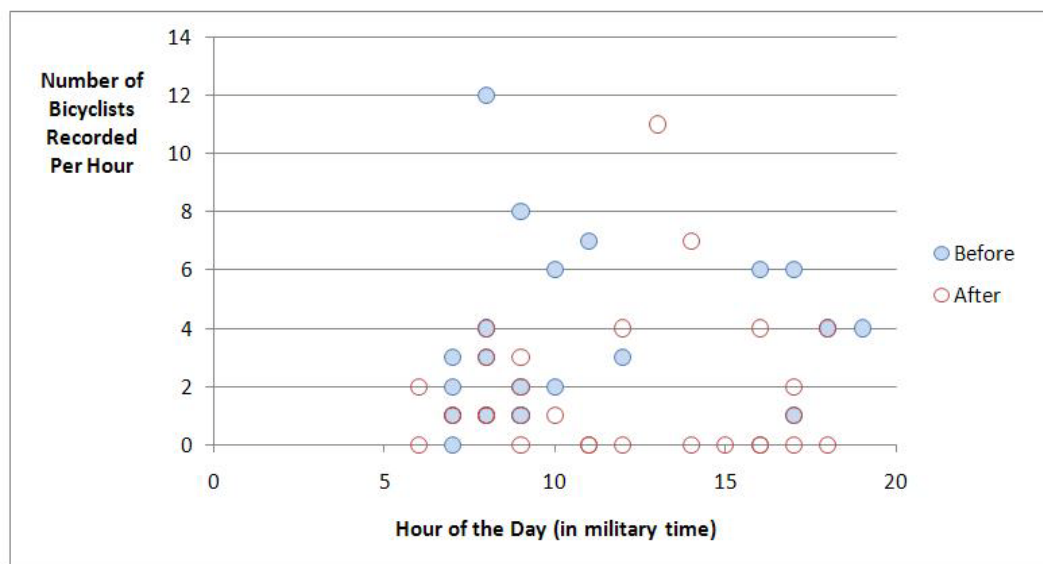


Figure 17. Number of bicycles recorded each hour of the day on Pleasant Valley Road

Figures 18 and 19 show the number of bicyclists recorded per hour for each day of the week for both sites. Lamar Boulevard saw an average of 7.9 bicyclists per hour during weekdays, when most of the data was collected (only four hours of data was collected from Lamar Boulevard on a Saturday), and this average is steady throughout the week, strengthening the hypothesis that Lamar Boulevard is used as a commuter route. Pleasant Valley Road saw low counts on weekday traffic, but saw higher counts on Saturday, indicating use by recreational bicyclists, possibly those traveling from East Austin neighborhoods to Lakeshore Park.

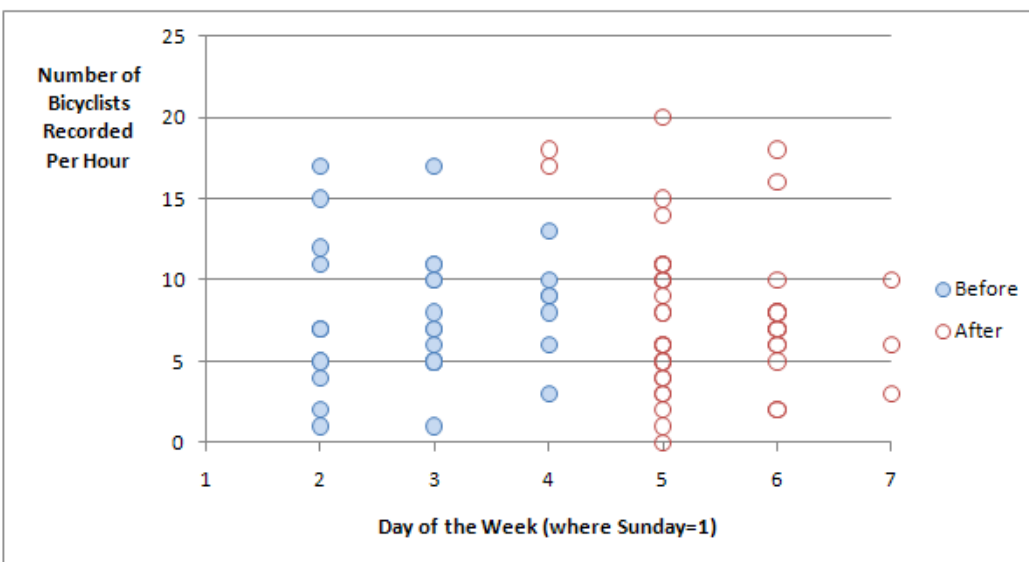


Figure 18. Number of bicycles recorded each day of the week on Lamar Boulevard

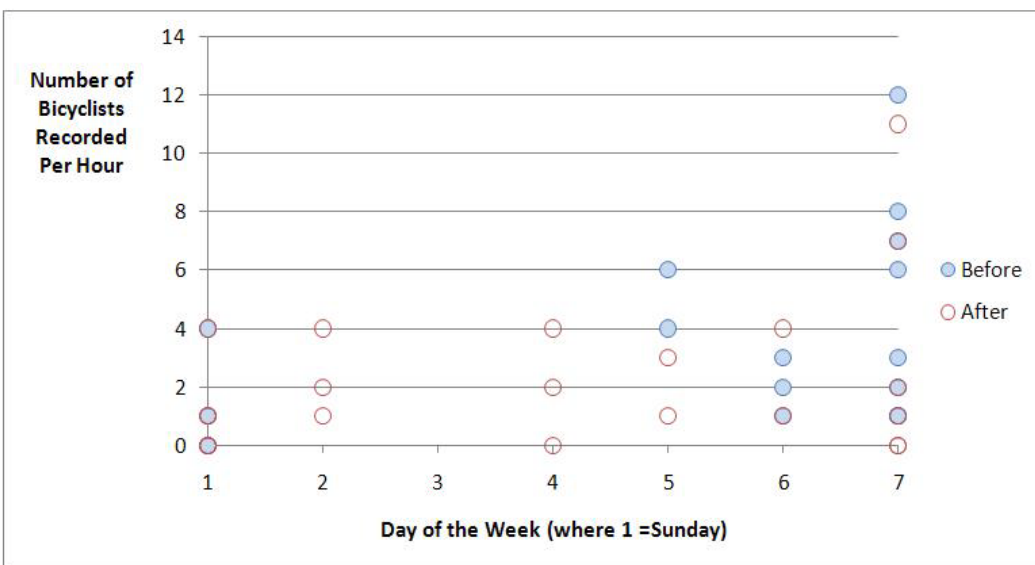


Figure 19. Number of bicycles recorded each day of the week on Pleasant Valley Road