Effects of Colored Lane Markings on Bicyclist and Motorist Behavior at Conflict Areas

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Executive Summary

As the number of trips made by bicycle continues to increase in Austin, there is a need to design existing roadways to safely accommodate bicyclists at areas where bicyclists and motorists must cross paths. Conflicts are common on facilities where a motorist must cross a bicycle lane in order to access a right turn bay and where highway exit ramps cross major arterials that have a bicycle lane. The use of colored bicycle lanes to highlight conflict areas is an experimental concept that has seen positive results both domestically and abroad. The goal of this study was to determine the change in bicyclist and motorist behavior that can be achieved by applying a colored lane treatment and an accompanying “Yield to Bikes” signs to two unique conflict areas in Austin, Texas.

To assess the effectiveness of the colored lane and sign treatment, pre- and post-implementation data for each site were compared to determine if the treatment indeed improved the safety of bicyclists and motorists. For this study, safety was defined along the following lines: (1) the bicyclist used the bicycle lane to approach the conflict area, (2) the bicyclist used the bicycle lane to negotiate the conflict area, (3) the motorist yielded to the bicyclist when crossing the colored lane area, and (4) the motorist used a turn signal when crossing the conflict area. To ensure that the data collected reflects the effectiveness of the treatment alone, no educational or outreach campaign was conducted. Input from the Austin bicycling community and the City of Austin Bicycle and Pedestrian program was considered in the site selection process. The two studied sites were located near The University of Texas at Austin, were subject to high use by commuting bicyclists, and had pre-existing bicycle lanes that were dashed through the conflict area. The two locations were chosen because they had different kinds of conflict areas. The geometry on San Jacinto Boulevard required right turning motorists to cross a bicycle lane in order to access a right turn bay. On Dean Keeton Street, motorists cross a bicycle lane at a right angle when turning onto an arterial from an interstate exit ramp. The colored lane treatment was applied at both sites by applying chartreuse thermoplastic to the bicycle lanes throughout the dashed conflict area.

This study found that the application of color to a conflict area can substantially improve bicyclist and motorist behavior. On Dean Keeton Street, motorists were more likely to yield to bicyclists and motorists were more likely to use a turn signal when crossing the conflict area after the colored lane was installed. On San Jacinto Boulevard, motorists were less likely to yield to bicyclists but more likely to use a turn signal. The difference in results can likely be attributed to site geometry. On San Jacinto Boulevard, motorists frequently chose to go around the bicyclist and change lanes after the end of the colored area, whereas motorists on Dean Keeton Street were more confined as to where they could cross the colored lane. It is possible that the proportion of yielding motorists decreased because the sign used at the San Jacinto Boulevard site could not be placed in plain view near the conflict area and because the public was not educated on how to properly use the facility. Additionally, the application of color resulted in a significant increase in the proportion of bicyclists who used the bicycle lane to both approach and negotiate the conflict area, meaning that bicyclists took a more predictable position on the facility.

Given these results, this report recommends that colored lanes be seriously considered for use at conflict areas where bicyclists and motorists cross perpendicular to one another. Colored lane treatments were shown to be effective at improving some indicators of safety at sites where the conflict area runs parallel to the motorist’s desired path, but the improvement was not as comprehensive as when the motorist must cross the conflict area perpendicularly.

Background

Over the last 20 years, the City of Austin 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 same 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 destination in Austin with approximately 68,000 students, faculty and staff members, estimates 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). Bicycle facilities are often absent or inadequate in areas of conflict between bicycles and motor vehicles - where they are most needed.

This research intended to assess the effectiveness of Colored Bicycle Lane markings in conflict zones where where right-turning vehicles must cross a bicycle lane and where motorists must cross a bicycle lane while exiting a freeway ramp, as shown in Figure 1. The primary goal of the colored lanes is to guide bicyclists and motorists to the correct positions on the roadway, thereby improve the safety of all road users, and to increase the predictability of yielding events at the colored bicycle lane conflict areas.

Figure 1. A colored bicycle lane in Austin emphasizes the conflict zone between the bicycle lane and the highway exit ramp

St. Petersburg, Florida painted the pavement in a bicycle lane weaving area next to a right-turn only lane near an intersection, and installed “Yield to Bikes” signs with a diagram to guide motorists. A variable message sign and the local press were used to spread awareness to the public about the project. The percentage of motorists who yielded to bicyclists was found to be significantly higher after the treatment was applied. One problem that arose was that some motorists misunderstood the solid green paint to mean that they should not cross, and would therefore cross behind or in front of the green weaving area.

Portland, Oregon experimented with blue bicycle lanes in areas where bicycles and vehicles come into conflict, such as an exit ramp, entrance ramp, and right turn lane. As in the sites studied in this paper, the Portland sites were previously defined with white dashed lines. The Portland study found significant increases in the percent of bicyclists following the path at the exit ramp location, and the percent of vehicles yielding to bicyclists at the exit ramp and right-turn locations. Bicyclists turned their head to check for traffic or used hand signals less frequently, leading to worries that the treatment lulled them into a false sense of security. Survey results showed that 75% of bicyclists and 49% of motorists felt safer after the installation, and 58% of bicyclists said drivers yielded more often.

Colored bicycle lanes are prevalent in many European countries including the Netherlands, Germany, Sweden, Denmark, Switzerland, Belgium, Denmark, and France. Several U.S. localities have experimented with or are currently experimenting with Colored Bicycle Lanes including New York City, St. Petersburg (Florida), Portland (Oregon), and Columbia (Missouri).

Colored Lanes Detail

A chartreuse-colored, reflective thermoplastic was chosen as the material to color the bike lanes through the conflict area. Thermoplastic is a highly reflective, brightly-colored material that, when heated with a torch, chemically bonds with the pavement. Figure 2 shows a City of Austin crew installing the thermoplastic colored lane on Dean Keeton Street in Austin, TX. The chartreuse thermoplastic was purchased at a cost of $4.46 per square foot and each colored lane included a bicycle symbol that cost $98.21 each. Given these numbers, a 50-foot long, 5-foot wide colored lane would cost $1,213.21 in materials. The colored lanes installed in Austin were approximately this size.

Figure 2. Thermoplastic colored lane during installation on Dean Keeton Street

To supplement the colored lane, "Yield to Bikes" signs were installed before the conflict area at each of the studied locations. The signs were designed to reflect the configuration of the bicycle lane conflict area in relation to the motorist's path. Figure 3 shows the "Yield to Bikes" sign as it was installed at one study site.

Note: Further information about colored lane maintenance, material cost, labor cost, and deterioration can be found in the Thermoplastic Appendix.

Figure 3. A colored lane and accompanying "Yield to Bikes" sign at a conflict area in Austin, Texas

Site Descriptions

Colored lane applications were installed on two facilities in Austin. Both of the facilities studied had existing bicycle lanes that were dashed through the conflict area and both were located along popular commuting bicycling routes between near-campus neighborhoods and The University of Texas at Austin campus.

Dean Keeton Street at Interstate 35

Dean Keeton Street is a four lane arterial that runs along the north side of The University of Texas and connects East Austin to campus. Bicycle lanes in both directions along Dean Keeton make the facility a popular route for students who commute by bicycle. Where the bicycle lane crosses the entrance and exit ramps of Interstate 35, colored lanes were installed to alert motorists of potential conflicts with bicyclists. A map of the three colored lane segments on Dean Keeton Street is shown in Figure 4 below. In addition to the application of color to the bike lane, a "Yield To Bikes" sign was installed on the westbound exit ramp to clarify the intention of the colored lane, as this was chosen as the study location. A detail of the "Yield To Bikes" sign used in this study wa shown in Figure 5.

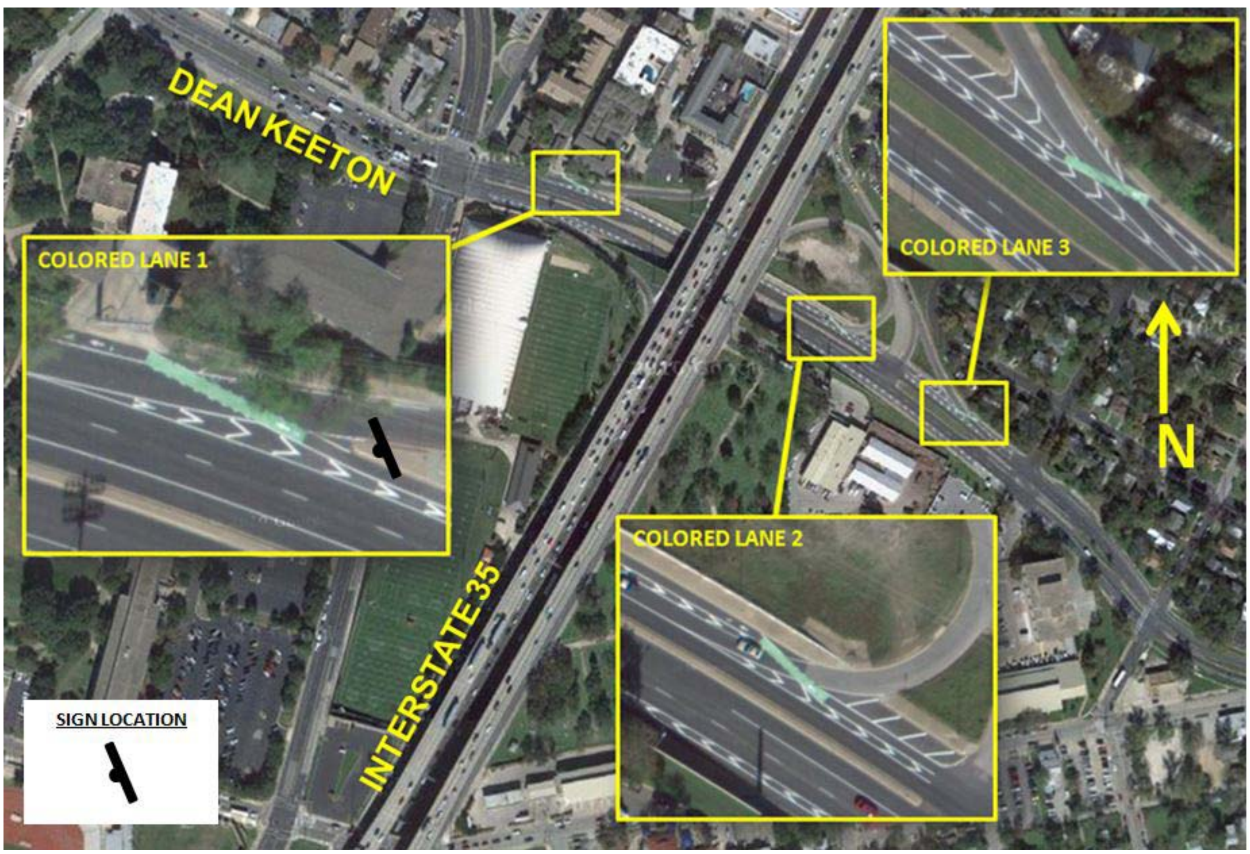

Figure 4. Map of the three colored lane segments on Dean Keeton Street

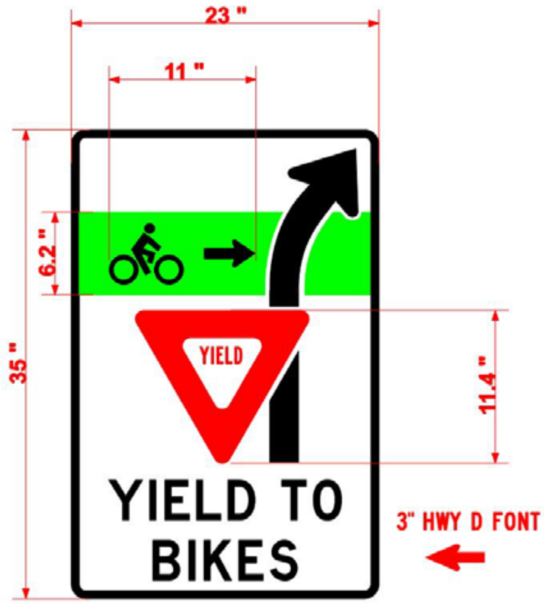

Figure 5. Detail of the "Yield to Bikes" sign that was installed at the study location on Dean Keeton

While three colored lanes were installed, data was collected from the colored lane that guides bicyclists across the westbound exit ramp on Interstate 35. A photograph of the studied colored lane is shown in Figure 6 and the study site is marked as 'Colored Lane 1' in Figure 4. The posted speed limit is 35 mph on Dean Keeton Street. The facility has an average AM peak volume of 500 vehicles per hour (vph) and 600 vph in the PM peak.

Figure 6. The colored bike lane on Dean Keeton Street at the westbound exit ramp of Interstate 35

San Jacinto Boulevard at Duval Street

San Jacinto Boulevard is a four lane arterial that connects The University of Texas to North Campus neighborhoods. Like Dean Keeton Street, the facility is a popular commuting route for students traveling between campus and their residence. Approximately 400 feet north of Dean Keeton Street, San Jacinto Boulevard flares to include a right turn lane for traffic turning toward Duval Street. Figure 7 shows how the colored lane highlights the conflict area on San Jacinto Boulevard. In addition to the application of color to the bike lane, a "Yield To Bikes" sign was installed before the conflict area on San Jacinto Boulevard to clarify the intention of the colored lane. A detail of the "Yield To Bikes" sign used at this site is shown in Figure 8. It should be noted that the sign location was not ideal. Due to the site geometry, the sign could not be placed very close to the conflict area. The sign was ultimately placed before the conflict area off to the right hand side, as illustrated in Figure 7. A photograph of the colored lane shortly after installation is shown in Figure 9.

The posted speed limit on San Jacinto Boulevard is 35 mph. Between 2:00 PM and 7:00 PM (when traffic departing campus is the highest) typical vehicle volumes are around 300 vph in the northbound direction.

Figure 7. Map of the colored lane installation on San Jacinto Boulevard

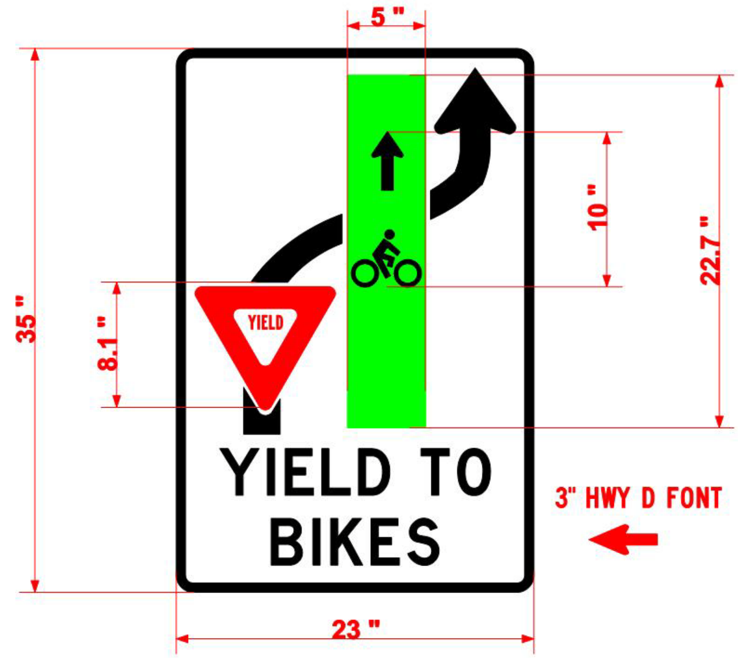

Figure 8. Detail of the "Yield to Bikes" sign that was installed at the study location on San Jacinto Boulevard

Figure 9. The colored lane installed on San Jacinto Boulevard

Experimental Design

In order to measure and evaluate bicyclist and motorist behavior, video footage of traffic movements at each site was collected. At San Jacinto Boulevard and Duval Street, video was recorded between 2:00 PM and 7:00 PM, when traffic leaving the university seemed to be highest. Video of the colored lane at Dean Keeton Street and Interstate 35 was recorded between 8:00 AM and 2:00 PM, when traffic entering the university seemed to be highest. The recordings were played back on flat panel monitors and a transparency placed over the screen helped researchers note the position of the bicyclist relative to pavement markings.

The primary goal of this study was to determine what effect, if any, colored lanes placed at conflict areas have on bicyclist and motorist safety. Therefore, before-color and after-color data for each site were compared to determine if safer conditions existed after the installation. For this study, safety was defined along the following lines: (1) The bicyclist used the bike lane to approach the conflict area, (2) the bicyclist used the bike lane to negotiate the conflict area, (3) the motorist yielded to the bicyclist when crossing the colored lane area, and (4) the motorist used a turn signal when crossing the conflict area.

To evaluate safety as defined above, several measures of bicyclist behavior, motorist behavior, and bicyclist-motorist interaction were recorded. Although no single measurement can comprehensively measure bicyclist and motorist safety, the improvement of several safety indicators can contribute to the conclusion that safety is indeed improved. Among the measurements taken were (1) the position of the bicyclist on the facility while approaching the conflict area, (2) the position of the bicyclist when navigating the conflict area, (3) the proportion of bicyclists that utilized the facility (as opposed to riding against traffic or on sidewalks), and (4) the actions of bicyclists and motorists when both attempted to navigate the conflict area at the same time.

Tests of statistical significance were conducted to determine if there were any notable differences between the before and after data. All proportions were compared using a two-sided test of equality, where the null hypothesis was that no change occurred and the alternative hypothesis was that behavior changed. While an educational campaign was not conducted for this experiment, City of Austin citizens were involved in the proposal's development. Bicyclists were surveyed 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 was given to the City's Bicycle Advisory Committee, where further comments from citizens were noted.

Terminology

When discussing the study results, several phrases and terms are used that have specific meaning to this study. Descriptions of those phrases and terms are included below:

- **Events (or observations)** - An event was recorded when a bicyclist was observed riding (1) parallel to traffic and (2) on the side of the street that included the colored lane. For example, a bicyclist who rode perpendicularly across multiple lanes of traffic without using the facility to travel parallel to traffic was not recorded.

Bicyclist used bicycle lane to approach - The bicyclist was traveling with traffic and used the bicycle lane to approach the conflict area.

Bicyclist used bicycle lane to navigate the conflict area - The bicyclist stayed within the bicycle lane when crossing the dashed or colored conflict area.

Yielding event - A yielding event occurred when a bicyclist and motorist both attempted to navigate the conflict area at the same time.

Car yielded to bicyclist - If the motorist allowed the bicyclist to navigate the conflict area first during a yielding event, the yielding event was described as 'car yielded to bicyclist'. If the motorist accelerated to cut off the bicyclist while the bicyclist was in the conflict area or the bicyclist yielded to the car during a yielding event, the yielding event was not described as 'car yielded to bicyclist'.

Motorist uses turn signal - If the motorist used a turn signal when crossing the conflict area during a yielding event, the yielding event was described as 'motorist uses turn signal'.

- **Illegal event** - An event was recorded as illegal if the bicyclist acted in a way that qualified as an event, but also acted illegally or very unsafely. Examples of illegal events include riding against traffic or cutting perpendicularly across several lanes of traffic. Illegal events were extremely rare at both of the sites studied in this report.

- **Conflict** - A conflict was recorded any time a bicyclist or a motorist near a bicyclist made a sudden maneuver to avoid a potential collision. Hard braking, sudden changes in direction, and swerving were considered signs of conflict. Conflicts were also extremely rare at both sites.

Results

The following section details the results of this study. All the tables below compare data collected before the colored lanes were installed ("before") and after the colored lanes were installed ("after"). Note that all p-values that appear with an asterisk (*) were calculated using sample sizes that did not meet the traditional rules of thumb for a two-proportion statistical test of significance and should not be heavily relied upon.

Dean Keeton Street at Interstate 35

The data collected from the conflict area on Dean Keeton Street was acquired between October 2009 and January 2010. Video of the site before the colored lane was installed was recorded in October and November of 2009, when fall semester classes were in session at The University of Texas. Video of the site after the colored lane was installed was recorded in January of 2010, when spring semester classes were in session. Bicyclists on Dean Keeton Street were very likely to utilize the bicycle lane when approaching and negotiating the conflict area with the Interstate 35 exit ramp. As shown in Table 1 and Table 2, over 95% of bicyclists both before and after the colored lane treatment used the facility as intended—they did not ride in the vehicle lane or use the sidewalk. This high compliance rate could, in part, be attributed to the site geometry. Bicyclists approaching the conflict area were traveling uphill and were therefore traveling at significantly lower speeds than motorists on Dean Keeton Street. Perhaps the difficulty of the terrain encouraged bicyclists who would otherwise prefer to use the full lane to instead use the bicycle lane at this site.

Table 1. Bicyclist behavior when approaching the conflict area on Dean Keeton Street

p= 0.278*		Among all legal bicyclists	
		Before	After
Used bicycle lane to approach the conflict area	Count	98	89
	%	99%	97%
Did not use bicycle lane to approach the conflict area	Count	1	3
	%	1%	3%
Total	Count	99	92
	%	100%	100%

**calculated with a sample size smaller than traditionally used for a test of significance*

Table 2. Bicyclist behavior when negotiating the conflict area on Dean Keeton Street

p= 0.775*		Among all legal bicyclists Before	After
Used bicycle lane to negotiate the conflict area	Count	95	89
	%	96%	97%
Did not use bicycle lane to negotiate the conflict area	Count	4	3
	%	4%	3%
Total	Count	99	92
	%	100%	100%

**calculated with a sample size smaller than traditionally used for a test of significance*

The behavior of bicyclists and motorists during yielding events—particularly, who yields the right of way—when both parties wish to negotiate the conflict area at the same instant, is an important indicator of safety. The yielding events observed at the Dean Keeton Street study site show that motorists were more likely to yield the right of way to bicyclists after the colored lane and "Yield to Bikes" sign were installed. As illustrated in Table 3, the proportion of yielding events that were resolved by the motorist yielding to the bicyclist increased from 63% to 78% after the colored lane treatment was installed. Additionally, the proportion of motorists who used a turn signal before crossing the conflict zone when a bicyclist was present increased significantly from 38% to 74% after the colored lane treatment. Turn signal use is shown below in Table 4. Taken together, these two pieces of information suggest that the use of color to highlight a conflict area makes motorists both more aware of the potential conflict with bicyclists (as indicated by the increased use of turn signals) and more likely to yield to oncoming bicyclists when necessary.

Table 3. Yielding behavior at the conflict area on Dean Keeton Street

p= 0.238		Among all yielding events Before	After
Motorist yielded to bicyclist	Count	15	18
	%	63%	78%
Motorist did not yield to bicyclist	Count	9	5
	%	38%	22%
Total	Count	24	23
	%	100%	100%

Table 4. Turn signal use by motorists during yielding events on Dean Keeton Street

p= 0.012		Among all yielding events	
		Before	After
Motorist used turn signal	Count	9	17
	%	38%	74%
Motorist did not use turn signal	Count	15	6
	%	63%	26%
Total	Count	24	23
	%	100%	100%

San Jacinto Boulevard at Duval Street

The data collected from the conflict area on San Jacinto Boulevard was acquired between August 2009 and April 2010. Video of the site before the colored lane installation was recorded in August and September of 2009 when fall semester classes were in session at The University of Texas. Video of the site after the colored lane installation was recorded in March of 2010 when spring semester classes were in session.

Table 5 below shows the turning movements observed before and after the colored lanes were installed. As previously illustrated in Figure 7, bicyclists who 'turned toward San Jacinto Boulevard' had to negotiate the conflict area, whereas bicyclists who 'turned toward Duval Street' followed a different bike lane that did not cross the conflict area. All of the following tables only compare data collected from bicyclists who 'turned toward San Jacinto Boulevard'. The similarities in turning movement distributions between the before data (collected in the fall) and the after data (collected in the spring) suggest that there is no fundamental difference in bicyclist behavior between these two seasons.

Table 5. Bicyclist turning movements observed on San Jacinto Boulevard

		Total Events		
		Before	After	p-value
Bicyclist turned toward San Jacinto Blvd	Count	227	132	0.349
	%	48%	44%	
Bicyclist turned toward Duval Street	Count	238	164	0.179
	%	50%	55%	
Bicyclist made an illegal maneuver	Count	12	3	0.136
	%	3%	1%	
Total	Count	477	299	
	%	100%	100%	

Table 6 and Table 7 compare how bicyclists utilized the facility when approaching and negotiating the conflict area. After the colored lane treatment and sign were installed, the proportion of bicyclists who utilized the bicycle lane to approach the conflict area increased significantly from 87% to 93% and the proportion of bicyclists who used the bicycle lane to negotiate the conflict area also increased significantly from 82% to 90%. These findings suggest that the colored lane treatment encouraged bicyclists to ride within the pre-existing bicycle facility. This shift increases the predictability of bicyclist behavior near the conflict area and may reduce instances of conflict or unsafe bicyclist-motorist interactions.

Table 6. Bicyclist behavior when approaching the conflict area on San Jacinto Boulevard

p= 0.077		Among all legal bicyclists Before	After
Used bicycle lane to approach conflict area	Count	198	123
	%	87%	93%
Did not use bicycle lane to approach conflict area	Count	29	9
	%	13%	7%
Total	Count	227	132
	%	100%	100%

Table 7. Bicyclist behavior when negotiating the conflict area on San Jacinto Boulevard

p= 0.045		Among all legal bicyclists Before	After
Used bicycle lane to negotiate conflict area	Count	187	119
	%	82%	90%
Did not use bicycle lane to negotiate conflict area	Count	40	13
	%	18%	10%
Total	Count	227	132
	%	100%	100%

The behavior of bicyclists and motorists during yielding events is an important measure of safety since collisions with motorists can be particularly dangerous for bicyclists. As shown in Table 8 below, yielding events are not common occurrences; they account for only about 10% of all San Jacinto-bound bicyclists. Note that there was no substantial change between the proportion of yielding events as a total of all San Jacinto-bound bicyclists before or after the colored lane was installed. This suggests, as did Table 5, that there is not a fundamental difference in bicyclist and motorist behavior between the fall months and spring months.

Table 8. Frequency of yielding events observed on San Jacinto Boulevard

p= 0.653		Among all legal bicyclists Before	After
Yielding event was observed	Count	24	16
	%	11%	12%
Yielding event was not observed	Count	203	116
	%	89%	88%
Total	Count	227	132
	%	100%	100%

After the colored lanes were installed, motorists were less likely to yield to bicyclists when both parties attempted to negotiate the conflict area simultaneously. Table 9 shows that the proportion of motorists who yielded to bicyclists decreased significantly from 83% to 44%, though more data is needed to verify this conclusion. After the colored lane marking was installed, motorists were less likely to cross the dashed and colored area during a yielding event. Motorists were observed turning across the conflict area both before and after the colored lane section when bicyclists were present. This decrease in motorist predictability when negotiating the conflict area may be the result of poor sign placement (as previously explained in the Site Description section) or motorists misconstruing the meaning of the color (since no educational campaign had been conducted).

Table 9. Yielding behavior at the conflict area on San Jacinto Boulevard

p= 0.009*		Among all yielding events Before	Among all yielding events After
Motorist yielded to bicyclist	Count	20	7
	%	83%	44%
Motorist did not yield to bicyclist	Count	4	9
	%	17%	56%
Total	Count	24	16
	%	100%	100%

**calculated with a sample size smaller than traditionally used for a test of significance*

Although motorists were less likely to yield to bicyclists, the proportion of motorists who used a turn signal before crossing the conflict area remained high after the installation of the colored lane. Table 10 shows that the proportion of motorists using a turn signal during yielding events increased from 63% to 75%. It may seem contradictory that turn signal use would increase while motorist instances of yielding decreased. However, this supports the hypothesis that while motorists are aware of the potential conflicts with bicyclists, they are unsure of how to cross the bicycle lane once the color was installed.

Table 10. Turn signal use by motorists during yielding events on San Jacinto Boulevard

p= 0.483*		Among all yielding events Before	Among all yielding events After
Motorist used turn signal	Count	15	12
	%	63%	75%
Motorist did not use turn signal	Count	9	4
	%	38%	25%
Total	Count	24	16
	%	100%	100%

**calculated with a sample size smaller than traditionally used for a test of significance*

Conclusions and Recommendations

The results of this study strongly suggest that a colored lane treatment and an accompanying "Yield to Bikes" sign can improve the safety of bicyclists and motorists at conflict areas located on multi-lane facilities. At both studied locations, the addition of the colored lane treatment resulted in an increase in turn signal use by motorists crossing the conflict area. This suggests that the presence of the colored lane made motorists more aware of the potential conflict with bicyclists.

On the Dean Keeton site, the installation of the colored lane and sign had a strong, positive impact on motorist behavior. Motorists were significantly more likely to yield to bicyclists and to utilize a turn signal after the addition of color. Bicyclists also behaved very predictably, leaving little room for improvement—well over 95% of bicyclists used the bicycle lane to approach and negotiate the conflict area before the colored lane treatment.

The colored lane on San Jacinto had a positive impact on bicyclist behavior and motorist turn signal use. After the colored lane installation, the proportion of bicyclists who used the bicycle lane to approach and negotiate the conflict area increased significantly, suggesting that the colored lane was able to encourage use of the bicycle lane well before the colored conflict area. Motorists on San Jacinto Boulevard were more likely to utilize a turn signal when crossing the conflict area, but were less likely to yield the right of way to oncoming bicyclists after the color was installed. This disparity suggests that while motorists are aware of the potential conflict with bicyclists (as indicated by their frequent use of turn signals), they are unsure how to cross the bicycle lane once the color is applied. This confusion on the part of motorists could be attributed to the lack of an educational campaign and the unfavorable sign placement of the "Yield to Bikes" sign on San Jacinto Boulevard, as explained in the Experimental Design and Site Description sections.

Given these results, this report recommends that colored bicycle lanes and the accompanying "Yield to Bikes" signs be strongly considered at conflict areas where bicyclists and motorists will cross perpendicular to one another. Color treatment and sign should also be considered at sites similar in geometry to San Jacinto Boulevard, where motorists must cross a parallel bicycle lane, due to the observed improvement in bicyclist predictability and increased motorist turn signal use. An education campaign targeted at motorists is likely important, especially in the latter case, to alert motorists of the proper way to cross the colored conflict area.

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Appendix A: Bicyclist Counts

The tables below display the minimum, maximum, and average number of bicyclists recorded during each hour of the day. Note that these bicycle counts only include bicyclists traveling in the direction of travel that was under study for this experiment, as explained in the table's caption.

Table 11. Counts of bicyclists traveling westbound on Dean Keeton Street at the intersection with Interstate 35

Time of Day	Minimum Bicyclists per Hour	Average Bicyclists per Hour	Maximum Bicyclists per Hour
9:00 AM	23	28	36
10:00 AM	18	28	33
11:00 AM	7	19	34
12:00 PM	26	26	26

Table 12. Counts of bicyclists traveling northbound on San Jacinto Boulevard near the intersection with Duval Street

Time of Day	Minimum Bicyclists per Hour	Average Bicyclists Per Hour	Maximum Bicyclists per Hour
1:00 PM	7	14	20
2:00 PM	11	19	32
3:00 PM	9	25	43
4:00 PM	18	25	30
5:00 PM	22	33	44

Appendix B: Thermoplastic Cost, Maintenance, and Upkeep

The colored thermoplastic, sharrows, and other thermoplastic forms were purchased from Flint Trading Inc (Thomasville, NC). Costs for these materials are provided in Table XX.

Table B1. Cost of thermoplastic units used in the studies

Item	Cost	Unit
Colored Thermoplastic	$4.46	SF
Sharrows	$126.30	EA
"WAIT HERE" Legend	$267.66	EA
Bicycle Symbol	$98.21	EA

Per manufacturer guidelines, the installation of the colored thermoplastic first required the application of an oil-based coating to the asphalt. The optimal installation of this initial layer would be an application to asphalt free of debris and sediment. The oil layer needed to dry (WC) before the colored thermoplastic could be laid out. Otherwise, the heat applied to the thermoplastic would cause the oil to burn through the material.

An installation error of the colored thermoplastic on Dean Keaton at the IH-35 exit ramp led to its quick deterioration. While waiting for the oil layer to dry one of the crew members spilled a large amount of water onto the oil. This water eventually led to inadequate bonding between the pavement and the thermoplastic, which resulted in the thermoplastic breaking up (illustrated in Figure B1).

Figure B1. Deteriorating thermoplastic on one of the I-35 exit ramps (breaking up in sheets)

The quality of pavement was a contributing factor to the quick deterioration of the colored thermoplastic, illustrated in Figure XX. In particular, the pavement on Speedway at 38th Street is cracked and uneven from the high volume of bus traffic. (The street is scheduled for reconstruction in the next few years.) Clearing debris from the deep cracks of the application surface was nearly impossible; applying the oil-layer to these same cracks and the other surface flaws was also troublesome. The resultant colored thermoplastic was only tenuously bonded to the street surface at best.

Figure B2. Poor quality of road lead to the deterioration of the thermoplastic bike boxes on Speedway Boulevard

Additionally, the colored thermoplastic on Speedway was discolored very quickly (see Figure B2). This discoloration is likely due to the heavy bus traffic on Speedway, where there is a peak hourly volume of over 15 buses/hour. This discoloration may have been compounded by the buses, wider than personal cars, driving in the colored lane. Another concern with the thermoplastic is shown in Figure B7. It is unclear whether the uneven application of thermoplastic shown in the photograph is the result of a misapplication, the rough nature of the street surface, or a deterioration problem.

Figure B3. Poor quality of road lead to the deterioration of the thermoplastic bike boxes on Speedway Boulevard

Installing colored thermoplastic on new pavement would be the optimal situation. In the future, the City of Austin will most likely be applying a fresh asphalt surface (seal coat, microsurface, or overlay) before the installation of any proposed colored thermoplastic. A fresh street surface will provide a surface free of cracks and other defects, which could lead to erroneous installation and quick deterioration. These properties also lessen the importance of the oil layer in creating a bond between the pavement and thermoplastic.

All sharrows were installed on top of a painted black box in order to provide visual contrast. Additionally, all sharrows were installed in the outside travel lanes. The sharrows on Guadalupe, Lavaca, and 51st Sts were installed in the center of the outside travel lanes as described by Figure B4. Each sharrow was individually placed in order to keep the sharrow out of the typical wheel paths and to avoid driveways where entering and exiting vehicles would have more variable wheel paths. By placing the sharrows outside of wheel paths the integrity of the thermoplastic was maintained.

Figure B4. Central placement of sharrow resulted in thriving thermoplastic five months after installation.

The east-bound sharrows on Dean Keeton St were installed in the center of the outside travel lanes (see Figure B5) in the same manner as the sharrows on Guadalupe, Lavaca, and 51st Sts. Like these other streets, centralizing the east-bound Dean Keeton sharrows helped to preserve the thermoplastic. Another reason these sharrows were installed in the center of the travel lane was to keep them out of the path of buses. Dean Keeton St has an extremely high volume of bus traffic (peak hourly volume of 40 buses/hour) and there a number of bus stops requiring buses to enter and exit the outer travel lane as shown in Figure B5. Finally east-bound bicyclists are also able to reach faster speeds because of the downhill allowing bicyclists and cars to travel at similar speeds.

Figure B5. Central placement of sharrows on east-bound, downhill Dean Keeton St.

The west-bound sharrows on Dean Keeton differed from the other locations as these sharrows were aligned closer to the curb (see Figure B6). These sharrows were aligned closer to the curb for the following reasons: the outside travel lane on west-bound Dean Keeton was very large, there were no bus stops, the sharrows were only utilized to provide a bicycle facility to link two bicycle lanes, and west-bound bicyclists slow down to travel uphill.

Figure B6. Curb-justified placement of sharrows on west-bound, uphill Dean Keeton St.

Figure B7. Thermoplastic thinning on the colored lane on San Jacinto Bouleveard