Technical Memorandum

To: Ted Curtis, *City of Columbia*

From: Paul Wojciechowski, *Alta Planning + Design*

Date: May 23 , 2016

Re: Columbia, MO Bicycle Pavement Marking Wayfinding Symbol RTE Findings

Executive Summary

The purpose of this study was to evaluate the effectiveness of bicycle wayfinding pavement markings through the use of a simulated bicycle route in Columbia, Missouri. The alternative wayfinding markings are intended to provide greater continuity across facility types along a bicycle route while also serving to indicate directionality in a more visible, clear way. Video footage of participants completing a simulated course was reviewed to provide performance data for three conditions: existing MUTCD markings, wayfinding markings with white only, and wayfinding markings with a green background. Markings were tested at two sizes: full-size markings on roadways and half-size markings on shared-use pathways. A participant survey following the simulated route provides further information regarding the participant's recognition of the pavement markings and signs. Analysis suggests that the alternative markings are more effective at clearly and visibly communicating a marked bicycle route than roadways with just existing MUTCD markings and signage. Further, the markings featuring the green background performed best for clarity and understanding bike routes. This result of this memorandum identified the preferred symbol that will be field tested along two corridors in Columbia for further analysis.

Introduction

Bicycle wayfinding signage can help guide a bicyclist along a designated bicycle route. Routes in Columbia, Missouri often follow a combination of shared-use paths, bicycle boulevards, streets with shared lane marking, and bike lanes. For those unfamiliar with the integrated network, improved information is critical to guiding them along the route. Due to bicycle positioning (i.e., often needing to look down for barriers and other hazards) as well as to reduce sign clutter, on-pavement markings can provide an alternative to replace or enhance bike route signage or wayfinding signage along a route.

Current MUTCD guidance provides for bike lane and shared lane markings, which are not recommended for use on side paths and best direct travel along routes that continue in a straight

direction. Transitions between facility types and along non-direct corridors have been addressed in many cities through the use of supplemental on-street markings.

This experiment tested the use of wayfinding pavement markings, in addition to standard bike markings that provide wayfinding and can be applied to range of bikeway types. Markings were tested in a simulated environment (Figure 1) on both on-street and off street bikeways.

The ZooSim bicycle simulator on the campus of the University of Missouri at Columbia was developed by the same leadership at the University as the vehicle simulator that is used to test roadway signs and markings for highways. Roadway types with several on-street bikeway scenarios, as well as trail and side path scenarios were provided in sketch up drawings and provided to the University staff for coding for the simulated network that participants would ride through. The streets were made to look like urban streets, patterned after the city of Columbia, yet were made different enough so that the participants would not be distracted by the environment.

Half-sized symbols were also tested on paved off-street facilities. These symbols not only provide wayfinding but can serve as verification symbols to confirm change in route direction. Both a white-only marking and an option with green color behind the circle were tested for both scenarios. Examples of these markings can be found in Figures 3 and 4.

Figure 1. Participant completing simulated course

Methodology

Assessment of the pavement markings was completed utilizing two tools, videotaping of test subjects on a simulated bicycle route and a qualitative user survey following the test subject navigating the simulated route.

Alta in coordination with the City, Alta and University of Missouri staff developed a questionnaire designed to gather user information for the three parts of the simulation; with signing only, with pavement markings only, and finally with both signing and pavement markings. The data was collected by University of Missouri staff and graduate students using the ZooSim Simulator on campus. The simulation focused on observed measurable behavior through the questionnaire, timing of participants riding through the virtual course, as well as video tape of the participants in the simulator.

The participants will perform three timed rides through a series of streets with a set of bikeways that include shared lane markings, bike lanes and shared use paths. The route types that were used in the simulation are provided in Appendix A. Appendix B exhibits the coded network that was used in the simulation. While the bikeways may resemble Columbia streets, it intended to simulate bikeway types used in any city.

The riders will traverse the same route one time for each condition:

1) Condition 1: markings on the pavement that include only those that are normally applied to the pavement with addition of MUTCD compliant wayfinding signage;
2) Condition 2: markings on the pavement that include only those that are normally applied to the pavement with the addition of the two sizes of Proposed Type 1 pavement symbols that are the subject of this experiment, and MUTCD compliant wayfinding signage.
3) Condition 3: Condition 2 with addition of Proposed Type 2 pavement symbols that are the subject of this experiment and MUTCD compliant wayfinding signage

Response to subjective survey questions assessing level of confidence in decision making, recognition of pavement markings and signs, and other questions to assess the perceived differences between the three route markings.

The MUTCD signage and shared lane markings are shown in Figure 2. Type 1 and type 2 pavement markings are shown in Figure 3 and 4 respectively.

Figure 2: MUTCD compliant signage and normal pavement marking

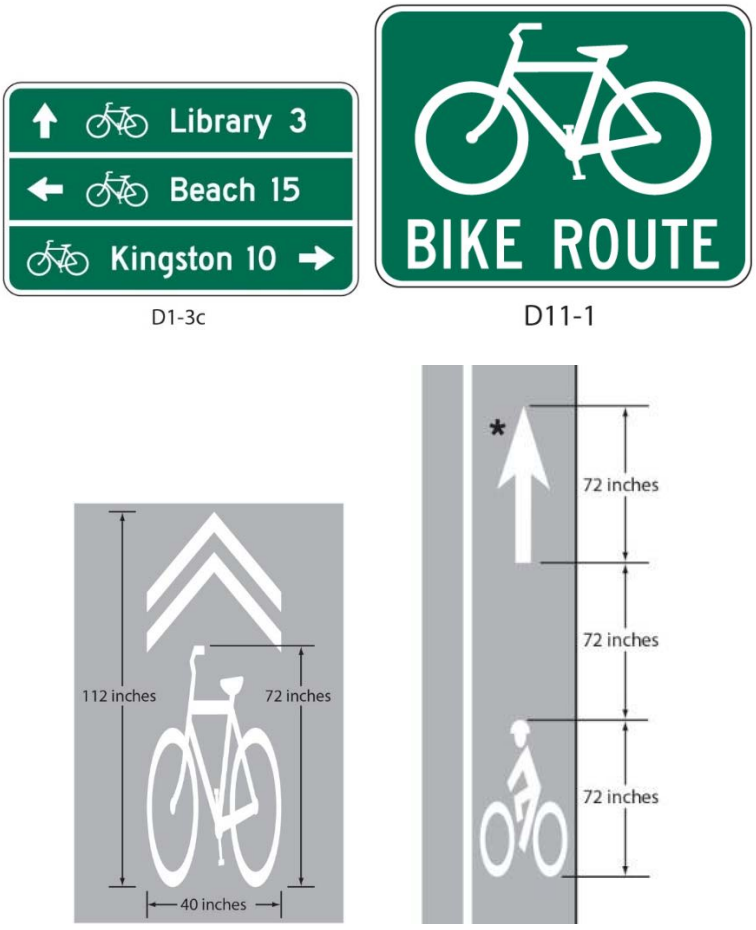


Figure 3: Type 1 Pavement Symbols

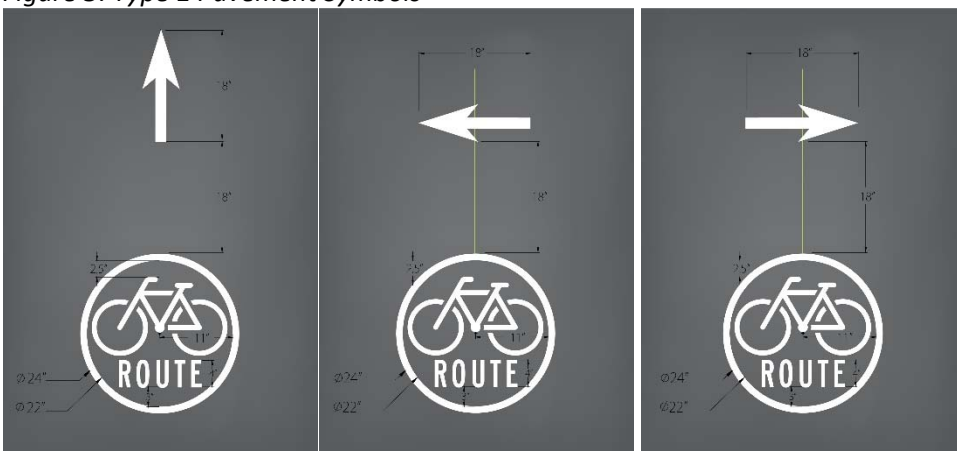
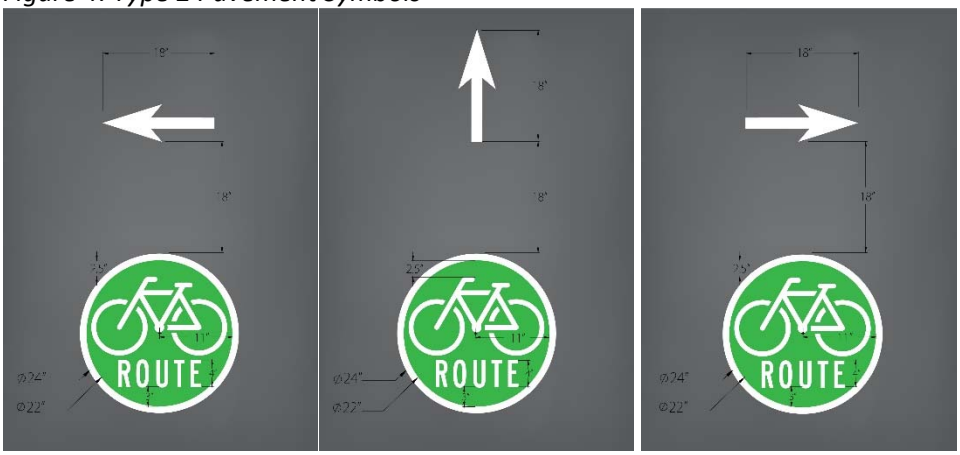


Figure 4: Type 2 Pavement Symbols



The simulated route was conducted in the University of Missouri – Columbia's vehicle simulator, ZooSim. Altered to accommodate a bicycle, the simulator included the use of a bicycle on a trainer, a large screen, and virtual reality (VR) glasses. The simulator has been used to test effectiveness of signing and markings for motor vehicle users and has been successfully used in experiments completed for the Missouri Department of Transportation. Adjusting the simulator to instead accommodate a bicycle on a trainer, the simulator framework better replicated the position of the bicyclist on the roadway.

Participants were recruited through several different avenues, including on campus advertisements, PedNet, the Missouri Bicycle and Pedestrian Federation, and bicycle shop advertisements. All participants are familiar with bicycling on roadways and off-street paths.

Video footage of each participant was then reviewed to assess the use of hand signals and turns that were missed during the riding of the routes to determine the effectiveness of each marking. Four Measures of Effectiveness (MOEs) were utilized for this evaluation.

1) Average elapsed time for the simulation run under each of the three configurations
2) Surrogate for relative perception/reaction time in seconds of the signage/marking based on when the participant start to hand signal
3) Relative distance to the signage/marking in feet when the participant started to hand signal
4) Average number of missed transitions; rider did not follow the signage/marking and went the wrong way

For Measure 2, a longer travel time for a participant traveling the simulated right was a worse result, where Measure 3, larger values indicate an earlier reaction time to the symbol. Recognition of the symbol was measured by use of hand signals from the participant to indicate the desired action.

Immediately following the participant rides, a survey was administered documented participants' current bicycle use, including frequency, trip purpose, and facility preference. The survey also solicited feedback regarding the visibility, clarity, and preference for the experimental markings in comparison to the just the existing MUTCD marking. The survey was administered through Survey Monkey and followed the simulated route activity.

Video Review Results

Video review of the simulator test run measured participants' response to the proposed wayfinding markings. Elapsed time to complete the route collected, as well as the time and distance prior to a decision point that a participant began to hand signal. If a participant did not use a hand signal it was noted. The time and distance prior to a decision point is a surrogate variable for relative reaction time to the pavement markings.

Results were aggregated based on the wayfinding marking alternative used. The use of on-street and off-street (half-sized) symbols were only relevant to the scale of roadways verses shared use or side paths.

Elapsed Time

The elapsed time to complete the route did not vary significantly between markings tested. Of the 25 participants who completed the route, times varied by approximately 8 seconds.

Condition	Average Elapsed Time
Condition 1 - MUTCD	08:16.337
Condition 2 - Proposed Type 1	08:10.604
Condition 3 - Proposed Type 2	08:07.087

Although Proposed Type 2 resulted in a lower average elapsed time, it also had a larger standard deviation across the participants. This indicates a larger variance in the time required to complete the course, while the MUTCD markings result in a lower standard deviation, indicating greater consistency among all participants to complete course. When observing individual participants, many completed the course in less time with Proposed Type 1 or Proposed Type 2 as compared to the MUTCD markings. However, this could be due to greater familiarity with the course and may not be attributable to the markings.

Reaction Time (in seconds)

The time (in seconds) prior to a symbol that a participant signaled is a surrogate variable for relative reaction time. An earlier signal suggests that the symbol was not only more visible but also more easily understood. A larger number indicates an earlier reaction time, while a negative number indicates that a participant passed the marking or sign before signaling. Both Proposed Type 1 and Proposed Type 2 resulted in participants signaling earlier in relation to the marking or sign.

Condition	Average Reaction Time (in seconds)
Condition 1 - MUTCD	0.039
Condition 2 - Proposed Type 1	2.110
Condition 3 - Proposed Type 2	3.078

Proposed Type 2 performed best in this measure of effectiveness, with an average reaction time of 3.078 seconds. This is over 3 seconds earlier than when participants signaled in response to MUTCD markings and nearly one second earlier than Proposed Type 1.

Reaction Time (distance)
The table below represents the average reaction time of a participant in relation to a marking or sign. Measured in feet, the measure indicates the distance prior to the sign a participant began to signal. A negative value indicates that the participant signaled after passing the marking or sign.

Condition	Average Reaction Time (in feet)
Condition 1 - MUTCD	13.689
Condition 2 - Proposed Type 1	38.644
Condition 3 - Proposed Type 2	50.969

Proposed Type 2 performed best in the measure of effectiveness, with participants signaling an average of approximately 51 feet prior to the marking or sign. Although there was greater variation among average Condition 3 - Proposed Type 2 signaling distances, participants overall signaled earlier in both proposals as compared to the MUTCD-only markings.

Missed Transitions
Transitions were used to indicate the effectiveness and clarity of the wayfinding markings. A missed transition was counted when a participant did not follow signage or markings and traveled the wrong way on the course. A missed transition was not counted if a participant simply did not signal yet followed the correct pathway.

Condition	Average Missed Transitions
Condition 1 - MUTCD	2.625
Condition 2 - Proposed Type 1	1.333
Condition 3 - Proposed Type 2	0.625

As in the previous measures of effectiveness, Condition 3 - Proposed Type 2 performed best, with an average of less than one missed transition. Although total number of missed transitions per participant varied, with some missing zero transitions and others missed up to 10, only three participants missed fewer transitions in the MUTCD course as compared to either Proposal.

Survey Results

Twenty seven (27) participants completed the survey following the simulation exercise. The experiment sought participants who presently bicycle on the roadway, as opposed to novice riders who may be unfamiliar with the context. Of these participants, 88.9% were residents of the City of Columbia, and 88.9% ride a bicycle at least one day per week.

Although more participants bicycle for non-work or recreation trips (92.6%), 81.5% commute to work or school via bicycle, with over 50% of commuting five or more days a week by bicycle. Recreation-based

trips occurred less frequently, with 60% of participants completing a recreation trip one to two days a week. Commute durations were shorter, with 54% measuring 15 minutes or less, while recreation trips were primarily longer than 30 minutes.

Over 90% (92.3%) of participants indicated that they ride on a combination of trails and streets. Participants primarily encounter bicycle lanes and shared lanes (with or without parking) on a daily basis, while shared use paths are utilized weekly and side paths are rarely encountered. This suggests that participants are familiar with existing on-street signage and markings and have some experience navigating an integrated network.

Fifty percent of participants agreed that the existing markings and signs on the bicycle routes they travel are effective at delineating the route; less than 30% disagreed with this statement. When compared to the number of missed transitions experienced on the MUTCD course, this suggests that the perception of effective route delineation may be due to familiarity with the route and does not necessarily indicate that these signs are effective in communication to prospective cyclists.

Participants were asked to rate the visibility and clarity of each Proposal.

These markings are highly visible.

Condition	Percent
Proposed Type 1	63.93%
Proposed Type 2	92.59%

These markings clearly indicate the direction of the bicycle route.

Condition	Percent
Proposed Type 1	81.48%
Proposed Type 2	92.30%

The majority of participants Strongly Agreed or Somewhat Agreed that both proposals were visible and clear. Participants agreed that Proposed Type 2 was both more visible and clearer than Proposed Type 1, however, with over 90% agreeing that the markings were highly visible and 92.3% agreeing that the markings clearly marked the route direction. In fact, 74% of participants strongly agreed that Proposed Type 2 clearly marked the direction of the bicycle route.

Overall, 81.5% of participants indicated that they preferred Proposal 2, while only 18.5% of participants preferred Proposed Type 1.

Comments on the markings were received from 14 participants. Feedback was divided between support for the white-only markings and support for a colored marking. Four participants indicated that the white was easier to see due to the contrast with the pavement and that the green was often difficult to differentiate from the pavement. However, other participants noted that the green color caused the

marking to stand out and signified something different requiring their attention was present. Comments were also divided regarding preference for on-street markings as compared to signs located along the route. Further analysis will be required based on feedback received from the field testing of the preferred symbol.

Discussion

The use of simulated route was an efficient method for gathering preliminary feedback regarding the two sets of proposed wayfinding markings. Participant performance on the route provided insight into the effectiveness of the proposed signs, yet may have also been influenced by increased familiarity with the route as participants completed subsequent runs.

Significant participant preference for Proposed Type 2 corresponds with the results of the simulated route performance and provides additional support for the effectiveness of the markings in the simulated test. Since the survey was administered following the simulated route, preference for markings and perception of visibility and clarity are more likely to be based on the participant's experience with the simulator. Overall, both proposed markings performed better than the existing MUTCD markings, suggesting that markings that are used on multiple facility types and provide greater clarity as to the direction of the bike route are effective and beneficial to bicyclists. Performance in field testing the preferred marking will be important to validate the findings of the simulated route and will provide for additional data and analysis related to effectiveness of the symbol.

Conclusion

The experimental markings resulted in improved reaction times and fewer missed facility transitions as compared to the existing MUTCD markings. Both set s of experimental markings performed better than the MUTCD pavement markings and signs; however participants missed fewer transitions and reacted to markings sooner in Proposed Type 2 as compared to Proposed Type 1.

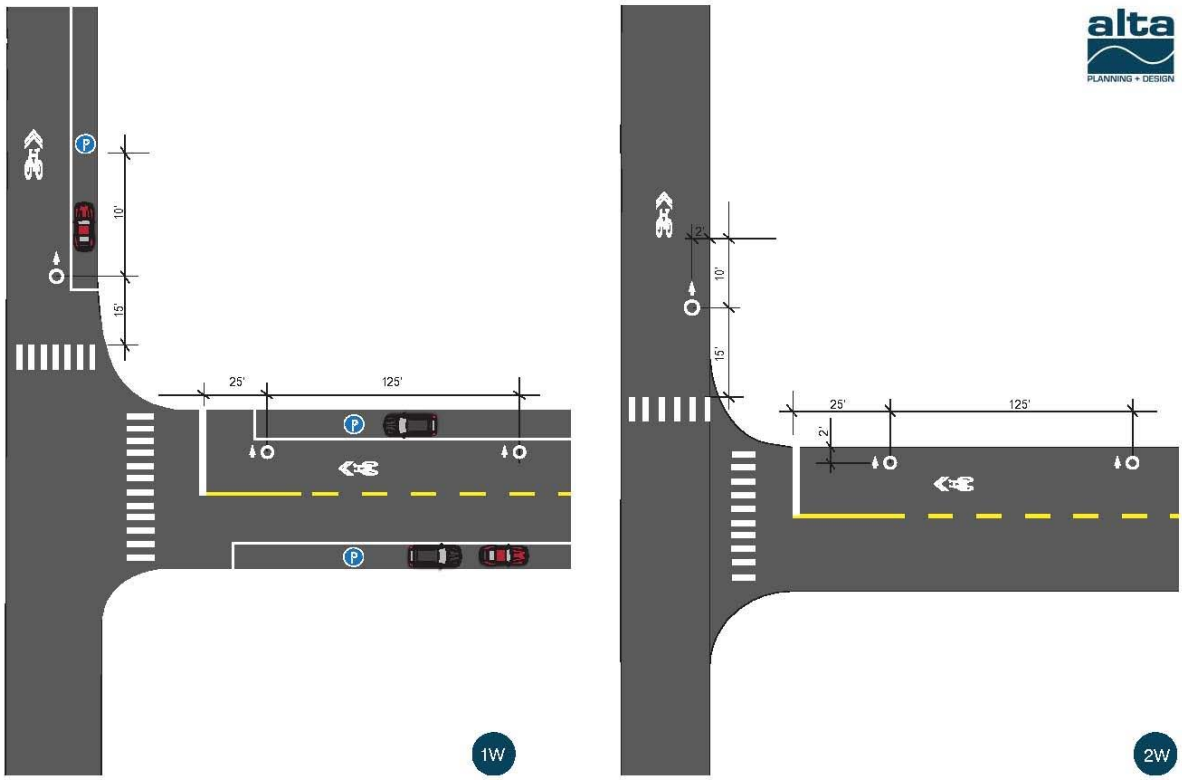
Participant survey responses indicate that Proposed Type 2 is preferred for visible, clear markings; 80% of participants indicated that Proposed Type 2 was their preferred set of markings.

Based on the results of the simulated route and survey, Proposed Type 2 is recommended for field testing along two major cross-city marked bicycle routes that traverse Columbia. These routes, as identified in the request to experiment, are composed of a variety of bicycle facilities, including shared-use paths, side paths, bike boulevards, and bike lanes. The test routes include:

1) Providence Bikeway – 10 miles in length; travels north-south
2) Worley-Hominey Bikeway – 9 miles in length; travels east-west

Field testing will provide further insight into the effectiveness of these marking and allow for additional analysis and recommendation that builds on the findings from the simulator testing reviewed here.

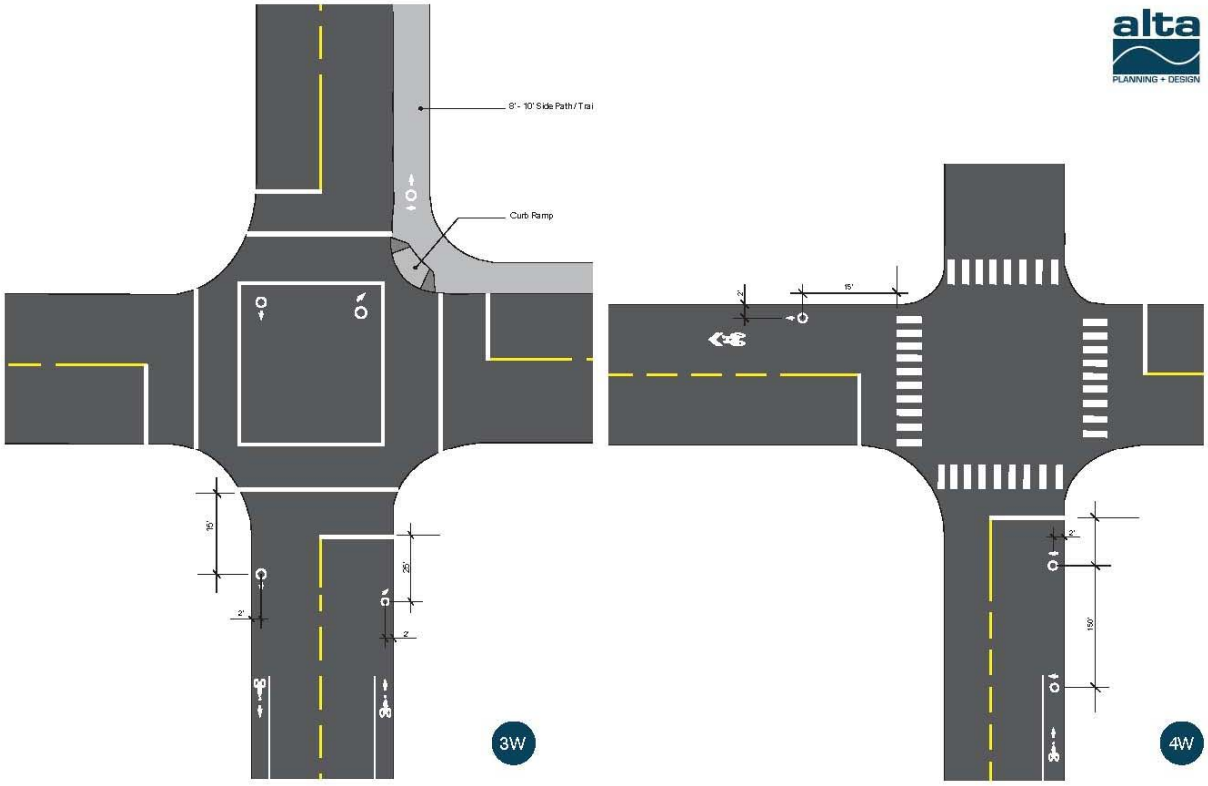
Appendix A



City of Columbia, Missouri

Bicycle Pavement Marking Symbols

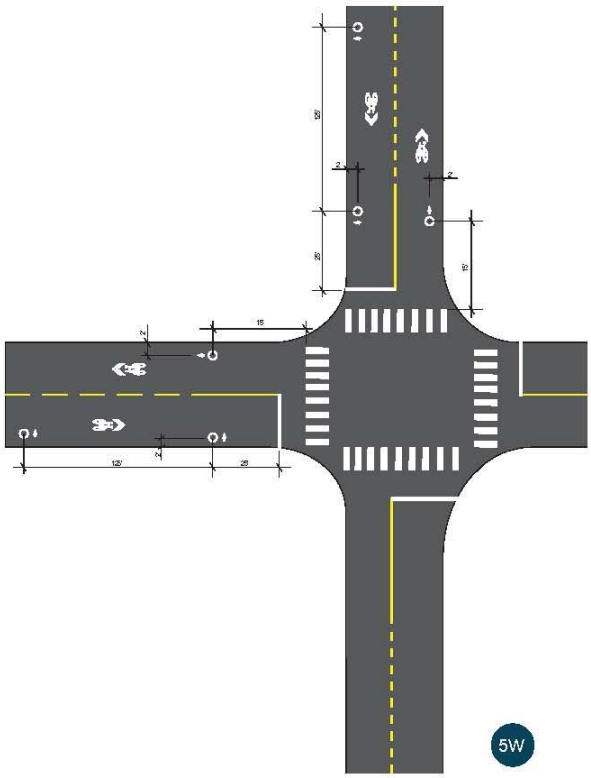
Right Turn Arrow - Parked and No Parked Cars

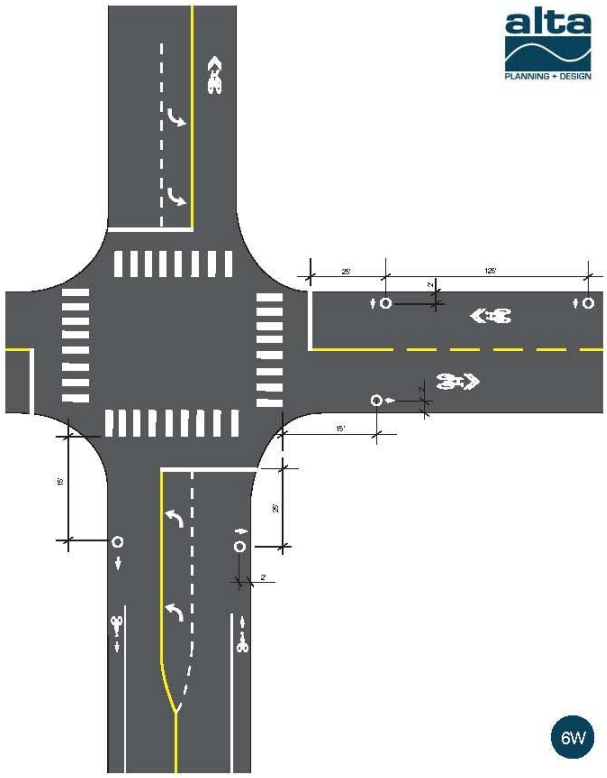


City of Columbia, Missouri

Bicycle Pavement Marking Symbols

Bike Lane to Sidepath
Left Turn Arrow Placement

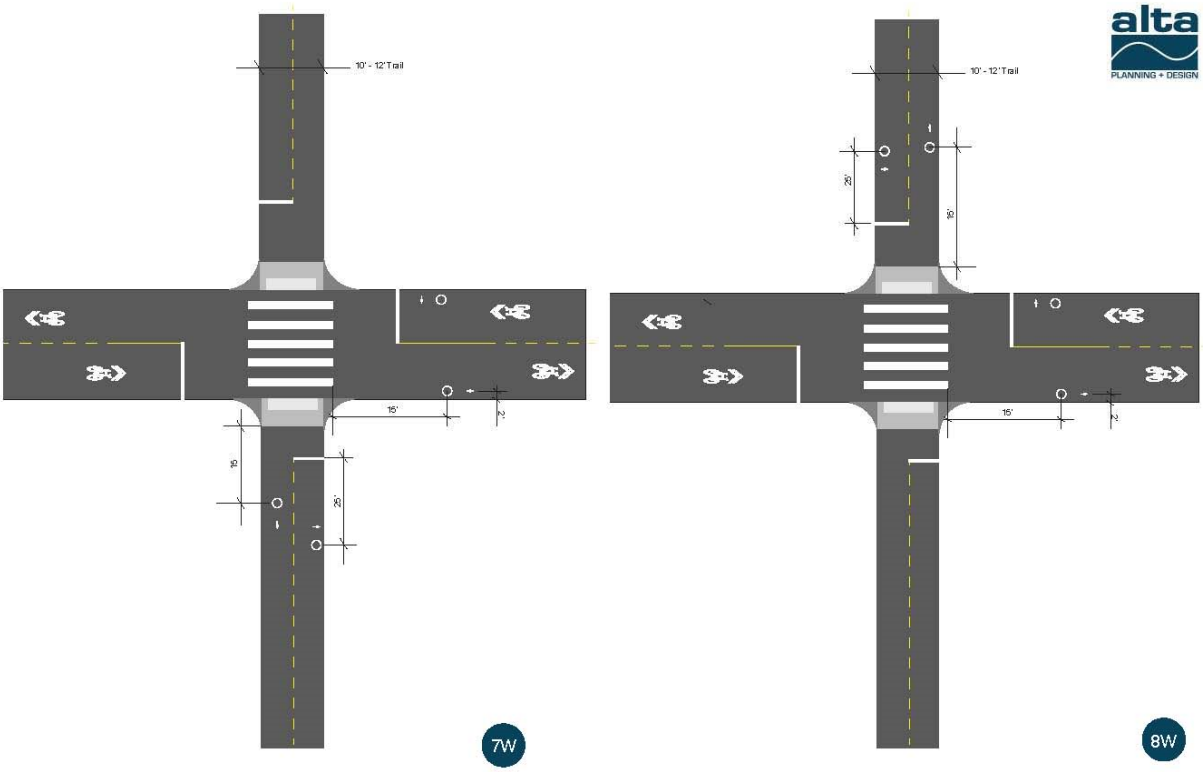




City of Columbia, Missouri

Bicycle Pavement Marking Symbols

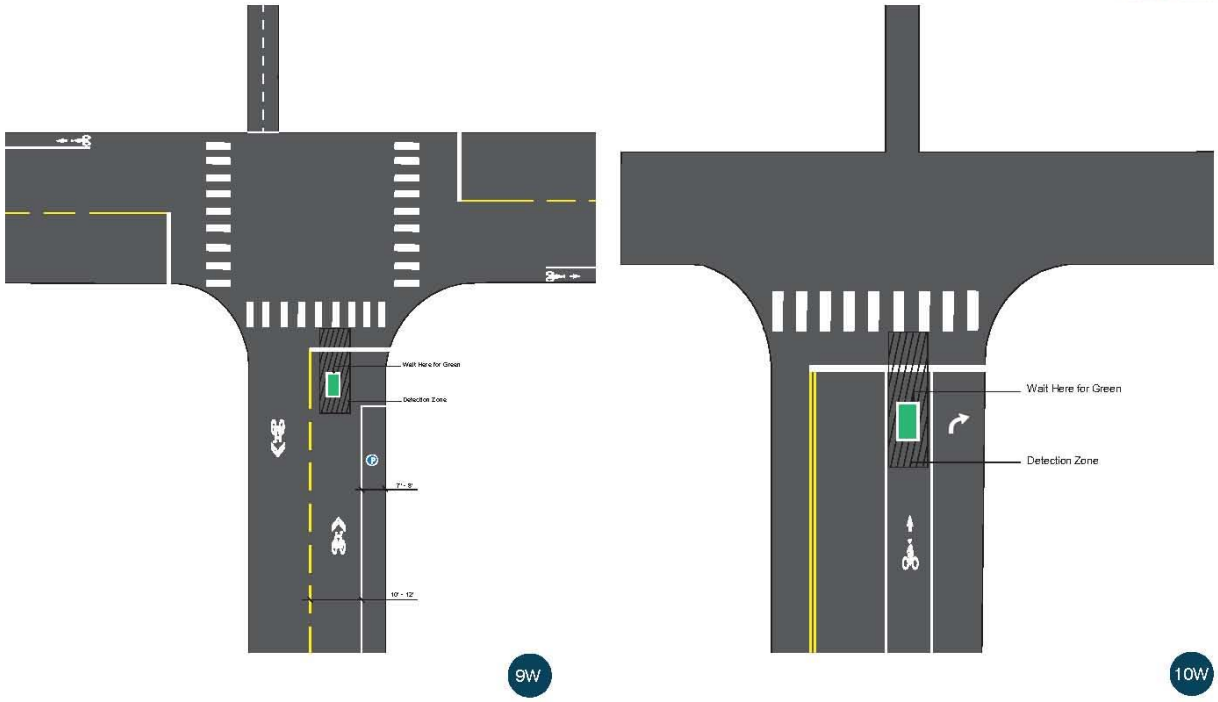
4 Way Intersection - Left Turn
4 Way Intersection - Left and Right Turn



City of Columbia, Missouri

Bicycle Pavement Marking Symbols

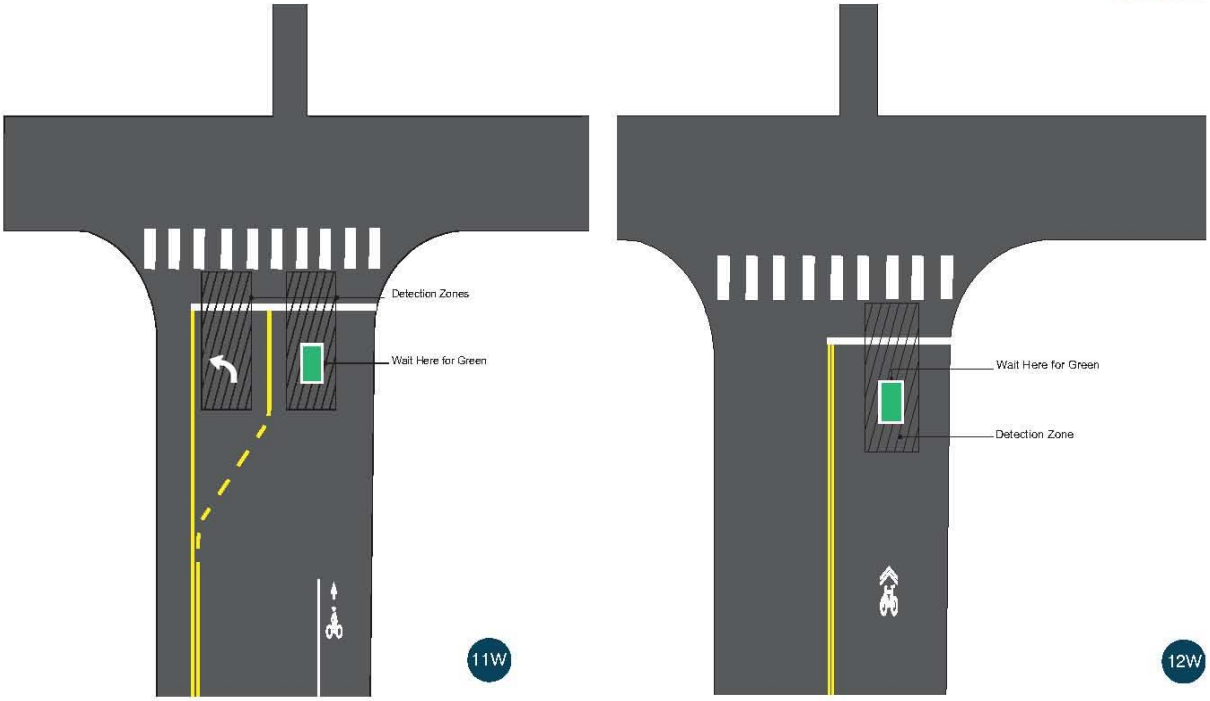
Trail to Trail - Case 1
Trail to Trail - Case 2



City of Columbia, Missouri

Bicycle Pavement Marking Symbols

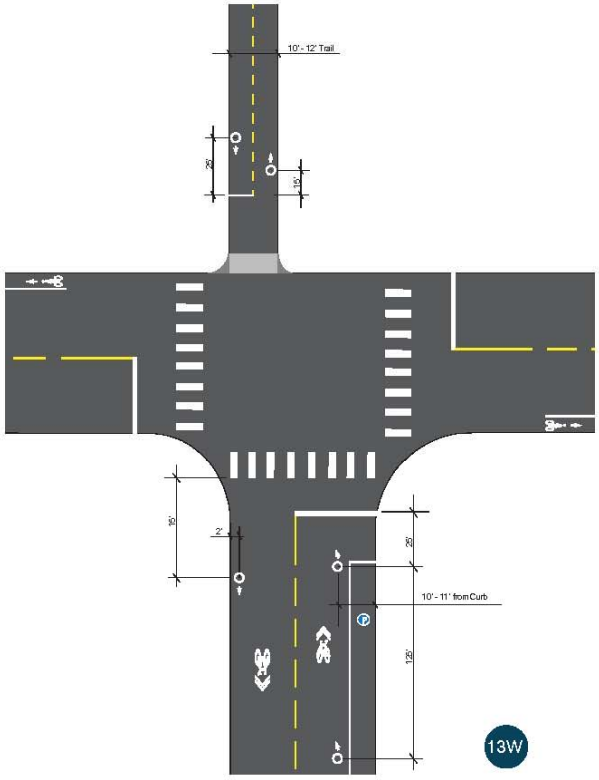
Road T to Trail - Detection Symbol
Arrow Placement Detection Symbol -C



City of Columbia, Missouri

Bicycle Pavement Marking Symbols

Arrow Placement Detection Symbol - A
Arrow Placement Detection Symbol - B

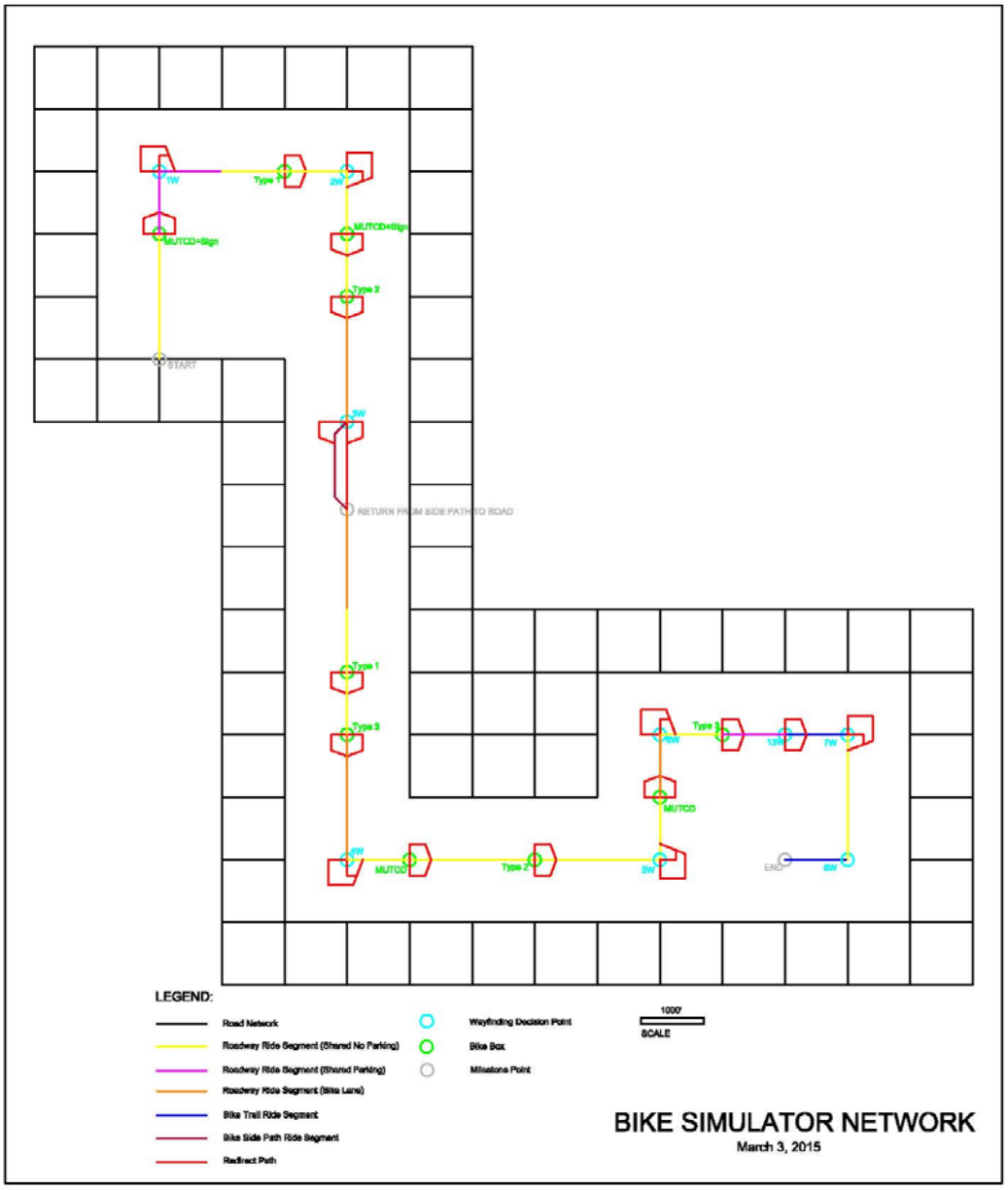


City of Columbia, Missouri

Bicycle Pavement Marking Symbols

Road T to Trail

Appendix B


1W
Type 1
2W
MUTCD+Sign
MUTCD+Sign
Type 2
START
3W
RETURN FROM SIDE PATH TO ROAD
Type 1
Type 2
4W
MUTCD
Type 2
5W
Type 3
6W
12W
7W
MUTCD
END
8W
LEGEND:
Road Network
Roadway Ride Segment (Shared No Parking)
Roadway Ride Segment (Shared Parking)
Roadway Ride Segment (Bike Lane)
Bike Trail Ride Segment
Bike Side Path Ride Segment
Redirect Path
Wayfinding Decision Point
Bike Box
Milestone Point
1000'
SCALE
BIKE SIMULATOR NETWORK
March 3, 2015