Technical Memorandum

To: Ted Curtis, *City of Columbia*

From: Paul Wojciechowski, *Alta Planning + Design*

Date: September 20, 2017

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

Executive Summary

The purpose of this study was to evaluate the effectiveness of three experimental bicycle detection pavement markings versus the existing MUTCD section 9C.05/Figure 9C-7 symbol. The initial phase of the RTE involved participants using the University of Missouri –Columbia's bicycle simulator to encounter the various options. A follow-up survey showed that 96% of the participants stated that Option A communicated the purpose of the symbol vs 19% for the MUTCD symbol. When asked to rank the markings based on preference, 85% selected Option 1 as first choice.

The second phase of the experiment was to field test Option A and survey Columbia residents on their interpretation, who were not given information on the purpose of the symbol, just the locations. 253 responses were received. When asked, 61% experienced problems activating a green light. Next the survey showed the MUTCD 9C-05 symbol and only 12% interpreted it "Bikes stop here for green light". Then they were shown Option A symbol and 87% interpreted it as "Bikes stop here for green light".

During this experiment, additional study was completed in Portland, OR that confirmed the preference for the "Columbia Experiment" preferred marking.

Because of the overwhelming preference for the experimental Option A symbol, it is recommended that FHWA give this symbol interim approval as the preferred bicycle actuator symbol over the existing 9C-05 symbol.

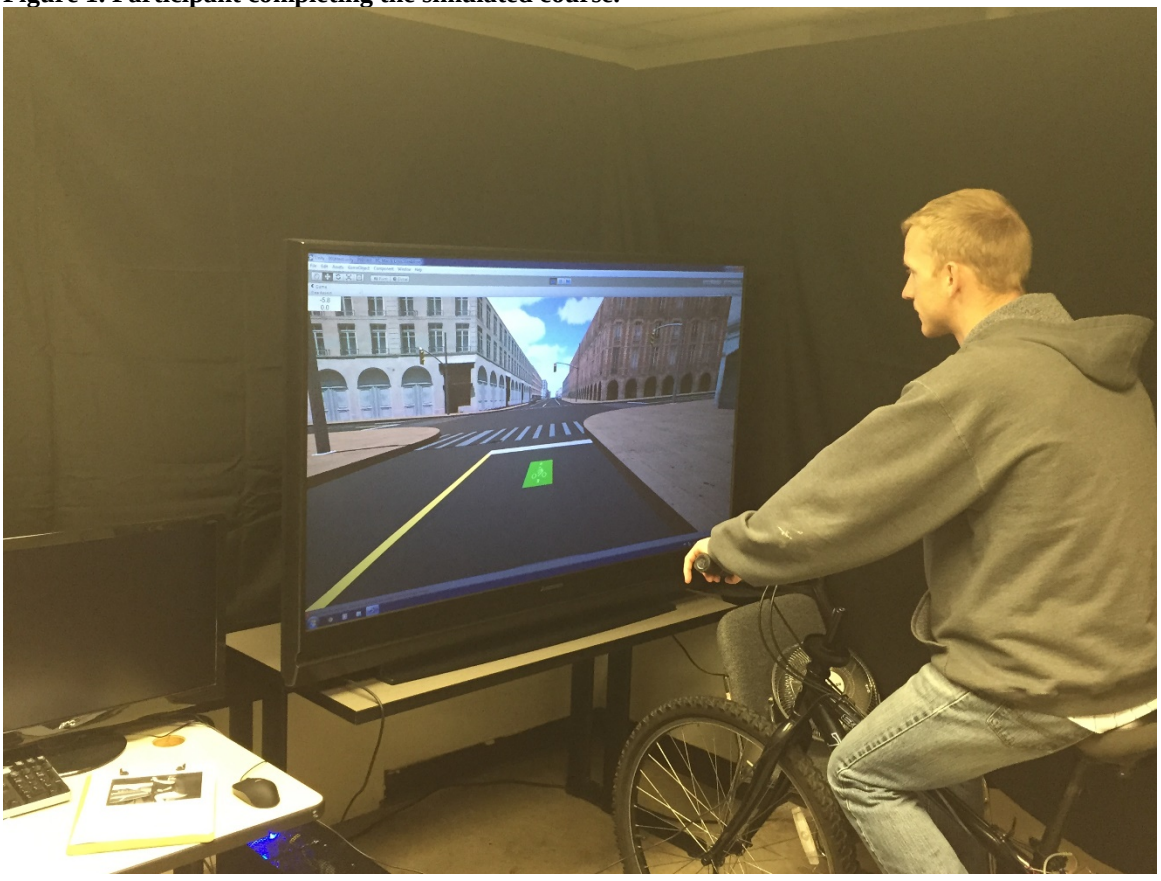
Introduction

Many bicyclists do not recognize, or understand, the MUTCD-approved bicycle detection pavement marking included in Section 9C.05 (Figure 9C-7) that is used to demarcate the location at an intersection where bicyclists should wait to activate a green signal phase. This lack of understanding means that bicyclists waiting at a signalized intersection often position themselves on the roadway where the loop detector will not detect them. This results in prolonged wait times for bicyclists, who then must wait for a vehicle to trigger the green signal phase or proceed through the

intersection against the red signal indication when it is clear of vehicles. Longer wait times also increase the likelihood that a bicyclist may illegally travel through the intersection without a green phase. This assertion is supported by research from Portland State University[1], which indicates that only 23.5% of bicyclists position themselves correctly when only the 9C-05 pavement marking is present; this increases to just 34.8% when accompanied by the optional R10-22 sign. The experimental markings tested here aim to more effectively communicate the purpose of the marking in order to improve bicyclist position within the lane at signalized intersections.

This memorandum documents the evaluation of experimental bicycle detection pavement markings tested through a bicycle simulation at the University Missouri-Columbia's ZooSim testing lab and accompanying participant survey, as well as during a field survey of resulting preferred markings on several streets in the City of Columbia. An example of the simulator testing can be found in Figure 1 below. The symbols tested utilize a combination of color markings, words, and bounding boxes, in addition to the MUTCD 9C-05 marking. Symbols for experimentation were selected based on feedback received from active transportation professionals and a group of non-professionals who regularly commute by bicycle.

Figure 1. Participant completing the simulated course.



[1] Bussey, Stefan W. "The Effect of the Bicycle Detector and R10-22 Sign on Cyclist Queuing Position at Signalized Intersections." 2013.

Simulator Testing Methodology

Assessment of the pavement markings was completed utilizing two tools: a simulated bicycle route and a subjective user survey following the simulated route. The simulation guided each participant through an identical route, during which they encountered 10 unique intersections. The drawings used for the bike simulator are provided in **Appendix A**. **Appendix B** exhibits the coded network that was used during the simulation. Pavement markings were randomly distributed along the route and included the following:

Option A: Type 1 proposed pavement marking
Option B: Type 2 proposed pavement marking
Option C: Type 3 proposed pavement marking (MUTCD 9C-05 on top of a green rectangle)
Option D: MUTCD 9C-05 pavement marking
Option D + Sign: MUTCD 9C-05 pavement marking plus complementary R10-22 sign

The pavement markings tested are shown below, along with the MUTCD 9C-05 pavement marking and R10-22 sign on the next page.

Figure 2. Option A - Type 1 proposed pavement marking.

Figure 3: Option B - Type 2 proposed pavement marking.

Figure 4. Option C: Type 3 proposed pavement marking.

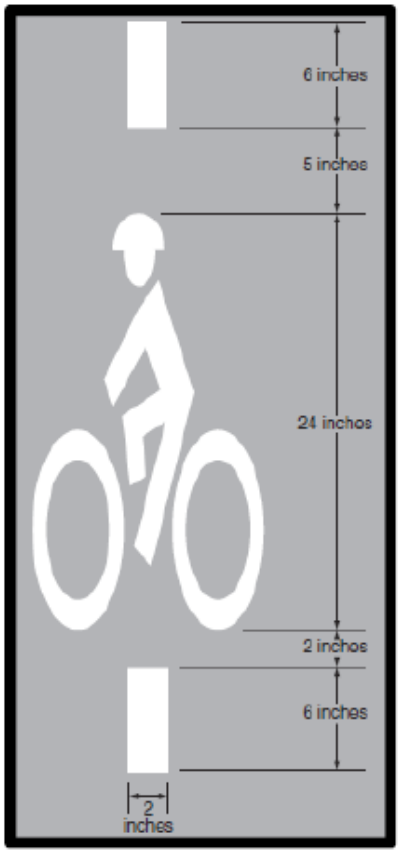


Figure 5. Option D: MUTCD 9C-05 pavement marking.

Figure 6. Option D + Sign: MUTCD complementary R10-22 sign.

The simulation tests were conducted in the University of Missouri – Columbia's vehicle simulator. Altered to accommodate a bicycle, the simulator included the use of a bicycle on a trainer and a large screen. 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 stand, the simulator framework better replicated the position of the bicyclist on the roadway.

Video footage of each participant was then reviewed to assess the bicyclists' positioning relative to the marking. Two specific measures of effectiveness were considered for each condition:

1) **Number of missed detections.** For each participant, missed detections for each marking were counted. A missed marking reflects an improper positioning of the bicycle relative to the pavement marking.
2) **Elapsed waiting time at signal.** For each participant, the total time spent waiting for the green light cycle was calculated. This captures improper positioning that does not result in a missed detection. Examples include a participant who incorrectly positions the bicycle at the marking but adjusts to initiate the green light cycle prior to the cycle timing out.

The web-based survey gathered information regarding participants' current bicycle use, including frequency, trip purpose, and facility preference. Additional questions solicited feedback regarding the visibility, clarity, and preference for the experimental markings in comparison to the existing MUTCD

marking. The survey was administered through Survey Monkey and followed the simulated route activity.

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.

Simulator Testing Results

Video review of the simulator test runs assessed the positioning of the bicyclist in relation to the loop detector. The average number of missed detections, meaning the bicyclist was not detected at the intersection in order to initiate the green light cycle, was counted, as well as the average waiting time at the signal. The number of missed detections indicates that the participant did not effectively position the bicycle within the lane to initiate the green light cycle. The average waiting time at the signal captures those who positioned correctly during the light cycle but may not have established correct placement when first arriving at the intersection.

This preliminary testing indicates that Options A and B are more effective at communicating the purpose of the symbol. The measures of effectiveness did not clearly identified a preferred symbol between Option A and Option B.

Simulator Survey Results

Thirty 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. Appendix C provides results of the survey responses.

Participants were asked to rate the visibility, effectiveness of communication, and clarity of the four markings listed below. In general, all markings scored well, with the exception of the existing MUTCD (9C-05) marking. Option A scored the best in all three measures, with at least 90% of participants indicating that the marking was visible, effective at communicating the purpose of the marking, and clear as to where a bicycle should be positioned.

	OPTION A	OPTION B	OPTION C	OPTION D
				
Symbol is visible	92.31%	69.23%	84.62%	44.0%
Symbol effective communicates purpose	96.15%	92.31%	50.0%	19.23%
Symbol is clear	92.31%	92.31%	46.15%	30.77%

Option B performed similarly to Option A, although fewer participants agreed that the marking was clear. Option C, while visible, was not effective at communicating the purpose of the marking, nor was it clear where a bicycle should be positioned within the lane. Participants primarily did not agree that Option D (MUTCD 9C-05) was visible, effective at communication, or clear. In fact, only 19% of participants indicated that the marking effectively communicated its purpose.

When asked to rank the markings based on preference, Option A received support from 85% of participants. Option B was ranked second by 58% of participants; Option C was ranked third by 65.4% of participants; and Option D was ranked last by 96.2% of participants.

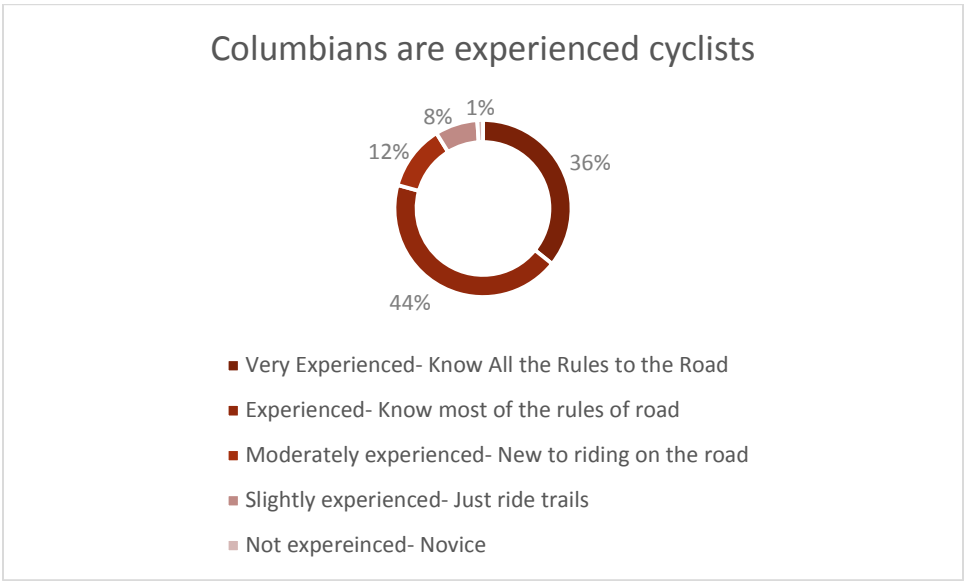
Pavement Marking	Ranking 1	Ranking 2	Ranking 3	Ranking 4	Average Ranking
Option A	22	4	0	0	1.15
Option B	2	15	9	0	2.27
Option C	2	6	17	1	2.65
Option D	0	1	0	25	3.92

Open-ended responses indicated support for the use of green markings and preference for text to further clarify the marking. In order to confirm these findings a Field Survey was conducted using Option A as the preferred signal actuator marking.

Field Installation and Field Survey Results

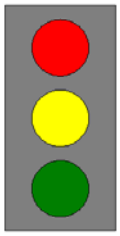
Based on the results of the simulator tests, Option A symbols were installed at four intersections and the public was asked to bike or drive through the intersections and then take a follow up survey about the new symbols there. The public was not informed as to the purpose of the symbols.

Two hundred and fifty three responses were collected the Field Survey of the signal actuator markings in Columbia, Missouri from April to July 2017. Appendix D provided the field test survey form and results of the survey. The survey asked on what mode people traveled through the intersections on Garth Avenue and West Boulevard including how often, where they traveled, as well as gauged people's understanding about signal actuator markings. Ninety-two percent of the respondents were Columbians and half of them bike once a week. Columbians are experienced cyclists, with 91 percent of them claiming moderate to very experienced in their knowledge of rules of the road.



Seventy-one percent of respondents ride their bikes for exercise or recreation. Over half of the respondents use both trails and streets for biking. The response from Columbians when asked about their experience activating a green light, 83 percent, have problems activating the green light.

How often do you experience problems when activating a green light?



38% Always or Often

45% Sometimes

20% Rarely

Eighty- one percent of survey respondents were unclear how to interpret the MUTCD 9C.05 signal actuator markings. When the Option A marking was presented, 97 percent of survey respondents correctly interpreted the "bikes wait here" proposed bike marking. The proposed bike marking alternative was favored by 90 percent of survey respondents for its visibility and effectiveness in communicating the purpose of the marking.

Discussion

Building off of the 2003 study from Portland State University, findings in the above survey and simulated route are consistent with the study's conclusion that existing MUTCD detector markings often do not clearly communicate the purpose of the marking. In the 2003 study, the addition of a green background to the symbol (Option C) improved use and understanding somewhat, which was also demonstrated in this experiment.

The use of a simulated route was an efficient method for testing several options for alternative detection pavement markings. Although some participants indicated that it did not mimic the feeling of riding on the roadway, the majority agreed that it felt similar to riding a bicycle. The simulated route resulted in similar performance metrics for both Option A and Option B; however, the survey stratified these results and showed greater preference for Option A due to its greater visibility. In field testing the preferred marking validated the findings of the simulated route and provided for additional data for the effectiveness of the symbol. The field test respondents overwhelmingly choose the proposed signal marking as the best detector marking for respondents for its visibility and effectiveness in communicating the purpose of the marking.

Support of this conclusion is supported by an abstract was developed by the City of Portland in July of 2015, for a Transportation Research Board publication at the 95th Annual Meeting of TRB regarding "Improving the Bicycle Detection Pavement Markings Symbols to Increase Comprehension at Traffic Signals".

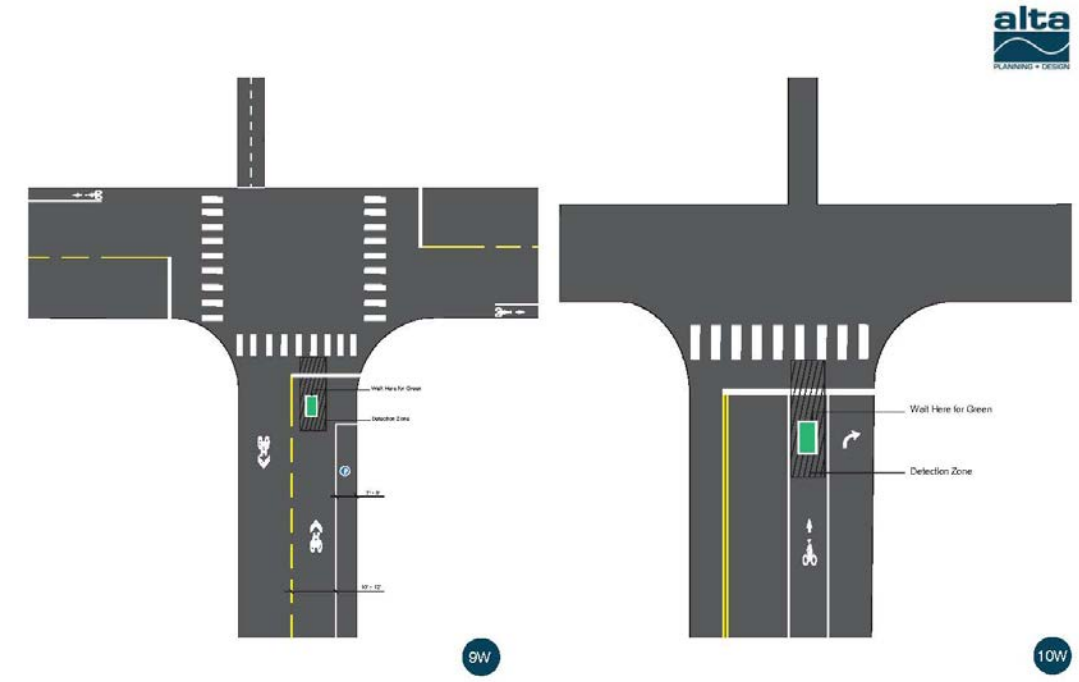
From: IMPROVING THE BICYCLE DETECTION PAVEMENT MARKING SYMBOLS TO INCREASE COMPREHENSON AT TRAFFIC SIGNALS Boudart, et all, City of Portland OR, submitted to the January 2016 TRB.
Page 11:
"After selecting the meaning for each marking individually, respondents were shown a figure containing the five detection markings and were asked to rank how well the markings perform in communicating the location where a bicyclist should be stopped in order for a signal to detect it. Respondents were asked to rank the best three and only to rank a marking if they thought it was helpful… The results of this ranking exercise are similar to the responses to the individual markings. The Columbia Experiment marking received the greatest number of best (i.e. 1) rankings, with about half of respondents indicating that they think it did the best job of communicating the intended message".

Conclusion

The experimental markings resulted in improved positioning relative to the detection marking. All experimental markings performed much better than the 9C.05 pavement marking. Participants missed fewer detection cycles during the simulated route when encountering the experimental marking Option A or Option B. Overall opinion expressed by participants indicates preference for a symbol with color, symbols, and words that communicates where to position themselves to activate the green signal.

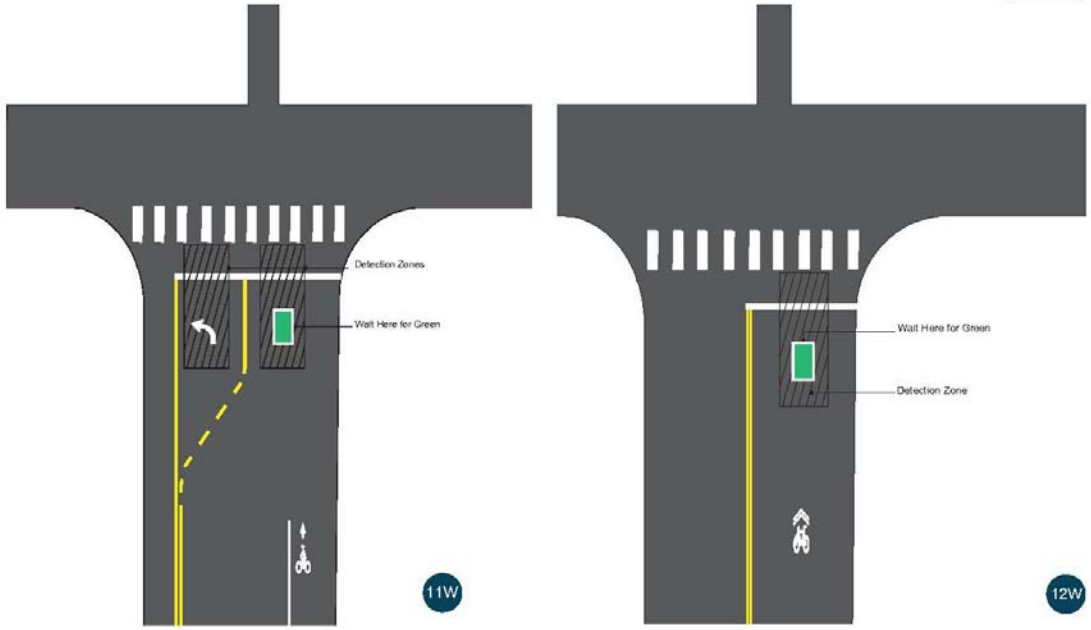
Field testing of Option A in intersections in Columbia, Missouri represented a variety of intersection contexts with data related to the effectiveness of this marking. The experimental markings resulted in improved positioning relative to the detection marking. The proposed marking, Option A, should be used as the preferred signal detection marking as opposed to the existing MUTCD 9C.05 symbol.

Appendix A – Bike Simulator Marking Location Graphics



City of Columbia, Missouri
Bicycle Pavement Marking Symbols

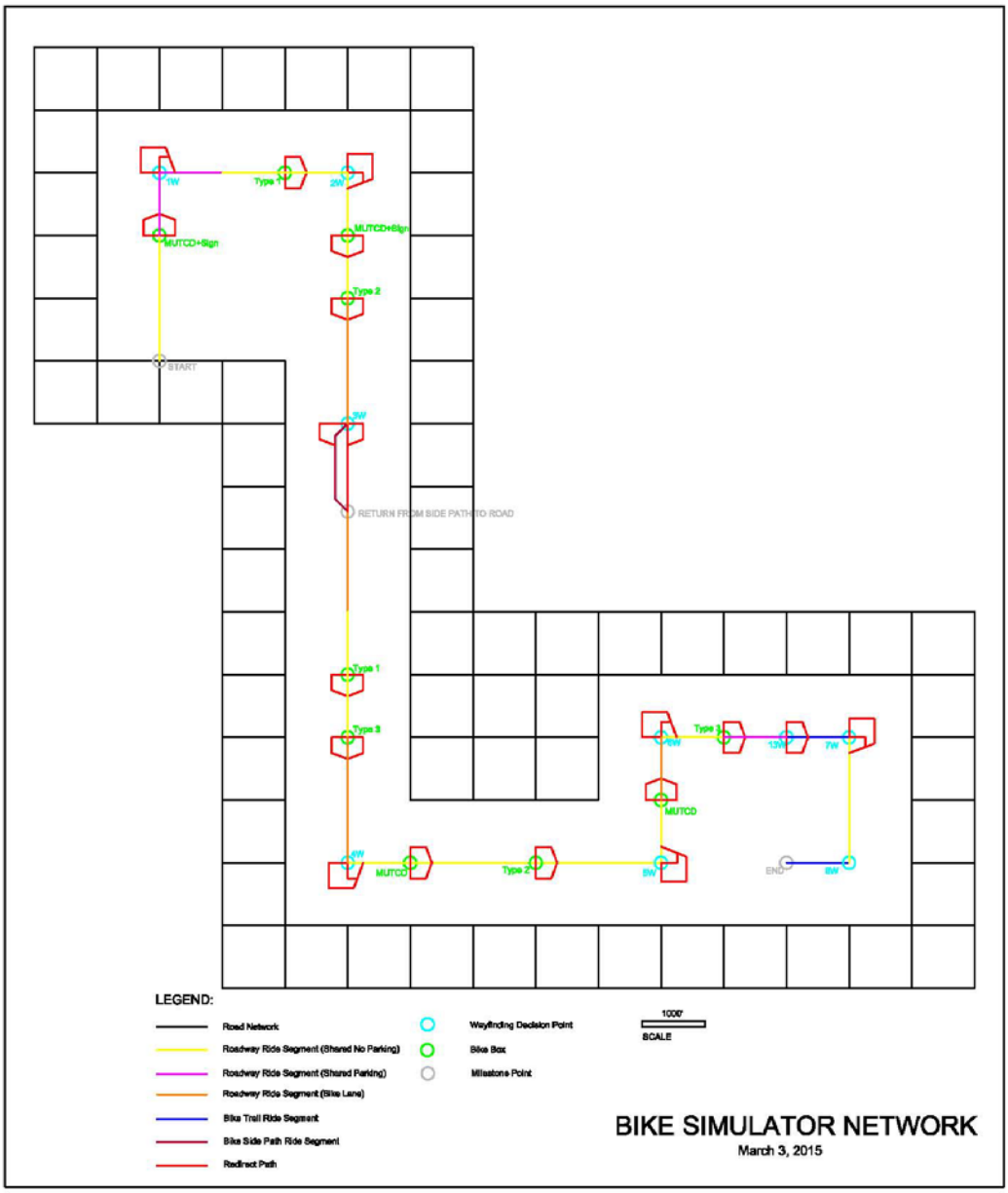
Road T to Trail - Detection Symbol



City of Columbia, Missouri
Bicycle Pavement Marking Symbols

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

Appendix B


1W
Type 1
2W
MUTCD+Sign
MUTCD+Sign
Type 2
START
3W
RETURN FROM SIDE PATH TO ROAD
Type 1
Type 3
6W
Type 3
12W
7W
MUTCD
6W
MUTCD
Type 2
8W
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

Appendix C

Bike Simulator Survey and Results

Bicycle Detection and Route Marking Survey

This survey will assist the City of Columbia to better understand bicyclist preferences for bicycle pavement markings. Thank you for your willingness to help improve bicycle facilities in the City.

1. Are you a resident of the City of Columbia?

- ◯ Yes
- ◯ No

2. How many times a week do you bicycle?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5+

3. Do you commute by bicycle to work or school?

- ◯ Yes
- ◯ No

4. Do you ride a bicycle for non-work trips or recreation?

- ◯ Yes
- ◯ No

5. If you commute, how many times per week?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5+

6. What is the average duration of your bicycle commute to work or school?

- ◯ 0-5 minutes
- ◯ 5-10 minutes
- ◯ 10-15 minutes
- ◯ 15-30 minutes
- ◯ 30+ minutes

7. If you ride for recreation or non-work trips, how many times per week?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5+

8. What is the average duration of your recreation or non-work bicycle trips?

- ◯ 0-5 minutes
- ◯ 5-10 minutes
- ◯ 10-15 minutes
- ◯ 15-30 minutes
- ◯ 30+ minutes

9. During your bicycle trips, what type of facilities do you ride on?

- ◯ Trails Only
- ◯ Streets Only
- ◯ Trails and Streets

Next

Bicycle Detection and Route Marking Survey

Bicycle Detection Markings

10. What is the typical number of signalized intersections that you encounter on a bicycle ride?

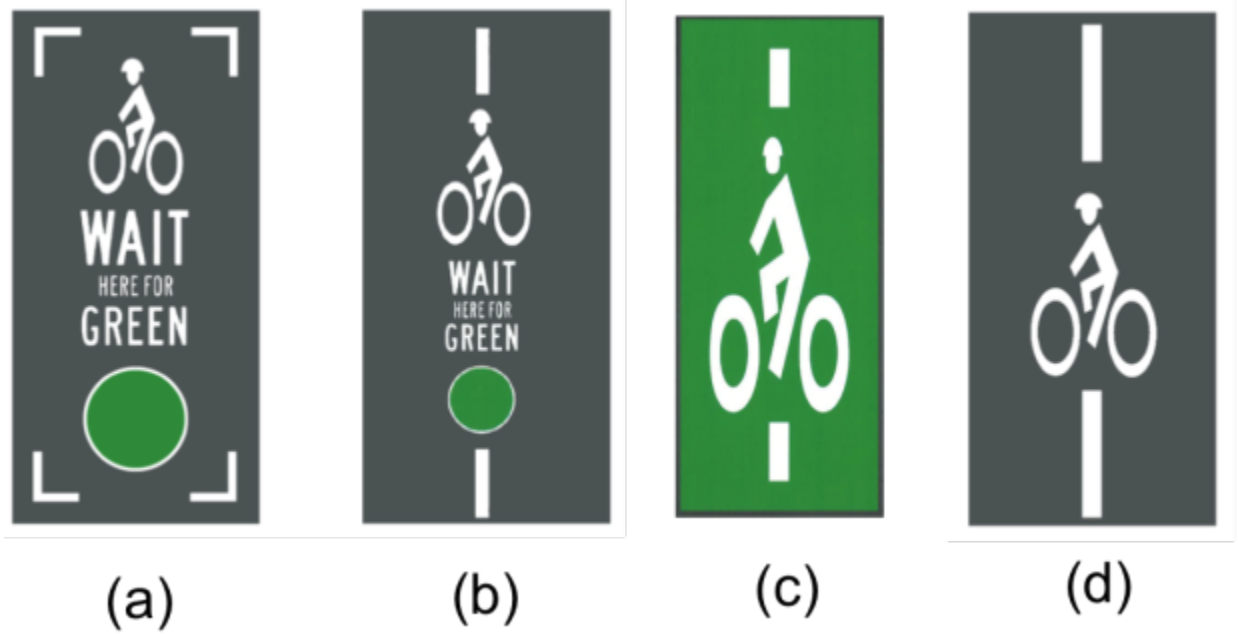
- 0
- 1-2
- 3-5
- 6-10
- 10+

11. While waiting at a signal, how frequently do you have problems with getting a green light at a signalized intersection while riding a bicycle?

- Very infrequently
- Infrequently
- Neutral
- Frequently
- Very frequently

For questions 11 through 15, refer to Figure 1 below. Each graphic in the Figure represents a type of pavement marking. These markings are intended to assist a rider in knowing where to place themselves so that they can obtain a green light.

Figure 1- Bicycle Detection Markings



12. These markings are highly visible.

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
(a)	○	○	○	○	○
(b)	○	○	○	○	○
(c)	○	○	○	○	○
(d)	○	○	○	○	○

13. These markings are effective at communicating to me that I need to place my bicycle on the marking to obtain a green light at the traffic signal

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
(a)	○	○	○	○	○
(b)	○	○	○	○	○
(c)	○	○	○	○	○
(d)	○	○	○	○	○

14. The area of the pavement where I need to locate my bicycle to activate the green signal is clear with this marking

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
(a)	○	○	○	○	○
(b)	○	○	○	○	○
(c)	○	○	○	○	○
(d)	○	○	○	○	○

15. Please rank these markings (1 to 4) to indicate your order of preference

- [ ] (a)
- [ ] (b)
- [ ] (c)
- [ ] (d)

16. Please enter any additional comments you may have regarding bicycle detection markings.

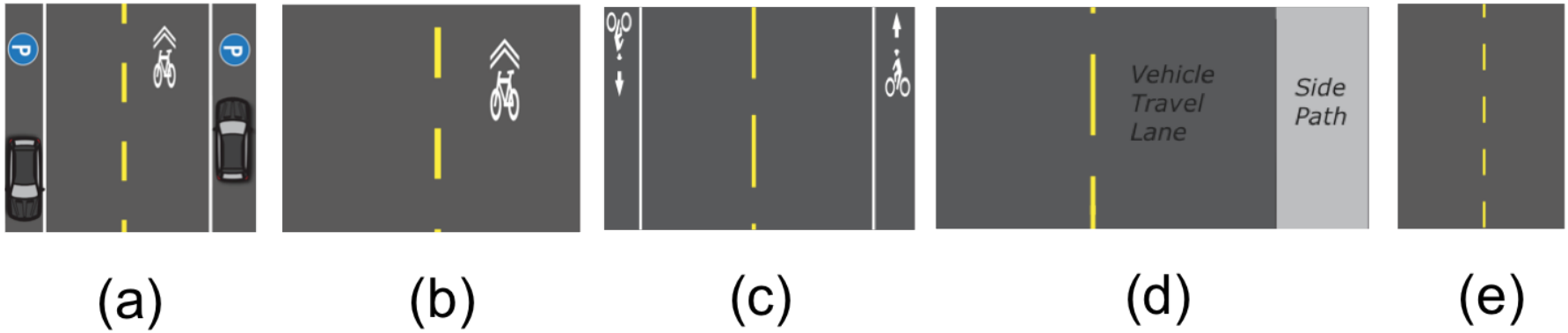
Bicycle Detection and Route Marking Survey

Wayfinding Markings

17. Refer to Figure 2. When you ride, how often do you encounter the following types of facilities?

	More than once per day	Daily	Weekly	Monthly	Rarely	Never
Road on shared lane with parking	○	○	○	○	○	○
Road on shared lane without parking	○	○	○	○	○	○
Road with bicycle lane	○	○	○	○	○	○
Side path	○	○	○	○	○	○
Shared use path	○	○	○	○	○	○

Figure 2- Bicycle Facility Types



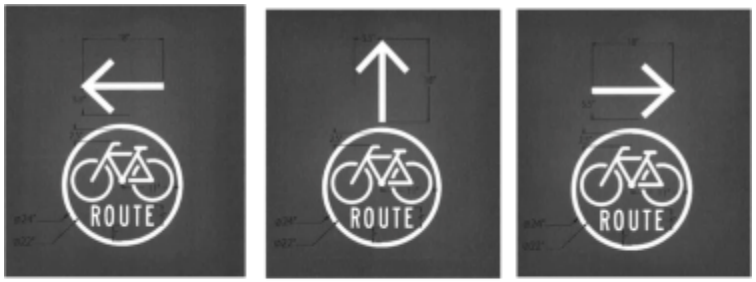
(a) Shared lane with parking
(b) Shared lane no parking
(c) Bike lane
(d) Side trail
(e) Bike trail

18. The existing markings and signs on the bicycle routes that I travel are effective in delineating the bicycle route.

- Strongly disagree
- Somewhat disagree
- Neutral
- Somewhat agree
- Strongly agree

For questions 18 through 21, refer to Figure 3 below which shows different type of pavement markings used for wayfinding on a bicycle route.

Figure 3 Wayfinding Markings



(a)

(b)

19. These markings are highly visible.

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
(a)	○	○	○	○	○
(b)	○	○	○	○	○

20. These markings clearly indicate the direction of the bicycle route

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
(a)	○	○	○	○	○
(b)	○	○	○	○	○

21. Which of these markings ((a) or (b)) do you prefer

- ○ (a)
- ○ (b)

22. Please enter any general comments you may have about wayfinding markings and other comments.

Prev Next

Bicycle Detection and Route Marking Survey

23. Please select your age group from the list below

- ◯ 0-18 years old
- ◯ 19-30 years old
- ◯ 31-40 years old
- ◯ 41-50 years old
- ◯ 51+ years old

24. Please select your gender

- ◯ Male
- ◯ Female

25. I felt like I was actually riding a bike.

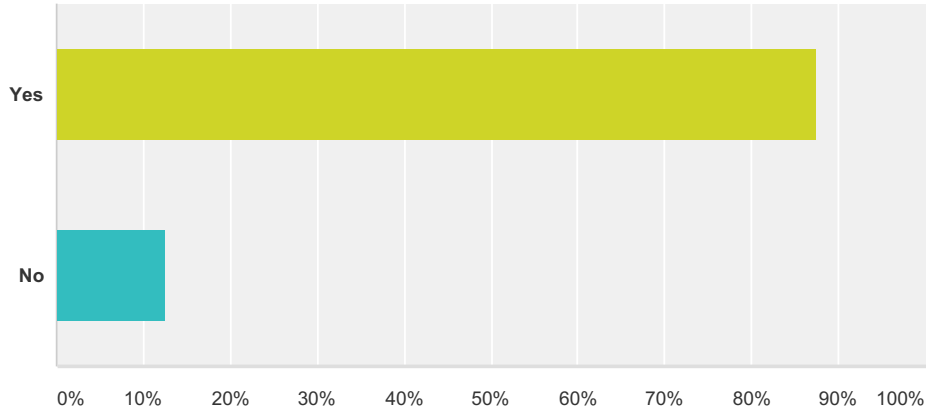
- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neutral
- ◯ Somewhat agree
- ◯ Strongly agree

Please contact Henry Brown at brownhen@missouri.edu if you have any questions or concerns regarding this survey. Thank you for your participation.

Prev Done

Q1 Are you a resident of the City of Columbia?

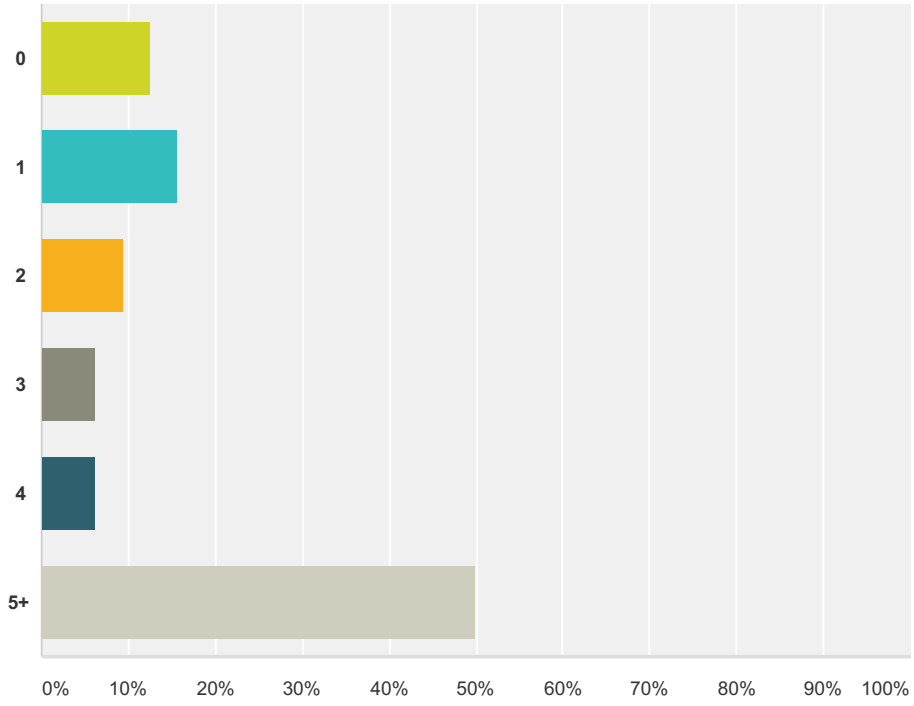
Answered: 32 Skipped: 1



Answer Choices	Responses	
Yes	**87.50%**	28
No	**12.50%**	4
Total		**32**

Q2 How many times a week do you bicycle?

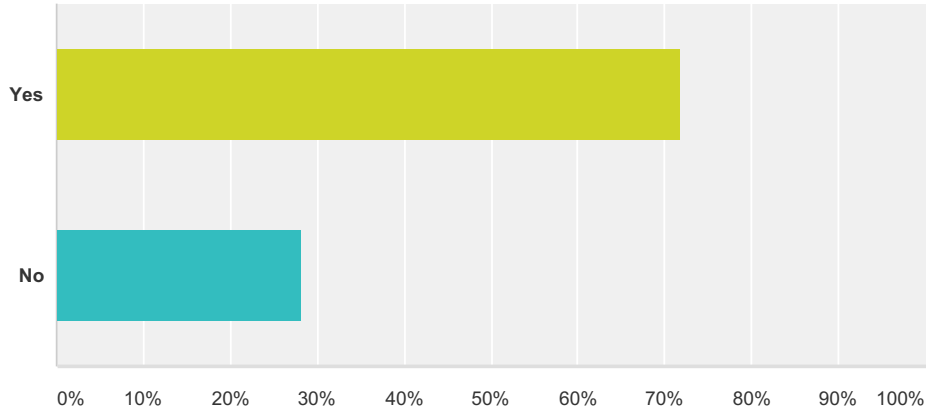
Answered: 32 Skipped: 1



Answer Choices	Responses	
0	12.50%	4
1	15.63%	5
2	9.38%	3
3	6.25%	2
4	6.25%	2
5+	50.00%	16
Total		32

Q3 Do you commute by bicycle to work or school?

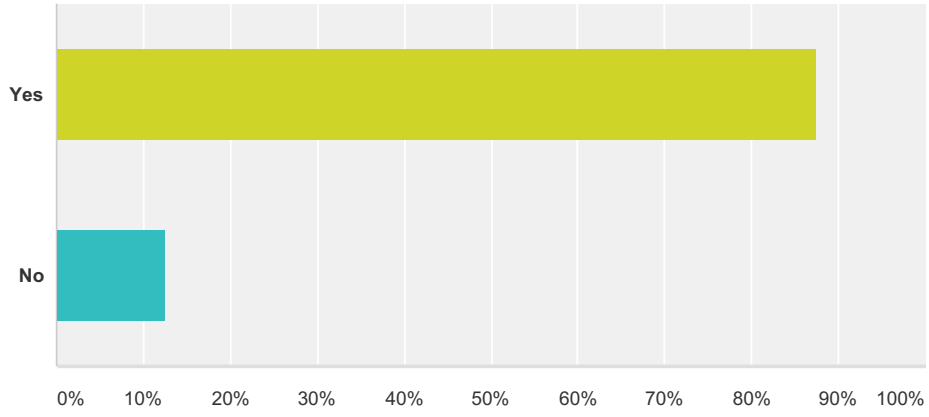
Answered: 32 Skipped: 1



Answer Choices	Responses	
Yes	**71.88%**	23
No	**28.13%**	9
Total		**32**

Q4 Do you ride a bicycle for non-work trips or recreation?

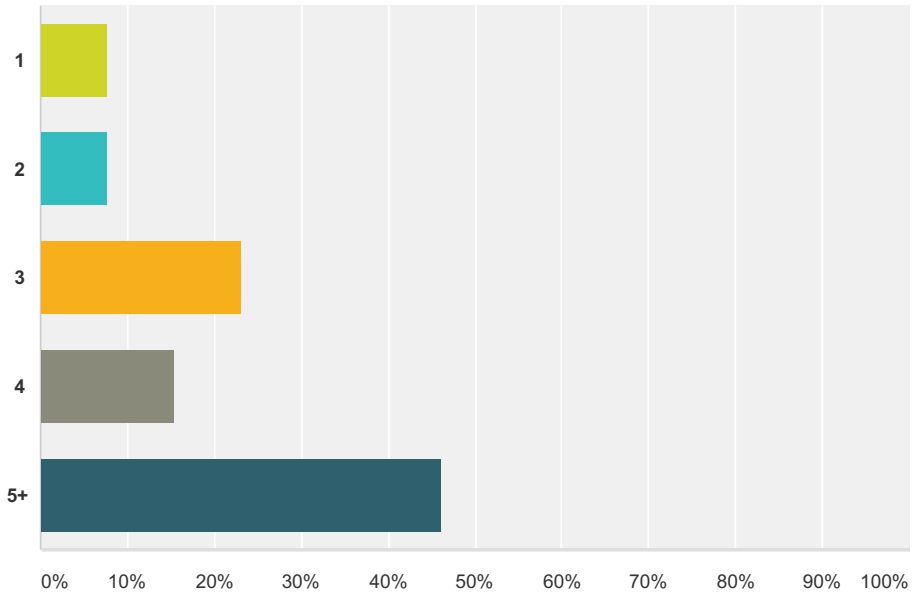
Answered: 32 Skipped: 1



Answer Choices	Responses	
Yes	**87.50%**	28
No	**12.50%**	4
Total		**32**

Q5 If you commute, how many times per week?

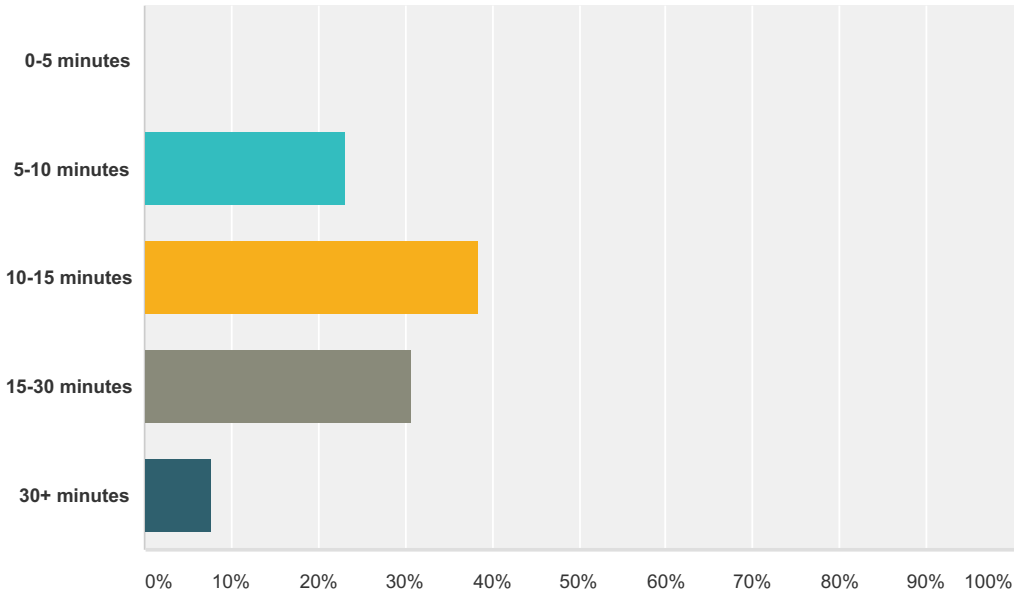
Answered: 26 Skipped: 7



Answer Choices	Responses	
1	**7.69%**	2
2	**7.69%**	2
3	**23.08%**	6
4	**15.38%**	4
5+	**46.15%**	12
Total		**26**

Q6 What is the average duration of your bicycle commute to work or school?

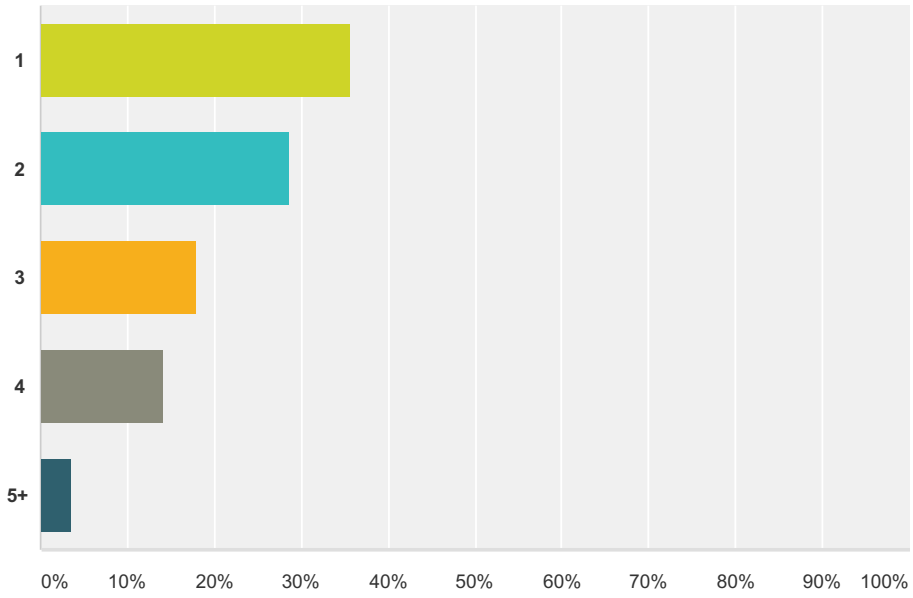
Answered: 26 Skipped: 7



Answer Choices	Responses	
0-5 minutes	**0.00%**	0
5-10 minutes	**23.08%**	6
10-15 minutes	**38.46%**	10
15-30 minutes	**30.77%**	8
30+ minutes	**7.69%**	2
Total		**26**

Q7 If you ride for recreation or non-work trips, how many times per week?

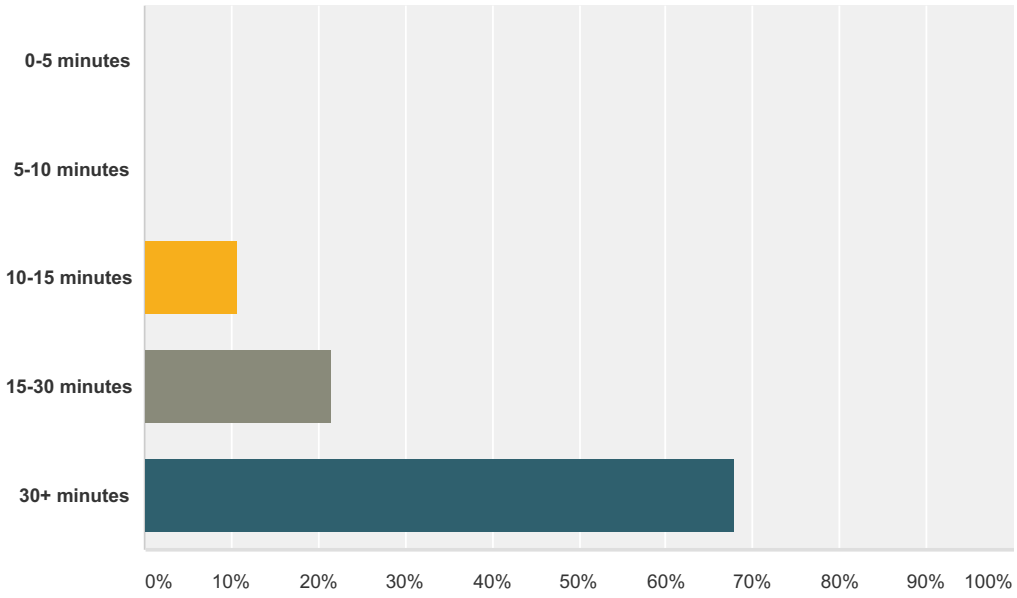
Answered: 28 Skipped: 5



Answer Choices	Responses	
1	**35.71%**	10
2	**28.57%**	8
3	**17.86%**	5
4	**14.29%**	4
5+	**3.57%**	1
Total		**28**

Q8 What is the average duration of your recreation or non-work bicycle trips?

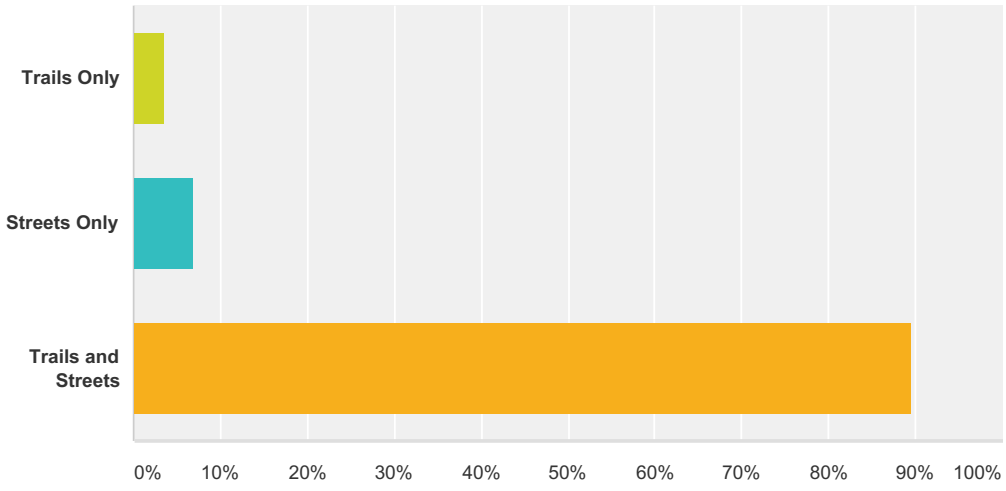
Answered: 28 Skipped: 5



Answer Choices	Responses	
0-5 minutes	**0.00%**	0
5-10 minutes	**0.00%**	0
10-15 minutes	**10.71%**	3
15-30 minutes	**21.43%**	6
30+ minutes	**67.86%**	19
Total		**28**

Q9 During your bicycle trips, what type of facilities do you ride on?

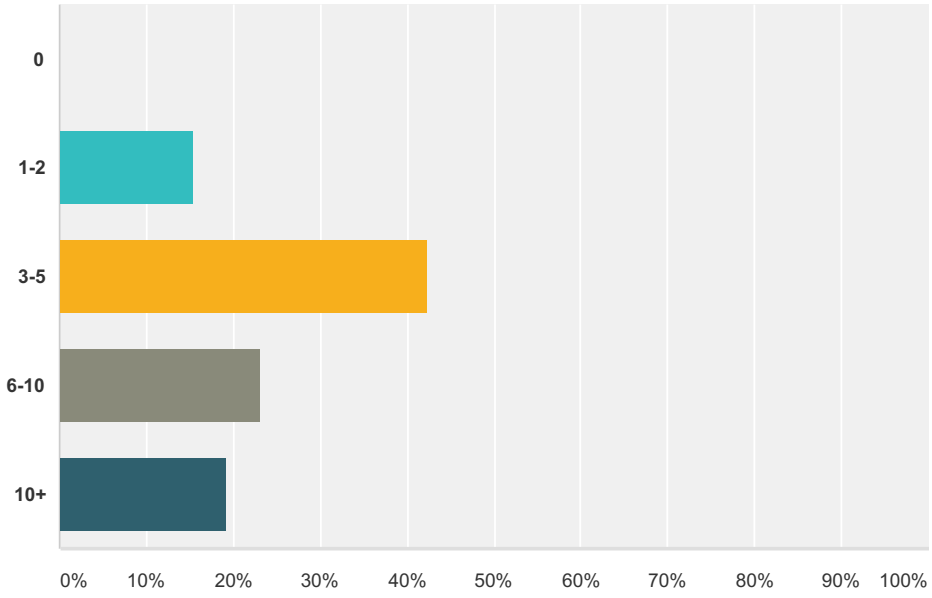
Answered: 29 Skipped: 4



Answer Choices	Responses	
Trails Only	**3.45%**	1
Streets Only	**6.90%**	2
Trails and Streets	**89.66%**	26
Total		**29**

Q10 What is the typical number of signalized intersections that you encounter on a bicycle ride?

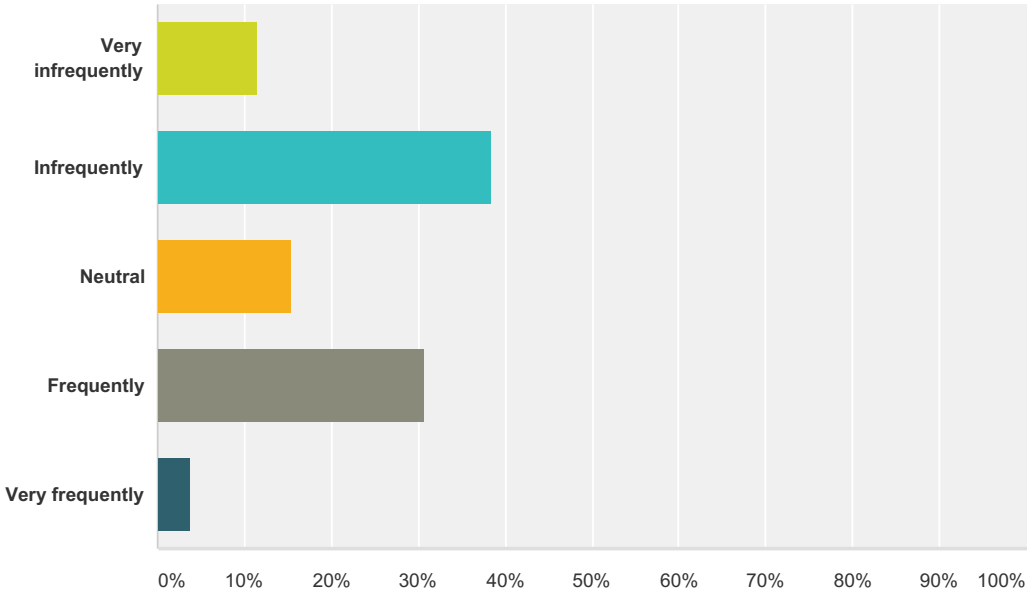
Answered: 26 Skipped: 7



Answer Choices	Responses	
0	**0.00%**	0
1-2	**15.38%**	4
3-5	**42.31%**	11
6-10	**23.08%**	6
10+	**19.23%**	5
Total		**26**

Q11 While waiting at a signal, how frequently do you have problems with getting a green light at a signalized intersection while riding a bicycle?

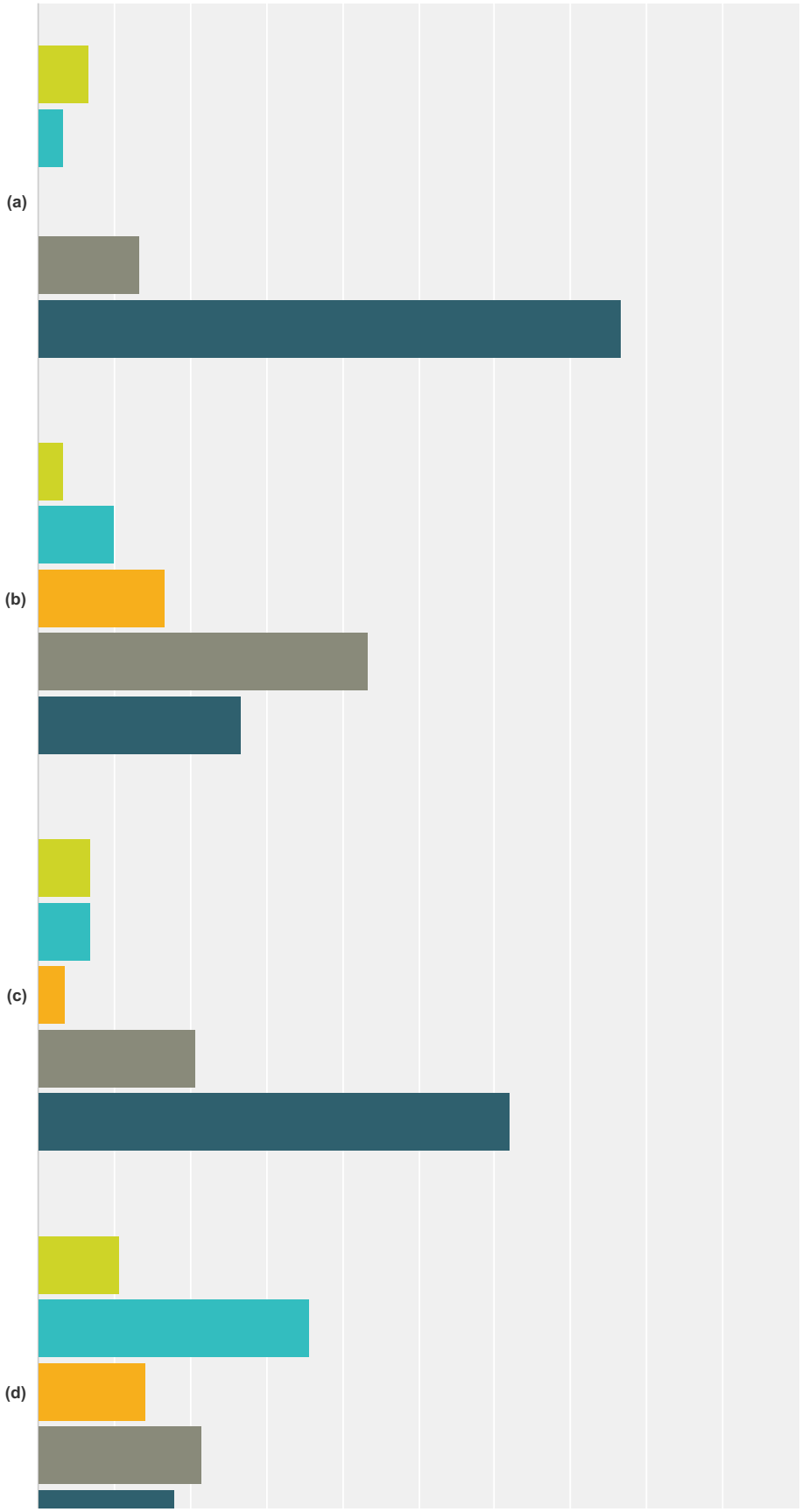
Answered: 26 Skipped: 7

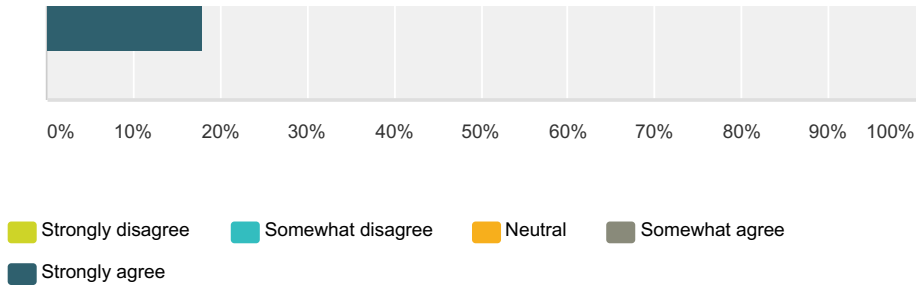


Answer Choices	Responses	
Very infrequently	**11.54%**	3
Infrequently	**38.46%**	10
Neutral	**15.38%**	4
Frequently	**30.77%**	8
Very frequently	**3.85%**	1
Total		**26**

Q12 These markings are highly visible.

Answered: 30 Skipped: 3

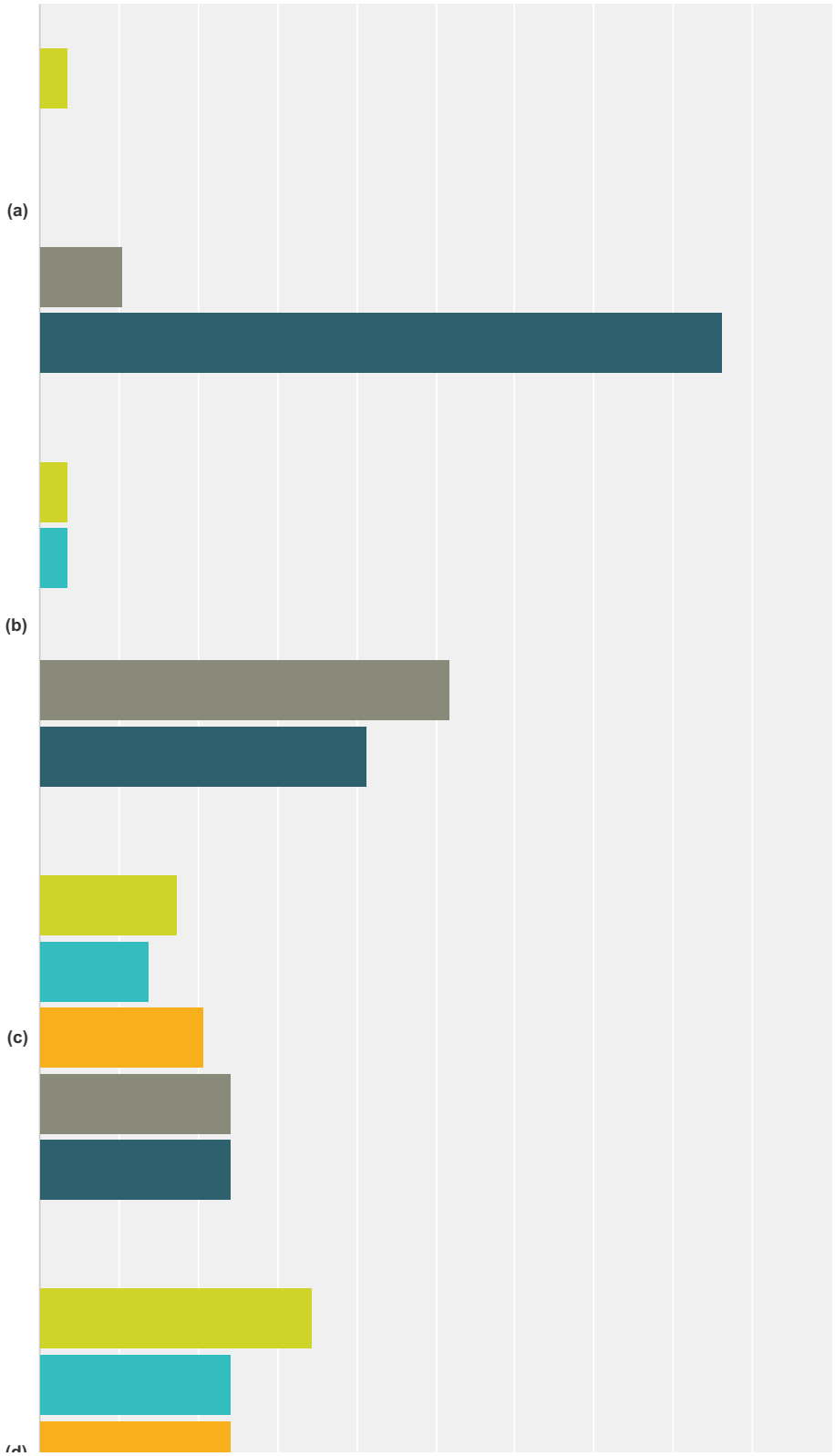


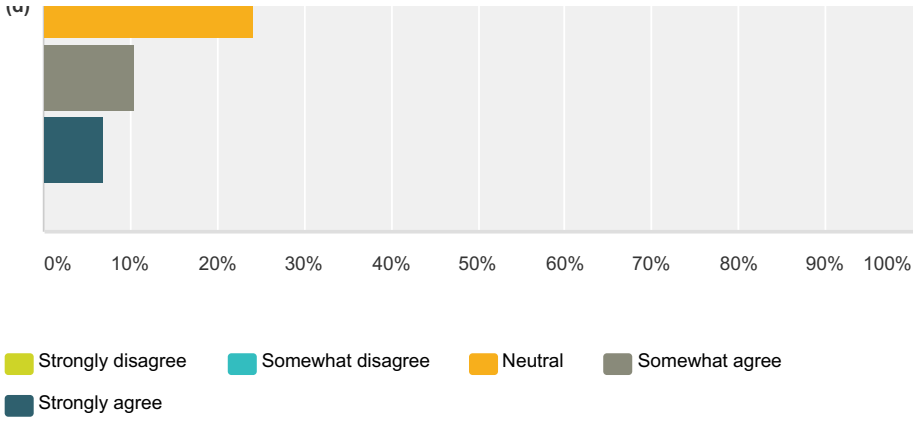


	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Total
(a)	**6.67%** 2	**3.33%** 1	**0.00%** 0	**13.33%** 4	**76.67%** 23	30
(b)	**3.33%** 1	**10.00%** 3	**16.67%** 5	**43.33%** 13	**26.67%** 8	30
(c)	**6.90%** 2	**6.90%** 2	**3.45%** 1	**20.69%** 6	**62.07%** 18	29
(d)	**10.71%** 3	**35.71%** 10	**14.29%** 4	**21.43%** 6	**17.86%** 5	28

Q13 These markings are effective at communicating to me that I need to place my bicycle on the marking to obtain a green light at the traffic signal

Answered: 29 Skipped: 4

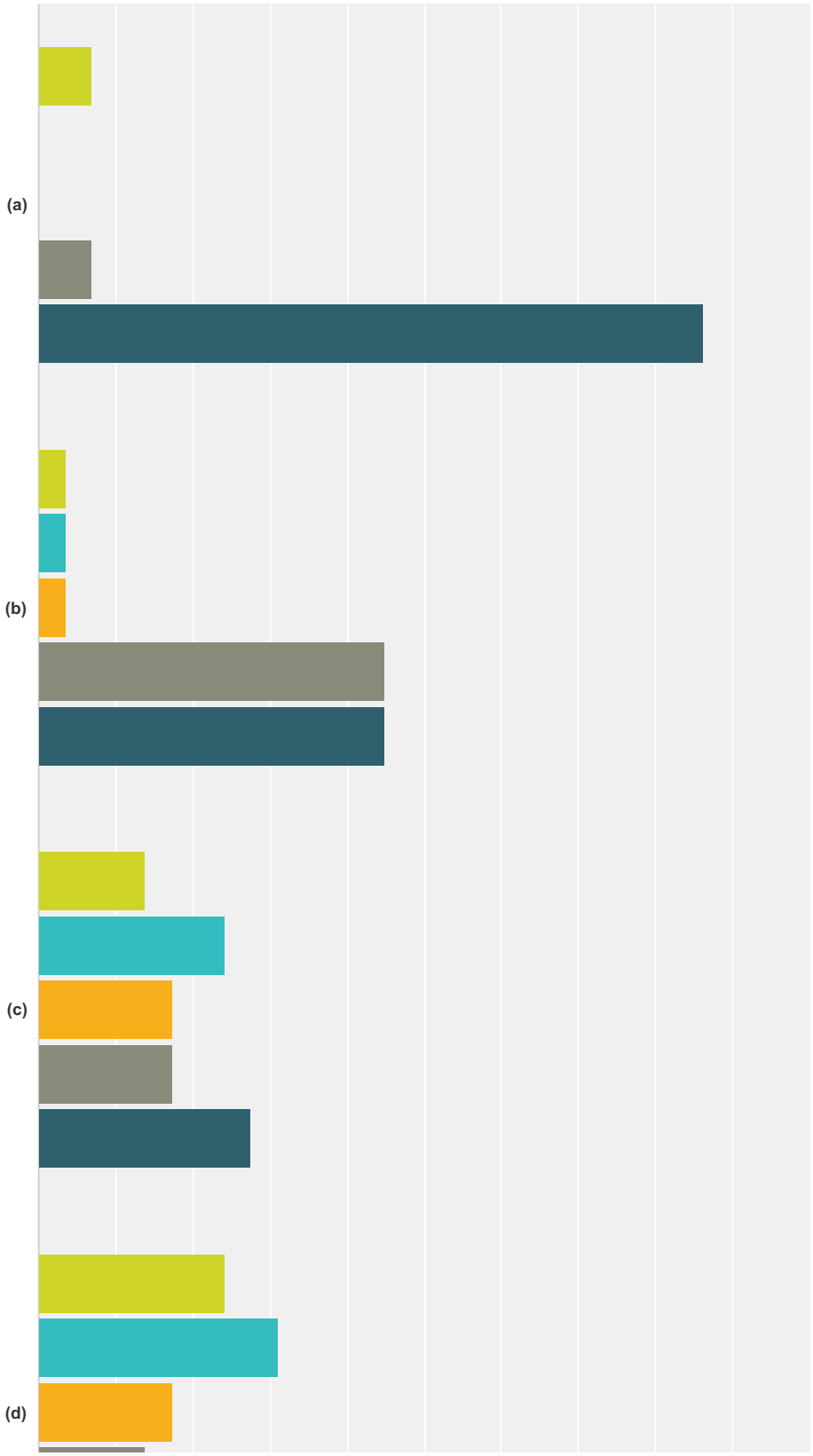


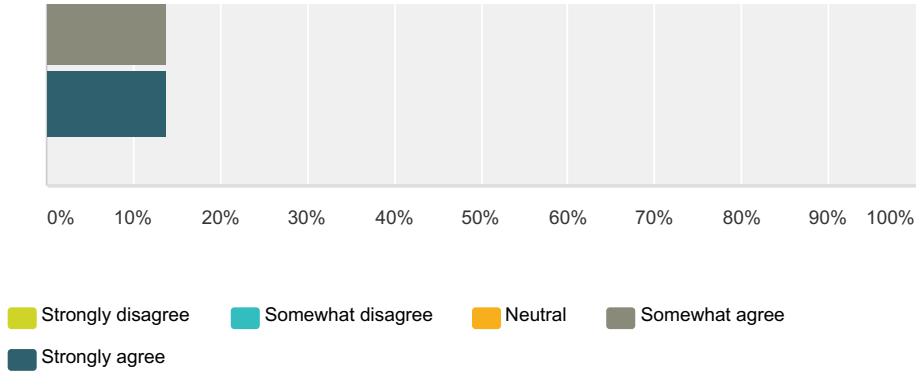


	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Total
(a)	**3.45%** 1	**0.00%** 0	**0.00%** 0	**10.34%** 3	**86.21%** 25	29
(b)	**3.45%** 1	**3.45%** 1	**0.00%** 0	**51.72%** 15	**41.38%** 12	29
(c)	**17.24%** 5	**13.79%** 4	**20.69%** 6	**24.14%** 7	**24.14%** 7	29
(d)	**34.48%** 10	**24.14%** 7	**24.14%** 7	**10.34%** 3	**6.90%** 2	29

Q14 The area of the pavement where I need to locate my bicycle to activate the green signal is clear with this marking

Answered: 29 Skipped: 4

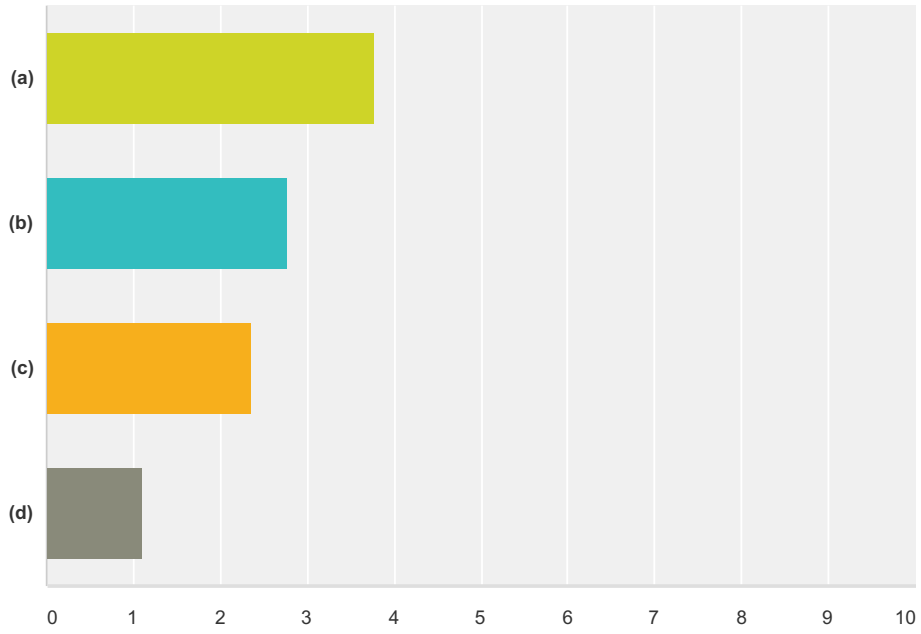




	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Total
(a)	**6.90%** 2	**0.00%** 0	**0.00%** 0	**6.90%** 2	**86.21%** 25	29
(b)	**3.45%** 1	**3.45%** 1	**3.45%** 1	**44.83%** 13	**44.83%** 13	29
(c)	**13.79%** 4	**24.14%** 7	**17.24%** 5	**17.24%** 5	**27.59%** 8	29
(d)	**24.14%** 7	**31.03%** 9	**17.24%** 5	**13.79%** 4	**13.79%** 4	29

Q15 Please rank these markings (1 to 4) to indicate your order of preference

Answered: 31 Skipped: 2



	1	2	3	4	Total	Score
(a)	**83.87%** 26	**12.90%** 4	**0.00%** 0	**3.23%** 1	31	3.77
(b)	**9.68%** 3	**58.06%** 18	**32.26%** 10	**0.00%** 0	31	2.77
(c)	**6.45%** 2	**25.81%** 8	**64.52%** 20	**3.23%** 1	31	2.35
(d)	**0.00%** 0	**3.23%** 1	**3.23%** 1	**93.55%** 29	31	1.10

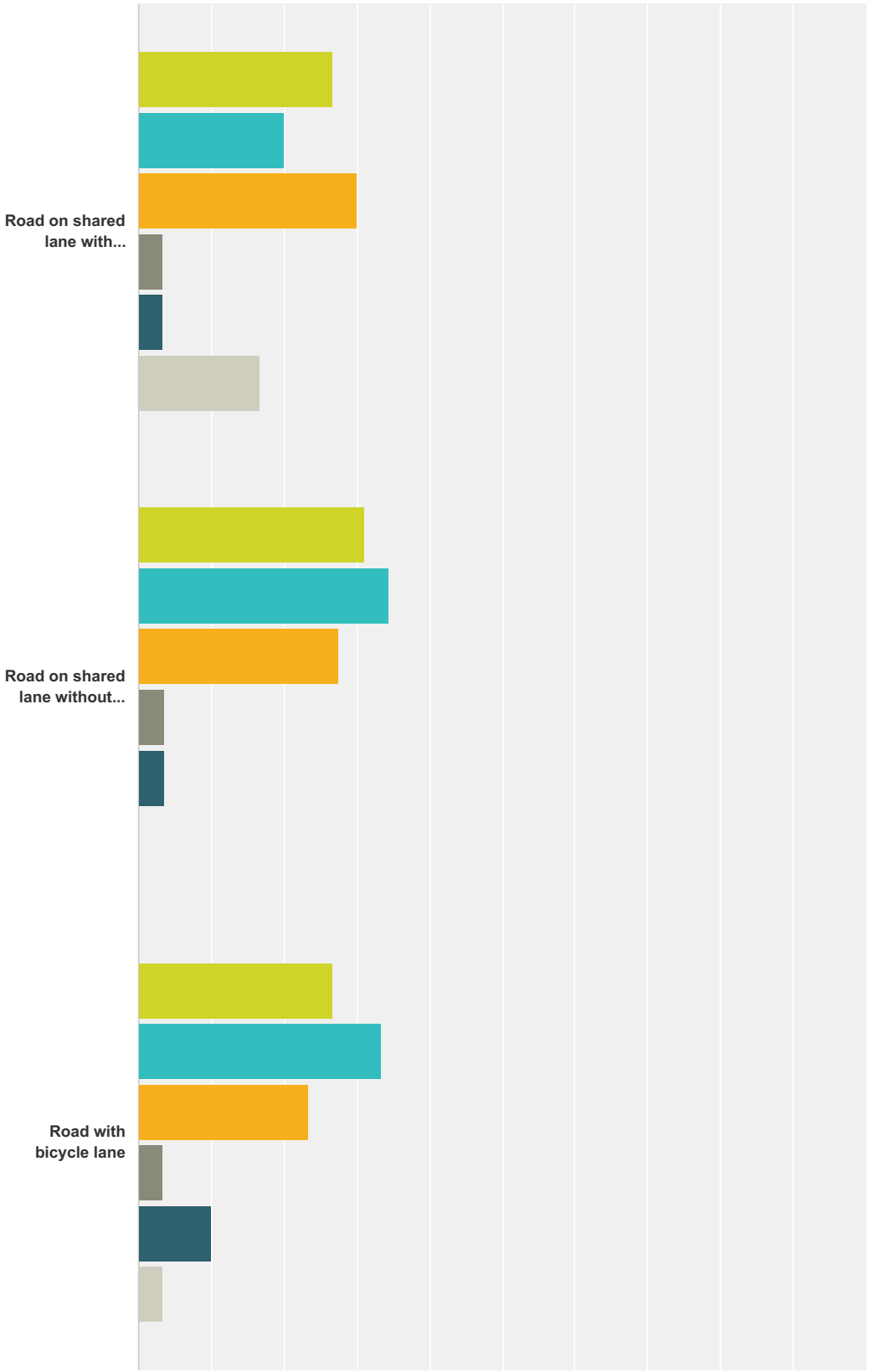
Q16 Please enter any additional comments you may have regarding bicycle detection markings.

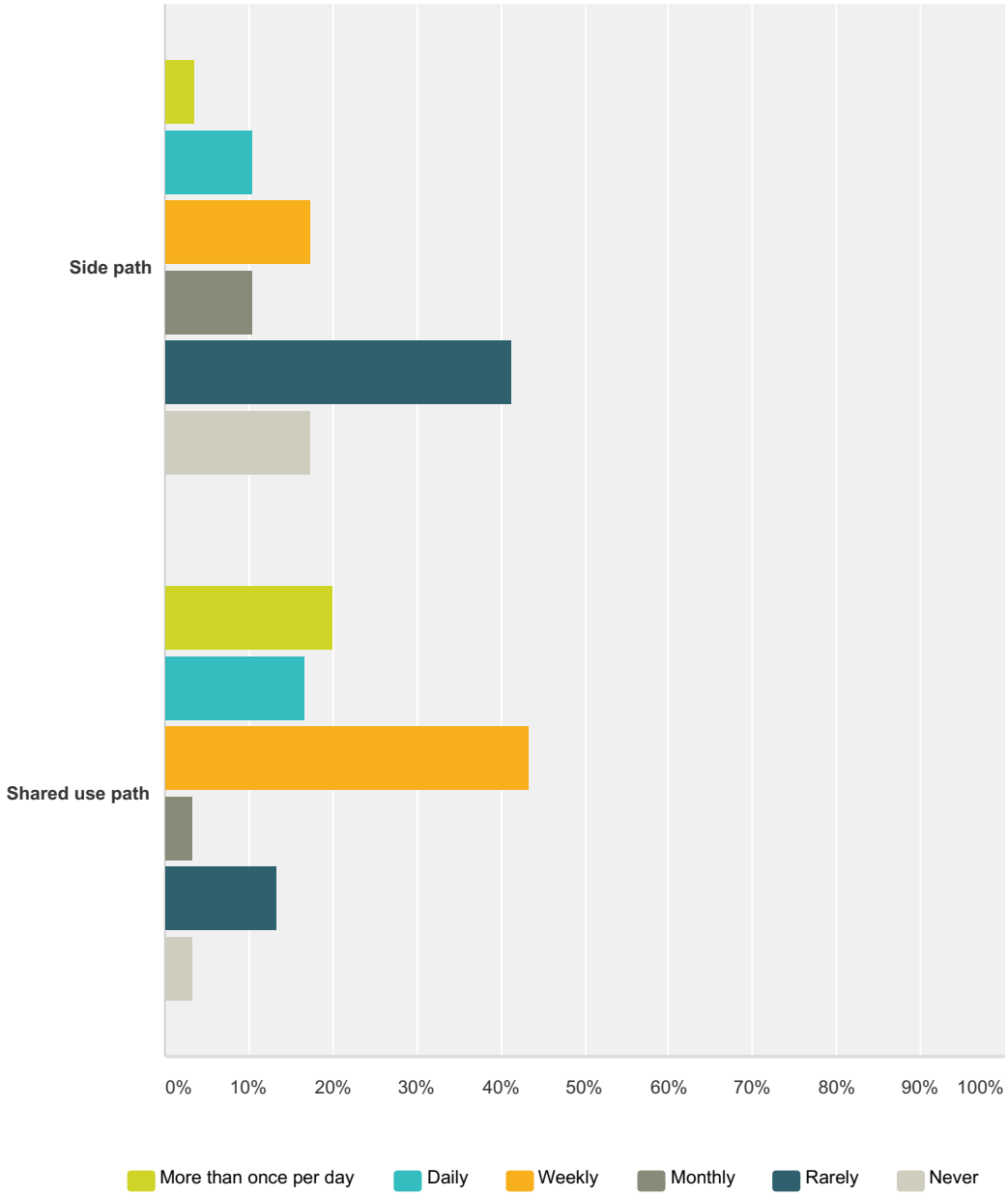
Answered: 16 Skipped: 17

#	Responses	Date
1	Much more effective with language in addition to the bicycle image!	11/24/2015 3:45 PM
2	Thank you!	11/24/2015 2:46 PM
3	The green really popped out for me. I especially liked the green directional markings.	11/16/2015 4:42 PM
4	When it ask about "communication", putting word instruction would work better, people may not know the meaning of the symbol without words.	11/13/2015 3:56 PM
5	Color and indicator of precise bike placement are most important to me here. I like the size & readability of A, but the line in the other markings gives a better idea of where to line up your bike. D has the best indicator in this regard, with the most precise "target area". Its lack of color and relatively smaller size is what makes me rank it lowest.	11/12/2015 9:45 AM
6	Stop box for the bicycles at intersections is somehow new. Therefore, a clear marking is needed. In case of visibility, the green color is very important. In term of content and message conveying, the text provided in a & b markings are useful. The box of the marking can help bicyclists to find the location they can stop. In summary, I think the marking type a is among the best which provide more information in an easy way.	11/11/2015 12:57 PM
7	on question 15, indicate (1-4) which is highest or lowest...	11/11/2015 8:58 AM
8	I have never seen a marking regarding placement of a bike for a green signal. If I have seen one, I didn't realize the purpose!	11/10/2015 12:36 PM
9	with regard to the striped bicycle lanes - these are misleading at times. At intersections, it is sometimes not clear whether the cyclist should take the lane (go to the center of the lane) or stay in the striped bike lane. This creates confusion for the cyclist and the drive. I would almost prefer no bicycle lane striping.	11/10/2015 10:34 AM
10	Maybe different with pedestrians and heavier traffic.	11/9/2015 3:26 PM
11	Such markings are very important. I am sure many do not even know where to locate their bike so the signals will know you are there.	11/6/2015 9:16 AM
12	The bold green is very effective and stands out on the road as much more visible to a bicycler's eye.	11/5/2015 1:24 PM
13	Sometimes the green bike marking color can blend in to the dark pavement background, which is why white wording would be helpful. Also, a green box with no word explanation means little to me regarding where to wait for a signal.	11/4/2015 3:47 PM
14	C & D are not clear at all to me.	11/2/2015 4:41 PM
15	test test	10/1/2015 3:29 PM
16	I preferred the wayfinding markings on the pavement as a cyclist but I believe the wayfinding road signs likely better communicate to both motorized and nonmotorized vehicles.	9/30/2015 9:42 AM

Q17 Refer to Figure 2. When you ride, how often do you encounter the following types of facilities?

Answered: 30 Skipped: 3

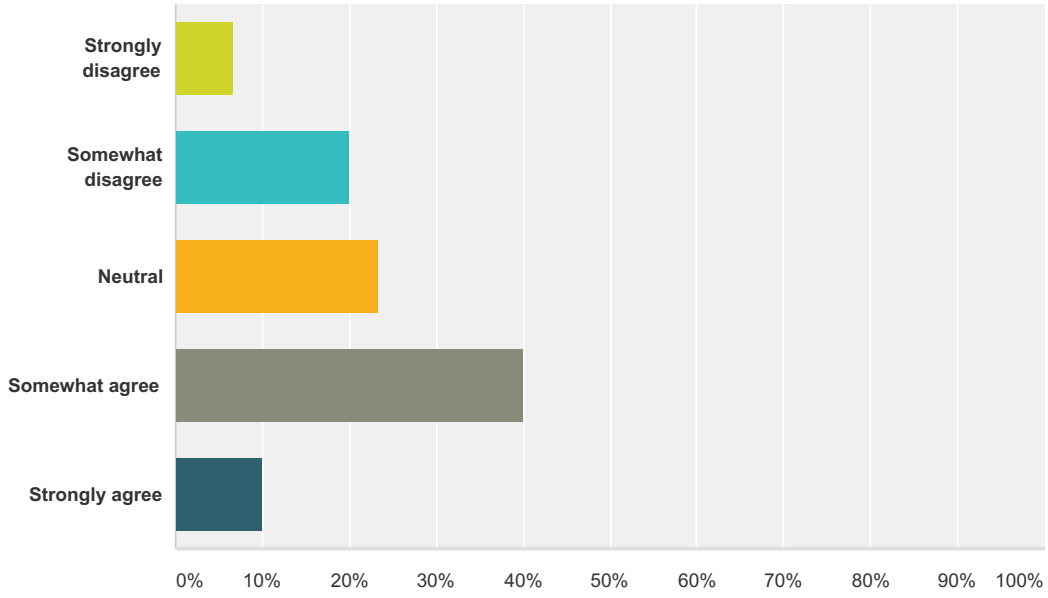




	More than once per day	Daily	Weekly	Monthly	Rarely	Never	Total
Road on shared lane with parking	**26.67%** 8	**20.00%** 6	**30.00%** 9	**3.33%** 1	**3.33%** 1	**16.67%** 5	30
Road on shared lane without parking	**31.03%** 9	**34.48%** 10	**27.59%** 8	**3.45%** 1	**3.45%** 1	**0.00%** 0	29
Road with bicycle lane	**26.67%** 8	**33.33%** 10	**23.33%** 7	**3.33%** 1	**10.00%** 3	**3.33%** 1	30
Side path	**3.45%** 1	**10.34%** 3	**17.24%** 5	**10.34%** 3	**41.38%** 12	**17.24%** 5	29
Shared use path	**20.00%** 6	**16.67%** 5	**43.33%** 13	**3.33%** 1	**13.33%** 4	**3.33%** 1	30

Q18 The existing markings and signs on the bicycle routes that I travel are effective in delineating the bicycle route.

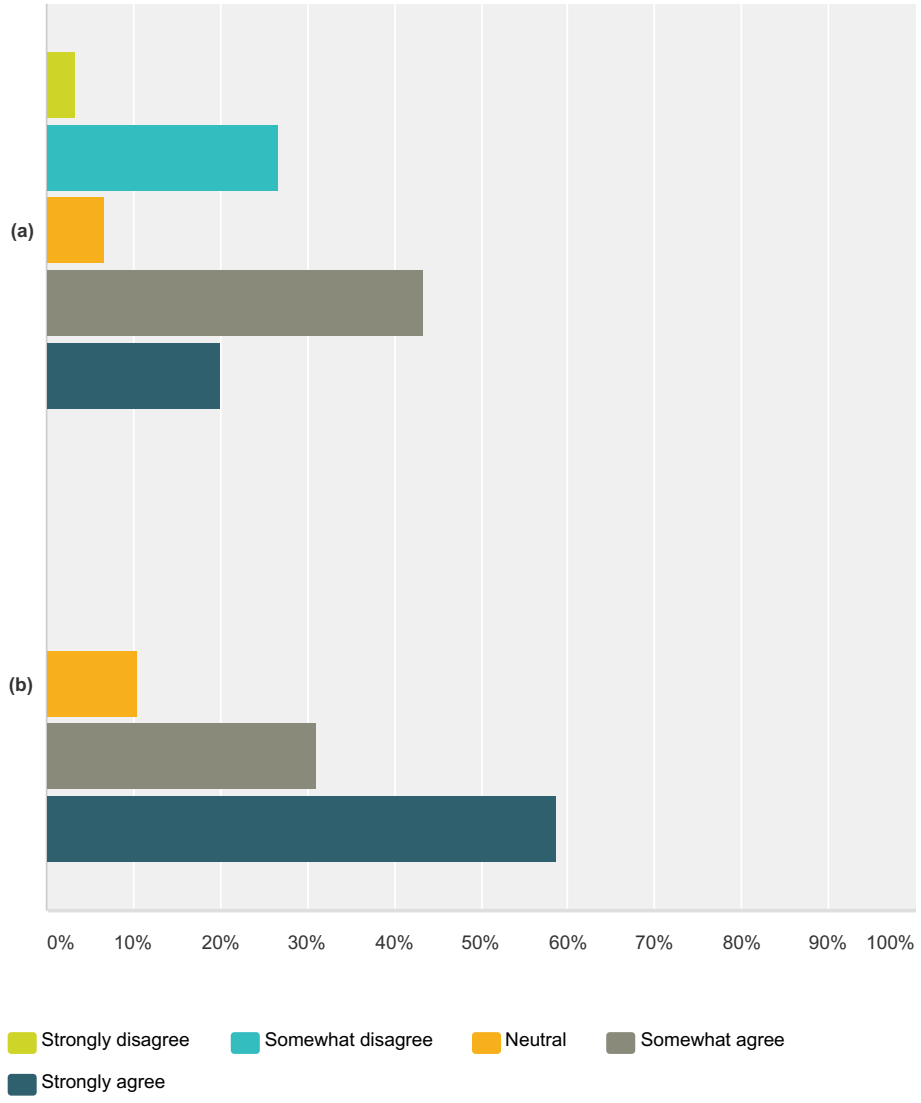
Answered: 30 Skipped: 3



Answer Choices	Responses	
Strongly disagree	6.67%	2
Somewhat disagree	20.00%	6
Neutral	23.33%	7
Somewhat agree	40.00%	12
Strongly agree	10.00%	3
Total		30

Q19 These markings are highly visible.

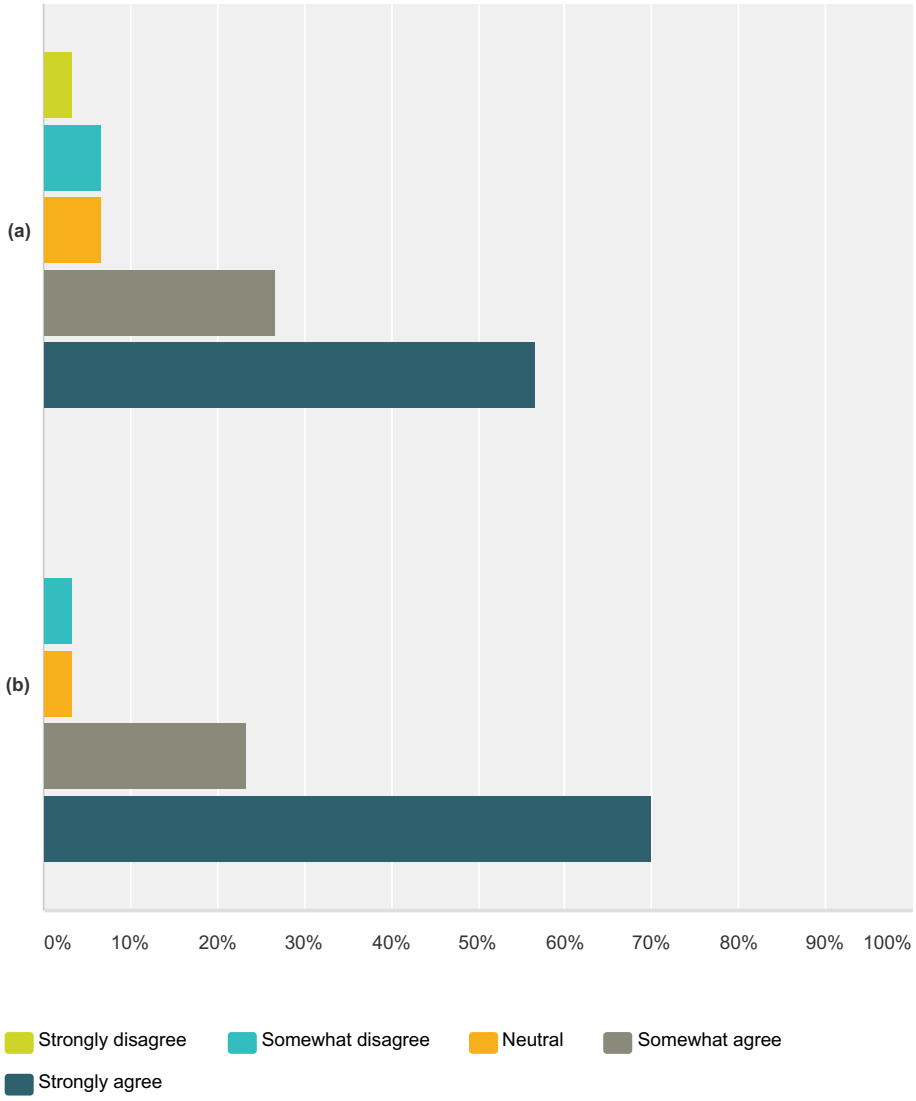
Answered: 30 Skipped: 3



	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Total
(a)	**3.33%** 1	**26.67%** 8	**6.67%** 2	**43.33%** 13	**20.00%** 6	30
(b)	**0.00%** 0	**0.00%** 0	**10.34%** 3	**31.03%** 9	**58.62%** 17	29

Q20 These markings clearly indicate the direction of the bicycle route

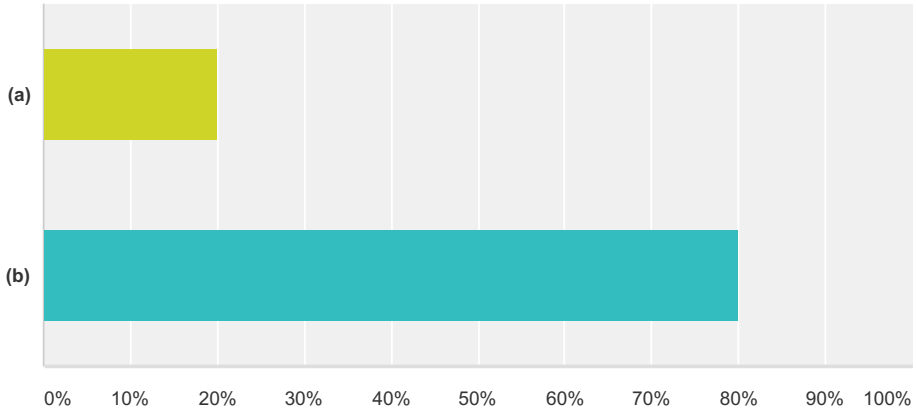
Answered: 30 Skipped: 3



	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Total
(a)	**3.33%** 1	**6.67%** 2	**6.67%** 2	**26.67%** 8	**56.67%** 17	30
(b)	**0.00%** 0	**3.33%** 1	**3.33%** 1	**23.33%** 7	**70.00%** 21	30

Q21 Which of these markings ((a) or (b)) do you prefer

Answered: 30 Skipped: 3



Answer Choices	Responses	
(a)	**20.00%**	6
(b)	**80.00%**	24
Total		**30**

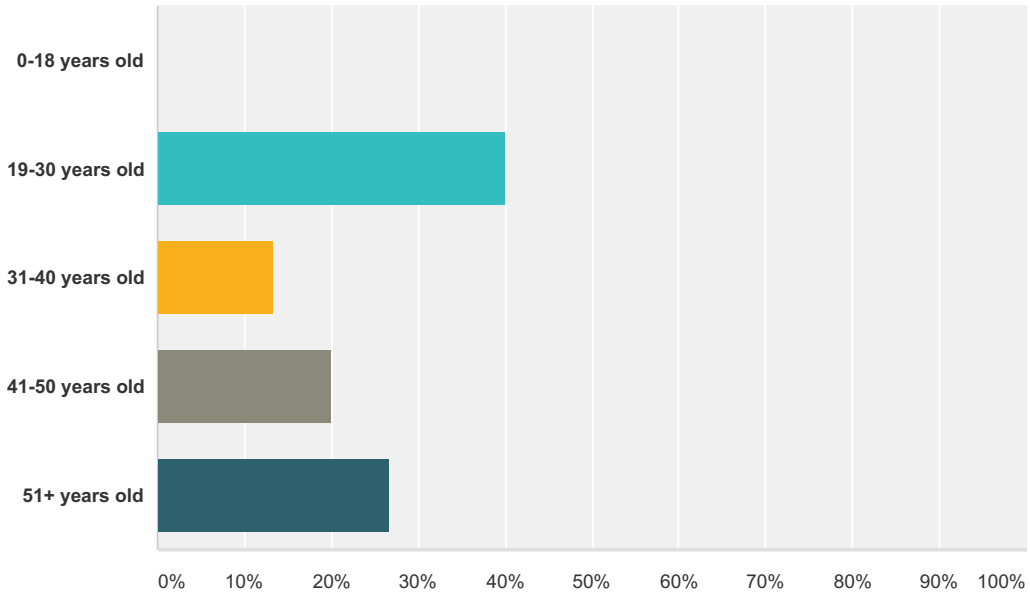
Q22 Please enter any general comments you may have about wayfinding markings and other comments.

Answered: 15 Skipped: 18

#	Responses	Date
1	Green paint makes the waymarking much more effective!	11/24/2015 3:47 PM
2	The white ones are more visible than the green one due to contrast.	11/13/2015 3:56 PM
3	I was most perceptive of the physical signs on the side of the road. I noticed when the markings were on the pavement I forgot to signal my direction at times.	11/12/2015 10:47 AM
4	Color is better. White-only markings tend to be more general indicators, but color indicates something different (like a specific route one is to take). Easier to recognize the colored shape at a distance when approaching, as well.	11/12/2015 9:47 AM
5	Maybe they would be more visible with yellow instead of green in the middle. The green blends in with the asphalt.	11/11/2015 3:41 PM
6	Green color is useful	11/11/2015 1:03 PM
7	It was much easier to see the white markings. The green ones made it easier to differentiate between the direction and the route. But, the white was easier to see in general.	11/10/2015 12:40 PM
8	To be honest, I don't go out of my way to follow a "bike route." I pick my route based on where I need to go and often on using the less trafficked routes (to stay off of major roads).	11/10/2015 10:38 AM
9	Very much prefer the road markings rather than posted markings on the side of the street, as my vision is not distracted which could obstruct vehicle awareness. Green and red coloring is helpful as well.	11/5/2015 1:29 PM
10	I prefer (a) because the white notation contrasts well with the dark asphalt background. However, while in the simulator, markings indicating to go diagonal on the bike route were confusing in all marking schemes.	11/4/2015 3:50 PM
11	Plain white is very hard to see and/or notice when biking. Green is needed. Best yet is sign AND markings on the road.	11/3/2015 12:13 PM
12	The problem with these kinds of markings is they may be hidden by snow, or vehicles, or wear off.	11/3/2015 11:19 AM
13	Color is very helpful for noticing markings.	11/2/2015 4:42 PM
14	Making sure drivers are also aware it is a bicycle route is also important.	11/2/2015 4:02 PM
15	test	10/1/2015 3:29 PM

Q23 Please select your age group from the list below

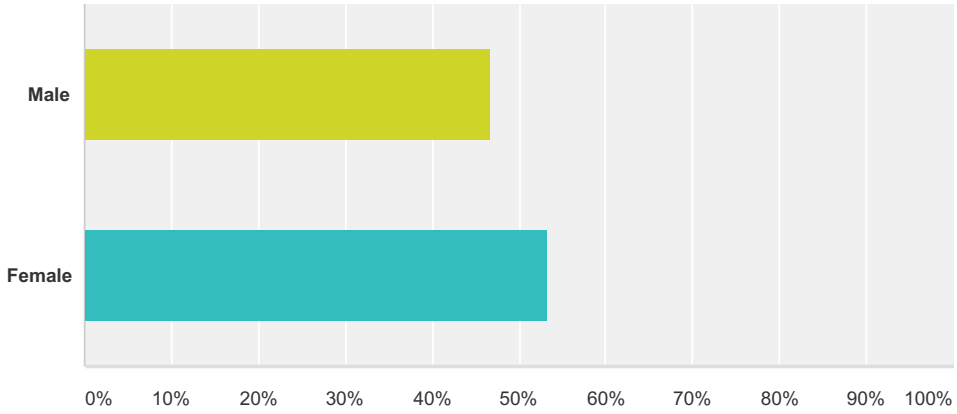
Answered: 30 Skipped: 3



Answer Choices	Responses	
0-18 years old	**0.00%**	0
19-30 years old	**40.00%**	12
31-40 years old	**13.33%**	4
41-50 years old	**20.00%**	6
51+ years old	**26.67%**	8
Total		**30**

Q24 Please select your gender

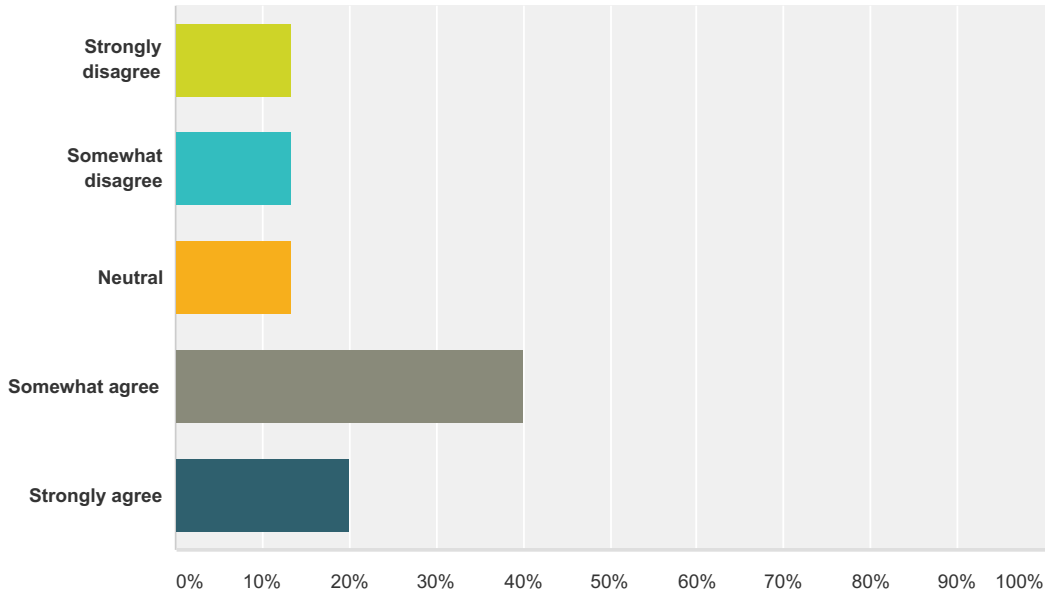
Answered: 30 Skipped: 3



Answer Choices	Responses	
Male	**46.67%**	14
Female	**53.33%**	16
Total		**30**

Q25 I felt like I was actually riding a bike.

Answered: 30 Skipped: 3



Answer Choices	Responses	
Strongly disagree	**13.33%**	4
Somewhat disagree	**13.33%**	4
Neutral	**13.33%**	4
Somewhat agree	**40.00%**	12
Strongly agree	**20.00%**	6
Total		**30**

Bicycle Detection and Route Marking Survey

1. Are you a resident of the City of Columbia?

Answer Options	Response Percent	Response Count
Yes	87.5%	28
No	12.5%	4
answered question		32
skipped question		1

2. How many times a week do you bicycle?

Answer Options	Response Percent	Response Count
0	12.5%	4
1	15.6%	5
2	9.4%	3
3	6.3%	2
4	6.3%	2
5+	50.0%	16
answered question		32
skipped question		1

3. Do you commute by bicycle to work or school?

Answer Options	Response Percent	Response Count
Yes	71.9%	23
No	28.1%	9
answered question		32
skipped question		1

4. Do you ride a bicycle for non-work trips or recreation?

Answer Options	Response Percent	Response Count
Yes	87.5%	28
No	12.5%	4
answered question		32
skipped question		1

5. If you commute, how many times per week?

Answer Options	Response Percent	Response Count
1	7.7%	2
2	7.7%	2
3	23.1%	6
4	15.4%	4
5+	46.2%	12
answered question		26
skipped question		7

6. What is the average duration of your bicycle commute to work or school?

Answer Options	Response Percent	Response Count
0-5 minutes	0.0%	0
5-10 minutes	23.1%	6
10-15 minutes	38.5%	10
15-30 minutes	30.8%	8
30+ minutes	7.7%	2
answered question		26
skipped question		7

7. If you ride for recreation or non-work trips, how many times per week?

Answer Options	Response Percent	Response Count
1	35.7%	10
2	28.6%	8
3	17.9%	5
4	14.3%	4

5+	3.6%	1
	answered question	**28**
	skipped question	**5**

8. What is the average duration of your recreation or non-work bicycle trips?

Answer Options	Response Percent	Response Count
0-5 minutes	0.0%	0
5-10 minutes	0.0%	0
10-15 minutes	10.7%	3
15-30 minutes	21.4%	6
30+ minutes	67.9%	19
	answered question	**28**
	skipped question	**5**

9. During your bicycle trips, what type of facilities do you ride on?

Answer Options	Response Percent	Response Count
Trails Only	3.4%	1
Streets Only	6.9%	2
Trails and Streets	89.7%	26
	answered question	**29**
	skipped question	**4**

10. What is the typical number of signalized intersections that you encounter on a bicycle ride?

Answer Options	Response Percent	Response Count
0	0.0%	0
1-2	15.4%	4
3-5	42.3%	11
6-10	23.1%	6
10+	19.2%	5
	answered question	**26**
	skipped question	**7**

11. While waiting at a signal, how frequently do you have problems with getting a green light at a signalized intersection while riding a bicycle?

Answer Options	Response Percent	Response Count
Very infrequently	11.5%	3
Infrequently	38.5%	10
Neutral	15.4%	4
Frequently	30.8%	8
Very frequently	3.8%	1
	answered question	**26**
	skipped question	**7**

12. These markings are highly visible.

Answer Options	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Response Count
(a)	2	1	0	4	23	30
(b)	1	3	5	13	8	30
(c)	2	2	1	6	18	29
(d)	3	10	4	6	5	28
					answered question	**30**
					skipped question	**3**

13. These markings are effective at communicating to me that I need to place my bicycle on the marking to obtain a green light at the traffic signal

Answer Options	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Response Count
(a)	1	0	0	3	25	29
(b)	1	1	0	15	12	29
(c)	5	4	6	7	7	29
(d)	10	7	7	3	2	29
					answered question	**29**
					skipped question	**4**

14. The area of the pavement where I need to locate my bicycle to activate the green signal is clear with this marking

Answer Options	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Response Count
(a)	2	0	0	2	25	29
(b)	1	1	1	13	13	29
(c)	4	7	5	5	8	29
(d)	7	9	5	4	4	29
					answered question	29
					skipped question	4

15. Please rank these markings (1 to 4) to indicate your order of preference

Answer Options	1	2	3	4	Rating Average	Response Count
(a)	26	4	0	1	1.23	31
(b)	3	18	10	0	2.23	31
(c)	2	8	20	1	2.65	31
(d)	0	1	1	29	3.90	31
					answered question	31
					skipped question	2

16. Please enter any additional comments you may have regarding bicycle detection markings.

Answer Options	Response Count
	16
answered question	16
skipped question	17

Number	Response Date	Response Text	Categories
1	Nov 24, 2015 9:45 PM	Much more effective with language in addition to the bicycle image!	
2	Nov 24, 2015 8:46 PM	Thank you!	
3	Nov 16, 2015 10:42 PM	The green really popped out for me. I especially liked the green directional markings.	
4	Nov 13, 2015 9:56 PM	When it ask about "communication", putting word instruction would work better, people may not know	
5	Nov 12, 2015 3:45 PM	Color and indicator of precise bike placement are most important to me here. I like the size & readability of A, but the line in the other markings gives a better idea of where to line up your bike. D has the best indicator in this regard, with the most precise "target area". Its lack of color and relatively smaller size is what makes me rank it lowest.	
6	Nov 11, 2015 6:57 PM	Stop box for the bicycles at intersections is somehow new. Therefore, a clear marking is needed. In	
7	Nov 11, 2015 2:58 PM	on question 15, indicate (1-4) which is highest or lowest...	
8	Nov 10, 2015 6:36 PM	I have never seen a marking regarding placement of a bike for a green signal. If I have seen one, I didn't realize the purpose!	
9	Nov 10, 2015 4:34 PM	with regard to the striped bicycle lanes - these are misleading at times. At intersections, it is sometimes not clear whether the cyclist should take the lane (go to the center of the lane) or stay in the striped bike lane. This creates confusion for the cyclist and the drive. I would almost prefer no bicycle lane striping.	
10	Nov 9, 2015 9:26 PM	Maybe different with pedestrians and heavier traffic.	
11	Nov 6, 2015 3:16 PM	Such markings are very important. I am sure many do not even know where to locate their bike so the signals will know you are there.	
12	Nov 5, 2015 7:24 PM	The bold green is very effective and stands out on the road as much more visible to a bicycler's eye.	
13	Nov 4, 2015 9:47 PM	Sometimes the green bike marking color can blend in to the dark pavement background, which is why white wording would be helpful. Also, a green box with no word explanation means little to me	
14	Nov 2, 2015 10:41 PM	C & D are not clear at all to me.	
15	Oct 1, 2015 8:29 PM	test test	
16	Sep 30, 2015 2:42 PM	I preferred the wayfinding markings on the pavement as a cyclist but I believe the wayfinding road signs likely better communicate to both motorized and nonmotorized vehicles.	

17. Refer to Figure 2. When you ride, how often do you encounter the following types of facilities?

Answer Options	More than once per day	Daily	Weekly	Monthly	Rarely	Never	Response Count
Road on shared lane with parking	8	6	9	1	1	5	30
Road on shared lane without parking	9	10	8	1	1	0	29
Road with bicycle lane	8	10	7	1	3	1	30
Side path	1	3	5	3	12	5	29
Shared use path	6	5	13	1	4	1	30
						answered question	30
						skipped question	3

18. The existing markings and signs on the bicycle routes that I travel are effective in delineating the bicycle route.

Answer Options	Response Percent	Response Count
Strongly disagree	6.7%	2
Somewhat disagree	20.0%	6

Neutral	23.3%	7
Somewhat agree	40.0%	12
Strongly agree	10.0%	3
	answered question	30
	skipped question	3

19. These markings are highly visible.

Answer Options	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Response Count
(a)	1	8	2	13	6	30
(b)	0	0	3	9	17	29
					answered question	30
					skipped question	3

20. These markings clearly indicate the direction of the bicycle route

Answer Options	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Response Count
(a)	1	2	2	8	17	30
(b)	0	1	1	7	21	30
					answered question	30
					skipped question	3

21. Which of these markings ((a) or (b)) do you prefer

Answer Options	Response Percent	Response Count
(a)	20.0%	6
(b)	80.0%	24
	answered question	30
	skipped question	3

22. Please enter any general comments you may have about wayfinding markings and other comments.

Answer Options	Response Count
	15
answered question	15
skipped question	18

Number	Response Date	Response Text	Categories
1	Nov 24, 2015 9:47 PM	Green paint makes the waymarking much more effective!	
2	Nov 13, 2015 9:56 PM	The white ones are more visible than the green one due to contrast.	
3	Nov 12, 2015 4:47 PM	I was most perceptive of the physical signs on the side of the road. I noticed when the markings were on the pavement I forgot to signal my direction at times.	
4	Nov 12, 2015 3:47 PM	Color is better. White-only markings tend to be more general indicators, but color indicates something different (like a specific route one is to take). Easier to recognize the colored shape at a distance when approaching, as well.	
5	Nov 11, 2015 9:41 PM	Maybe they would be more visible with yellow instead of green in the middle. The green blends in with	
6	Nov 11, 2015 7:03 PM	Green color is useful	
7	Nov 10, 2015 6:40 PM	It was much easier to see the white markings. The green ones made it easier to differentiate between the direction and the route. But, the white was easier to see in general.	
8	Nov 10, 2015 4:38 PM	To be honest, I don't go out of my way to follow a "bike route." I pick my route based on where I need	
9	Nov 5, 2015 7:29 PM	Very much prefer the road markings rather than posted markings on the side of the street, as my vision is not distracted which could obstruct vehicle awareness. Green and red coloring is helpful as well.	
10	Nov 4, 2015 9:50 PM	I prefer (a) because the white notation contrasts well with the dark asphalt background. However, while in the simulator, markings indicating to go diagonal on the bike route were confusing in all marking schemes.	
11	Nov 3, 2015 6:13 PM	Plain white is very hard to see and/or notice when biking. Green is needed. Best yet is sign AND markings on the road.	
12	Nov 3, 2015 5:19 PM	The problem with these kinds of markings is they may be hidden by snow, or vehicles, or wear off.	
13	Nov 2, 2015 10:42 PM	Color is very helpful for noticing markings.	
14	Nov 2, 2015 10:02 PM	Making sure drivers are also aware it is a bicycle route is also important.	
15	Oct 1, 2015 8:29 PM	test	

23. Please select your age group from the list below

Answer Options	Response Percent	Response Count
0-18 years old	0.0%	0
19-30 years old	40.0%	12
31-40 years old	13.3%	4

41-50 years old	20.0%	6
51+ years old	26.7%	8
	answered question	30
	skipped question	3

24. Please select your gender

Answer Options	Response Percent	Response Count
Male	46.7%	14
Female	53.3%	16
	answered question	30
	skipped question	3

25. I felt like I was actually riding a bike.

Answer Options	Response Percent	Response Count
Strongly disagree	13.3%	4
Somewhat disagree	13.3%	4
Neutral	13.3%	4
Somewhat agree	40.0%	12
Strongly agree	20.0%	6
	answered question	30
	skipped question	3

Appendix D

Detection Implemented Markings Survey Questionnaire and Results

Section 1 of 7

Bike Marking Survey

This survey will help us better serve the bicycling community by evaluating some new experimental bike markings located at four Columbia intersections.

Are you a full-time resident of the City of Columbia?

- ○ Yes
- ○ No
- ○ Student

How often do you bike on Columbia roadways? *

- ○ More than 3 times per week
- ○ One time per week
- ○ One time per month
- ○ Less than one time per month
- ○ Never

You may submit this survey via email, mail or in person.

E-MAIL: pubw@CoMo.gov

Mailing Address: Public Works, 701 E. Broadway, Columbia, MO 65201

Walk-in: 3rd Floor, City Hall, 701 E. Broadway, Columbia

Section 2 of 7

Bicycling Experience

How experienced a bicyclist would you consider yourself? *

- ( ) Very expereinced - Know all rules of the road
- ( ) Experienced- Know most of the rules of road
- ( ) Moderately experienced- New to riding on the road
- ( ) Slightly experienced- Just ride trails
- ( ) Not expereinced- Novice

Why do you ride your bicycle? (check all that apply) *

- [ ] Recreation
- [ ] Exercise
- [ ] Commute to work
- [ ] Commute to school/university

Where do you primarily ride your bicycle? *

- Streets
- Trails
- Both City streets and trails

When riding on streets do you experience problems with activating a green light?

- Yes
- No

Section 3 of 7

Green Light Activation

How frequently do you experience problems with activating a green light? *

- Always
- Often
- Sometimes
- Rarely
- Never

Section 4 of 7

Markings

How do you interpret this bike marking? *

- Bikes stop here for green light
- Bikes belong on this roadway
- Didn't know the marking meant anything
- Bikes to place front bicycle tire here for green light
- Bikes to place rear bicycle tire here for green light

How do you interpret this bike marking? *

- ( ) Bikes stop here for green light
- ( ) Bikes belong on this roadway
- ( ) Didn't know the marking meant anything
- ( ) Bikes to place front bicycle tire here for green light
- ( ) Bikes to place rear bicycle tire here for green light

In the last 2 months, have you ridden a bike through the following intersections (check all that apply)

- [ ] On Garth Avenue crossing Worley Street
- [ ] On West Boulevard crossing Worley Street
- [ ] On Garth Avenue crossing Broadway
- [ ] On West Boulevard crossing Broadway

In the last 2 months, have you driven a motorized vehicle through the following intersections (Check all that apply)

- [ ] On Garth Avenue crossing Worley Street
- [ ] On West Boulevard crossing Worley Street
- [ ] On Garth Avenue crossing Broadway
- [ ] On West Boulevard crossing Broadway

Section 5 of 7

Did you notice?

When traveling through any of the above mentioned intersections did you notice this symbol?

- ( ) Yes
- ( ) No
- ( ) N/A

Section 6 of 7

Comparing Bike Markings

Which bike marking is more visible? *

- ( ) MUTCD 9C-05

- ( ) Proposed Bike Marking

Which bike marking communicates the purpose of the marking better? *

- MUTCD 9C-05

- Proposed Bike Marking

Which bike marking communicates where the bike is to be positioned better? *

- MUTCD 9C-05

- Proposed Bike Marking

Section 7 of 7

Thank you for your time.

This survey will help us better serve the bicycling community.

Signal Actuator Survey Summary, Columbia Missouri 2017

Two hundred and fifty three responses were collected the Signal Actuator Survey for Columbia, Missouri from April to July 2017. The survey asked on what mode people traveled through the intersections, how often, where and gauged people's understanding about signal actuator markings. The results are shown below:
-92 percent of the respondents were residents
-50 percent biked at least once per week
-91 percent claimed to be moderately experienced, experienced, or very experienced of a bicyclist
-71 percent of respondents ride their bikes for exercise or recreation
-58 percent of respondents use both trails and streets

The results of the survey about the signal activators point to a need to change the symbol used to activate the light.
-61 percent of respondents have problems activating the green light
-83 percent of people stated that they sometimes, often, or always have problems activating the green light
-81 percent of survey respondents were unclear how to interpret the current signal actuator markings
-97 percent of survey respondents correctly interpreted the "bikes wait here" proposed bike marking

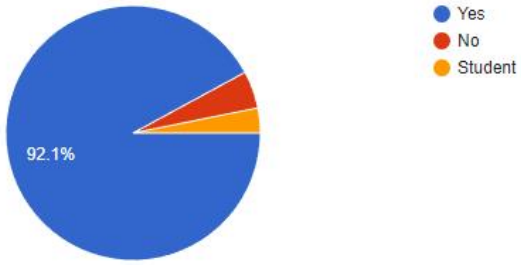
When riding their bikes over the past two months, respondents used the Garth Avenue crossing Broadway and West Boulevard crossing Broadway intersections slightly more than the Worley Street intersections. Sixty percent of respondents crossed all four intersections using cars in the last two months. The actuator markings largely went unnoticed by 66 percent of survey respondents. The proposed bike marking alternative was favored by 90 percent of survey respondents for its visibility and effectiveness in communicating the purpose of the marking. Columbia should switch to marking the signal actuator marking from the current marking to the proposed bike marking.

QUESTIONS RESPONSES 253

SUMMARY INDIVIDUAL

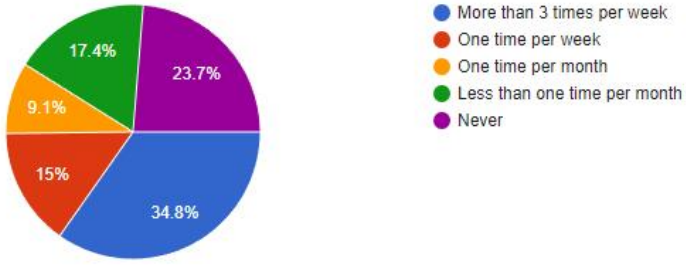
Are you a full-time resident of the City of Columbia?

253 responses



How often do you bike on Columbia roadways?

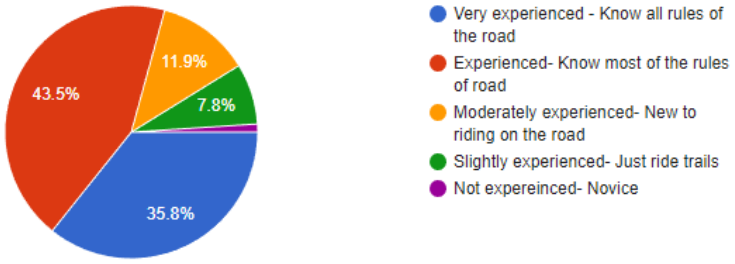
253 responses



Bicycling Experience

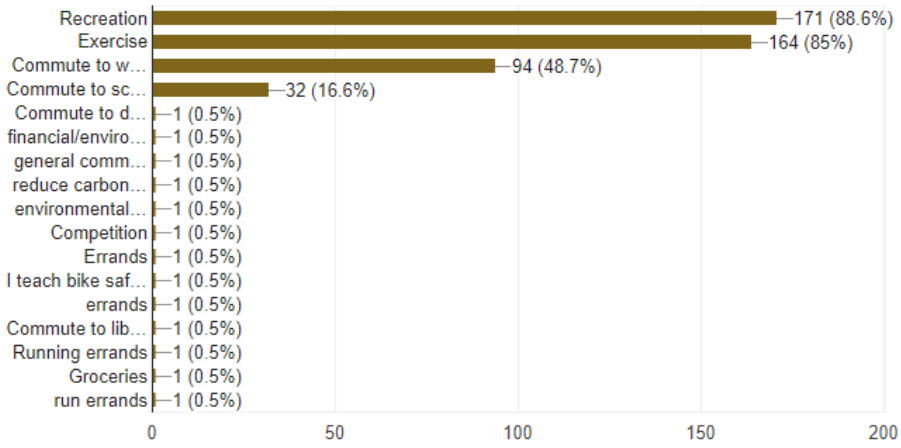
How experienced a bicyclist would you consider yourself?

193 responses



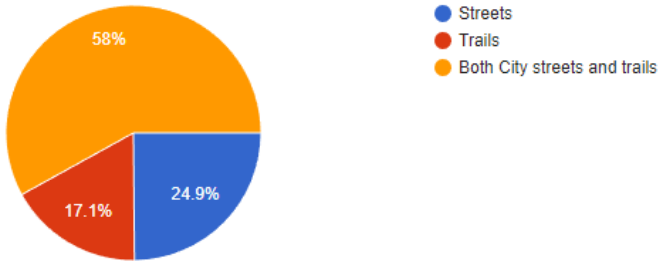
Why do you ride your bicycle? (check all that apply)

193 responses



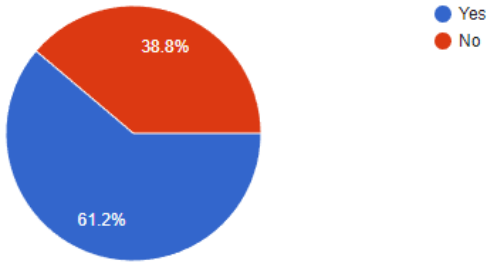
Where do you primarily ride your bicycle?

193 responses



When riding on streets do you experience problems with activating a green light?

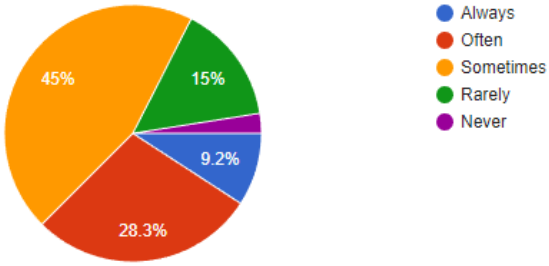
188 responses



Green Light Activation

How frequently do you experience problems with activating a green light?

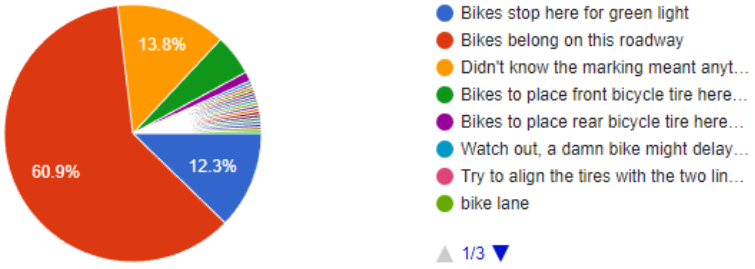
120 responses



Markings

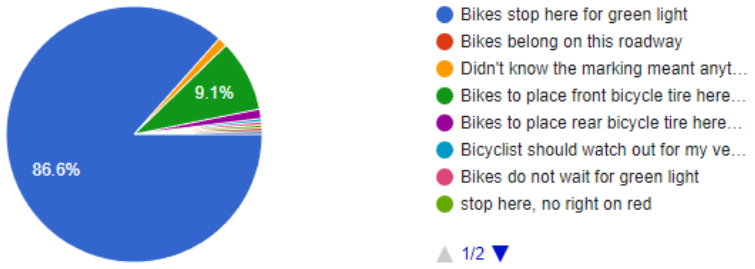
How do you interpret this bike marking?

253 responses



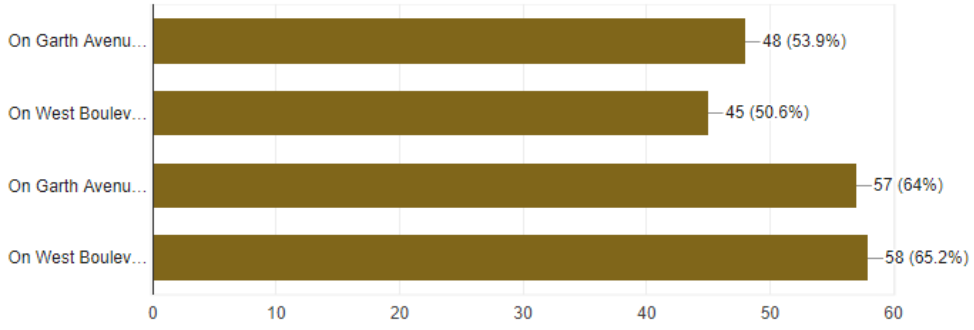
How do you interpret this bike marking?

253 responses



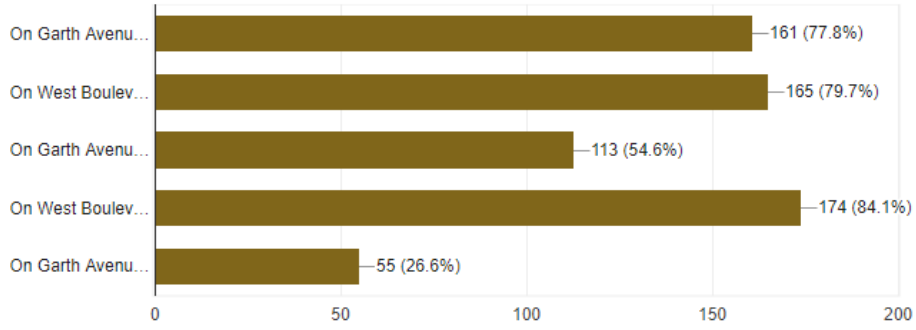
In the last 2 months, have you ridden a bike through the following intersections (check all that apply)

89 responses



In the last 2 months, have you driven a motorized vehicle through the following intersections (Check all that apply)

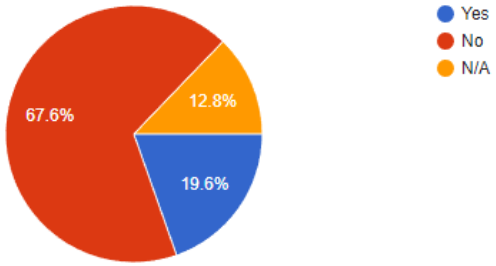
207 responses



Did you notice?

When traveling through any of the above mentioned intersections did you notice this symbol?

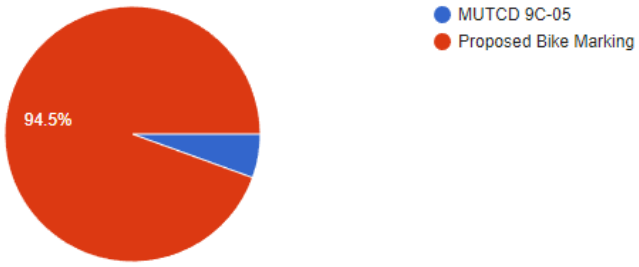
250 responses



Comparing Bike Markings

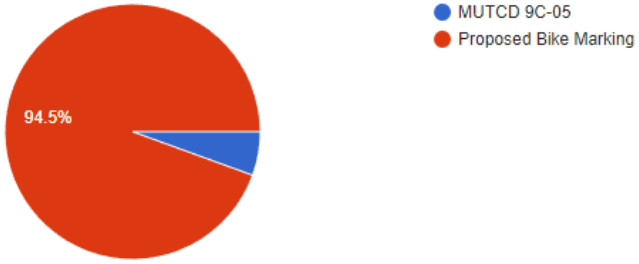
Which bike marking is more visible?

253 responses



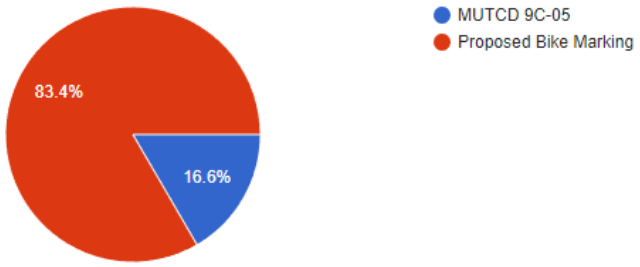
Which bike marking communicates the purpose of the marking better?

253 responses



Which bike marking communicates where the bike is to be positioned better?

253 responses



Appendix E

IMPROVING THE BICYCLE DETECTION PAVEMENT MARKING SYMBOLS TO INCREASE COMPREHENSON AT TRAFFIC SIGNALS Boudart, et all, City of Portland OR, submitted to the January 2016 TRB.

IMPROVING THE BICYCLE DETECTION PAVEMENT MARKING SYMBOLS TO INCREASE COMPREHENSION AT TRAFFIC SIGNALS

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July 31, 2015

Submitted for Publication:
95th Annual Meeting of the Transportation Research Board
Washington, DC
January 10-14, 2016

Word Count: 4,222 + 4 Tables (1,000 Words) + 9 Figures (2,250 Words) = 7,472 Words
Abstract: 210 Words
* Corresponding Author

ABSTRACT

The City of Portland and many other agencies provide pavement markings such as the MUTCD standard 9C-7 bicycle detector marking to help people using bicycles call for a green indication at a signalized intersection. Previous research has shown that approximately half of cyclists do not intuitively understand the marking, and therefore may not be detected by the traffic signal necessitating running the red indication. Building on previous research with the 9C-7 bicycle detector marking and blue light detector feedback devices, there are two objectives of this research: 1) do users comprehend the 9C-7 marking and the blue light detector feedback device? 2) Does bicyclist behavior change due to a descriptive bicycle detector marking?

In this study, 60% of intercept survey respondents correctly identified the existing 9C-7 marking and approximately 72% correctly identified the meaning of the blue light detector feedback device. A survey of cyclists in the field showed a 30% increase of user comprehension when descriptive text was added to the 9C-7 marking. When the more descriptive bicycle detector marking was installed at a recently re-constructed intersection, there was a statistically significant increase of bicyclists waiting on the new bicycle detector stencil. However, there was not enough data to support a statistically significant reduction of red light running cyclists.

INTRODUCTION AND MOTIVATION

To help bicyclists identify where they should wait at a signalized intersection in order to be detected by an inductive loop detection system, the City of Portland and many other agencies use the bicycle detector pavement marking shown as Figure 9C-7 in the current Manual on Uniform Traffic Control Devices [MUTCD] *(1)*. Previous research has shown that many people do not intuitively understand what this symbol means *(2, 3)* and as a result do not position themselves over it *(3)*. Cyclists not waiting over the detection loop will not receive a green indication to proceed through the intersection until another bicycle or motor vehicle arrives at the intersection and stops over the loop or until someone pushes the pushbutton to cross the street. Receiving no green indication results in excessive delay and frustration to the cyclist, which may lead to risky red light running behavior. Furthermore, bicycles and motor vehicles typically use the same traffic signal detector loop in mixed-traffic situations, which means the loop is typically located in the center of the motor vehicle travel lane. This location may not be an intuitive or comfortable place for many cyclists to stop and wait.

Some agencies have added pushbuttons in convenient locations for bicyclists to trigger the signal or have tried different forms of detection (e.g. video). However, pushbuttons add costs and additional design considerations to a project and may obstruct the pedestrian space. City of Portland staff have also not seen satisfactory results from other forms of detection in all weather conditions and plan to continue to use loop detection. Consequently there is interest in improving cyclist positioning over loop detectors. Previous research has shown that providing additional information (e.g., a blue light feedback device adjacent to the signal head, the MUTCD R10-22 sign, and a descriptive bicycle detection informational sandwich board sign) can improve cyclist understanding and positioning *(3, 4)*.

Building on this previous research, the City of Portland undertook a project to determine whether a different type of pavement marking may be more intuitive to cyclists, and as a result, increase the proportion of cyclists positioning themselves correctly over inductive loops. First, video data of the two study intersections were collected to establish a baseline understanding of how people utilize the existing intersection's pavement markings. Then, a postcard intercept survey was administered to gauge how well people understand the existing 9C-7 pavement marking and the blue light feedback device; and to determine whether another pavement marking design may provide a more intuitive indication of the detector location. After the results of this survey were compiled, a new detection pavement marking was selected for temporary installation at two locations. Finally, "after" video data was collected at each location to determine whether the new marking affected cyclist positioning to receive a green light.

This paper presents previous research on the topic, a description of the study sites, the project's methods and findings, and the project team's discussion and conclusions based on the findings.

PREVIOUS RESEARCH

Previous research on the 9C-7 marking is limited. *Boot et al.,* surveyed 68 Florida residents, only 17 of which rode a bicycle more than 5 miles per week, for their comprehension of various bicycle related signs and pavement markings, including the 9C-7 marking. No participants correctly identified the meaning of the marking, though the researchers acknowledged that the marking is rarely used in the study area *(2)*.

Bussey conducted a video survey of three locations in Portland, Oregon with the 9C-7 marking. This research found that about 24% of cyclists position themselves over the 9C-7 marking when it is installed on its own. This proportion increases to approximately 35% of cyclists when the R10-22 sign is installed in conjunction with the marking, and to nearly 50% of cyclists when the 9C-7 marking is installed on top of a green rectangle, but without the R10-22 sign. The research team also conducted a survey of Portland cyclists and found that under half, about 45%, understand what the marking meant *(3)*.

Most recently, the City of Portland conducted a study to determine the effects of a blue light feedback device on cyclist positioning over the 9C-7 marking. The study included one location and found that about 15% of cyclists positioned themselves over the 9C-7 marking before the blue light was installed. This number increased to 20% after the blue light was installed and to nearly 50% when an informational sandwich board sign explaining the blue light feedback device was placed at the intersection *(4)*. The lack research associated with the 9C-7 marking demonstrates the need to solicit public feedback on its educational effectiveness to wait on a stencil and "call" a green light.

SITE SELECTION

Two intersections in Portland, Oregon were chosen for this study: NE Tillamook Street/NE Martin Luther King Jr. Boulevard and SE Division Street/SE 21st Avenue. Photos of these intersections are shown in Figures 1 and 2. Both intersections feature inductive loop bicycle detection with a blue light feedback indication on the side street approaches. Figure 3 illustrates the traffic signal and blue light feedback indication assembly. These two sites were chosen to test out two different situations. The NE Tillamook Street site is a shared street where cyclists must stop near the center of the shared travel lane in order to position themselves over the detector. The NE Tillamook Street "bicycle boulevard" was established in approximately the year 2010, and the blue light feedback detector light was installed in the summer of 2014. The SE Division Street site features a green bike box at the intersection, bicycle symbol in the center of the bike box, and a curb tight bicycle stencil in the natural continuation of the bike lane. The SE 21st Avenue/SE Division Street intersection was recently reconstructed in the last quarter of 2014, and the striping installed in the first quarter of 2015. The blue light feedback detector light was installed in the first quarter of 2015 as well, meaning the presence of the bicycle infrastructure at the SW 21st Avenue site is relatively new.

1

FIGURE 1 NE Tillamook Street/NE MLK Boulevard Westbound Approach

FIGURE 2 SE 21st Avenue/SE Division Street Northbound Approach with an inset image of the Modified Columbia Experiment Bicycle Stencil Marking.

FIGURE 3 A Close-up of a Traffic Signal with a Blue Light Feedback Device at the NE Tillamook Street Site

POSTCARD INTERCEPT SURVEY

The purpose of the intercept survey was to gauge how well individuals understand the bicycle detection blue light signal indication and the 9C-7 marking, and determine whether another pavement marking design may provide a more intuitive indication of the detector location.

Survey Administration

Survey administrators handed out postcards to people bicycling through the NE Tillamook Street/NE MLK Jr. Boulevard and SE Division Street/SE 21st Avenue intersections on May 7, 2015 during three time periods: 7-9 a.m., 12-2 p.m., and 4-6 p.m. The postcards provided a brief introduction to the survey's purpose and included a link to the online survey, which was tailored to each location. Table 1 summarizes the number of postcards handed out at each location and their respective response rates.

TABLE 1 Survey Postcards Distributed and Number of Responses

Location	Time Period			Total Distributed	# of Responses	Response Rate
	7-9 a.m.	12-2 p.m.	4-6 p.m.			
NE Tillamook St/ NE MLK Jr. Blvd	102	21	79	202	107	53%
SE Division St/ SE 21st Ave	184	16	44	244	106	44%
Total	**286**	**37**	**123**	**446**	**213**	**48%**

The a.m. periods were the most productive in terms of the number of postcards distributed. Survey administrators noted that a number of individuals refused a postcard during the 4-6 p.m. period because they had already received a card during the a.m. period.

Intercept Survey Findings

Blue Light Indication

The minor street approaches of the two intersections surveyed (i.e., NE Tillamook Street and SE 21st Avenue) have a blue light feedback device adjacent the signal heads to indicate when the traffic signal's inductance loop has detected a bicycle. About 93% of respondents stated that they had noticed the blue light before with a slightly higher recognition level on NE Tillamook Street (97%) than on SE 21st Avenue (89%).

When asked, most respondents correctly identified the meaning of the blue light as shown in Figure 4.

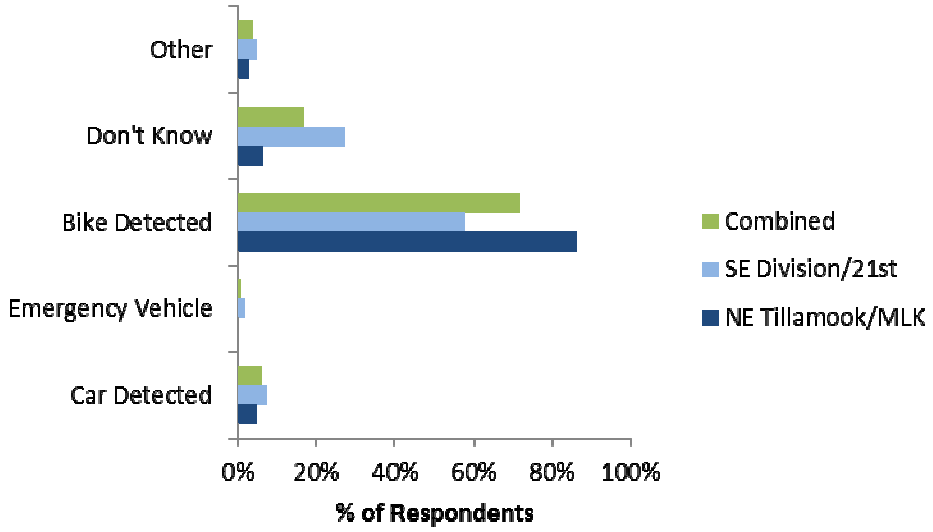

FIGURE 4 Meaning of Blue Light Indication Responses

There was a discrepancy between the two locations surveyed, with about 86% of the respondents at the NE Tillamook Street survey providing the correct response, compared to 58% of the respondents at the SE 21st Avenue survey. One of the survey administrators at the NE Tillamook location talked to a couple of the prospective respondents about the blue light, but this alone could not account for much of this discrepancy. Another explanatory factor could be that the blue light has been active longer at the NE Tillamook location or that the SE 21st location generally has more pavement markings present and the detector confirmation is wired to the automobile detection, which may dilute the meaning of the feedback devices. Lastly, the automobile traffic on NE Tillamook is much lower than the other site.

Finally, the most common "other" response is that the blue light feedback device means either a bicycle or car has been detected.

Bicycle Detector Pavement Marking

Survey respondents were presented with seven different pavement markings and asked to choose from a set of responses the one that best described what that marking would mean to them if they saw it while approaching a signalized intersection. As shown in Figure 5, the markings include:

- the 9C-7 marking (9C-7);
- the 9C-7 marking with a red-yellow-green signal (9C-7 + RYG);
- the bicycle lane pavement marking (Bike Lane);
- the bicycle route pavement marking used by PBOT in certain locations (Bike Route);
- a green-backed version of the 9C-7 marking (Greenback 9C-7);
- a modified version of the 9C-7 marking approved for experimentation by the Federal Highway Administration (FHWA) in Columbia, Missouri (Columbia Experiment); and
- the 9C-7 marking plus the text "Wait on Lines for Green" (9C-7 + Text).

The Bike Lane and Bike Route markings were included to avoid respondents figuring out that the response to every marking should be the same. The 9C-7 marking was always shown first to avoid other designs with more information influencing responses to the marking. The Columbia Experiment marking and the 9C-7 + Text marking were shown last because they both include text. All other symbols were shown in a randomized order. The 9C-7, Greenback 9C-7, Bike Lane, and Bike Route markings all exist in Portland today. The project team developed the 9C-7 + RYG and 9C-7 + Text markings; Alta Planning + Design provided the Columbia Experiment marking design.

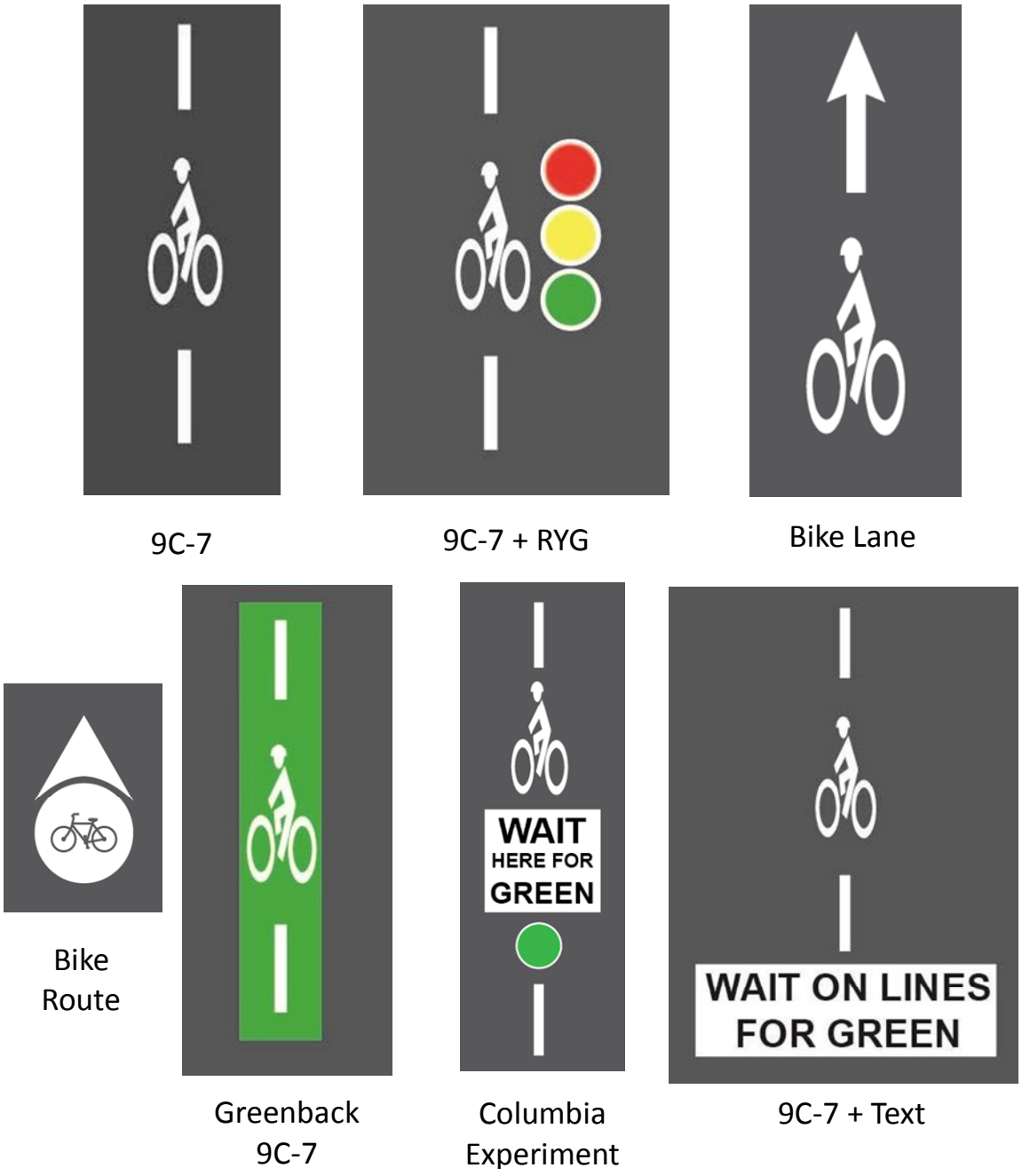

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FIGURE 5 Pavement Markings Surveyed

2 Figure 6 summarizes responses to the meaning of each marking.

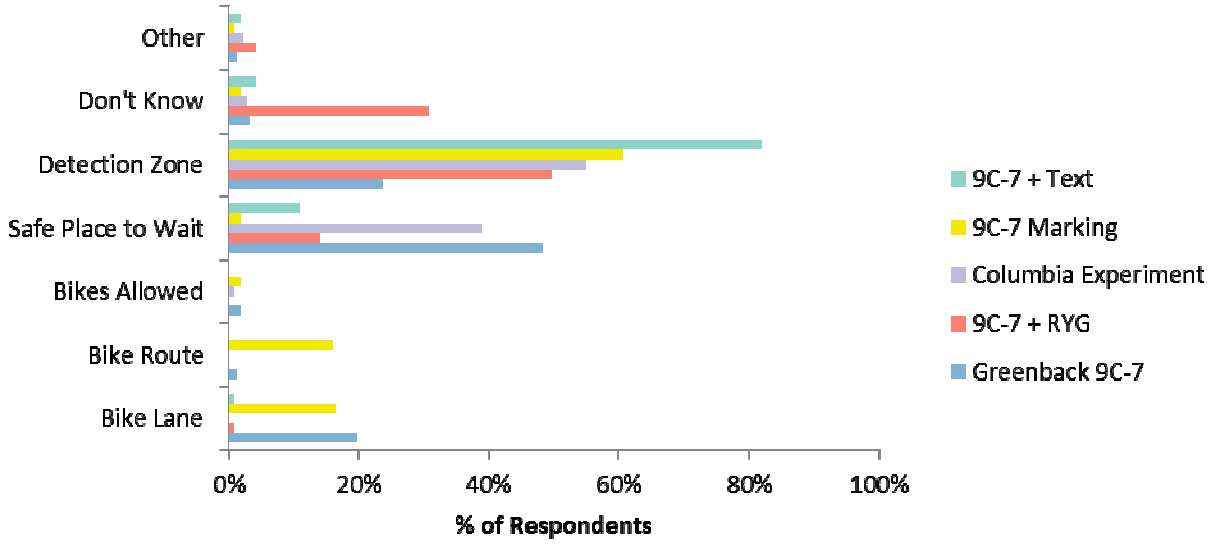

FIGURE 6 Meaning of Each Pavement Marking Responses

The 9C-7 + Text, 9C-7, and Columbia Experiment markings had the highest percentage of comprehension, with over half of respondents selecting that the marking means "where a bicyclist should wait to be detected by the signal." Notably, a majority of respondents identified the Columbia Experiment markings and the Greenback 9C-7 marking as a "safe place for a bicyclist to wait on a red light," 39% and 48%, respectively. While not necessarily the correct response, this interpretation of the marking should produce a similar practical effect (i.e., people stopping their bikes on top of the marking, thereby being detected by the inductive loop). If both the "safe place to wait" and "detection zone" responses are considered acceptable, then the two markings with text, Columbia Experiment and 9C-7 + Text, have the highest level of comprehension, approximately 94-93%, followed by the Greenback 9C-7 (72%) and the 9C-7 + RYG and existing 9C-7 markings (64-63%). This level of understanding of the 9C-7 marking is roughly similar to previous research on the marking, which found about 57% of respondents understood that the marking was a place for people on bicycles to wait at a traffic signal to receive a green indication *(3)*.

After selecting the meaning for each marking individually, respondents were shown a figure containing the five detection markings and were asked to rank how well the markings perform in communicating the location where a bicyclist should be stopped in order for a signal to detect it. Respondents were asked to rank the best three and only to rank a marking if they thought it was helpful. Figure 7 summarizes the overall rankings for the markings.

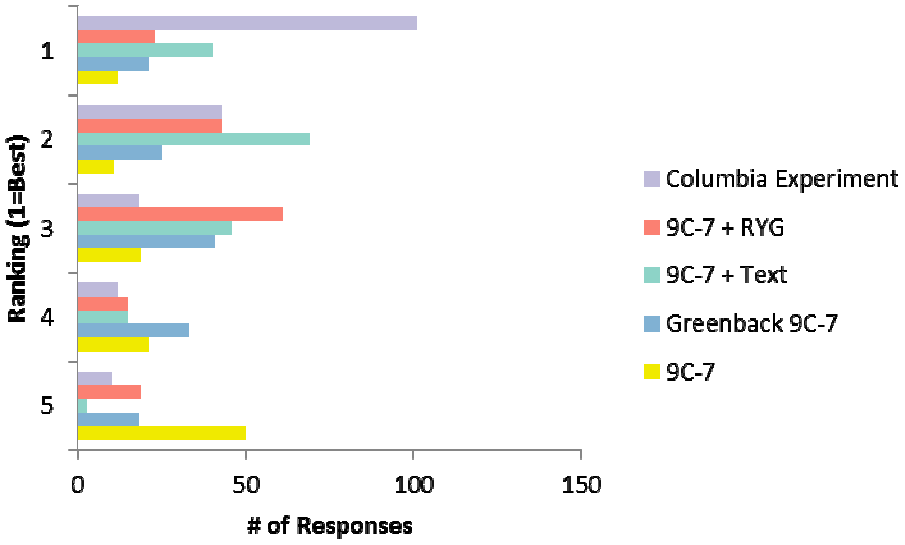

FIGURE 7 Detector Pavement Markings Ranking Responses

The results of this ranking exercise are similar to the responses to the individual markings. The Columbia Experiment marking received the greatest number of best (i.e. 1) rankings, with about half of respondents indicating that they think it did the best job of communicating the intended message. The 9C-7 + Text marking received the greatest number of second place rankings and the second highest number of first place rankings.

Based on these responses and that it is currently undergoing an official experiment, the Columbia Experiment marking was chosen to be installed at the two test locations. However, due to cost constructability, a modified Columbia Experiment was used which will be shown later in this study.

Demographics

Survey respondents are generally regular bicycle riders who are familiar with the intersection at which they received the postcard. As shown in Figure 8, nearly 90% of all respondents ride a bicycle through the subject intersection at least two to four days per week and about 57% of respondents ride through the study intersection five or more days per week. The majority of the remainder of respondents rides through the intersection one to three days per month. These results suggest that respondents are likely to be more familiar with bicycle-related pavement markings than the general population that may only ride occasionally, if ever.

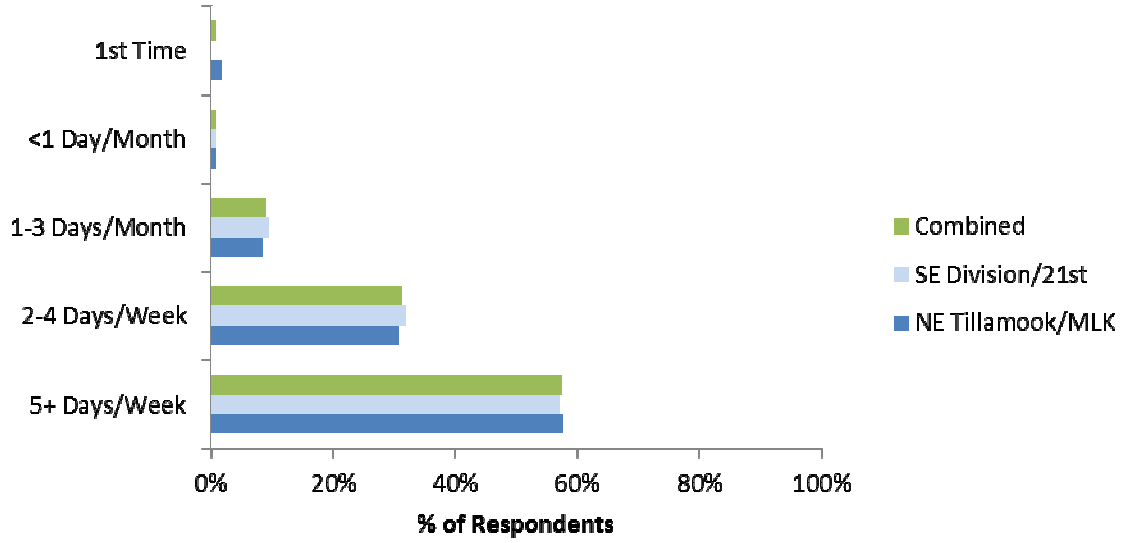

FIGURE 8 Frequency of Riding through the Study Intersection

A small majority, about 57%, of respondents are male. The median age of respondents is 38 years old, and 30-39 years old was the most common age range, followed by 40-49 years old and 20-29 years old, as shown in Figure 9.

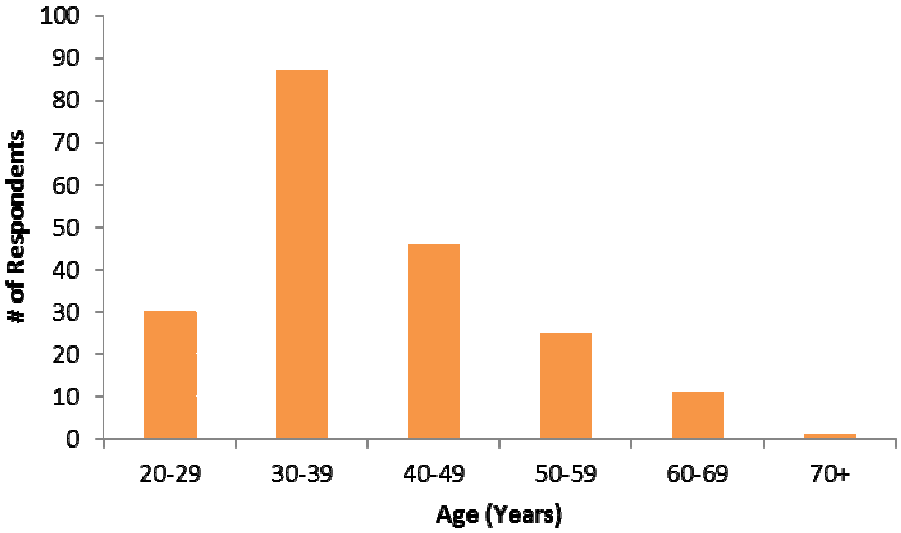

FIGURE 9 Age Range of Respondents

VIDEO OBSERVATIONS

Video Data Collection

Video data was collected and reduced in order to observe cyclist positioning with respect to the detector pavement markings. Two periods of video data collection were administered at the NE Tillamook Street and three at the SE Division Street site from 7:30 a.m. to 6:00 p.m. Table 2

describes the dates of data collection, postcard intercept surveys dates, and the Columbia Experiment marking installation date. Also, the Columbia Experiment marking was modified because the original design was difficult to construct. Figure 2 illustrates the final design of the stencil as it was installed in the field.

TABLE 2 Dates of Video Data Collection, Weather Conditions, and Hawthorne Bridge Bicycle Counts

Information	Before		Postcard Intercept Survey	After Postcard Intercept Survey	Stencil Install	After Stencil Install	
	Video Data Collection			Video Data Collection		Video Data Collection	
NE Tillamook Street/ NE MLK Jr. Boulevard	May 4, 2015			na		June 29, 2015	
SE 21st Avenue/ SE Division Street/		May 6, 2015	May 7, 2015	May 8, 2015	June 22, 2015		July 7, 2015
Weather (Conditions/Precipitation, Minimum Temperature, Maximum Temperature) <www.wunderground.com>	Sunny, 46°F, 64°F	Rainy (0.05 inches of precipitation) 47°F, 63°F		Sunny, 48°F, 80°F		Sunny, 63°F, 90°F	Sunny, 88°F, 79°F
Hawthorne Bicycle Counts <http://portland-hawthorne-bridge.visio-tools.com/>	6,917	6,163		7,532		7,002	7,327

Video Data Findings

Tables 2 and 3 shows the results of the video observations for the NE Tillamook Street and SE 21st sites, respectively.

TABLE 3 Bicyclist Behavior Observations from 7:30 am to 6:00 pm at NE Tillamook Street

Observation Type	Before Stencil	Percentage of Behavior Observations	After Stencil	Percentage of Behavior Observations
Total Number of Behavior Observations	168		188	
User Waits on Stencil Only	145	86.3%	155	82.4%
Pushes Button	7	4.2%	14	7.4%
Other Location	13	7.7%	17	9.0%
Runs Red Light	3	1.8%	2	1.1%
Runs Red Light (out of total cyclists)	3	0.8%	2	0.5%

TABLE 4 Bicyclist Behavior Observations from 7:30 am to 6:00 pm at SE 21st Avenue

Observation Type	Before Stencil & Survey	Percentage of Behavior Observations	After Survey, but Before Stencil	Percentage of Behavior Observations	After Stencil & Survey	Percentage of Behavior Observations
Total Number of Behavior Observations	228		250		231	
User Waits on Stencil Only	107	46.9%	135	59.2%	144	63.2%
User Waits Elsewhere Off Stencil	97	42.5%	86	37.7%	69	30.3%
Pushes Button	4	1.8%	3	1.3%	3	1.3%
Runs Red Light	20	8.8%	26	11.4%	15	6.6%
Runs Red Light (out of total cyclists)	20	3.5%	26	3.5%	15	2.0%

Cyclist positioning before and after the installation of the modified Columbia Experiment marking was essentially unchanged at the NE Tillamook Street location. The vast majority (86.3%) of cyclists were already positioning themselves over the existing detection pavement marking. The percentage of cyclists positioning over the detection marking slightly decreased with the installation of the modified Columbia Experiment marking; however, this result is not statistically significant.

In contrast, the before/after video observations at the SE 21st Street location produced different results. The proportion of cyclists positioning themselves over the detection pavement marking increased after the intercept survey was conducted and also increased after the modified Columbia Experiment marking was installed. While the impact of the postcard intercept survey to bicyclist behavior was not statistically significant, the installation of the Modified Columbia Experiment marking was statistically significant with over 95% confidence using a chi-squared statistics test. Also, there is a notable decrease of bicyclists running the red light from before the survey and after the new stencil installation. However, the "after survey but before stencil" data do not indicate a statistically significant decrease of cyclist red light running.

There was a significant difference in cyclist positioning between the two sites. Only about half of the cyclists at the SE 21st Street site waited over the detection pavement marking before and after the modified Columbia Experiment marking was installed, compared to over 80% at the NE Tillamook Street site. Observations and conversations with cyclists at the SE 21st Street site indicate that this may be because many cyclists are turning left at this location. As a result, they are positioning themselves to the left-hand side of the bike box, as opposed to the right-hand side where the detection marking is located. Also, the SE 21st Street location contains a green bicycle box and a large bicycle symbol in addition to the modified Columbia Experiment marking. Therefore, the message to 'wait here for green' may be diluted due to the other pavement markings present.

DISCUSSION AND FUTURE RESEARCH

Based on the results of this postcard intercept survey, the addition of text explaining the purpose of the 9C-7 marking positively influences how well the 9C-7 marking is understood. Furthermore, the experimental marking approved for use in Columbia, Missouri (Columbia Experiment) appears to have the best potential for being intuitively understood by people bicycling. The 9C-7 + Text marking also appears to better inform roadway users on its purpose.

The results of the video observations were mixed. Observed changes in cyclist positioning were insignificant at the mixed-traffic NE Tillamook Street location, while statistically significant at the SE 21st Avenue location. These differences appear to be related to the geometry and age of infrastructure at both locations.

The NE Tillamook Street bicycle boulevard is approximately five years old and the original 9C-7 have been present for that amount of time as well. The survey results also indicate 86% of Tillamook site respondents knew the correct meaning of blue light feedback device and approximately 84% total observed bicyclists were observed to wait on the stencil correctly, indicating they were more people positioning themselves on the 9C-7 marking correctly, as compared with the SE 21st Avenue site.

The SE 21st Avenue site has been recently reconstructed and restriped in early 2015 and therefore, the bicycle infrastructure is relatively new for bicyclists. Also, there are relatively more pavement markings at the SE 21st Avenue site as compared with the NE Tillamook Street site: a 10’ by 10’ bicycle box, a 5’ by 5’ bicycle symbol in the center of the box, and a curb-tight 9C-7 marking are present. Also, a blue light feedback device is installed, which will illuminate when a bicycle is positioned in approximately 90% of the bicycle box area including on top of the 5’ by 5’ bicycle symbol. Interestingly, the postcard intercept survey results indicate approximately 58% of SE 21st Avenue respondents understand the meaning of the blue light feedback device and approximately 47% of observed bicyclists were waiting on the 9C-7 marking correctly before intercept survey was performed and new stencil was installed. When the Modified Columbia Experiment marking was installed, the increase of bicyclists waiting on the stencil was statistically significant. These results indicate the modified Columbia Experiment marking provided positive guidance on where bicyclists should wait to receive a green light, which also corresponds to survey responses indicating that the modified Columbia Experiment marking is the most intuitive.

Further, video data was collected after the postcard intercept survey at SE 21st Avenue (but before the stencil was installed) to understand if the educational aspects of participating in the intercept survey modified bicyclist behavior. While there was a greater proportion of bicyclists waiting the stencil as compared with the “before” condition, the change of behavior was not statistically significant with over 90% confidence.

Also, while understanding red light non-compliance (red light running) is a motivation of this research, it’s difficult to determine whether the more descriptive stencil marking impacted bicyclist behavior. As past research has indicated, bicycle red-light compliance may be a function of a number of different intersection and environmental factors such as intersection size (crossing distance), intersection complexity, sight distance, cross traffic volume, average waiting time, weather, etc. For example, 2014 research at the SW Moody Avenue/SW Sheridan Street intersection measured bicyclist non-compliance between 7.1%-8.1% of total bicyclists (*4).* Whereas this research indicates bicyclist non-compliance between 0.5%-3.5% of total bicyclists. More research on bicycle signal compliance and intersection geometry is needed to understand

1 the motivations behind bicycle non-compliance with traffic signals so intersection improvements
2 can be made.

3 **CONCLUSIONS**

4 Based on the results of the postcard intercept survey and before/after video data results,
5 we believe that the Columbia Experiment marking has the potential to improve cyclist
6 positioning at signalized intersections with inductive loop detection. However, further
7 investigation into traffic signal non-compliance by bicyclists should be made.
8

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