ASSESSMENT OF BICYCLE DETECTION CONFIRMATION AND COUNTDOWN DEVICES

Final Report

PROJECT SPR 825

Oregon Department of Transportation

ASSESSMENT OF BICYCLE DETECTION CONFIRMATION AND COUNTDOWN DEVICES

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SPR 825

by

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16. Abstract: This research examined alternate designs for bicycle detection feedback confirmation devices. The research used quantitative data from a video review and responses from surveys to study how the information provided by the confirmation and feedback device affects the overall cycling experience. An online survey was conducted to determine comprehension rates of blue light feedback systems and countdown timers. The findings from the online survey (1,048 responses) revealed that the comprehension of the blue light detection confirmation devices by themselves was generally poor. Comprehension improved when a supplemental sign explaining the blue light was added. The countdown timer elicited high comprehension. Following the online survey, blue light detection confirmation systems were installed at six intersections farside and one nearside. A bicycle signal countdown timer was installed at one intersection. Video has recorded and analyzed and intercept surveys were conducted. A total of 2,428 persons on bicycle were analyzed and 234 intercepted persons were surveyed. Findings from the farside installations suggest that the design where the blue light was embedded in the sign was more visible to cyclists and observed by higher proportions of cyclists in the field. Findings from the nearside location were limited due to the single location. Results from the countdown timer indicate high comprehension rates. At all locations, cyclists indicated that the devices improved their waiting experience. There were changes to bicycle compliance and waiting location but they were site-specific. Observations at the nearside locations were conducted during the COVID-19 pandemic.

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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	millimeters squared	mm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.093	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.									
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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1.0 INTRODUCTION

Bicycling is increasing in the United States -- the number of trips made by bicycle more than doubled from 1.7 billion trips in 2001 to 4 billion in 2009 (NHTS 2009). With the increase in bicycling rates, there is a critical need for cycling infrastructure, which includes on and off-road bicycle lanes and paths, signs, markings, and signals. Investing in active transportation can help create a safer, more connected, and accessible transportation system (OBPP 2016). One of the key goals in the Oregon Bicycle and Pedestrian Plan is to improve the mobility and efficiency of the entire transportation system by providing high quality walking and biking options for trips of short and moderate distances (OBPP 2016).

One of the key links in a bicycle network is signalized crossings of high volume and high-speed roadways. At these intersections in Oregon, cyclists are primarily detected by inductive loops, often using the same inductive loops that are used for automobile detection. While vehicles are almost always detected automatically due to their size and predictable stopping location, that is not the case for bicycles. If a cyclist does not position themselves for detection, they may experience unnecessary delays. These delays lead to a lower quality experience and may lead to increased risk-taking behavior (i.e., signal non-compliance). Improved detection for bicycles can be accomplished by proper loop placement, calibration of loop sensitivity, alternative detection technologies, or by encouraging the optimal waiting location for bicyclists with pavement markings (i.e., MUTCD 9C-7 bicycle stencil or alternatives (Boudart et al., 2015)). Additionally, there has been interest in the adoption of bicycle detection confirmation devices. These devices communicate to a user that have been detected and in case of countdown type devices, an estimate of the amount of waiting time. Research is needed to evaluate the comprehension of these devices, to determine if additional signage is needed, and whether they influence the quality of the cycling experience.

1.1 OBJECTIVES OF RESEARCH

The objectives of this research were to:

- explore how well alternate designs for detection confirmation devices with or without supplemental signs are understood by the general public;
- establish quantitative information about the behavioral impacts of the confirmation devices from observations of the devices installed in the field ;
- qualitatively study how the information provided by the detection confirmation device affect the overall cycling experience; and
- provide guidance to practitioners regarding the use of detection confirmation devices for bicycles.

Overall, the research methodology used three methods to accomplish these objectives:

- a broad online survey to elicit the public's comprehension on the bicycle detection confirmation systems (blue lights and countdown timers) and supplemental signs.
- observations of persons on bicycle before and after the installation of the blue light detection confirmation detection system and a countdown timer, and
- an intercept survey of persons on bicycles at the locations with the devices installed.

1.2 ORGANIZATION OF REPORT

This *Final Report* summarizes the research and is organized into six chapters. Chapter 2 presents a brief literature review. Chapter 3 presents the overview of the methodology that was adopted in this study to achieve the objectives. Chapter 4 presents the analysis of a survey that was conducted both in Oregon and nationally using postcard and social media recruitment. Chapter 5 describes the findings of video analysis conducted at sites in Portland and Eugene before and after the installation of a blue light detection confirmation system with and without an accompanying sign. Chapter 6 presents the findings of an intercept survey that was administered to cyclists at sites in Portland and Eugene after the blue light detection confirmation detection system was installed. Chapter 7 summarizes the findings of the major research tasks, synthesizes the results, and presents recommendations. Cited references are summarized in Chapter 8. Appendix A contains the online survey questionnaire while the intercept survey questionnaire is presented in Appendix B and C.

2.0 LITERATURE REVIEW

This chapter documents the literature and practice review. The chapter is organized by topical area and concludes with a summary.

2.1 DETECTION AT SIGNALIZED INTERSECTIONS

The purpose of detection is to sense the presence of roadway users and provide the signal controller with the information, which it can then use to determine whether a phase needs to be served (NCHRP Report 812). According to the *Traffic Signal Timing Manual* (NCHRP Report 812), detectors are responsible for identifying user presence for a movement and corresponding phase, extending a phase, identifying gaps in traffic to determine when a phase should end, providing safe phase termination for high-speed vehicle movements at the onset of the yellow indication (dilemma zone protection), monitoring intersection performance measures, and counting traffic volumes and identifying vehicle types. Detection has primarily been used at signalized intersections for detection of motor vehicles. While Oregon has been a leader in designing intersections to accommodate bicycles, the concept of bicycle detection gained more national visibility following a policy directive implemented by the California DOT in 2009. This section reviews the history of detection and summaries, briefly, current technologies for detection.

2.1.1 History of Detection

Traffic signals which had been operated manually began to be replaced by pretimed traffic signal control devices starting in the 1920s (Klein et al., 2006). This change necessitated a need for a device that automatically collected data, which was previously collected manually. The initial sensor consisted of a microphone that was mounted in a small box on a utility pole at the intersection and was activated when a vehicle's horn was sounded (Klein et al., 2006). Around the same time, a pressure-based sensor was developed by Henry Haugh using two metal plates that acted as electric contacts that came together when a vehicle passed over them (Klein et al., 2006). However, this sensor experienced mechanical problems and subsequently an electro-pneumatic sensor was developed, which was only capable of passage detection and had limited accuracy (Klein et al., 2006). Subsequent improvements and technological advances led to the development of many types of sensors such as magnetometers, video imaging, microwave, and radar, ultrasonic, acoustic, and passive infrared. However, the inductive loop detector is the most widely used sensor in practice today at signalized intersections to detect both vehicular and bicycle traffic.

2.1.2 Types of Detection

This section describes the types of detection used for cyclists at signalized intersections.

2.1.2.1 Inductive Loop Detector

The inductive loop is most commonly used to detect vehicles and bicycles because of its flexibility to suit a wide range of conditions. The inductive loop consists of a wire that is coiled to form a loop in typical shapes such as rectangle, square, or circle. When a vehicle passes over the loop, a change in magnetic field is detected and the inductance of the loop is decreased. The presence of a vehicle is recorded by observing the change in resonant frequency caused by a change in inductance (Kidarsa et al., 2006). The inductive loop is insensitive to inclement weather conditions such as fog, snow, and rain and can provide basic traffic parameters. However, the operation of the inductive loop detector may be impacted by pavement deterioration, improper installation, street and utility repair, and weather-related effects (Klein et al., 2006).

The *Traffic Detector Handbook* recommends that inductive loop detectors be set in the presence mode to detect bicycles and motorcycles and hold the call until the green phase. If the call is dropped prematurely (pulse mode), the bicycle or the motorcycle may be trapped on the red phase (Klein et al., 2006). Klein et al. document the inherent problems with bicycle detection which include: locating the loop on the street to detect the bicycle (ideally in a bike lane which may not always be present); sequencing the traffic signal to accommodate a detected bicycle, which may not be possible with some control techniques; and providing sufficient signal timing for bicycles to safely cross the intersection (Klein et al., 2006). To address these issues, extension timing and delay features are recommended with inductive loops. This system consists of a pair of inductive loops, one typically located at the stop bar, and the other some distance upstream of the stop bar. When a bicycle is detected at the first upstream loop, the extension time is provided to hold the green to allow the bicycle to reach the loop at the stop bar. If a bicycle is detected at the stop bar loop, extension time is provided to allow the bicycle to move far enough into the intersection to safely clear it before the onset of the yellow indication (Klein et al., 2006). If a bicycle is detected during a red phase, the minimum green timing feature ensures that the bicyclist receives enough green time to safely cross the intersection during the next phase (Klein et al., 2006). The delay feature is used when vehicles merge into the bike lane to turn right. The detection is not captured immediately, so that the turning vehicle maneuvers may be completed without calling up a green light for that approach. (Klein et al., 2006).

Klein et al. provide recommendations on the types of loop configurations that impact the ability to detect small vehicles such as bicycles. These include the shape of the loop, the width of the lanes and loop placement within the lane (Klein et al., 2006). Sequential short loops improve sensitivity towards bicycles than the conventional single long loop (Klein et al. 2006). A series of loops also provides a fail-safe option in case one of the loops malfunctions. The quadrupole loop configuration also improves the detection of smaller vehicles. In a quadrupole configuration, the loops are wired in a figure eight patterns as shown in Figure 2.1. This type of configuration allows the center wires to have current flowing in the same direction, which allows them to reinforce each other, thus improving the detection capability (Klein et al., 2006). Additionally, the center wires counteract the fields of outer wires, which have their current flowing in the opposite direction, thus reducing the false calls.

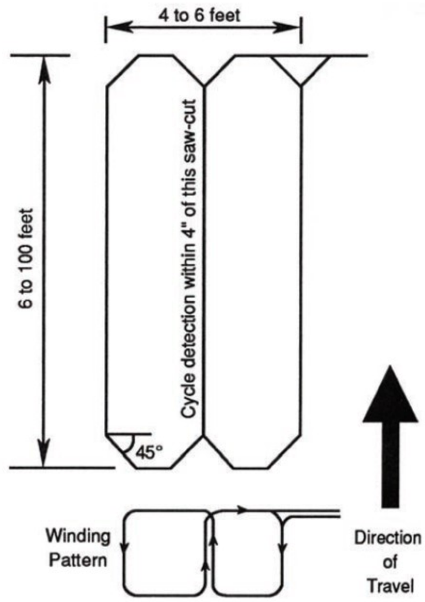


Figure 2.1: Quadrupole loop configuration (Klein et al., 2006)

At the time of the study, Klein et al. found that the 6-ft quadrupole loop detected bicycles better than other loop configurations (Klein et al. 2006). However, this configuration requires the bicyclists to ride close to the center of the loop to be detected (Klein et al., 2006). Pavement markings to show the location of wire and signs to communicate the purpose of markings to the bicyclist have been developed to enable better detection. Klein et al. also suggest that the chevron configuration can be used to detect small vehicles. This type of configuration consists of one or more four-turn parallelogram loops with the short section in the direction of traffic and the long section at an angle of 30 degrees with the short section (Klein et al., 2006). Figure 2.2 shows the chevron loop configuration. Loop sections are wound alternately clockwise and counterclockwise so that the currents in adjacent loop ends are always in the same direction (Klein et al., 2006). If long loops are used, Klein et al. suggest using a small powerhead at the stop bar to increase the detection signal (Klein et al. 2006). The use of sequential short loops than a single loop removes the need for the powerhead use (Klein et al., 2006).

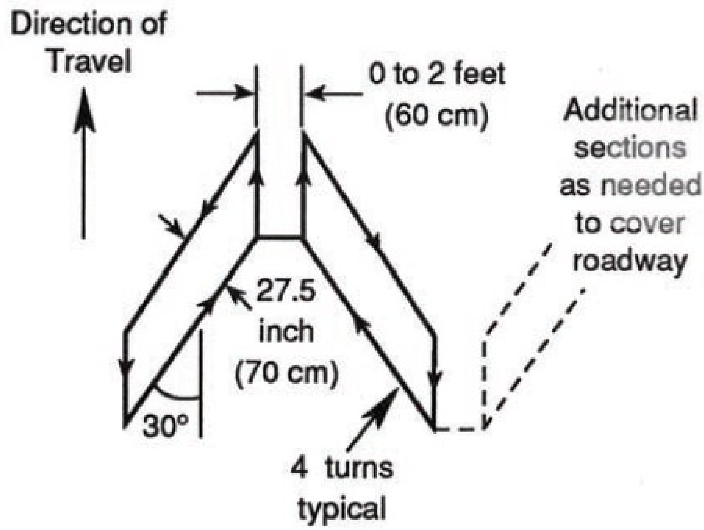


Figure 2.2: Chevron loop configuration (Klein et al., 2006)

Kidarsa et al. developed a model of loop detector-bicycle interaction and validated the model with field measurements and provided the location of bicycle detection zone hotspots (Kidarsa et al., 2006). While the model results showed that the performance of the circular loops was identical to those of octagonal loops for detecting bicycles, field measurements showed that when these loops are connected in series, their performance is degraded (Kidarsa et al., 2006). They recommend connecting these loops independently rather than in series, which would result in larger detection zones and increase loop sensitivity (Kidarsa et al., 2006).

Other studies have tested the accuracy of inductive loops for the purpose of counting bicycles. Presumably, prior to counting, bicycles need to be detected first and therefore the counting accuracy reflects on the detection. Nordback and Janson tested traditional loops, which do not distinguish between bicycles and motor vehicles for counting bicycles on off-road multi-use paths (Nordback and Janson, 2010). They also tested novel inductive loops capable of distinguishing between bicycles and other vehicles on off-road paths and on shared roadways (Nordback et al. 2011). The traditional inductive loops had an average accuracy of -4% compared to manual counts, while the novel inductive loops showed -3% accuracy on separated paths and +4% accuracy on shared roadways (Nordback and Janson, 2010; Nordback et al., 2011). ViaStrada tested two models of inductive loops in New Zealand at both on-road and multi-use sites and found mixed results. Three of the four on-road sites were over counted, while at the off-road sites, two locations experienced undercounting and one location experienced over counting (ViaStrada, 2009). Hjelkrem and Giaever tested four models of inductive loops in Norway on sidewalks, mixed traffic and bike lanes and found error rates between -16.5% to -2.5% (Hjelkrem and Giaever, 2009). As part of NCHRP 797, Proulx et al. tested six bicycle and pedestrian counting technologies and found an average error of 0.55% for inductive loops (Proulx et al., 2016). Kothuri et al. tested diamond and parallelogram loop configurations for counting bicycles in mixed traffic and found significant over counting, due to motor vehicles being counted as bicycles as they passed over the loop (Kothuri et al., 2017).

Shladover et al. conducted limited tests on commercially available detectors to explore their ability to detect bicyclists. A 6-foot Type D loop, a 3-foot square loop, a magnetometer sensor and a video imaging system were tested. Their results found that the inductive loops were able to detect the test bicycle at all locations within the loop and up to 3 inches outside the loop boundary, however, accuracy dropped to 50% when the bicycle was 6 inches outside the loop boundary (Shladover et al., 2009). Veenstra et al. compared the counts from inductive loops to manual counts at three signalized intersections in the Netherlands (Veenstra et al., 2013). They found that at lower bicycle volumes (< 200 cyclists per hour), the inductive loop counts were accurate. However, at higher volumes, the inductive loop detectors undercounted bicyclists (Veenstra et al., 2013)

2.1.2.2 Video and Thermal Cameras

With advances in image processing, video cameras are being increasingly used at signalized intersections for detection purposes. Their advantages are that they provide a non-intrusive form of detection and an ability to monitor multiple lanes and multiple detection zones per lane and multiple zones per signal input (Klein et al., 2006). It is also relatively easy to add and modify detection zones and monitor a large area by linking the information provided by individual cameras (Klein et al., 2006). They can be cost-effective when many detection zones within the camera field of view are required. However, the accuracy of traditional video cameras is affected by inclement weather conditions such as fog, snow, and rain; light conditions such as shadows, dawn, dusk; occlusion; vehicle/road contrast and grime on the camera lens (Klein et al., 2006). Additionally, night-time actuations may require the presence of street lighting and camera angle and placement also impact accuracy.

Obtaining bicycle and pedestrian counts using automated video processing techniques is an area of emerging research. Many researchers have developed algorithms to automatically track and classify bicyclists and pedestrians (Zaki and Syed, 2013; Ismail et al. 2010; Zangenehpour et al. 2015). There have been limited tests on commercially available video sensors. A study performed for the Minnesota Department of Transportation evaluated passive infrared, infrared, microwave, video, and inductive loops for bicycle and pedestrian detection on a trail and found that the Autoscope-Solo video sensor was accurate in detecting bicycles (SRF Consulting Group, Inc., 2003). Prasad et al. tested video cameras, microwave and inductive loop detectors and found detection difficulties with video cameras and bicycles in darkness, and false calls due to vehicle shadows appearing in the bicycle lane (Akbarzadeh et al., 2007). Shladover et al. found that the Traficon video detection system was able to consistently detect the bicyclist near the lane center and midway between the lane center and lane edge (Shladover et al., 2009). Li et al. tested a pedestrian and bicycle tracking and classification system using video cameras at three sites in Beijing, China and found that on average 9.64% fewer bicycles were detected and tracked (Li et al., 2010). While these studies present interesting findings, an important point to note is that there have been technological advances in passive detection in the last decade leading to improvements in the technologies themselves, therefore continuing evaluation is needed.

Thermal cameras have the potential to overcome the drawbacks of video cameras, especially in low-light conditions. These devices detect the presence of vehicles or bicyclists by observing changes in heat patterns and differentiating them by their shapes. Kothuri et al. evaluated FLIR's TrafiSense thermal camera at a signalized intersection for counting bicycles and found undercounting in the bike lane and sidewalk and overcounting in the right-turn and left-turn lanes (Kothuri et al., 2017). Thermal cameras can also have challenges with background filtering of pavement hear to detect users.

2.1.2.3 Radar Detection Technology

A number of agencies including ODOT have adopted radar as their standard technology for detection. The radar technology allows the use of more inputs that can specifically be tied to bicycle detection. In order to provide more efficient signal timing for cyclists, CalTrans has been experimenting with the use of a radar detector. The advantage of the radar over an inductive loop lies in its ability to distinguish between motor vehicles and bicycles, thus allowing the engineers to provide bicycle-specific minimum green when a bicycle is detected (Styer and Slonaker, 2017). Field tests were conducted at intersections in Chico and Sacramento. High accuracy was observed both for vehicle presence detection (99-100%) and bicycle presence detection (95%-97%) at the Chico site. Lower accuracy was obtained at the Sacramento intersection for bicycle presence detection (87%-100%). The radar device was observed to misclassify high-speed bicycles as cars. Occlusion could also be a problem especially if large vehicles block the cyclists. Follow up field tests were also conducted at Huntington Beach and results revealed high accuracy when detecting cars and bicycles (100%, 99%). Styer and Slonaker also found that the radar may misclassify groups of cyclists as vehicles, especially if they travel very close together. The overall findings also revealed the importance of verifying and validating detection zones (Styer and Slonaker, 2017). Figure 2.3 shows the sign that informs the cyclists they are detected by radar.

2.1.2.4 MicroRadar

Radar sensors are embedded in the pavement and detect bicycles as they pass over the sensor. They operate by emitting electromagnetic pulses and deducing information about the surroundings based on the reflected pulses (Ryus et al., 2014). Although these sensors are available commercially, there is no documented literature that has evaluated these sensors. The City of Vienna, Austria uses radar sensors to obtain automated counts and they are reported to operating flawlessly (AMEC E&I and Sprinkle Consulting, 2011).

2.1.2.5 Pushbuttons

Pedestrian pushbuttons are also sometimes used for bicycle detection as shown in Figure 2.4. However, these require the bicyclist to dismount and push the pedestrian pushbutton if available. These are considered active detection devices. The accessible pedestrian signal (APS) pushbuttons if present, can provide a confirmation tone. However, according to BIKESAFE, the Bicycle Safety Guide and Countermeasure Selection System, agencies should not expect on-road bicyclists to leave the road to actuate a signal using a pushbutton (BIKESAFE). Instead, they recommend the provision of passive detection systems, where the signal system automatically detects the presence of bicyclists.

ENGLISH UNITS (inches)

A	B	C	D	E	F	G	H	J
36	24	.625	.94	2.50	10	1.5	3C	2.25

Figure 2.3: CalTrans “Radar Actuated” detection sign

Figure 2.4: Push button for bicycle detection (Photo: P. Singleton)

2.2 POLICIES FOR BICYCLE DETECTION

The research team briefly reviewed the detection policy for bicycles for the adjacent state DOTs. In addition, any policies or statements by local agencies that could be identified are provided.

2.2.1 State DOT

ODOT's default standard detection type is radar (ODOT, 2020). The ODOT Traffic Signal Design Manual states that bike detection should be installed at an intersection where bike lanes are present (ODOT, 2020). At locations where bike lanes are absent, but a high volume of bicyclists are present, the manual recommends using engineering judgement to determine if bike detection should be considered on the shoulder or other locations (ODOT, 2020). The Oregon Bicyclist Manual developed by the Oregon Pedestrian and Bicycle Program at ODOT provides guidance to bicyclists on how to trigger the inductive loops at signalized intersections. For diamond loops, they recommend positioning the bicycle closer to the edge, up front and in the middle for rectangular loops and about a quarter of the way in for circular loops (ODOT, 2016). They also recommend waiting in the detection zone until a green light is received and using the pushbutton on the sidewalk in the event of detection failure (ODOT, 2016). Figure 2.5 shows the recommended bicycle positioning on the various loop configurations.

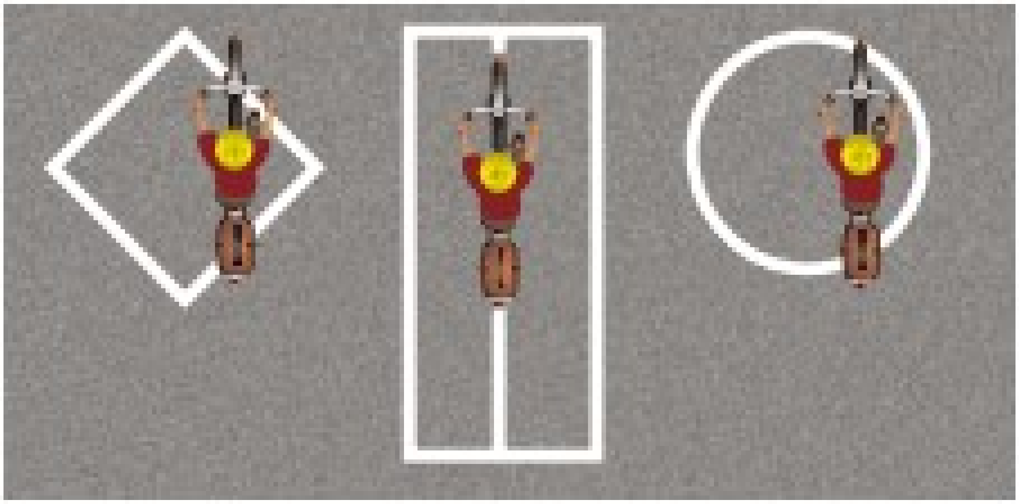


Figure 2.5: Bicycle positioning to trigger detection at inductive loops (Source: Oregon Bicyclist Manual)

Oregon laws (ORS 811.360) permit a person on a bike to proceed through a signalized intersection if they wait for one complete cycle without being detected (Oregon State Legislature, 2015).

In 2018, the Washington Department of Transportation (WSDOT) published their updated Design Manual. In division 15, chapter 1520, they stated, "*Intersections with separated bike lanes, other complex multimodal intersection treatments or those with a specific baseline need to increase bicycle user safety performance may incorporate a dedicated bike signal head with detection or actuation systems*." However, the specifications of these signals should follow the Interim Approval for Optional Use of a Bicycle Signal Face (IA-16) by FHWA, 2013. Furthermore, the detection system should follow the MUTCD standard including the modification in the WSDOT MUTCD supplement. Implemented loop detectors must be able to detect vehicles but also motorcycles and bicycles (RCW47.36.025-WSDOT, 2018).

In California, the California Vehicle Code (CVC) 21450.5 was amended effective January 1, 2008, to state that bicycles must be detected at new or modified traffic actuated signals, or else the traffic signal must be set to vehicle recall for all phases without bicycle detection. Initial implementation was in Traffic Operations Policy Directive 09-06 which was then incorporated in the 2012 California Manual on Uniform Traffic Control Devices which stated that "all new limit line detector installations and modifications to the existing limit line detection on a public or private road or driveway intersecting a public road shall provide a Limit Line Detection Zone in which the Reference Bicycle-Rider is detected or be placed on permanent recall or fixed time operation" (CA MUTCD, 2012).

2.2.2 Local Agency

The National Association of City Transportation Officials (NACTO) 2011 Urban Bikeway Design Guide includes a chapter that defines required, recommended and optional attributes of bicycle signal heads. The NACTO guide requires that appropriate detection and actuation shall be installed together with bicycle signals. The guide recommends that pushbuttons can be used for the detection of bicycles at bicycle-specific traffic signals but they should be located where bicyclists do not need to dismount to activate them. Optional features include a countdown timer to green to provide bicyclists information about when the green indication will next be displayed.

In 2013, City of Salem released their Transportation System Plan report (Providing Mobility for New Century). Chapter seven of the report provides an executive summary of bicycle system elements. They suggest that FHWA approved treatments for bicycle detection at signalized intersections are the right approach to move forward for a better design. The report indicates that cyclist delay at intersections is due to poor detectors that do not correctly place calls for service that enable green signal intervals. Therefore, they recommended pushbuttons, advanced loop detectors, or video detectors for mitigating this problem.

The City of Phoenix's Street Transportation Department in Arizona is trying to make their city a more bicycle-friendly place. Since 2013, they have been trying to implement various innovative ideas regarding bicycling infrastructure. Starting in June 2013, the Street Department of Transportation set a goal to improve the bicycling experience by improving efficiency, decreasing delay, and discouraging red light running. Therefore, they implemented type D loop detectors along with the 9C-7 pavement marking and the R10-22 sign. In 2015, they started implementing a new sign that encourages cyclists to obey the law and not ride against traffic. While in 2016, they installed their first bicycle traffic signal at the intersection of 12th Street and Campbell Ave.

In 2017, Southern Nevada released a regional bicycle and pedestrian plan document. They recommended replacing existing loop detectors with ones that are more sensitive so that bicycles could be more easily detected. These in-pavement loops should have pavement markings to inform cyclists where to best position themselves to be detected. The authors did not support the idea that a cyclist should maneuver to and push a button. However, they suggested installation of passive detection in the form of video cameras and microwave sensors.

In December 2015, Salt Lake City released its pedestrian and bicycle master plan document (Alta Planning + Design, 2015). Chapter six of the report provides an executive summary of bicycling recommendations and tabulates design specifications from various state agencies. The document outlines an action plan to address deficiencies within the current state of practice. The goal of Salt Lake City is to determine the safety effects of bike detection, specifically identifying a need for better understanding of the relationship between improved traffic flow and safety. Their recommendation is to find a standard detection technology for both vehicles and bicycles. Accordingly, Salt Lake City and the Utah Department of Transportation selected radar as the preferred sensor type. They also endorsed the bicycle detector confirmation light as a necessary system component (by citing the City of Portland's study of blue lights).

In 2010, the City of Kitchener, Canada issued their final report titled Cycling Master Plan for the 21st Century. The document discusses how to improve bicycle detection at intersections. They claimed that signs for bicyclists are lacking in Canada. Therefore, they recommended three different treatments: 9C-7 pavement marking on the loop detector, an accessible push button, and/or video detection so that bicycles can be more easily detected and experience reduced wait times for green signals.

2.3 BICYCLIST COMPLIANCE WITH TRAFFIC SIGNALS

Crossing an intersection against a red signal can contribute to cyclist-motor vehicle collisions (Watson and Cameron, 2006). There is limited literature on cyclist compliance at intersections. Some studies have found that non-compliance by cyclists is considered as typical behavior by drivers and something that annoys them (O'Brien et al., 2002; Kidder, 2005; Fincham, 2006).

Johnson et al. explored the compliance rate (signals were not bicycle specific) and associated factors at 10 locations in the Melbourne metropolitan area using a cross-sectional observational study (Johnson et al., 2011). Their results revealed a non-compliance rate of 6.9%. The main factor affecting compliance was the direction of travel, with cyclists turning left (similar to right-turns in the U.S.) who were 28.3 times more likely to non-comply than cyclists who travelled straight through the intersection (Johnson et al., 2011). Presence of other road users had a negative effect on non-compliance (Johnson et al., 2011). They found that cyclists do not consider the left-turns on a red signal as an unsafe maneuver (Johnson et al., 2011). In a later study, Johnson et al. investigated cyclist behavior and factors affecting signal non-compliance (Johnson et al., 2013). 2,061 cyclists who were at least 18 years or older completed an online survey providing demographic characteristics and answered questions regarding the frequency with which they stopped at red lights and reasons for cycling through a red light (Johnson et al., 2013). Their findings revealed that male riders, younger riders, and riders who were previously not involved in a crash were more likely to non-comply (Johnson et al., 2013). Respondents stated that they were more likely to non-comply when they had to turn left, failure of the inductive loop to detect them, where other road users were not present, and at a pedestrian crossing (Johnson et al., 2013). Richardson and Caulfield examined the compliance behavior of cyclist in Dublin city using an observational survey and an online questionnaire (Richardson and Caulfield, 2015). The results from the observational study revealed a high non-compliance rate of 61.9% with males associated with a higher likelihood of non-compliance (Richardson and Caulfield, 2015). Overall, 49% of the survey respondents stated that they would not non-comply with the signal indication (Richardson and Caulfield, 2015).

At locations with bicycle-specific signals, Parks, Monsere, McNeil and Dill (2012) studied compliance with signals in the Washington, D.C., area as part of a wider evaluation of the cycling infrastructure. They found compliance at signals strongly related to crossing traffic and somewhat related to delay or progression for cyclists. Each of these intersections is unique so while it is difficult to state definitively, a trend is apparent. The results of this analysis are in Figure 2.6, which shows the rate of compliance as? a function of the conflicting vehicle flow rate (expressed as a 15-minute flow rate).

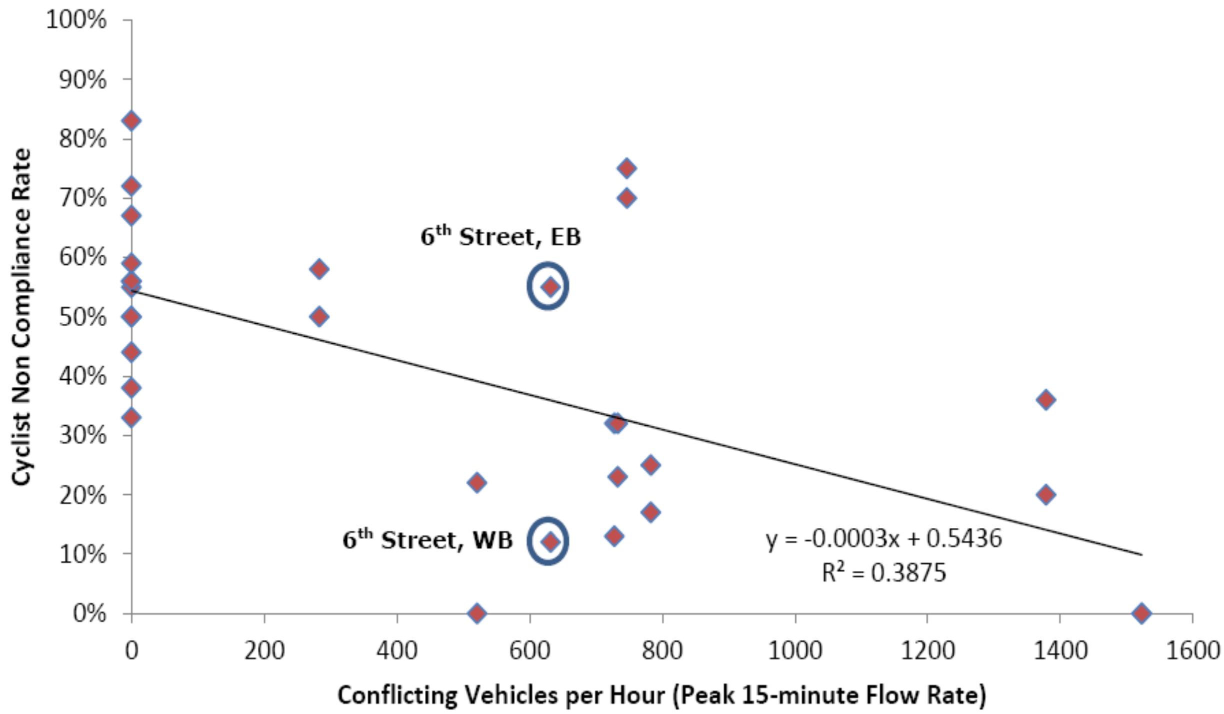


Figure 2.6: Observations of bicyclist non-compliance, Pennsylvania Ave.., Washington, D.C. (Parks et al., 2012)

Monsere et al (2014) studied user behavior at signalized intersections as part of a larger project. Compliance rates by drivers and bicycles to the traffic control were comparable and users appeared to comprehend the design. Figure 2.7 summarizes the compliance of bicyclists at all the intersections where video data collection was conducted. The compliance is the highest at the Oak/Divisadero intersection in SF, followed closely by the intersections on NE Multnomah in Portland. Compliance is lowest on Milwaukee, L St.., and the remaining SF locations. These are all areas with relatively high bike volumes and some of these intersections have low minor street traffic. Many of the non-compliance observations are "jumping" the signal (e.g., starting before green but during the clearance interval for crossing traffic that is sometimes low). Finally, the low compliance at L St. is partially explained by the observation that many L St. bicyclists following the leading pedestrian interval. It should be noted the council of the District of Columbia passed an amendment, cited as the "Bicycle Safety Amendment Act of 2013" making it legal for bicyclists to follow the leading pedestrian interval at an intersection. At the three intersections studied in Chicago on Dearborn Ave., 77-93% of observed bicyclists complied with the bicycle signal and 84-92% of observed motorists complied with the left-turn signal.

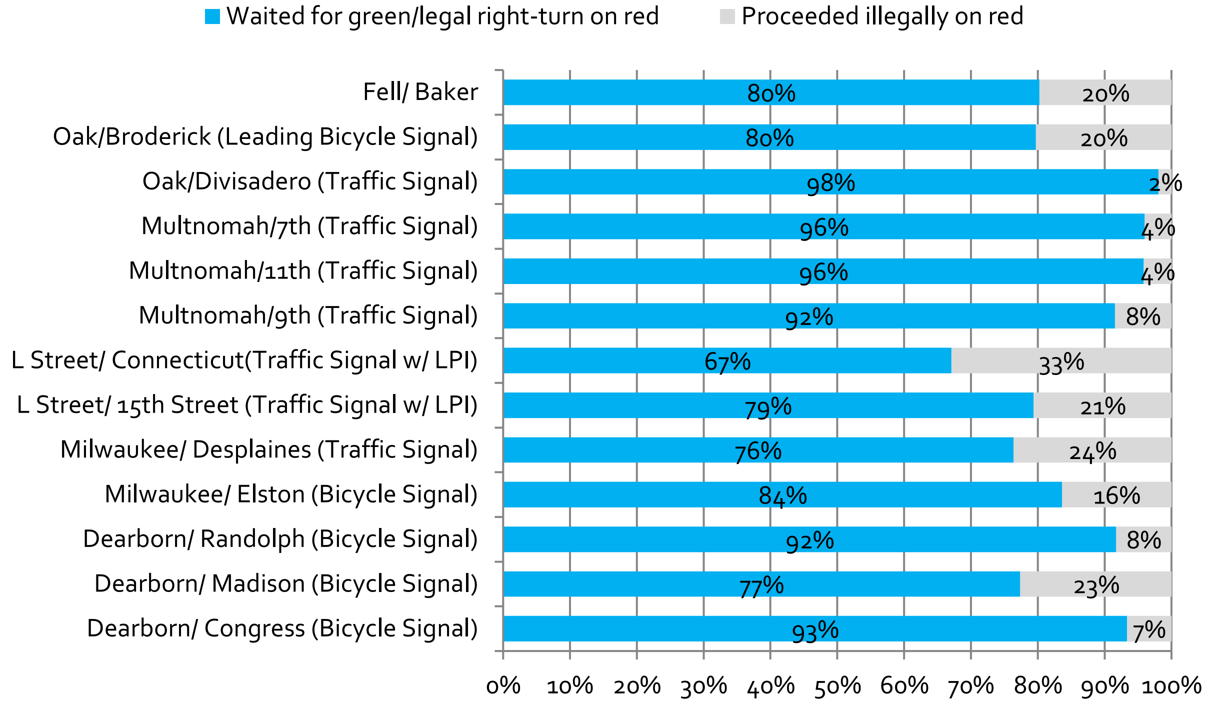


Figure 2.7: Observed cyclist compliance with traffic signals (Monsere et al, 2014)

Smith et al. explored the positioning of bicyclists at signalized intersections in Portland OR using an observational study at 6 locations with 9C-7 pavement marking (Smith et al., 2018). A review of the video data collected at the six locations showed high compliance rates (98.2%) with traffic signals, excluding the right turn on red (Smith et al. 2018). Boudart et al. studied bicyclist behavior at traffic signals with a blue-light detector feedback confirmation device at one location in Portland, OR. Their findings revealed a high compliance rate with more than 92.7% of bicyclists complying with traffic signals at the location with the detector feedback confirmation device having a negligible effect on compliance (Boudart et al., 2015).

Thompson investigated cyclist compliance at signalized intersections equipped with and without bicycle signals in Portland, OR (Thompson, 2014). Two types of cyclist compliance were evaluated, those that moved straight through the intersection violating the red signal or those that made an illegal right turn. Factors that acted as a deterrent to red light running include number of cyclists already waiting at the signal, the presence of a vehicle in the adjacent lane, and female sex (Thompson, 2014). However, certain types of signal phasing, witnessing a violation, and lack of helmet increased the likelihood that the cyclist would non-comply with the signal indication. A survey of cyclists was also conducted to determine the characteristics in compliance decisions. Age was found to be negatively correlated with stated non-compliance, while gender was not significant. Helmet use was negatively associated with non-compliance (Thompson, 2014).

For cyclists that do not position themselves for optimal detection, there can be unnecessary delays which leads to a lower quality experience and may lead to increased risk-taking behavior (i.e. signal non-compliance). Huan, Yang and Zia (2012) explored cyclists’ behavior at five signalized urban intersections in Beijing, China using video camerasand found that when the wait time exceeds 51 seconds only 5% of cyclists obey the traffic rules and wait for the onset of the green indication to enter the intersection (Figure 2.8). Additionally, Huan indicated that male cyclists have a higher tendency to violate traffic rules as compared to female cyclists. Men were approximately twice as likely to have shorter waiting times as females. However, the work by Thompson and Parks found a stronger correlation with cross-traffic gaps.

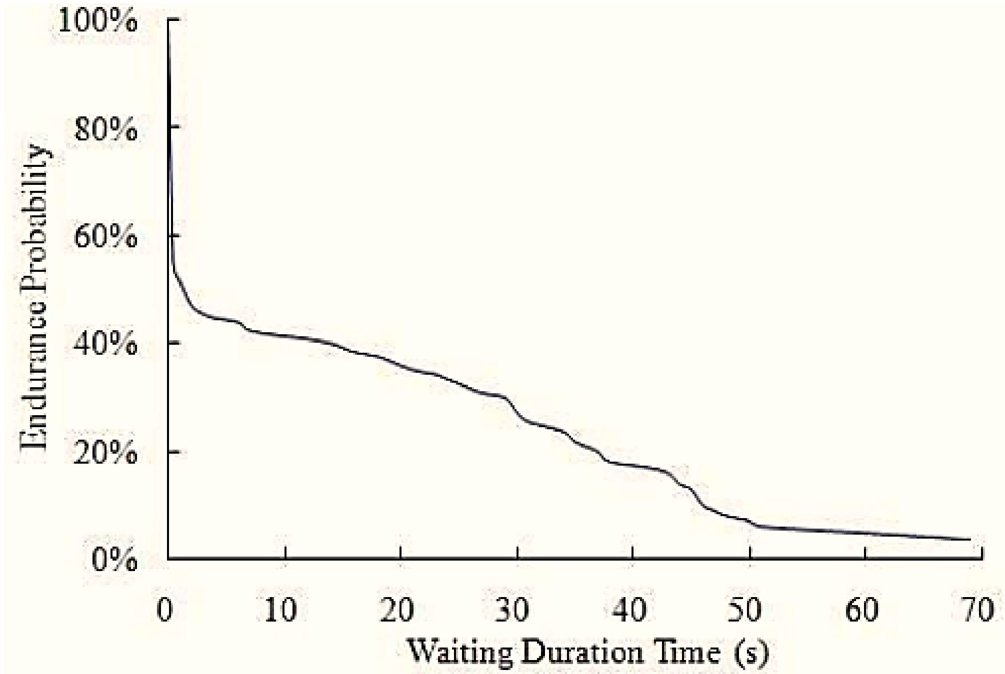


Figure 2.8: Endurance probabilities versus waiting duration (Huan et al, 2012)

2.4 MITIGATION TO CHALLENGES WITH BICYCLE DETECTION

Although loop and/or non-invasive detectors are increasingly used to detect bicyclists at signalized intersections, in the absence of bicycle-specific facilities and especially on shared roadways, they are often placed in the middle of the roadway to detect automobiles. The placement of the detection can be problematic to bicyclists since they often ride close to the curb (Boudart et al., 2015; Maki et al., 1997; Kidarsa et al., 2006). This is especially pertinent for new or inexperienced cyclists, who may be uncomfortable riding in the middle of the lane. In the absence of vehicles, bicyclists who do not position themselves properly on an inductive loop possibly due to intersection geometry, approach grade or sight line issues, may fail to get detected and not get a green phase. This may lead to excessive delays and red-light running behavior. Therefore, pavement markings, signs and feedback confirmation devices can provide better information to bicyclists regarding detection and appropriate placement.

2.4.1 Use of Pavement Markings to Communicate Bicycle Stopping Position

Pavement markings can be used to inform the cyclist about appropriate waiting area on the roadway to get detected. Boudart et al. suggest that a contributing factor to cyclists' misunderstanding of traffic signal detection is the lack of consistency in marking and signage that is used (Boudart et al., 2015). The MUTCD provides the 9C-7 bicycle detector pavement marking, which consists of a vertical symbol of a person with a helmet, riding a bicycle with a vertical line segment above and below. An accompanying sign R10-22 helps explain the purpose of the 9C-7 bicycle detector pavement marking. Figure 2.9 shows the 9C-7 marking and R10-22 sign.

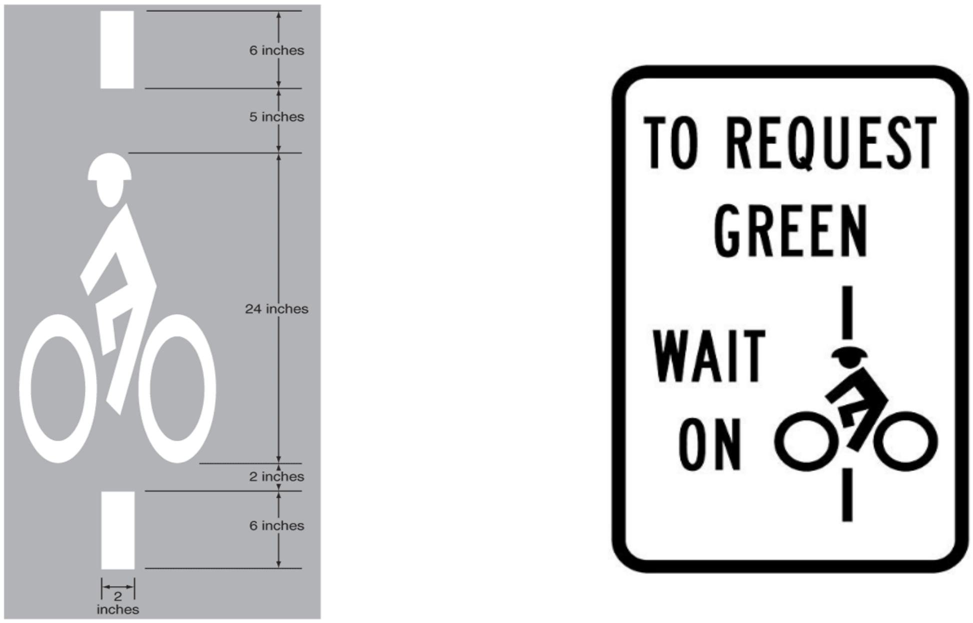


Figure 2.9: 9C-7 Bicycle detector pavement marking and R10-22 sign (MUTCD, 2009)

The markings and signs were placed in the MUTCD in 2003 by recommendation of the NCUTCD rather than through experimentation. The literature review did not find any published research on comprehension of the 9C-7 marking and the R10-22 sign. Personal communication with Rich Mouer (AZ DOT) and Kevin Dunn (FHWA) suggest that the pavement marking was recommended for use in the AASHTO 1999 Guide and believed to have originated in California. The sign was recommended to FHWA by the NCUTCD. Van Houten (personal communication, 1999) shared unpublished work supporting comprehension of the sign that was used by NCUTCD. In the test, four signs were a “TO REQUEST GREEN WAIT ON “SYMBOL”, WAIT ON “SYMBOL” TO CHANGE SIGNAL; WAIT FOR GREEN LIGHT ON “SYMBOL”; and WAIT ON “SYMBOL” FOR GREEN. A total of 160 participants were randomly divided into four groups to evaluate each of the four signs. The groups viewed a slide showing an intersection with a red light and the bicycle detector symbol along with the following instruction: “*Imagine you are riding a bicycle along the road and you come to a red light. The slide shows the view you see as you stop at the red light. You also see the above sign mounted on a post to your right*.” The results of the test are shown in Figure 2.10. Approximately 68% of the participants who saw the now R10-22 sign knew they had to wait on the detector to get a green light, that this action would change the signal but would not do it immediately.

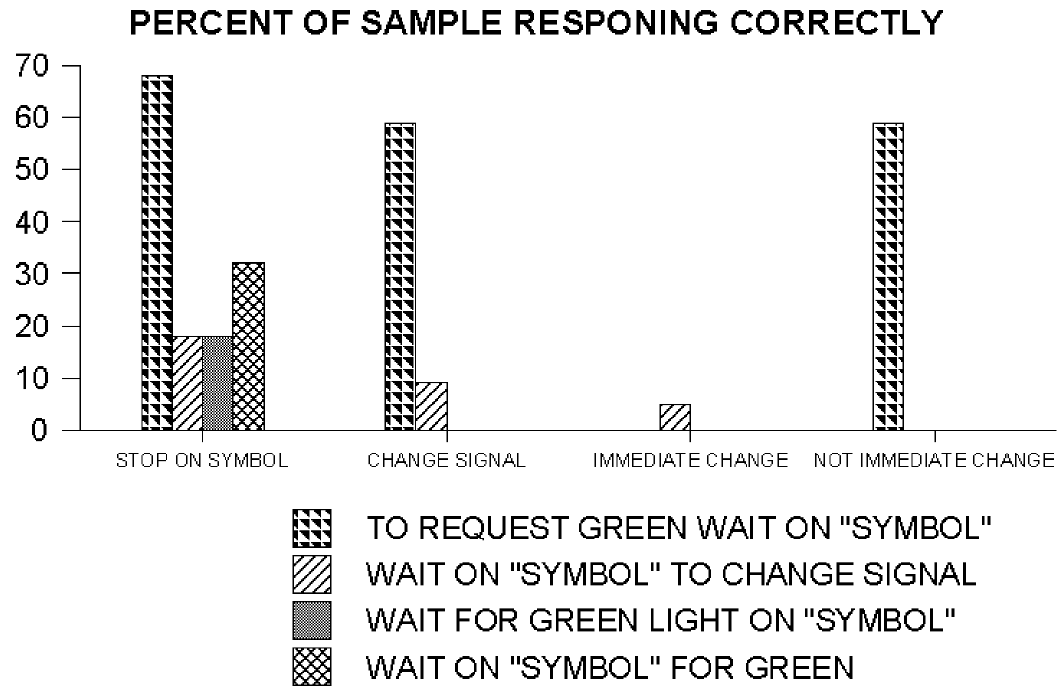


Figure 2.10: Results of R10-22 human factors test (Van Houten, personal communication, 1999)

The Final Rule for the 2003 Edition adopting these signs and pavement markings reads:

> *"The FHWA adds a new section following existing Section 9B.10 (new Section 9B.11) Shared-Use Path Restriction Sign (R9–7). The new section is numbered and titled ''Section 9B.12 Bicycle Signal Actuation Sign (R10–22)'' and provides a new sign giving information to bicyclists on how to best situate themselves within the proposed new Bicycle Detector pavement marking symbol so that they can actuate the traffic signal. The remaining sections are renumbered accordingly. Fifteen commenters, representing the NCUTCD, State and local highway agencies, as well as private citizens, supported the new section. The FHWA adopts the changes as proposed in the NPA."*

More recently, a study conducted by the Department of Psychology at Florida State University for the Florida Department of Transportation evaluated the comprehension of bicycle signs and pavement markings and found that the bicycle detector pavement marking (9C-7) was frequently misunderstood even by cyclists (Boot et al., 2013). Out of 68 participants, no one comprehended the bicycle detector marking correctly, leading the authors to hypothesize that the lack of familiarity with the marking may have contributed to the incorrect responses (Boot et al., 2013).

Bussey evaluated the impacts of roadway marking with and without a sign and an alternative detector marking on cyclist queuing position at actuated signalized intersections in Portland, OR (Bussey, 2013). After observing over 300 hours of before and after video data with 688 observations, Bussey found that only 23.5% of the cyclists position themselves correctly over the 9C-7 marking when installed alone. When the marking was paired with the R10-22 sign, 34.8% of the cyclists positioned themselves correctly (Bussey, 2013). The alternate detector marking resulted in 48.4% of the cyclists positioning themselves correctly (Bussey, 2013). Figure 2.11 shows the modified detector marking that was tested in the study. An accompanying survey of 227 participants was also conducted by Bussey and the results revealed that 45.4% of cyclists understood the purpose of the roadway marking to show the cyclists where to wait in order to be detected (Bussey, 2013). An additional 11.5% of the survey respondents stated that the purpose of the roadway marking was to showcase the recommended waiting location for the cyclist but did not correlate that with detection (Bussey, 2013). The findings of the survey also revealed the preference of some respondents to wait close to the curb for safety and visibility purposes, however, this positioning places them away from the detector (Bussey, 2013).

Figure 2.11: Modified 9C-7 pavement detector marking (Bussey, 2013)

Another study conducted at the University of Missouri-Columbia's bicycle simulator tested three alternate pavement markings in addition to the 9C-7 pavement marking both with and without an R10-22 sign. Thirty participants completed the simulator experiment. The participants were recruited using on-campus advertisements, the Missouri Bicycle and Pedestrian Federation, and bicycle shop advertisements (Wojciechowski, 2017). The results from the bicycle simulator experiment revealed that two of the alternate pavement markings were preferred over the MUTCD marking. A survey that was administered to thirty participants following the simulator experiment also revealed that all markings except the MUTCD marking were associated with good comprehension rates. The most preferred marking from the simulator and survey experiments was further subjected to field testing and an in-field survey was conducted. The findings of the field survey revealed that 81% of the respondents were unclear about how to interpret the 9C-7 MUTCD bicycle detector pavement marking, however, 97% of the survey respondents correctly interpreted the alternate pavement marking that was also preferred in the simulator and survey experiments (Wojciechowski, 2017).

Figure 2.12: Modified Columbia experimental bicycle pavement marking (Wojciechowski, 2017)

2.4.2 Providing Detection Confirmation with Farside Blue Light

A blue light is a feedback confirmation device that provides information to the cyclist that they have been detected at a signalized intersection. Official MUTCD experimental requests exist for the City of Portland, OR and the Oregon DOT. The research team has identified additional deployments in Palo Alto, CA, Edmonton, AB, Fort Collins, CO, Austin, TX through their research and professional networks. There are likely other installations. In the typical application, the blue light is placed on the far side of the intersection near the signal head that the cyclist is monitoring for information. When the cyclists are detected and a call is placed, the blue light illuminates. Photos of example installations are shown in Figure 2.13.

Boudart et al. first evaluated the impacts of blue light feedback confirmation device at one signalized intersection in Portland, OR (Boudart et al., 2015). Video data were collected in three phases – before condition, after blue light installation and after blue light and informational sign installation. In the before condition, cyclists primarily used the pushbutton to be detected, despite the presence of 9C-7 pavement detector marking (the R10-22 sign was absent). After the blue light and informational sign installation, a statistically significant decrease in cyclists using the pushbutton was observed (Boudart et al., 2015).

Portland, OR Blue Light Feedback (Photo: J. Maus)

Austin, TX, Blue Light Feedback (Photo: C. Monsere)

Salem, OR Commercial and Union Streets Blue Confirmation Light and Explanatory Sign (ODOT)

Figure 2.13: Photos of blue detection confirmation lights

Boudart et al. continued their work and tested the modified UM-Columbia pavement marking along with the blue light feedback confirmation device at two intersections in Portland, OR (Boudart et al., 2017). A postcard intercept survey was also administered at the two sites, with the postcard containing a link to an online survey. A total of 213 people responded to the online survey. The findings of the survey revealed differences in comprehension regarding the blue light indication at the two sites (86%, 58%) (Boudart et al., 2017). The authors hypothesized that the higher comprehension at one site could be related to the longer length of time the blue light had been active at that location compared to the other location (Boudart et al., 2017). They also opined that it could be related to a large number of pavement markings at the second location, which could have diluted the comprehension of the detection confirmation device resulting in a lower comprehension rate (Boudart et al., 2017). Survey respondents were also asked to provide their understanding of seven different pavement markings and asked to choose from a set of responses that best described what the marking meant to them (Boudart et al., 2017). Respondents were also asked to provide a ranking to indicate how well each marking communicated the correct location where a cyclist should wait to be detected (Boudart et al., 2017). The modified UM-Columbia pavement marking received the highest ranking and was installed at two field locations for testing and before-after video data was collected. While, the positioning of the cyclists at one location slightly decreased pre- and post-installation of the modified Columbia experiment marking, which was not statistically significant (86.3% vs. 82.4%); the proportion of cyclists positioning themselves over the detection marking at the second location increased after the installation of the marking and the intercept survey (46.9% (before), 59.2% (after survey but before Columbia experiment), 63.2% (after Columbia experiment) (Boudart et al., 2017). The pavement markings and the blue light confirmation device did not have a statistically significant impact on compliance (Boudart et al., 2017).

Recently, ODOT conducted an experiment at the intersection of Commercial and Union Streets in Salem, OR with the blue light and accompanying sign (ODOT, 2018). In the before test, a bicycle stencil (MUTCD marking) was located on the westbound approach to indicate where the cyclists should position themselves. In phase 1, a blue light detection confirmation device was installed on the eastbound and westbound approaches. In phase 2, an explanatory sign was placed next to the blue light detector confirmation device. In each phase including the pre-installation phase, 40 cyclists were observed via video footage. The findings revealed that in phases 1 and 2, higher rates of the call being held until the bicyclist entered the intersection (31% before, 42% phase 1, 47% phase 2). More cyclists were also observed to arrive and wait within the video camera's detection zone after phases 1 and 2. The blue light confirmation devices may also help in reducing sidewalk riding. In this study, while the pushbutton usage reduced in phase 1 after blue light installation (32% to 18%), it, however, increased in phase 2 and returned to regular usage levels (to 33%) (ODOT, 2018). The authors opine that the increase in pushbutton usage may be related to a continued lack of understanding on how cyclists are detected at intersections. Video observations revealed that after the addition of the sign, a higher number of cyclists approached the signal from the vehicle lanes rather than the sidewalk, however many of them left the street to activate the pushbutton (ODOT, 2018). These cyclists were observed to rejoin the bike lane downstream of the intersection. High compliance rates with respect to red lights were observed in all phases.

The study raises questions about the conspicuity of the blue light detection confirmation device due to its small size and the blue light being illuminated only when a rider is within the detection zone (ODOT, 2018). The report also suggests that there is a very low probability of the cyclist noticing the blue light unless they are looking directly at it when it is illuminated and the informational sign may not be useful to riders if they read the sign, when the light is not illuminated (ODOT, 2018). The study also reports on anecdotal observations at another location suggesting that cyclists were becoming gradually aware of the presence and meaning of blue light detection confirmation light (ODOT, 2018). According to PBOT, the cost of each blue light installation per approach is estimated at $2,000 ($4,000 if installed on two approaches at an intersection).

2.4.3 Providing Detection Confirmation with Nearside Devices

An alternative to the far-side detection confirmation systems would be to place feedback confirmation on the near-side, perhaps more easily visible to the waiting cyclist. One vendor, Iteris, has a "SmartCycle Bike Indicator" that can be mounted on traffic signal poles and illuminates when cyclists waiting at an intersection has been detected. Figure 2.14 shows the device mounted on a pole. The promotional video includes a demonstration of the product at an intersection but no analysis of user behaviors was found.

Figure 2.14: Iteris "Bike Indicator"

In Christchurch, New Zealand a nearside indication device has been in use for some time. As described on the "Cycling in Christchurch" blog, the city adapted the standard pedestrian pushbutton confirmation device to work for bicycles. The button is dark when the call is not active but lights up red when bicycles are detected. Figure 2.15 shows the device illuminated (left) and dark (right).

Figure 2.15: Nearside confirmation system in Christchurch, NZ (Source: G. Korrey)

2.4.4 Providing Feedback with Countdown Timers

Countdown timers are clock-like displays that indicate the remaining time for a signal indication providing users with real-time information to make better decisions. In the U.S., they are only for pedestrian operations though they are common internationally for bicycles and vehicles. The pedestrian countdown signals were first approved and included in the 2003 MUTCD (FHWA, 2003). These countdown signals show the amount of time remaining in the clearance interval (FLASHING DON'T WALK). The MUTCD requires the use of pedestrian countdown timers when the pedestrian change interval is more than 7 secs (MUTCD, 2003). A number of studies have reported a reduction in pedestrian-motor vehicle conflicts and improved pedestrian safety as a result of the pedestrian countdown timer installation (Huang And Zegeer 2000; Markowitz et al. 2006; Chen et al., 2015; Lambrianidou et al., 2013; Schmitz 2011; Scott et al., 2012; Vasudevan et al., 2011; Eccles et al., 2004). Additionally, studies have suggested that pedestrians prefer countdown timer information, "because it gives them more information and lets them make better crossing decisions (Singer and Lerner, 2004)." The pedestrian countdown timers were also found to improve driver safety (Kwifizile et al. 2015; Kitali et al., 2018). Drivers have been found to use the pedestrian countdown timers to make informed decisions when approaching the intersection (Chen et al., 2015; Schmitz 2011; Elekwachi 2010; Nambisan and Karkee 2010).

Although vehicular countdown timers are not in use currently in the U.S. and not approved by FHWA, they are in use in other countries and many studies have explored their impact. These studies have found that countdown timers can decrease vehicular delay (Chiou and Chang, 2010; Limanond et al, 2010, 2009; Sharma et al., 2009) and increase throughput by efficient queue discharge (Chiou and Chang, 2010; Limanond et al., 2010; Sharma et al., 2009; Ibrahim et al., 2008; Liu et al., 2012) by providing drivers more information about the start-of-green. Islam et al. studied the impacts of a red signal countdown timer, which would alert the driver about an upcoming green indication (Ismail et al., 2016). Using observed driver responses in a driving simulator, their findings revealed a headway reduction of 0.72s for the first vehicle in the queue, which would lead to a reduction in start-up lost time, thus improving efficiency (Islam et al., 2016). In another study, Islam et al. explored driver responses to green signal countdown timers using a driving simulator experiment using 55 subjects (Islam et al., 2017). Their findings revealed increased in average driver stopping probability in the dilemma zone by 13.10% and also led to decrease in average driver deceleration rates by 1.5 ft/s^2, leading the authors to conclude that the implementation of green signal countdown timers can improve intersection safety (Islam et al., 2017). International studies examining the effects of implementing TSCTs all tend to suggest that drivers favor the idea of TSCT implementation, particularly the implementation of the GSCT (Factor et al., 2012; Rijavec et al., 1970).

No published research literature was found regarding bicycle countdown timers. However, these are commonly used in northern European countries to inform the cyclists about the time remaining until the green indication. In the Netherlands, the "Wacht" countdown timers consist of a display of white LEDs in a circle that reduces as the time for the green indication approaches to decrease the startup lost time of cyclists responding to the onset of green indications. In Copenhagen, a numerical countdown timer is also sometimes used. Both are shown in Figure 2.16. Dutch traffic engineers have noticed that it increased the capacity of junctions from 10 to 15%, reducing lost time and improving the credibility of the signalized intersections (Bicycle Dutch, 2016). The city of Portland has installed a Wacht countdown timer with FHWA experimental use exception, at the intersection of NE Oregon St. and NE Interstate Ave. to facilitate a diagonal crossing for cyclists (it is on the far-side). According to PBOT's estimates, countdown timers cost $3,500 per installation.

"Wacht" Countdown Timer (Source: Bicycle Dutch, 2016)

Copenhagen Numerical Countdown Source (All rights reserved by Mikael Colville-Anderson)

Figure 2.16: Countdown timers for bicycles in Netherlands and Copenhagen

2.4.5 Connected Infrastructure for Bicycles

With the advent of connected and autonomous vehicles, detection of bicyclists is critical in ensuring safety. Detection of vehicles and communication from the infrastructure to users could be significantly different. Vehicle and bicycle manufacturers are focused on improving bicycle-to-vehicle (B2V) communication to enable the vehicle and drivers to see bicyclists on the roadway. For example, Trek, a bicycle manufacturing company is partnering with Ford and Tome (a software company) to create a communication system between bicycles and vehicles that will exchange data such as speed, location and direction (Lindsey, 2018). PBIC has developed a white paper identifying ten challenge areas that encompass the safety and mobility considerations for pedestrians and bicyclists in the era of automated and connected vehicles (Sandt & Owens, 2017). These include detection, communication, right-of-way, passing, speed, pickup/drop off, driver handoff, mode shift and data issues (Sandt & Owens, 2017).

Through a National Institute for Transportation and Communities award that is currently in-progress[1], Professors Stephen Fickas and Marc Schlossberg at the University of Oregon are tackling the problem of allowing pedestrians and bicyclists to place virtual calls on a traffic signal. The approach is to develop a Bike Connect Signal Box that extends the capabilities of a signal controller, part of the RSE (gray metal boxes) at signalized intersections (see Figure 2.17). Fickas and Schlossberg developed an inexpensive box that connects directly to a controller (see

[1]https://nitc.trec.pdx.edu/research/project/1160/Fast_Track:_Allowing_bikes_and_pedestrians_to_participate_in_a_smart-transportation_system

Figure 2.17a). The connection points on the controller are the same as those for existing pedestrian pushbuttons and bike detection loops. The prototype box uses the Particle Electron board with a cellular connection to cloud software. These devices cost under $200 to make it attractive to a city's transportation office. Figure 2.17c shows the Bike Connect Signal Box installation at an intersection of the heavy bike and pedestrian use. The pilot site was chosen because of (a) the complicated nature, having separate lights (phases) for pedestrians, bikes and cars and (b) on the large number of pedestrians and bicyclists observed crossing without their own green light, i.e., displaying risky (and illegal) behavior.

(a) (b) (c)

(a) Testing the box in our lab, (b) connecting to RSE at test site, (c) siting box placement at test site.

Figure 2.17: Photos of the connected infrastructure project in Eugene, OR

2.5 OTHER DYNAMIC BICYCLE FEEDBACK DEVICES

In 2017, Utrecht, another city in the Netherlands, developed an innovative technology called Flo, a dynamic bicyclist feedback system that reacts to the current traffic conditions aiming to reduce travel time and make cycling more attractive and fun. The technology is based on sensors that determine cyclists' speed from 120 feet upstream and display fun symbols recommending how cyclists should adjust their speed to be able to catch the green indication at the next downstream intersection. It is a blue kiosk that displays a hare if the cyclist needs to speed up, a tortoise if they need to slow down, a thumbs-up if their pace is well timed or a cow if they will not catch the green light no matter how fast they travel (Figure 2.18). The idea is on feedback from urban cyclists that were frustrated by the number of signalized intersections in the city that resulted in stopped time delay. Flo decreases cyclist wait times, and cyclists have responded positively to the implementation of the system (Metcalfe, 2017).

Figure 2.18: Flo system messages (Metcalfe, 2017)

Hertogenbosch, Netherlands was the first city in the Netherlands to develop the Dynamic Route Information Panel for cycling (i.e., Cycle DRIP). This system informs cyclists about the fastest crossing route at the moment they are detected in the lane (Figure 2.19). It quickly informs if the optimal crossing route is the nearest right then left at the intersection, or if the best is to first cross and turn right. This system detects cyclists 25 meters upstream and saves a significant amount of time while increasing safety (Bicycle Dutch, 2016).

Figure 2.19: Dynamic route information panel (Bicycle Dutch, 2016).

Finally, as described in the Copenhagenize blog and in a Streetfilms video, Copenhagen has used in pavement lights to communicate rider's required speed to capture the "green wave" of traffic signals which are timed at 20 kph (Figure 2.20). If a cyclist sees the green lights and continues riding at 20 kph, they will make the downstream green signal. If the lights go dark, the cyclist needs to ride faster to make the downstream green.

Figure 2.20: Green Pavement Lights in Copenhagen (Source: Sofie Amalie Klougart, the New York Times)

2.6 SUMMARY

While the basic inductive loop remains the most common technology currently in use for detecting bicycles at intersections, other technologies are being continuously evaluated and used when appropriate. Detecting bicycles at signalized intersections gained additional attention following the policy directive by CalTrans in 2009 which required detection for cyclists at all actuated signalized intersections. Emerging technologies for detection include video cameras, thermal imaging and micro-radar have been deployed. Some locations require cyclists to dismount and use pedestrian-style pushbuttons. Connected infrastructure offers promise in the detection area.

There are two detection modes – presence and pulse (passage) that can be used to detect bicycles at intersections especially with inductive loop detectors. In the presence mode, the detectors detect bicycles and hold the call until the green phase. The presence mode is used in video cameras and other passive detection devices. In the pulse (passage) mode, the call is dropped once the bicycle passes over the loop. If the call is dropped prematurely (pulse mode), the bicycle may be trapped on the red phase (Klein et al., 2006).

The purpose of these detection confirmation devices for persons on bicycles is to improve the level of service for cyclists (knowing that they are detected) which should lead to less signal compliance issues. It is worth noting that most new accessible pedestrian push buttons in the U.S. have confirmation lights that indicate the call has been received. For bicycles, a “blue light” detection confirmation device has been tested sometime in combination with pavement markings and signs. These deployments have mostly been mounted on the far side of the intersection near the signal face the bicyclist is monitoring for green. A recent installation in Salem OR included a basic sign to help communicate the purpose of the device. It appears that cyclist comprehension or detection of the blue light remains an issue and whether the devices help with red-light running is not yet clear. Countdown timers are widespread for pedestrians but not for vehicles or bicycles in the U.S. In European countries, these devices are also common. No research was identified on comprehension or perception issues for people on bicycles.

3.0 METHODOLOGY

This chapter presents an overview of the methodology. The research methodology consisted of a three steps - a) conducting an online survey to elicit the public's comprehension on the blue light feedback detection systems with supplemental signs and countdown timers b) field video data collection to compare cyclists' operational performance characteristics before and after the installation of the blue light detection confirmation detection system and a countdown timer and c) an intercept survey to elicit cyclists comprehension of the blue light detection confirmation and countdown timer systems.

3.1 ONLINE SURVEY

An online survey was conducted to elicit the public's comprehension of the blue light detection confirmation systems and countdown timers. Respondents were recruited from Oregon and the U.S. The survey was conducted in two ways: a) online, with recruitment through postcards that were mailed to 10,003 addresses in Oregon and b) via social media through an advertisement on Facebook. The surveys were administered via Qualtrics, an online survey platform. The results from the survey questionnaire were analyzed to determine comprehension rates and preference for supplemental signage. Additional details about the design, administration and results are discussed in Chapter 4.

3.2 TESTED DEVICES

The blue light detection confirmation system had four variations that were tested in the field: 1) blue light in back plate, 2) blue light in back plate with supplemental sign, 3) blue light embedded in sign placed far side, and 4) blue light embedded in sign placed near side. Note that the design of the supplemental sign was guided based on the preference of respondents from the survey. These devices are briefly described in the following sections.

3.2.1 Blue Light Detection Confirmation in Backplate

This setup consists of a blue light embedded in the backplate of the signal head as shown in Figure 3.1. In this setup an accompanying sign was not included. This blue light can be included either with a bike signal as shown in Figure 3.1 or a regular traffic signal.

Figure 3.1: Blue detection confirmation light in backplate

3.2.2 Blue Light Detection Confirmation in Backplate with Sign, Farside

This setup consists of the blue light embedded in the signal backplate with a supplemental sign (36 in x 36 in) placed next to the signal head as shown in Figure 3.2. While the blue light in the backplate is dynamic (i.e., it turns on and off with detection) the blue light in the supplemental sign is a symbol only.

Figure 3.2: Blue detection confirmation light in backplate with supplemental sign, farside

3.2.3 Blue Light Detection Confirmation Embedded in Sign, Farside

This setup consists of blue light embedded within the supplemental sign instead of the backplate as shown in Figure 3.3. The blue light in the sign is dynamic (it turns on and off with detection and the sign is placed on the far side of the intersection).

Figure 3.3: Blue detection confirmation light embedded in supplemental sign

3.2.4 Blue Light Detection Confirmation Embedded in Sign, Nearside

This setup consists of a blue light embedded in the supplemental sign instead of the backplate and this sign is placed on the near side of the intersection. For this installation, the sign was a green lettering on white background.

Figure 3.4: Blue detection confirmation light in embedded in supplemental sign, nearside

3.2.5 Countdown Timer, Placed Nearside

This setup consists of a countdown timer signal placed on the near side of the intersection. When a person on a bicycle was detected, the countdown face illuminated and the dots disappear as a representation of the waiting time left before the green indication. If there is no bicycle detected, the countdown lens is dark.

Figure 3.5 Nearside countdown timer

3.3 VIDEO DATA ANALYSIS

The objective of the video data collection was to compare if there was any change in the behavior of persons on a bicycle with respect to their arrival location, compliance, and stopping position at intersections as a result of the installation of the blue light detection confirmation and countdown timer systems. A vendor set up video cameras at the six sites in Portland. The vendor was familiar with the data collection protocol as they had previously collected data at the Portland locations. At the Eugene sites, the vendor recorded video data for the before condition and the after-condition post installation of the blue light detection confirmation detection system and accompanying sign. The vendor collected video data at the approaches from 7:00 am to 7:00 pm. The following subsections describe each of the field intersection test sites.

3.3.1 Farside Blue Light Confirmation Locations

3.3.1.1 N Ainsworth St. at N Interstate Ave (Embedded in Sign)

N Ainsworth St. at N Interstate Ave. in the westbound direction consists of one shared lane for vehicles and bicycles as shown Figure 3.6. The stencil pavement marking for bicycles is positioned in the center of the shared lane (shown by the arrow). A pedestrian pushbutton is present close to the curb, which can also be accessed by bicyclists without getting onto the sidewalk. The speed limit is 20 mph. At this location, the before data was collected in June 2017. A blue light was installed in the backplate and video data was collected post installation in 2018. The blue light in the backplate was removed and instead the blue light was embedded in a sign and installed in 2019 and video data was again collected post installation.

Figure 3.6: N Ainsworth St. Westbound at N Interstate Ave.

3.3.1.2 NE US Grant Pl at NE 33rd Ave. (Embedded in Sign)

In the eastbound direction is an undivided shared street shown in Figure 3.7. A stencil pavement marking is present in the center of the lane (shown by the arrow). A pedestrian pushbutton is located on the sidewalk, but is not close the curb, thereby requiring bicyclists to dismount and go onto the sidewalk to use the button if they chose to. The speed limit on this street is 20 mph. At this location, the before data was collected in June 2017. A blue light was installed in the backplate and video data was collected post installation in 2018. The blue light in the backplate was removed and instead the blue light was embedded in a sign and installed in 2019 and video data was again collected post installation.

Figure 3.7: NE US Grant Pl. Eastbound at NE 33rd Ave.

3.3.1.3 NE 53rd Ave at NE Glisan St. (Supplemental Sign)

In the southbound direction consists of a left turn lane and a shared lane for vehicles and bicyclists going through the intersection or turning right as shown in Figure 3.8. At this location, although a sign is present informing the cyclists to stop on the stencil pavement marking to be detected, the stencil marking itself was not visible in the video post installation of blue light and sign. A pedestrian pushbutton was present on the sidewalk but is not easily accessible to bicyclists. The speed limit was 20 mph. At this location, the before data was collected in June 2017. A blue light was installed in the backplate and video data was collected post installation in 2018. The blue light in the backplate was retained and a static sign was installed in 2019 and video data was again collected post installation.

Figure 3.8: NE 53rd Ave Southbound at NE Glisan St.

3.3.1.4 SW Terwilliger Blvd at SW Capitol Hwy. I (Supplemental Sign)

The southbound direction consists of one shared lane for left, through and right turning vehicles and a separate bike lane for bicyclists (Figure 3.9). The waiting space for cyclists is marked with green paint and the stencil pavement marking is located within the green paint (shown with arrow). A pedestrian pushbutton is present on the sidewalk but is not easily accessible to the waiting cyclists. The speed limit on this street is 25 mph. At this location, the before data was collected twice, once in June 2017 (called Before 1 henceforth) and next in April 2018 (called Before 2 henceforth). A blue light was installed in the backplate and video data was collected post installation in 2018. The blue light in the backplate was retained and a static sign was installed in 2019 and video data was again collected post installation.

Figure 3.9: SW Terwilliger Blvd Southbound at SW Capitol Hwy

3.3.1.5 W 5th Ave at Blair Blvd (Embedded in Sign)

The intersection in Eugene is an undivided facility and consists of one shared lane for vehicles and bicycles in the eastbound direction as seen in Figure 3.10. A stencil pavement marking is present in the center of the lane (shown with arrow). In the westbound direction, the street is divided with one shared lane for bicycles and vehicles as seen in Figure 3.11. The speed limit is 25 mph in both directions. The stencil is placed to the far right of the lane. Pedestrian pushbuttons are present in both directions on the sidewalk but are not easily accessible to bicyclists. The before data in both directions was collected in September 2019. The blue light embedded in sign devices were installed on the far side at Blair Blvd in the north and south bound directions in October 2019 and video data was collected post installation.

Figure 3.10: W 5th Ave Eastbound at Blair Blvd

Figure 3.11: W 5th Ave Westbound at Blair Blvd

3.3.1.6 Monroe St at W 6th Ave (Embedded in Sign)

The intersection in Eugene consists of one shared lane for vehicles and bicycles in the north and south bound directions as seen in Figure 3.12 and Figure 3.13. Stencil pavement markings are present in the center of the lane in both directions (not visible in the photos due to vehicles). The speed limit is 20 mph in both directions. Pedestrian pushbuttons are present in both directions on the sidewalk but are not easily accessible to bicyclists. The before data in both directions was collected in September 2019. The blue light embedded in sign devices were installed on the far side at Blair Blvd in the north and south bound directions in October 2019 and video data was collected post installation.

Figure 3.12: Monroe St. Northbound at W 6th Ave.

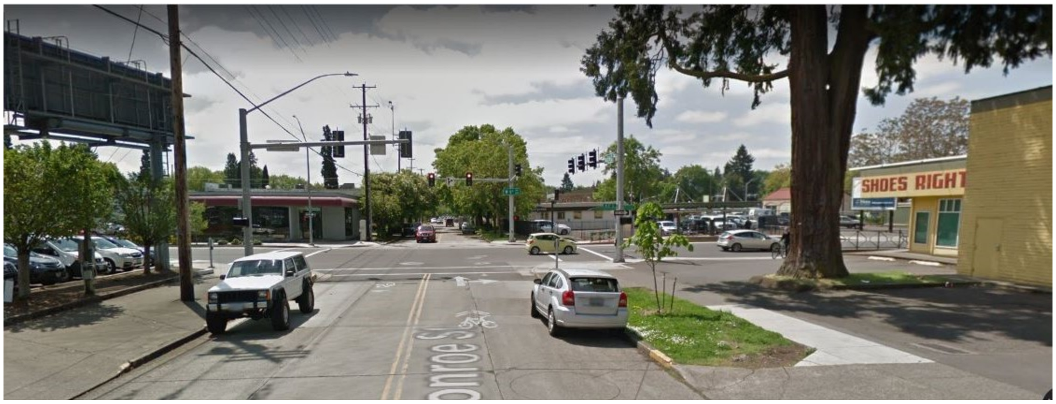


Figure 3.13: Monroe St. Southbound at W 6th Ave.

Table 3.1: Summary of Farside Bluelight Intersections

Location	Approach	Detection Device Type	Number of Lanes	Type of Lane	Speed Limit (mph)
N Ainsworth St. and N Interstate Ave.	N Ainsworth St. WB	Embedded Sign	1	Shared Left, Thru, Right	20
NE US Grant Pl. and NE 33rd Ave.	NE US Grant Pl. EB	Embedded Sign	1	Shared Left, Thru, Right	20
NE 53rd Ave. and NE Glisan St.	NE 53rd Ave. SB	Supplemental Sign	2	Left, Shared Thru and Right	20
SW Terwilliger Blvd and SW Capitol Hwy	SW Terwilliger Blvd SB	Supplemental Sign	2	Shared Left, Thru, Right, Bike Lane	25
Monroe St. and W 6th Ave.	Monroe St. NB and SB	Embedded Sign	1	Shared Left and Thru (NB), Shared Thru and Right (SB)	20
W 5th Ave. and Blair Blvd	W 5th Ave. EB and WB	Embedded Sign	1	Shared Left, Thru, Right	25

3.3.2 Nearside Blue Light Detection Confirmation

3.3.2.1 SW Brooklane Dr. at OR-34 (Embedded in Sign)

Video data was collected at the northbound approach of SW Brooklane Dr. at OR-34 in Corvallis, OR where a nearside blue light detection confirmation system implemented. On the northbound approach, there is one shared lane for bicyclists and vehicles as seen in Figure 3.14. A sidewalk bike path is also present at this location, which is heavily used by bicyclists. The speed limit on the street was 25 mph. There is a uphill grade on the on-street northbound approach to the intersection. The dates of the video data collection are shown in Table 3.2. Before video data was collected at the northbound approach of the SW Brooklane Dr. from 7:00 am to 7:00 pm on Thursday, February 20, 2012 and Friday, February 21, 2020. At this location, one new stencil (bicycle on black background) was added to the pavement and located in the center of the lane. Video data was collected two weeks and four weeks post stencil installation from 7:00 am to 7:00 pm on Thursday, Friday and Saturday, July 23, 2020 to July 25, 2020 and August 6, 2020 to August 8, 2020. Following the installation of the blue light in sign placed near side, video data was collected after two weeks and five weeks from 7:00 am to 7:00 pm on Thursday, Friday and Saturday, September 3, 2020 to September 5, 2020 and September 24, 2020 to September 26, 2020.

Figure 3.14: SW Brooklane Dr. Northbound at OR-34

Table 3.2: Video Data Collection Sites for Nearside Bluelight Device

Location	Approach	City	Before Date	With Stencil	With Stencil, Blue Light, and Sign
OR-34 at 26th St. at SW Brooklane Dr.	SW Brooklane Dr.	Corvallis	2/20/2020 - 2/21/2020	7/23/2020 – 7/25/2020 8/6/2020 – 8/8/2020	9/3/2020 – 9/5/2020 9/24/2020 – 9/26/2020

3.3.3 Nearside Countdown Timer

3.3.3.1 NE Broadway St. at N Williams Ave

Video data was collected at the westbound approach of NE Broadway St. at N Williams Ave. in Portland, OR before and after a nearside countdown timer was installed as shown in Table 3.3. Along the northbound approach, there is a bike lane next to the curb, two right turn only lanes and two through lanes (Figure 5.10). The outer through lane also contains streetcar tracks, (not shown in the figure). There are bicycle signal faces (both near and far side at this location. The countdown timer was installed below the nearside bicycle signal head (location indicated with the arrow). The signal phasing separates the bicycle through movement from the right-turning vehicles.   An important clarification is that right turns on red are prohibited for vehicles and bicycles by the NTOR prohibition sign. The before video data was collected between 7:00 am and 7:00 pm on Thursday and Friday, May 28, 2020, and May 29, 2020 and on Saturday, June 6, 2020. Post countdown timer installation, video data was collected between 7:00 am and 7:00 pm on Thursday through Saturday, August 20, 2020 to August 22, 2020.

Figure 3.15: NE Broadway St. Westbound at N Williams Ave.

Table 3.3: Video Data Collection Sites for Nearside Countdown Device

Location	Approach	City	Before	With Countdown Timer
NE Broadway St. and N Williams Ave.	NE Broadway St.	Portland	5/28/2020 – 5/29/2020, 6/6/2020	8/20/2020 – 8/22/2020

3.4 INTERCEPT SURVEYS

An intercept survey was conducted to determine the cyclists' comprehension of the blue light detection confirmation device at traffic signals equipped with the supplemental sign. Postcards were handed out to cyclists at intersections equipped with the blue light detection confirmation systems and supplemental signs. These postcards contained a link to the online survey questionnaire along with a code that allowed the researchers to determine the intersection where the postcards were picked up by the survey respondents. The online survey questionnaire was designed to study cyclists' attitudes towards the blue light detection confirmation devices and whether they perceived them to be beneficial. The results of the survey are further described in Chapter 6.

3.5 SUMMARY

This chapter outlined a three-step methodology consisting of an online survey administered both in Oregon and nationally via a post card and social media, field video data collection and an intercept survey was developed to understand the public and cyclist's comprehension of the blue light detection confirmation systems with supplemental signs and countdown timers and the actions taken by cyclists when encountering these devices. The design, administration and results from the online survey are presented in the next chapter.

4.0 ONLINE SURVEY

A survey was conducted to understand how well respondents comprehend: (1) the use of blue light for detection, and (2) bicycle countdown timers. Open-ended, multiple-choice, and Likert scale questions were developed to elicit each user's understanding and self-reported response to potential traffic signals with blue light bicycle detection implementation and bicycle countdown timers. The survey was conducted in two ways: a) online, with recruitment through postcards that were mailed to 10, 003 addresses in Oregon and b) via social media through an advertisement on Facebook. This chapter describes the development and administration of the survey and the results of the analysis.

4.1 SURVEY OBJECTIVES

The objective of the survey was to determine which detection confirmation device is best understood by users. The survey was designed to elicit common correct, incorrect, or partially incorrect interpretations of the detection confirmation device meanings.

4.2 DESIGN AND REFINEMENT

The first step in designing the survey was the development of a generic template for survey images. The research team designed the initial image template by considering a recent ODOT report (Hurwitz et al. 2018). A Google Sketch Up image was used instead of a real photo, to enable explicit modification of the scene. Every effort was made to present questions neutrally, allowing respondents to provide meaningful answers reflecting their comprehension of the signal indications. Several rounds of review and refinement followed the internal development of the survey questions. Transportation graduate students at OSU and PSU and members of the project Technical Advisory Committee (TAC) from ODOT tested a pilot survey and provided feedback for further improvements of the format and content of the survey questions. Once the project team was satisfied with the survey design, the survey was finalized. The finalized survey, distribution methods, and record handling were reviewed and determined exempt by the IRB of PSU (196376-18).

4.3 INSTRUMENT

The survey consisted of 21 questions, which included a mix of open-ended, close-ended questions. The survey design included random branches so that open-ended questions could be presented in an unbiased manner. Figure 4.1 illustrates the flow of the survey.

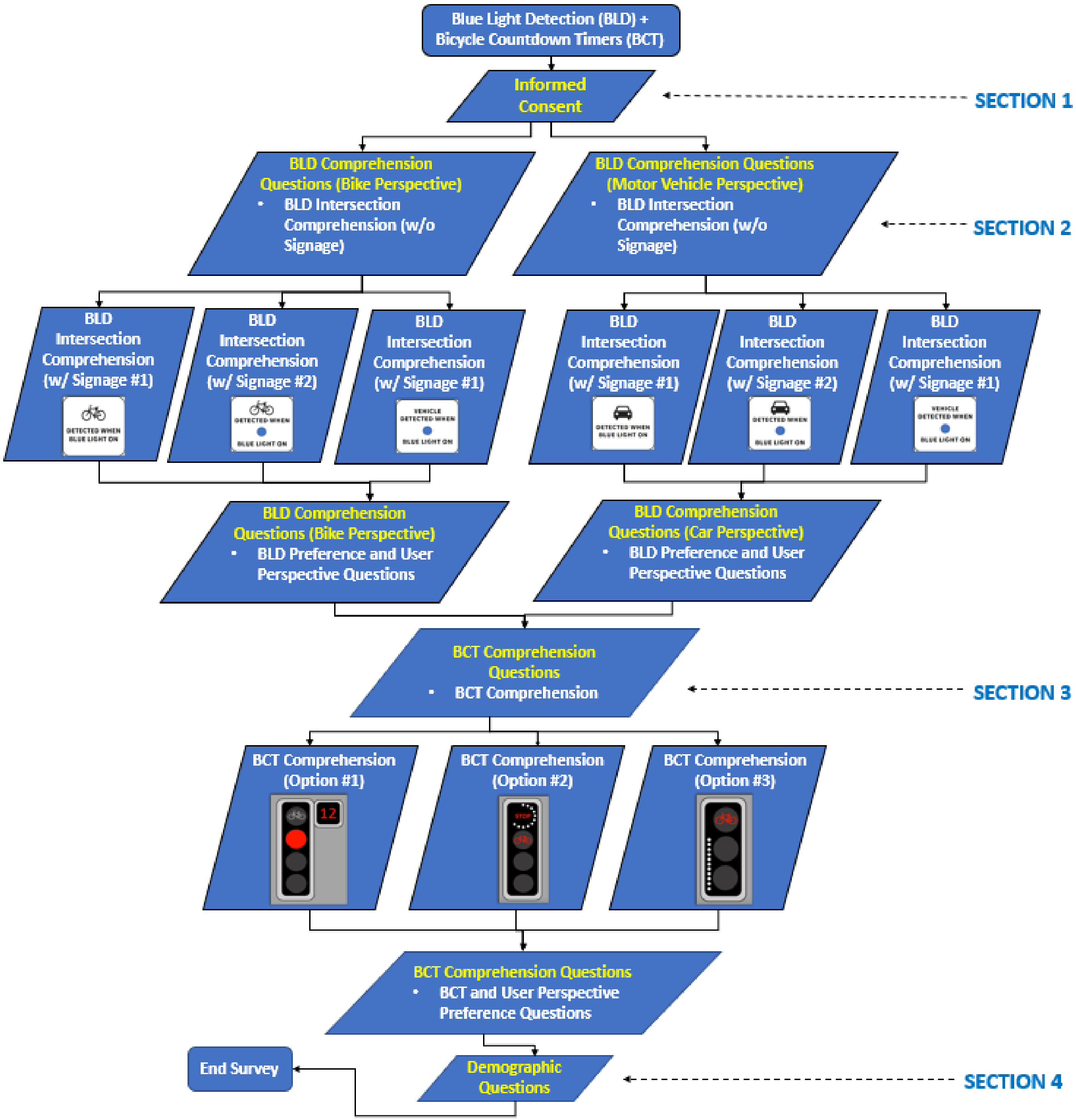


Figure 4.1: Online survey flow

Before being shown the questions, all respondents had to provide informed consent for the survey, certifying that they are over 18 years of age. Section 2 of the survey included open-ended questions, which asked respondents to report their understanding of a blue light indication on the traffic signal head. In this section, the survey randomly branched into two options: a) one where the user was assumed to be a cyclist (i.e., bicycle is provided in the foreground of the image) or one where the user was assumed to be a driver (i.e., car is provided in the foreground of the image). Based on the randomized choice of the survey (i.e., either cyclist or vehicle based), respondents were initially presented a computer image of an intersection from either a cyclists' or driver's perspective and were asked to indicate their meaning of the blue light indication on the signal head, without supplemental signage included. For purposes of the survey, the signal heads and signage were slightly enlarged to make the displays more prominent in the image. Next, respondents were presented a computer image of an intersection from either a cyclists' or driver's perspective and were asked to indicate their meaning of the blue light indication on the signal head, with supplemental signage included. Three supplemental signs were tested in the survey, and it was designed such that all respondents were presented one version of the three possible sign options randomly. After completing these, respondents were then asked to both indicate which of the three sign options conveyed the best meaning for the blue light indication and to provide feedback regarding their perspective of the use of the signage.

In Section 3 of the survey, respondents were presented a series of questions regarding bicycle countdown timers. Initially, respondents were randomly presented one of three bicycle countdown timers and asked to describe their meaning. Following this, respondents were presented all three options and asked to indicate which of the three countdown timer options displayed best conveyed their meaning.

Section 4 of the survey consisted of close-ended multiple-choice demographic questions on the respondent's income and education levels, cycling and driving habits, and eyesight. The entire survey instrument is included in Appendix A.

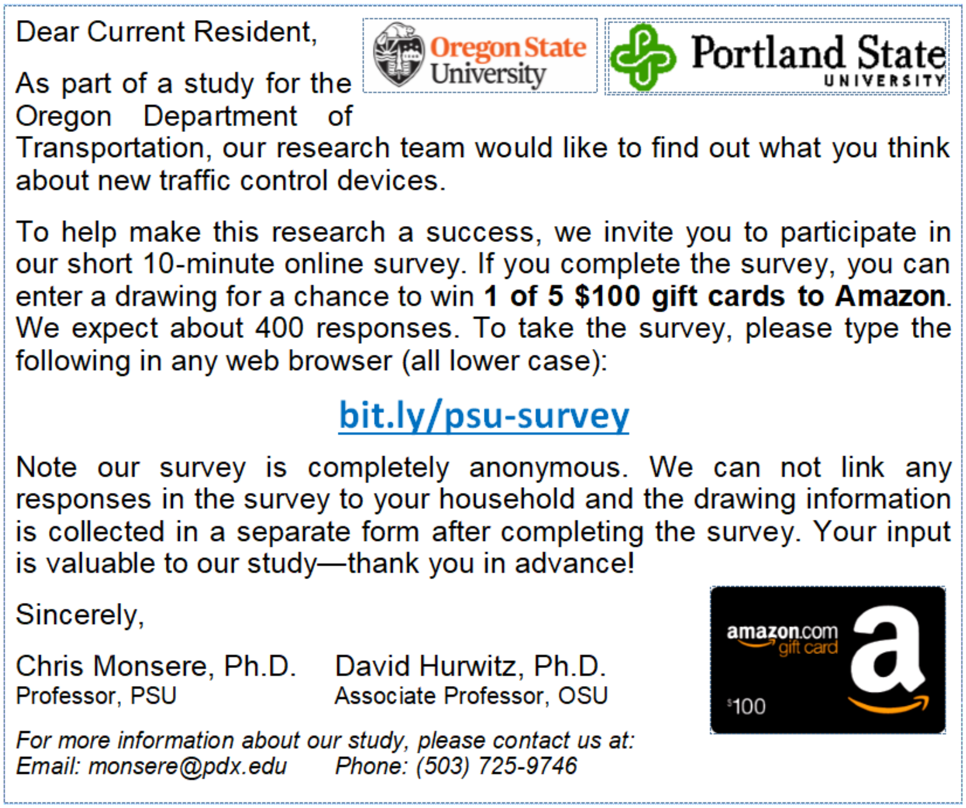
4.4 ADMINISTRATION

A survey response rate of 6–8% was assumed based on a previously conducted postcard/online design by researchers at PSU (Currans et al., 2015). A sample size of 10,004 respondents was selected based on the assumed response rate. A sampling scheme was designed based on the proportion of the population in each medium/large city in Oregon (Table 4.1). Only cities were chosen for the postcard mailing because of the higher prevalence of bicycling in urban areas. Based on this scheme, a random sample of addresses within each city was purchased through Info USA. After removing incorrect/ missing addresses from the purchased address sample, 10,003 households remained.

Table 4.1: Sampling Scheme for Survey

City	Population	Percentage of Sample Population	Number of Addresses
Albany	53,145	2.65	265
Ashland	20,815	1.04	104
Beaverton	97,000	4.83	483
Bend	89,505	4.46	446
Corvallis	59,280	2.95	295
Eugene	169,695	8.45	845
Fairview	8,990	0.45	45
Grants Pass	37,285	1.86	186
Gresham	110,505	5.50	550
Hillsboro	101,920	5.07	507
Klamath Falls	21,890	1.09	109
La Grande	13,340	0.66	66
Lake Oswego	38,215	1.90	190
Medford	80,375	4.00	400
Oregon City	34,860	1.74	174
Pendleton	16,810	0.84	84
Portland	648,740	32.30	3230
Redmond	29,190	1.45	145
Salem	165,265	8.23	823
Springfield	60,865	3.03	303
Tigard	52,785	2.63	263
Troutdale	16,185	0.81	81
Tualatin	27,055	1.35	135
West Linn	25,830	1.29	129
Wilsonville	25,250	1.26	126
Wood Village	3,920	0.20	20
Total	2,008,715	100.00	10,004

A recruitment postcard (shown in Figure 4.2) containing pertinent information about the survey objectives, and the online link was sent to each address. Survey responses were never linked to the names of respondents answering the survey, thus ensuring the confidentiality of responses. Recipients were provided with the option of providing their contact information at the end of the online survey, to be entered into a drawing for one of five $100 Amazon.com gift cards.


Dear Current Resident,

As part of a study for the Oregon Department of Transportation, our research team would like to find out what you think about new traffic control devices.

To help make this research a success, we invite you to participate in our short 10-minute online survey. If you complete the survey, you can enter a drawing for a chance to win **1 of 5 $100 gift cards to Amazon**. We expect about 400 responses. To take the survey, please type the following in any web browser (all lower case):

bit.ly/psu-survey

Note our survey is completely anonymous. We can not link any responses in the survey to your household and the drawing information is collected in a separate form after completing the survey. Your input is valuable to our study—thank you in advance!

Sincerely,

Chris Monsere, Ph.D.
Professor, PSU

David Hurwitz, Ph.D.
Associate Professor, OSU

For more information about our study, please contact us at:
Email: monsere@pdx.edu *Phone: (503) 725-9746*

Figure 4.2: Recruitment postcard for the online survey

Additionally, a social media post (shown in Figure 4.3) containing pertinent information about the survey objectives and the online link was posted to Facebook. Like the postcard recruitment, survey responses were never linked to names of respondents answering the survey, thus ensuring confidentiality of responses. Recipients were provided with the option of providing their contact information at the end of the online survey, to be entered into a drawing for one of five $50 Amazon.com gift cards.

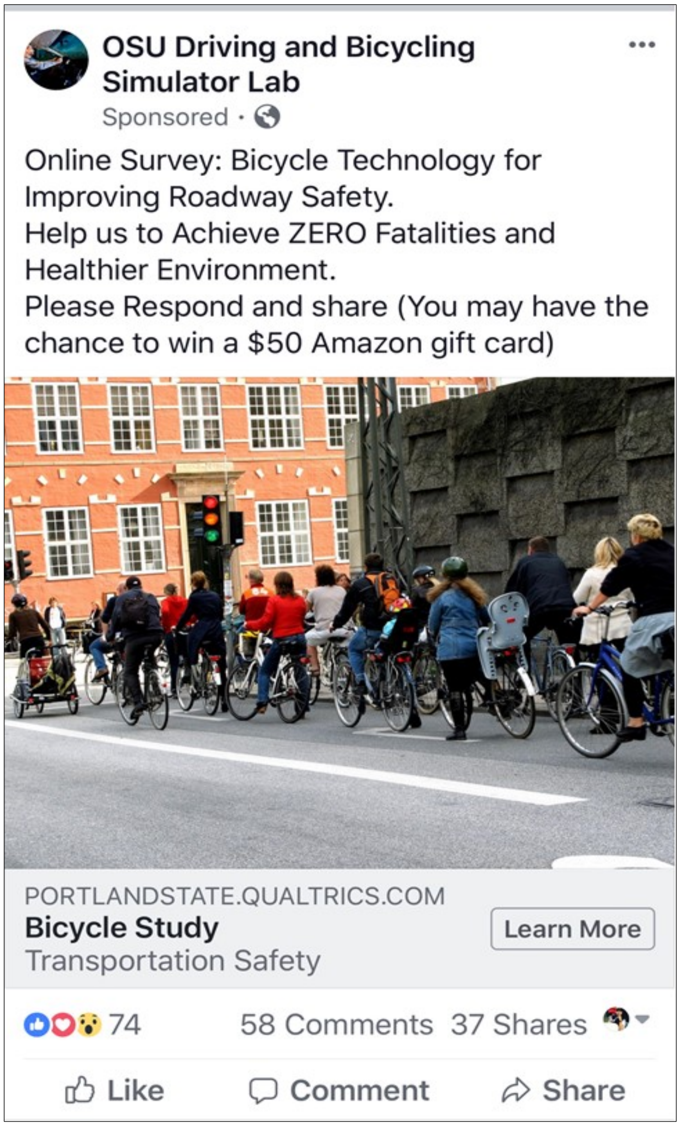


Figure 4.3: Recruitment social media post on Facebook for the online survey

4.5 RESPONSE RATE

Responses were collected from both post card recruitment and social media. The results are presented in the following sections.

4.5.1 Postcard Response Rate

Postcards were mailed to 10,003 addresses. A total of 568 respondents clicked the online link to respond to the survey. As of the time of writing this report, 271 postcards were returned as undeliverable. The calculated response rate was 5.8%. Figure 4.4 shows the geographic distribution of respondents for the postcard survey.

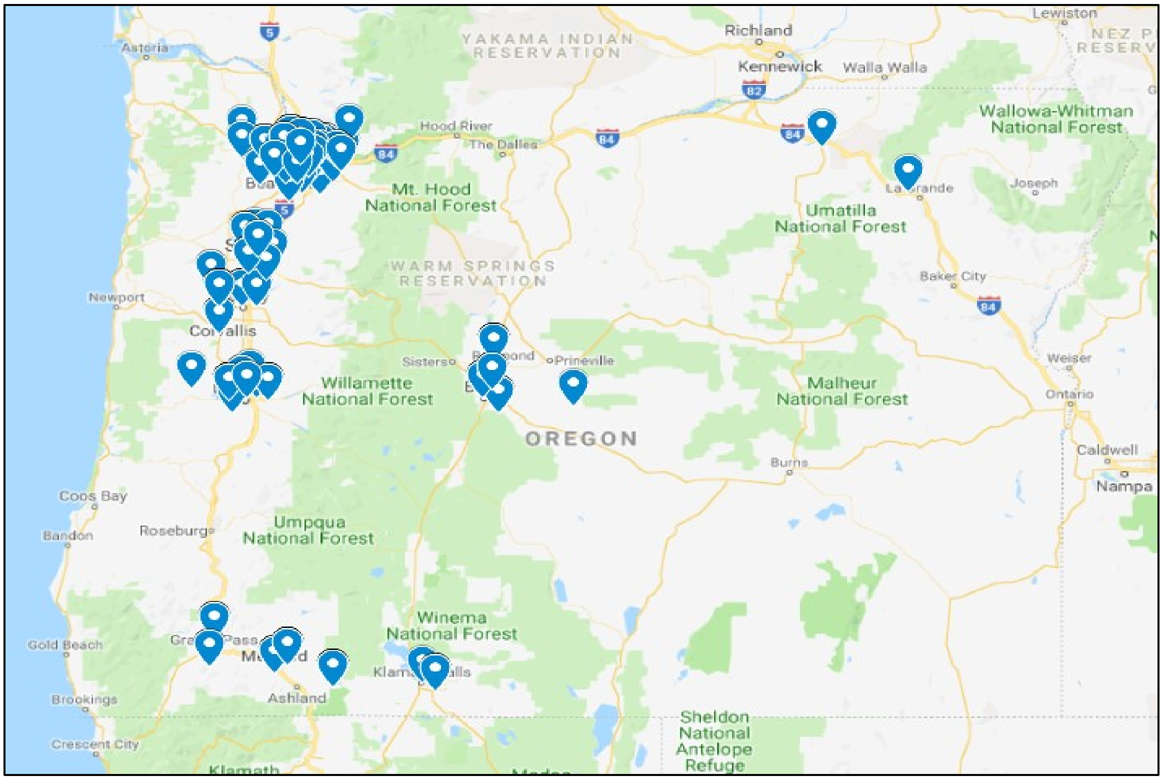


Figure 4.4: Geographic distribution of postcard survey respondents

4.5.2 Social Media Response Rate

A social media post was provided on Facebook with pertinent information regarding the study and an online link to the survey. A total of 1,550 respondents clicked the online link to begin the survey; however, only 535 respondents completed the survey. It is not possible to calculate a response rate. Figure 4.5 shows the geographic distribution of respondents. Responses were received from all over the country. It should be noted that there were additional responses from outside the continental United States, including the states of Hawaii and Alaska, and from Australia, which are not shown in Figure 4.5.

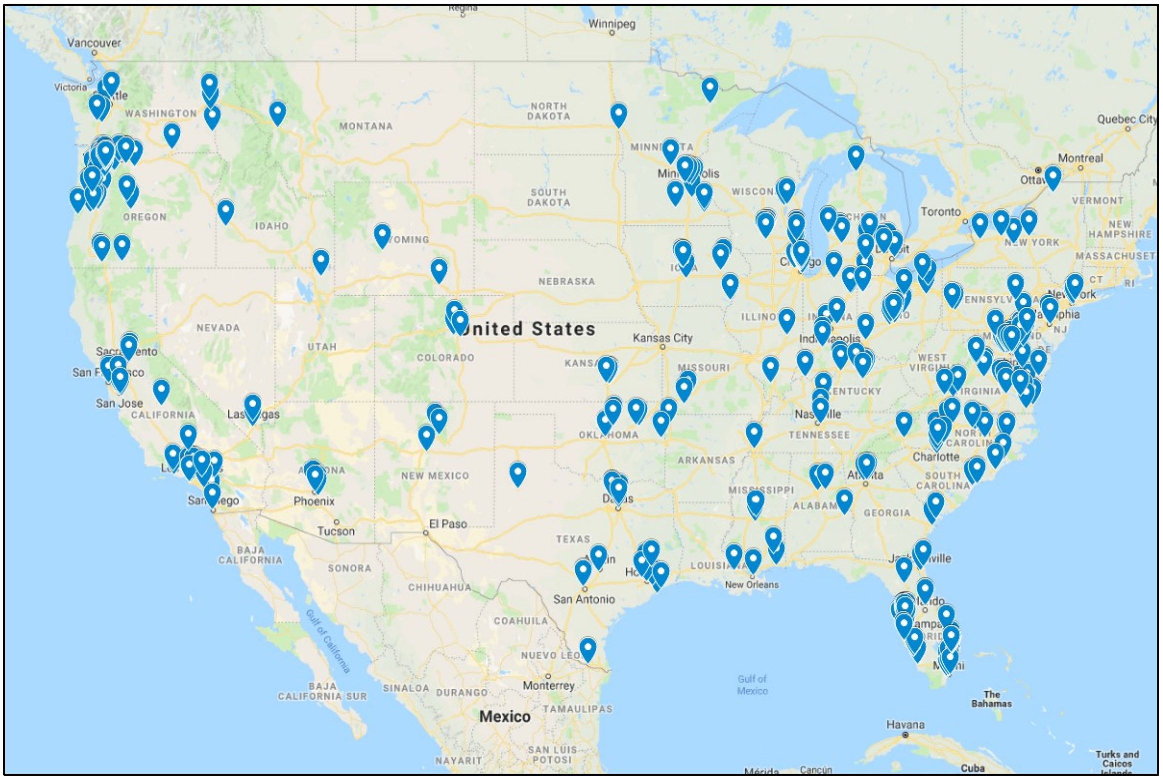


Figure 4.5: Geographic distribution of social media survey respondents

4.6 RESULTS

4.6.1 Demographic Summary

Of the 1,340 people who responded to the survey (568 postcard, 772 social media), 1,064 people provided some or all the requested demographic information. The records with no demographic information were removed for analysis resulting in 529 usable responses from the postcard survey and 535 responses from the social media survey. The responses from the social media survey were further categorized into those from Oregon (zip code starting with 97) and national (all other zip codes except Oregon).

Table 4.2 presents demographic information for all survey respondents, categorized by survey source ("Post Card" vs. "Social Media (Oregon)" vs. "Social Media (Nationally)" in tables). Proportions from the Census for Oregon and the U.S. are also provided in the table for comparison purposes. Older, educated white males were overrepresented as survey respondents on the postcard survey compared to 2010 Census estimates for Oregon and the United States (US Census). Male respondents from the postcard survey had the highest overrepresentation (60% male compared to 49% male for the total population in both Oregon and US). Survey respondents were generally older than the general population, with larger representation in the 55–64 and 65+ years categories, for data collected from Oregon (48.5% postcard survey, 34.4 social media (OR)) as compared to the census estimates (29.9 (OR); 27.6% (national)). The social media survey administered nationally yielded a larger representation in the 25-34-year category (32.8%) as compared to the census (13.7%). Postcard respondents were 81%

White/Caucasian (vs. 77% reported in the Census) and overrepresentations were also seen with both social media national and Oregon data. Proportions of higher income respondents ($100,000 or greater) on both postcard and social media surveys were overrepresented when compared with census estimates (34.2% (postcard), 33.3% (social media Oregon), 38% (social media national) vs. 26.2% (national) and 23.8% (social media Oregon). Respondents with a bachelor's degree were overrepresented on all forms of the survey as compared to the census proportions.

Table 4.3 summarizes the riding and driving behaviors of respondents. Respondents from Oregon via the postcard tended to cycle far less than 5 miles per week (74%) in comparison to respondents from Oregon on social media who tended to cycle over 10 miles per week (74%). Furthermore, respondents from Oregon via the postcard had a lower propensity of utilizing a bike ride for either fun/exercise or for transportation within the last month (28% for fun/exercise and 15% for transportation), in comparison to respondents from Oregon and nationally on social media who had higher propensity to use a bike ride for fun/exercise or for transportation within the last month (86% for fun/exercise and 73% for transportation for Oregon social media; 65% for fun/exercise and 38% for transportation for national social media). Generally, respondents from all sources were licensed (97%) and held a license for over ten years (95% for postcard vs. 90% Oregon social media vs. 82% US social media). Three quarters (75%) of respondents reported that they drove less than 15,000 miles each year. A small percentage of respondents (3% for all sources) indicated that they were colorblind. Most respondents indicated that they used corrective glasses or contacts for vision (62%).

Table 4.2: Demographic Summary, Online Survey and Census, Percentage

Category	Demographic variable	Post Card (Oregon) (n=529)	Social Media (Oregon) (n=90)	Census (Oregon)	Social Media (National) (n=465)	Census (USA)
Gender	Male	59.6	47.8	49.5	51.6	49.2
	Female	38.0	48.9	50.5	42.2	50.8
	Prefer not to answer	1.5	0.0	-	1.5	-
	Prefer to self	0.6	3.3	-	1.9	-
	Did not Respond	0.4	0.0	-	2.8	-
Age	18–24	1.0	3.3	12.7	7.3	13.6
	25–34	12.9	16.7	13.9	32.0	13.7
	35–44	22.3	22.2	13.1	12.9	12.7
	45–54	15.1	23.3	12.8	14.2	13.4
	55–64	19.6	21.1	13.5	20.2	12.7
	65+	28.5	13.3	16.4	10.1	14.9
	Did not Respond	0.6	0.0	-	3.2	-
Race	American Indian or Alaska Native	0.8	1.1	0.9	0.0	0.7
	Asian	3.0	1.1	4.1	2.6	5.3
	Black or African American	0.8	1.1	1.8	2.8	12.3
	Hispanic or Latino/a	2.3	6.7	12.7	6.0	17.6
	White or Caucasian	80.9	82.2	76.5	76.6	61.5
	Other	3.2	3.3	4.1	2.8	2.7
	Prefer not to answer	8.5	4.4	-	5.8	-
	Did not Respond	0.6	0.0	-	3.4	-
Income	Less than $25,000	4.4	6.7	21.3	6.9	21.4
	$25,000 – $50,000	14.4	10.1	23.5	12.9	22.5
	$50,000 – $75,000	16.6	15.6	18.5	14.0	17.7
	$75,000 – $100,000	15.3	22.2	12.9	15.3	12.3
	$100,000 – $200,000	26.3	28.9	18.8	27.5	19.9
	$200,000 or more	7.9	4.4	5.0	9.2	6.3
	Prefer not to answer	14.6	12.2	-	10.8	-
	Did not Respond	0.6	0.0		3.4	

Education	Some High school (grades 9–12, no degree)	1.1	0.0	6.0	0.0	7.2
	High-school graduate (or equivalent)	4.9	1.1	23.4	2.4	27.3
	Some college (1–4 years, no degree)	13.2	11.1	25.8	10.3	20.8
	Trade/Vocational School	4.5	2.2	-	1.1	-
	Associate degree (incl. occup. or academic degrees)	7.4	12.2	8.7	4.7	8.3
	Four Year Degree (BA, BS, AB etc.)	32.0	37.8	20.1	40.2	19.1
	Master's degree (MA, MS, MENG, MSW, etc.)	24.2	28.9	12.2	26.5	11.8
	Doctorate degree (PhD, EdD, etc.)	8.9	5.6		8.8	
	Prefer not to answer	3.2	1.1	-	2.6	-
	Did not Respond	0.6	0.0	-	3.4	-

Table 4.3: Characteristics of Survey Respondents, Percentage

Category	Demographic Variable	Post Card (n=529)	Social Media (Oregon) (n=90)	Social Media (National) (n=465)
Cycling Frequency	Never	47.4	1.1	21.7
	1-5 miles	26.5	15.6	17.8
	6-10 miles	9.6	10.0	12.9
	10-20 miles	9.6	48.9	26.2
	20-30 miles	3.8	22.2	14.0
	Did not Respond	3.0	2.2	7.3
Most Recent Time you Rode a Bicycle (For fun or exercise)	In the last month	27.6	85.6	63.4
	In the last year	28.4	7.8	14.0
	In the last five years	13.4	3.3	8.6
	More than five years ago	21.6	0.0	6.0
	Never	6.1	1.1	2.2
	Did not Respond	3.0	2.2	5.8
Most Recent Time you Rode a Bicycle (for transportation)	In the last month	14.6	73.3	38.5
	In the last year	11.7	10.0	12.7
	In the last five years	8.1	4.4	6.7
	More than five years ago	22.9	3.3	9.7
	Never	39.1	6.7	26.5
	Did not Respond	3.6	2.2	6.0
Driver's license	1 – 2 years	0.6	0.0	1.3
	3 – 5 years	0.8	2.2	3.4
	6 – 10 years	1.5	5.6	9.7
	10+ years	94.7	90.0	80.4
	Did not Respond	2.5	2.2	5.2
Miles driven per year	Less than 5,000	14.9	18.9	16.6
	5,000 – 9,999	30.1	32.2	23.7
	10,000 – 14,999	33.8	30.0	28.4
	15,000 – 19,999	10.6	10.0	13.5
	Greater than 20,000	8.1	6.7	12.7
	Did not Respond	2.5	2.2	5.2

Driver's License	Yes	97.5	97.8	94.8
	No	2.5	2.2	3.0
	Did not Respond	-	-	2.2
Color blind	Yes	2.5	3.3	3.7
	No	96.0	95.6	91.6
	Don't want to provide this information/Don't Know	1.0	1.1	1.3
	Did not Respond	0.6	0.0	3.4
Corrective glasses or contacts	Yes	61.2	74.4	60.0
	No	37.2	25.6	35.7
	Don't want to provide this information/Don't Know	0.9	0.0	0.9
	Did not Respond	0.6	0.0	3.4

4.6.2 Coding

Since the survey contained open-ended questions designed to assess comprehension of the blue light display and the bicycle countdown timers, the responses needed to be categorized for further analysis. The research team reviewed each open-ended response. Responses were coded as correct, partially correct, or incorrect based on established criteria shown in Table 4.4. The same coding convention was followed for coding both the responses from all forms of the survey (postcard and social media).

Table 4.4: Error Coding of Narrative

Display Indication	Correct	Partially Correct	Incorrect
Blue Light Intersection Scenario (w/o signage) with car or bicycle	Blue light indicates that either the bicyclist or vehicle has been "detected" at the intersection	Blue light indicates that a car or bike has been "detected" nearby or that that traffic signal has been triggered.	Anything else
Blue Light Intersection Scenario (w/ signage) with car or bicycle	Blue light indicates that either the bicyclist or vehicle has been "detected" at the intersection	Blue light indicates that a car or bike has been "detected" nearby or that that traffic signal has been triggered.	Anything else
Bicycle Countdown Timer	That either the dots or the number indicates the amount of time left until the cyclist will be given the green signal.	That the system was used to instruct operations (e.g., "Stop" or "Go") for the bicyclist.	Anything else

For the blue light indication without supplemental signage, responses were coded as correct if the respondents indicated that either the bicycle or vehicle has been "detected" at the intersection. In the coding, several non-technical responses were accepted to indicate this level of comprehension. A response was coded as partially correct, if the respondent indicated that there was some form of detection, but maybe indicating the someone else was being detected or that the light cycle has been triggered (e.g., a vehicle or car has been detected nearby or indicating that the light cycle has been triggered to change). A response was coded as incorrect if the respondents indicated anything else. This same response was coded as correct for the scenario with supplemental signage included.

For the bicycle countdown timer, a response was coded as correct, if the respondent stated that system (i.e., disappearing dots or numerical values) indicates the amount of time left until the cyclist will be given the green signal (e.g., amount of time left till the signal turns green). Responses were coded as partially correct if the respondent indicated that the countdown indicated operations for the cyclists but did not indicate anything about the countdown (e.g., people on bikes or bicyclists should not proceed until green). Responses were coded as incorrect if the respondents indicated anything else.

4.6.3 Open-ended Comprehension Questions

Each respondent was asked three open-ended questions to determine their comprehension of the blue light indication without and with supplemental signage and their comprehension of bicycle preemption countdown timers. Respondents were presented with the following wording for the three displays.

Blue Light Detection (without signage)

Imagine that you are waiting at an intersection on a bicycle. What does the **BLUE LIGHT** (to the left of the arrow) mean to you? Please type your response in the box below and be as descriptive as possible.

Blue Light Detection (with signage)

There has been a sign added to the photo. Again, imagine that you are waiting at an intersection on a bicycle. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.

Bicycle Countdown Timer

Imagine that you are stopped at an intersection on a bicycle on a red signal indication and you see the signal head above. What does the **DISPLAY** mean to you as a person on a bicycle? Please type your response in the box below and be as descriptive as possible.

Responses to each question were reviewed and classified as correct, partially correct, or incorrect. A sample of the open-ended responses is included in Appendix B. A discussion of each of these signal display indications follows.

4.6.3.1 Blue Light Detection Intersection Scenario (without signage)

Participants were presented a digital image of an intersection with a blue light on the signal head. Half of the participants were presented the intersection scenario as a cyclist (i.e., Figure 4.6), while the other half were presented the intersection scenario as a vehicle (i.e., Figure 4.7). Participants were then prompted to describe what the blue light means to them. Responses were coded as following the coding convention outlined in Table 4.4.

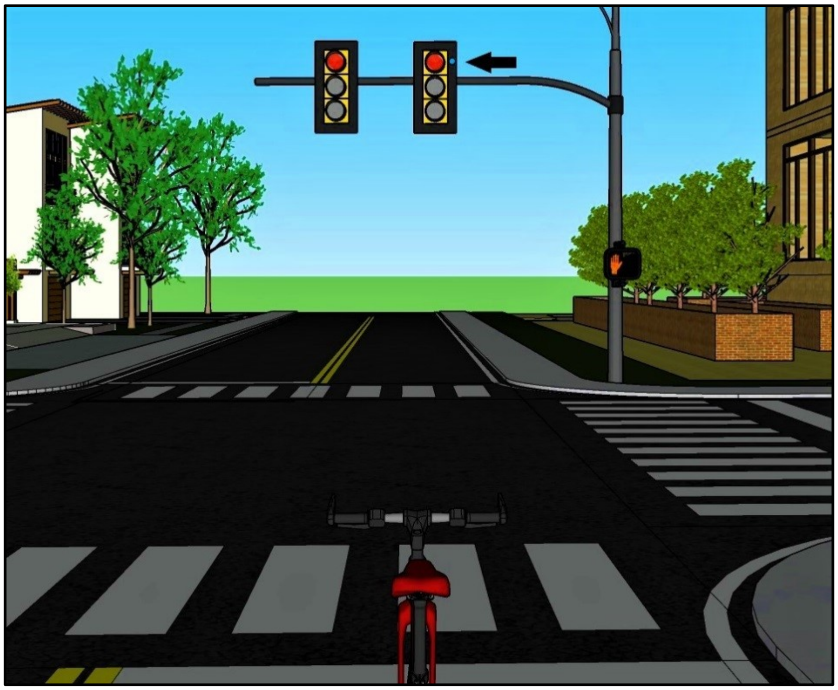


Figure 4.6: Image used for open-ended question on blue light detection for cyclists (without signage)

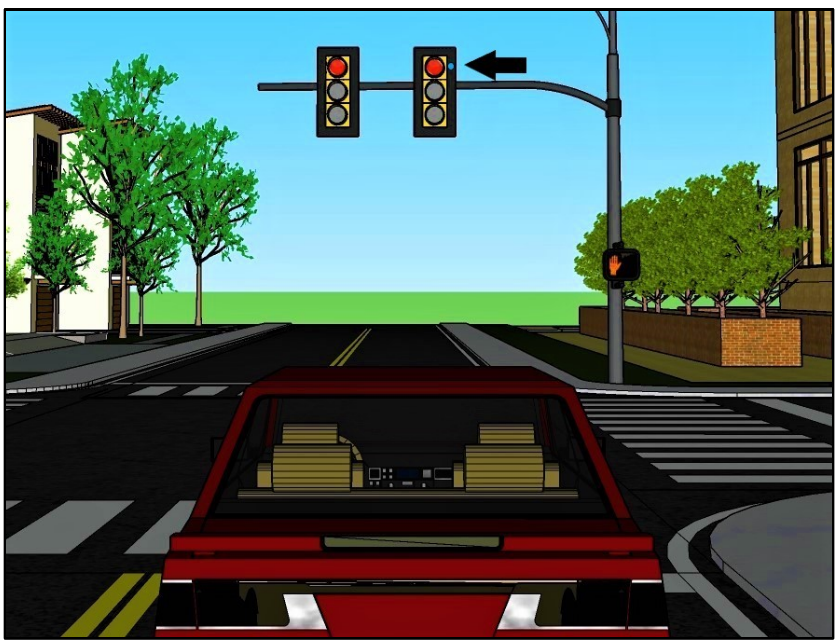


Figure 4.7: Image used for the open-ended question on blue light detection for vehicles (without signage)

Results of the analysis of the responses are shown in Table 4.5, which was answered by 1084 participants (548 with bicycle scenario and 536 with vehicle scenario). Most respondents (approximately 90% average of all three sources) incorrectly indicated that they did not know what the blue light meant or provided a response that was not accurate. Of the respondents who correctly answered the question, Oregonians, both from the postcard and social media sources, generally showed higher rates of correctness (7.6% for PC-OR and 23.3% for SM-OR) compared to the national respondents (4.3% for SM-US). For the social media respondents from Oregon, 29.7% had a correct response to the blue light. The recruitment for social media attracted more persons who cycle. We suspect that many of the samples are familiar with the blue light through experience or education in Portland.

Table 4.5: Responses to open-ended question on blue light indication (without signage)

Response	Bicycle (n=537)			Vehicle (n=527)			Total (n=1064)			
	Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)		Total Average
	OR	OR	USA	OR	OR	USA	OR	OR	USA	-
Correct	7.6%	29.7%	4.3%	7.5%	18.9%	3.9%	7.6%	23.3%	4.1%	17.7%
Partially Correct	1.4%	2.7%	0.9%	4.4%	0.0%	0.9%	2.8%	1.1%	0.9%	2.4%
Incorrect	88.4%	67.6%	92.7%	88.1%	81.1%	95.2%	88.3%	75.6%	94.0%	90.3%
Did Not Respond	2.5%	0.0%	2.1%	0.0%	0.0%	0.0%	1.3%	0.0%	1.1%	<1%

4.6.3.2 Blue Light Detection Intersection Scenario (with signage)

Participants were presented with a digital image of an intersection with a blue light on the signal head with the supplemental signage included on the mast arm. The signage was randomly chosen between the three options provided for the cyclist and vehicle scenarios, as shown in Figure 4.8 and Figure 4.9.

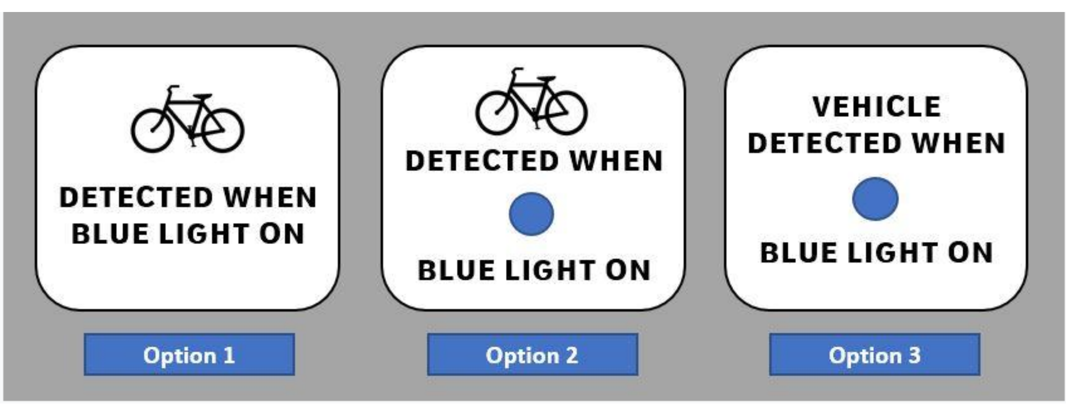


Figure 4.8: Images used for sign options with blue light detection for cyclists

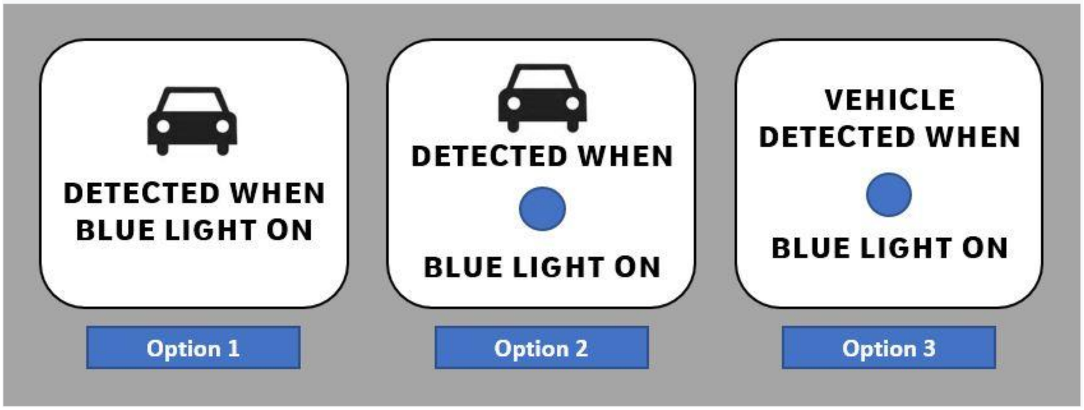


Figure 4.9: Images used for sign options with blue light detection for vehicles

Participants were then presented the same intersection scenario that was shown to them earlier as either a cyclist (i.e., Figure 4.6) or a vehicle (i.e., Figure 4.7), with the additional signage, drawn from one of the three sign options randomly (Figure 4.10, Figure 4.11). Participants were then prompted to describe what the blue light meant to them. The objective was to assess if the addition of the sign increased the comprehension rate of the blue light device. Responses were coded as following the coding convention outlined in Table 4.4.

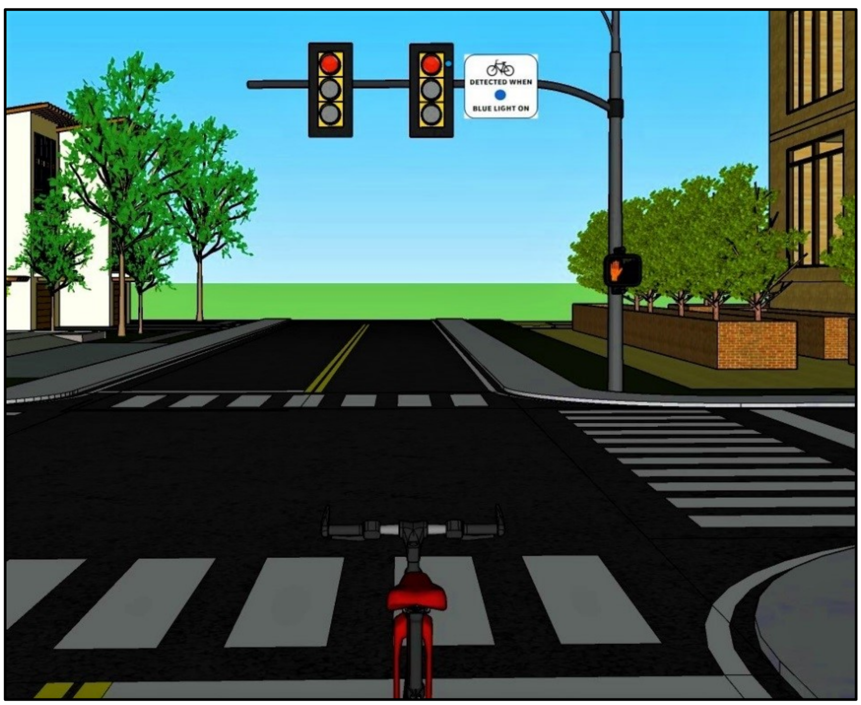


Figure 4.10: Image used for the open-ended question on blue light detection for cyclists (with signage)

Figure 4.11: Image used for the open-ended question on blue light detection for drivers (with signage)

Table 4.6 summarizes the findings for this question, which was answered by 1084 participants (548 with Bicycle Scenario and 536 with Vehicle Scenario). For Sign Option #1 (i.e., Symbol without Blue Dot), respondents generally were split between correct and incorrect responses (44% for correct vs. 45% for incorrect responses) the understanding of the blue light system. In comparison, respondents with the bicycle scenario were more likely to correctly respond (47% average of three sources) versus respondents with the vehicle scenario who had a lower propensity to answer correctly (40% average of three sources). An additional 10% were coded partially correct because they did not provide additional detail on the location of detected vehicle or only indicated that signal was triggered.

Similar to the Sign Option #1, Sign Option #2 (i.e., Symbol with Blue Dot) respondents generally were split between correct and incorrect responses (44% for correct vs. 45% for incorrect responses) the understanding of the blue light system. In comparison, respondents with the bicycle scenario were more likely to correctly respond (48% average of three sources) versus respondents with the vehicle scenario who had a lower propensity to answer correctly (41% average of three sources). An additional 11% were coded partially correct because they did not provide additional detail on the location of detected vehicle or only indicated that signal was triggered.

For Sign Option #3 (i.e., Text with Blue Dot), respondents indicated more incorrect responses to correct responses (41% correct vs. 49% incorrect averages of three sources). However, compared to the first two signs, the use of text indicated a decline in comprehension rates from respondents in both scenarios (41% average vs. 44% for Sign Options 1 and 2). An additional 10% were coded partially correct because they did not provide additional detail on the location of detected vehicle or only indicated that signal was triggered.

Table 4.6: Responses to Open-Ended Question Blue Light Indication (with signage)

Response	Bicycle (n=548)			Vehicle (n=536)			Total (n=1084)		
	Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)	
	OR	OR	USA	OR	OR	USA	OR	OR	USA
Sign Option #1 (Symbol without Blue Dot) (n=191 for Bicycle; n=189 for Vehicle)									
Correct	58.6%	35.7%	37.8%	50.0%	44.4%	30.1%	54.3%	40.6%	34.1%
Partially Correct	9.2%	7.1%	14.4%	5.7%	0.0%	12.0%	7.4%	3.1%	13.3%
Incorrect	29.9%	51.7%	44.4%	44.3%	55.6%	57.8%	37.1%	56.3%	50.9%
Did not Respond	2.3%	0.0%	3.3%	0.0%	0.0%	0.0%	1.1%	0.0%	1.7%
Sign Option #2 (Symbol with Blue Dot) (n=178 for Bicycle; n=191 for Vehicle)									
Correct	52.2%	25.0%	45.0%	46.7%	16.7%	40.7%	49.5%	19.2%	42.9%
Partially Correct	5.6%	12.5%	10.0%	10.9%	22.2%	13.6%	8.2%	19.2%	11.8%
Incorrect	42.2%	62.5%	45.0%	42.4%	61.1%	45.7%	42.3%	62.5%	45.3%
Did not Respond	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sign Option #3 (Text with Blue Dot) (n=177 for Bicycle; n=158 for Vehicle)									
Correct	39.2%	46.7%	35.4%	45.3%	35.3%	42.4%	41.9%	40.6%	38.9%
Partially Correct	9.3%	6.7%	18.5%	4.0%	11.8%	12.1%	7.0%	9.4%	15.3%
Incorrect	51.5%	46.7%	46.2%	50.7%	52.9%	45.5%	51.2%	50.0%	45.8%
Did not Respond	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

4.6.3.3 Bicycle Countdown Timers

Respondents were randomly presented an animated GIF of one of the three bicycle countdown timer options and asked a question designed to probe their comprehension of the system, as shown in Figure 4.12. Online, the bicycle countdown timer would animate countdown operations (e.g., countdown numbers, white dots disappearing, change from red indication to green indication). Responses were coded following the coding convention outlined in Table 4.4.

Table 4.7 presents the results for this question, which was answered by 1,084 respondents (361 with Option 1, 362 with Option 2, and 361 with Option 3). For Countdown Timer #1 (i.e., Numeric Countdown), most respondents (57% average of three sources) understood the countdown timer and indicated that it was counting down until they received green or could proceed. An additional 11% were coded partially incorrect because respondents indicated the operations of the signal but did not indicate the purpose of the countdown timer. Similarly, Countdown Timer #3 (i.e., Vertical Disappearing Dots) had most respondents (52% average of three sources) understanding the countdown timer and indicating the correct meaning. An additional 25% were coded partially incorrect because respondents indicated the operations of the signal but did not indicate the purpose of the countdown timer.

In comparison to Countdown Timer #1 and #2, Countdown Timer #1 (i.e., Circular Disappearing Dots) had 41% (average of three sources) of respondents indicate correct responses; however, there was a much higher propensity of respondents who were coded as partially correct (32% average of three sources). Many respondents who were coded as partially correct indicated the operations of "Stop" and "Go," which appears during the animation of the countdown timer, but did not describe or indicate the purpose of the disappearing dots serving as a countdown till the signal turns green.

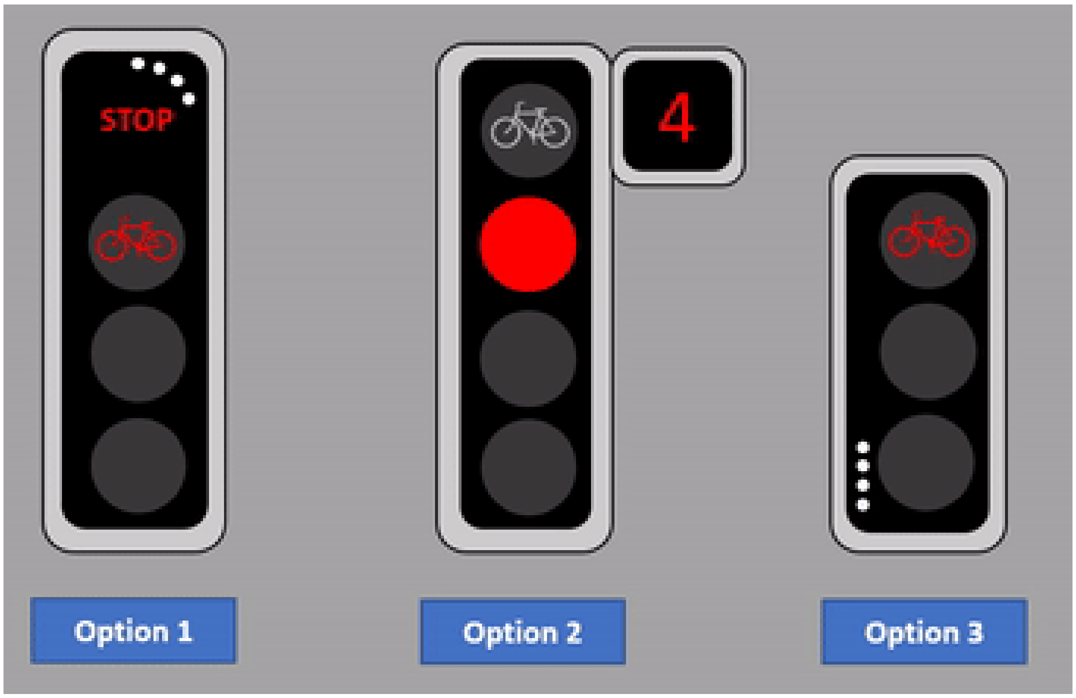


Figure 4.12: Bicycle countdown timer options (animated in the survey)

Table 4.7: Responses to Open-Ended Question on the Bicycle Countdown Timer

Response	Total		
	Post Card	Social Media (Facebook)	
	OR	OR	USA
Countdown Timer #1 (Circular Disappearing Dots; n=362)			
Correct	42.6%	51.4%	38.0%
Partially Correct	34.6%	29.7%	29.4%
Incorrect	22.8%	18.9%	31.3%
Did Not Respond	0.0%	0.0%	1.2%
Countdown Timer # 2 (Numeric; n=361)			
Correct	64.6%	60.9%	48.4%
Partially Correct	11.6%	17.4%	9.6%
Incorrect	23.8%	21.7%	39.5%
Did Not Respond	0.0%	0.0%	2.5%
Countdown Timer #3 (Vertical Disappearing Dots; n=361)			
Correct	44.1%	66.7%	42.8%
Partially Correct	28.0%	20.0%	26.9%
Incorrect	28.0%	13.3%	29.0%
Did Not Respond	0.0%	0.0%	1.4%

4.6.4 Multiple-Choice and Likert Scale Questions

Multiple-Choice and Likert Scale questions were provided to each respondent regarding their preferences, level of agreement, and experience with blue light indication signage and bicycle countdown timer systems. A discussion of these questions is listed below.

4.6.4.1 Blue Light Detection Signage Preference

Respondents were presented all three sign options based on whether they were initially presented the intersection scenario as a cyclist or vehicle, as shown in Figure 4.8 and Figure 4.9, respectively. Respondents were then asked to choose the sign that conveyed the meaning of the sign best to them and to provide justification for their choices. After making their preference selection, respondents were then provided a Likert scale to evaluate their level of "agreement" with designated statements regarding the signage.

Table 4.8 summarizes results for this question, which was answered by 1,084 respondents (548 with bicycle scenario signage and 536 with vehicle scenario signage). Respondents who were provided the bicycle scenario signage, as shown in Figure 4.8, generally indicated that Option #2 (67% for PC vs. 81% for SM-OR vs. 68% for SM-US) conveyed the best meaning, followed by Option #3 (24% for PC-OR vs. 8% for SM-OR vs. 20% for SMUS). Similarly, respondents who were provided the vehicle scenario signage, as shown in Table 4.8, generally indicated that Option #2 (57% for PC vs. 60% for SMO vs. 55% for SMUS) conveyed the best meaning, followed by Option #3 (35% for PC vs.

60% for SMO vs. 35% for SMUS); however, overall, there was a higher propensity for respondents with the vehicle scenario signage to indicate that Option #3 was viable, in comparison to respondents with bicycle scenario signage.

Table 4.8: Responses to Closed-Ended Question on BLD Sign Preference

Response	Total		
	Post Card	Social Media (Facebook)	
	OR	OR	USA
Sign Options for Bicycle Scenario			
Option #1	8.4%	10.8%	11.1%
Option #2	67.2%	81.1%	68.4%
Option #3	23.7%	8.1%	20.1%
Did not Respond	0.7%	0.0%	0.4%
Sign Options for Vehicle Scenario			
Option #1	7.8%	5.7%	9.5%
Option #2	56.5%	60.4%	54.5%
Option #3	34.9%	34.0%	35.5%
Did not Respond	0.8%	0.0%	0.4%

4.6.4.2 Blue Light Signage "Level of Agreement"

After making their preference selection, respondents were then provided a Likert scale to evaluate their level of "agreement" with designated statements regarding the signage, as shown in Figure 4.13.

Table 4.9 summarizes results for the three Likert questions, which were answered by 1,084 respondents (548 with bicycle scenario and 536 with vehicle scenario). For Question 1, respondents generally indicated that they "Strongly Agree" (57% average of all three sources) followed by "Agree" (27% average of all three sources) that the addition of the sign helped with their understanding of the purpose of the blue light. Similarly, for Question 2, respondents generally indicated that they "Strongly Agree" (45% average of all three sources) followed by "Agree" (29% average of all three sources), that they would support the use of the blue light system at some intersections in their community.

For Question 3, respondents were spread evenly indicating that they "Strongly Agree" (34% average of all three sources), followed by "Agree" (27% average of all three sources) and "Indifferent" (21% average of all three sources), that they would feel better about waiting on a bicycle at an intersection if a blue light system was present.

Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Level of Agreement				
	Strongly Disagree	Disagree	Indifferent	Agree	Strongly Agree
The addition of the sign helped with my understanding of the purpose of the blue light.	○	○	○	○	○
I would support the use of a blue light system at some intersections in my community.	○	○	○	○	○
I would feel better about waiting on a bicycle at an intersection if a blue light system was present.	○	○	○	○	○

Figure 4.13: "Level of Agreement" questionnaire for blue light

Table 4.9: Responses to "Level of Agreement" of Statements Regarding Blue Light

Response	Bicycle (n=548)			Vehicle (n=536)			Total (n=1084)		
	Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)	
	OR	OR	USA	OR	OR	USA	OR	OR	USA
Q1: The addition of the sign helped with my understanding of the purpose of the blue light.									
Strongly Disagree	7.3%	8.1%	3.8%	8.2%	9.4%	9.1%	7.8%	8.9%	6.5%
Disagree	3.7%	5.4%	3.8%	7.1%	3.8%	4.3%	5.3%	4.4%	4.1%
Indifferent	4.0%	16.2%	3.4%	5.1%	7.5%	5.2%	4.5%	11.1%	4.3%
Agree	27.5%	24.3%	25.6%	25.5%	39.6%	25.1%	26.5%	33.3%	25.4%
Strongly Agree	57.5%	45.9%	62.4%	54.1%	39.6%	55.8%	55.8%	42.2%	59.1%
Did not Respond	0.0%	0.0%	0.9%	0.4%	0.0%	0.4%	0.2%	0.0%	0.6%
Q2: I would support the use of the blue light system at some intersections in my community.									
Strongly Disagree	12.1%	5.4%	6.4%	8.2%	11.3%	9.9%	10.2%	8.9%	8.2%
Disagree	5.5%	5.4%	3.4%	7.0%	3.8%	4.3%	6.2%	4.4%	3.9%
Indifferent	12.1%	5.4%	10.3%	5.1%	13.2%	17.2%	8.7%	10.0%	13.8%
Agree	27.5%	27.0%	29.6%	25.4%	30.2%	33.6%	26.5%	28.9%	31.6%
Strongly Agree	42.5%	56.8%	49.4%	53.9%	41.5%	34.1%	48.0%	47.8%	41.7%
Did not Respond	0.4%	0.0%	0.9%	0.4%	0.0%	0.9%	0.4%	0.0%	0.9%
Q3: I would feel better about waiting on a bicycle at an intersection if a blue light system was present.									
Strongly Disagree	11.4%	5.4%	6.9%	13.7%	7.5%	10.8%	12.5%	6.7%	8.8%
Disagree	4.4%	5.4%	5.2%	12.1%	7.5%	7.8%	8.1%	6.7%	6.5%
Indifferent	16.1%	13.5%	15.0%	25.8%	32.1%	24.1%	20.8%	24.4%	19.6%
Agree	27.5%	29.7%	30.0%	20.7%	28.3%	31.0%	24.2%	28.9%	30.5%
Strongly Agree	39.9%	45.9%	42.1%	27.0%	24.5%	25.4%	33.6%	33.3%	33.8%
Did not Respond	0.7%	0.0%	0.9%	0.8%	0.0%	0.9%	0.8%	0.0%	0.9%

4.6.4.3 Blue Light Experience at Intersections

Respondents were then asked whether they had ever experienced the blue light system at an intersection before.

Table 4.10 summarizes results for this question, which was answered by 1,064 respondents (533 with bicycle scenario and 531 with vehicle scenario). Respondents generally indicated "No" (84% average of all three sources) for having experienced the blue light system at the intersection before. However, in both scenarios presented, respondents nationally from social media had a higher proportion of "No" (97%) responses for experiencing this system in comparison to the respondents from Oregon via the postcard (86%) and social media (70%).

Table 4.10: Responses to Experience with Blue Light Systems at Intersections

Response	Bicycle (n=548)			Vehicle (n=536)			Total (n=1084)		
	Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)		Post Card	Social Media (Facebook)	
	OR	OR	USA	OR	OR	USA	OR	OR	USA
Yes	13.9%	32.4%	1.7%	14.5%	28.3%	3.5%	14.2%	30.0%	2.6%
No	86.1%	67.6%	97.4%	85.5%	71.7%	95.7%	85.8%	70.0%	96.6%
Did not Respond	0.0%	0.0%	0.9%	0.0%	0.0%	0.9%	0.0%	0.0%	0.9%

4.6.4.4 Bicycle Countdown Timer Preference

Respondents were presented all three bicycle countdown timer options, as shown in Figure 4.12. Online, the bicycle countdown timers would animate countdown operations (e.g., countdown numbers, white dots disappearing, change from red indication to green indication). Respondents were then asked to choose the countdown timer that best conveys the purpose of the system, and to provide justification for their choices. Responses were coded following the coding convention outlined in Table 4.4.

Table 4.11 presents the results for this question, which was answered by 1,084 respondents. Respondents indicated that Option #2 (41% average for all sources) best conveyed the purpose of the system, followed by Option #1 (32% average for all sources) and Option #3 (25% average for all sources).

Table 4.11: Responses to Closed-Ended Question on Bicycle Countdown Timer Preference

Response	Total		
	Post Card	Social Media (Facebook)	
	OR	OR	USA
Option #1	31.0%	30.0%	32.7%
Option #2	42.3%	40.0%	40.9%
Option #3	26.1%	28.9%	24.1%
Did not Respond	0.6%	1.1%	2.4%

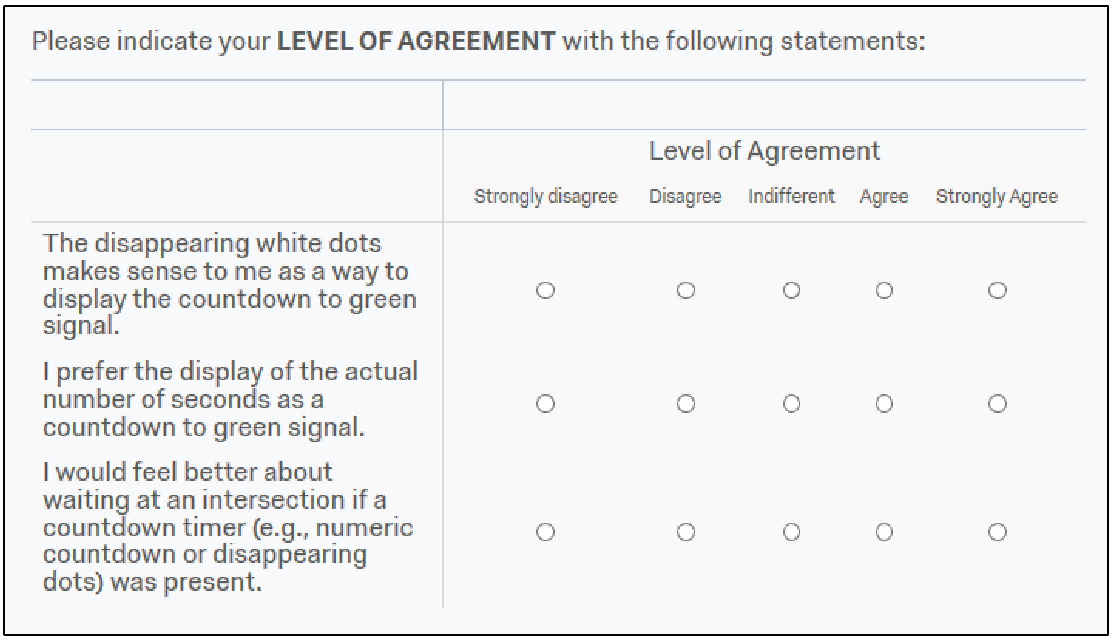
4.6.4.5 Bicycle Countdown Timer "Level of Agreement" Questionnaire

After making their preference selection, respondents were then provided a Likert scale to evaluate their "level of agreement" with designated statements regarding the countdown timers, as shown in Figure 4.13. Responses were coded following the coding convention outlined in Table 4.4.

Table 4.12 summarizes results for the three Likert questions, which were answered by 1,084 respondents. For Question 1, respondents generally indicated that they "Strongly

Agree" (38% average of all three sources) and "Agree" (34% average of all three sources) that the disappearing white dots makes sense to them as a way to display the countdown to green. For Question 2, respondents indicated that they either "Strongly Agree" (31% average of all three sources) or they are "Indifferent" (25% average of all three sources) that they prefer the display of the actual number of seconds as a countdown to green signal.

Similar to Question 1, respondents for Question 3 generally indicated that they "Strongly Agree" (40% average of all three sources) or that they "Agree" (32% average of all three sources) that they would feel better about waiting on a bicycle at an intersection if a countdown timer (e.g., numeric countdown or disappearing dots) was present.



Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Level of Agreement				
	Strongly disagree	Disagree	Indifferent	Agree	Strongly Agree
The disappearing white dots makes sense to me as a way to display the countdown to green signal.	○	○	○	○	○
I prefer the display of the actual number of seconds as a countdown to green signal.	○	○	○	○	○
I would feel better about waiting at an intersection if a countdown timer (e.g., numeric countdown or disappearing dots) was present.	○	○	○	○	○

Figure 4.14: "Level of Agreement" questionnaire for bicycle preemption countdown timers

Table 4.12: Responses to "Level of Agreement" of Statements Regarding Bicycle Preemption Countdown Timers

Response	Total		
	Post Card	Social Media (Facebook)	
	OR	OR	USA
Q1: The disappearing white dots makes sense to me as a way to display the countdown to green signal.			
Strongly Disagree	8.5%	0.0%	5.6%
Disagree	12.9%	5.6%	7.7%
Indifferent	13.0%	6.7%	7.7%
Agree	31.2%	46.7%	35.5%
Strongly Agree	34.0%	41.1%	41.1%
Did not Respond	0.4%	0.0%	2.4%
Q2: I prefer the display of the actual number of seconds as a countdown to green signal.			
Strongly Disagree	11.0%	8.9%	8.6%
Disagree	19.5%	20.0%	16.6%
Indifferent	23.4%	28.9%	25.6%
Agree	13.2%	15.6%	16.8%
Strongly Agree	32.3%	26.7%	30.3%
Did not Respond	0.6%	0.0%	2.2%
Q3: I would feel better about waiting at an intersection if a countdown timer (e.g., numeric countdown or disappearing dots) was present.			
Strongly Disagree	7.6%	3.3%	4.9%
Disagree	6.4%	4.4%	4.3%
Indifferent	19.5%	20.0%	13.8%
Agree	31.8%	27.8%	30.8%
Strongly Agree	34.2%	44.4%	43.9%
Did not Respond	0.6%	0.0%	2.4%

4.7 SUMMARY

A survey was conducted to understand how well respondents comprehend blue light detection systems at intersections and bicycle preemption countdown timers. The survey was conducted online with recruitment through postcards that were mailed to 10,003 addresses in Oregon and nationally through social media (i.e., Facebook advertisement). The survey consisted of 21 questions comprised of open-ended, multiple-choice, and Likert-scale questions.

Of the 1,340 people who responded to the survey (568 postcard, 772 social media), 529 responses from the postcard survey and 555 responses from the social media survey were usable with some or all of the demographic information available, resulting in a total of 1,084 responses. Older, educated, high-income, white males were overrepresented as survey respondents on the postcard survey compared to 2010 Census estimates for Oregon and the United States (US Census), and male respondents from the postcard survey had the highest overrepresentation. Survey respondents were generally older than the general population, with larger representation in the 55–64 and 65+ year's categories, for data collected from Oregon. The social media survey administered nationally yielded a larger representation in the 25-34-year category as compared to the census. Postcard respondents were largely White/Caucasian, and proportions of higher income respondents ($100,000 or greater) on both postcard and social media surveys were overrepresented when compared with census estimates. Respondents with a bachelor's degree were overrepresented on all forms of the survey as compared to the census proportions. Respondents from Oregon via the postcard tended to cycle far less than 5 miles per week in comparison to respondents from Oregon on social media who tended to cycle over 10 miles per week. Also, respondents from Oregon via the postcard were less likely to use a bike for either fun/exercise or transportation within the last month in comparison to respondents from Oregon and nationally on social media who had higher propensity to use a bike ride for fun/exercise or for transportation within the last month. Generally, majority of the respondents from all sources were licensed drivers, held a license for over ten years, drove less than 15,000 miles each year, and used corrective glasses or contacts for vision.

The first section of the survey included questions which asked respondents to report their understanding of the blue light system at an intersection. Respondents were presented an image of intersection as either a bicyclist or vehicle and asked, "*Imagine that you are waiting at an intersection on a bicycle.* What does the blue light (to the left of the arrow) mean to you? In the first scenario, respondents were presented the scenario without supplemental signage, and in the second scenario, supplemental signage was included. Following these questions, respondents were asked to indicate which of three sign options best indicates the meaning for blue light detection at intersections and then asked to provide their "level of agreement" regarding statements related to blue light detection systems. In the second section of the survey, respondents were randomly presented an animated GIF of one of the three bicycle countdown timer options and asked a question designed to probe their comprehension of the system. Following this question, respondents were then asked to choose the countdown timer that best conveys the purpose of the system and then asked to provide their "level of agreement" regarding statements related to bicycle preemption countdown timers. The third and final section of the survey consisted of closed-ended multiple-choice demographic questions on the respondent's income and education levels, bicycling habits, driving habits, and eyesight. Overall, the survey received responses from a wide geographical area of both Oregon and the United States. It should be noted that there were responses collected from outside the United States in Australia. The research team reviewed each open-ended response and coded them as correct, partially correct, or incorrect by three reviewers independently, based on established criteria for each signal display.

Concerning the blue light detection system, the results revealed that most respondents (approximately 94% average of all three sources) indicated that they did not know what the blue light meant or provided a response that was not accurate. Of the respondents who correctly answered the question, Oregonians, both from the postcard and social media sources, generally showed higher rates of correctness compared to the national sample. In general, the addition of supplemental signage increased the comprehension rates for both bicycle and vehicle scenarios. The correct response rates increased to 40 to 50% with the addition of an accompanying sign. Additional variations of the sign may need to be explored as the word "detection" may not be clear to the public. There was a strong preference for sign option #2.

Majority of the respondents across all three survey sources felt that the addition of the sign helped with their understanding of the purpose of the blue light, and that they would support the use of blue light system at some intersections in their community and would feel better about waiting on a bicycle at an intersection if a blue light system was present. Majority of the respondents also reported that they did not experience the blue light system previously.

The scenarios with countdown timers elicited higher proportions of correct responses across all three options that were tested. Majority of the respondents across all platforms also preferred option two among the countdown timer options. Majority of the respondents either strongly agreed or agreed that the disappearing white dots made sense to them as a way to display the countdown to the green signal and that they would feel better about waiting at an intersection which was equipped with a countdown timer. The respondents did not feel strongly about the provision of a countdown timer that displayed the actual number of seconds as a countdown to the green signal.

5.0 VIDEO DATA ANALYSIS

The objective of the video data collection was to compare if there was any change in the behavior of persons on a bicycle with respect to their arrival location, compliance, and stopping position at intersections as a result of the installation of the blue light detection confirmation and countdown timer systems. The blue light detection confirmation device was placed on the far side at six intersections in Portland, OR and near side at one intersection in Corvallis, OR. The countdown timer was placed near side at an intersection in Portland, OR. Before and after video data was collected in the field to determine changes in cyclist's behavior.

5.1 DATA REDUCTION

The data reduction process required reviewing video data to extract the cyclist's arrival location, cyclist's decision to either stop or go upon arriving during a circular red indication and cyclists wait location. In addition, the data reduction included notes indicating any situations that might have impacted the cyclist's behavior or actions. At the Portland sites with the farside blue light detection confirmation systems, the original data was coded from 3:30 pm to 7:30 pm. Data reduced for this project was also coded from 3:30 pm to 7:00 pm. The video data collection did not extend past 7:00 pm as there was no ambient light. At the Eugene sites, data was reduced for two time periods between 7:00 am – 9:00 am and 4:00 pm – 6:00 pm on one weekday. At the site with nearside device installation, data was reduced between 7:00 am to 9:00 am and 4:00 pm to 6:00 pm on two weekdays and 11:00 am -1:00 pm on one weekend day.

5.2 RESULTS

The following section describes the cyclists' arrival location, compliance and waiting behaviors.

5.2.1 Farside Blue Light Detection

In the fall of 2019, video data was collected at four intersections in Portland, OR and two intersections in Eugene, OR where the blue light detection confirmation system with a sign was implemented at the far side. The approach characteristics for each of the sites are summarized in listed in Table 5.1. Cyclists' arrival location, compliance and waiting behavior for the farside blue light detection systems for both the embedded and separate installations is the subsections that follow.

Table 5.1: Video Data Collection Sites for Farside Devices

Location	Approaches	City	Before Date	With Blue Light in Backplate	With Blue Light in Back plate with Supplemental Sign	With Blue Light in Sign on the Far Side
N Ainsworth St. and N Interstate Ave.	N Ainsworth St. WB	Portland	6/14/2017	4/3/18	-	10/10/19
NE US Grant Pl. and NE 33rd Ave.	NE US Grant Pl. EB	Portland	6/14/2017	4/3/18	-	10/10/19
NE 53rd Ave. and NE Glisan St.	NE 53rd Ave. SB	Portland	6/14/2017	4/3/18	10/10/19	-
SW Terwilliger Blvd and SW Capitol Hwy	SW Terwilliger Blvd SB	Portland	6/4/2017, 4/3/18	4/24/18	10/10/19	-
Monroe St. and W 6th Ave.	Monroe St. NB and SB	Eugene	9/24/19	-	-	10/23/19
W 5th Ave. and Blair Blvd	W 5th Ave. EB and WB	Eugene	9/24/19	-	-	10/23/19

Note: “-“indicates that configuration was not installed at that location.

5.2.1.1 Cyclists' Arrival Location

The majority of cyclists arrived at intersections on the street versus the sidewalk, both before and after installation of the blue light detection confirmation system. Table 5.2 shows the cyclists' arrival location at the various approaches.

Table 5.2: Cyclists' Arrival Location

Location	Installation	Eastbound/ Northbound		Westbound/Southbound	
		Street n (%)	Sidewalk n (%)	Street n (%)	Sidewalk n (%)
N Ainsworth St. WB at N Interstate Ave.	Before	-	-	155 (99.4)	1 (0.6)
	With Blue Light in Backplate	-	-	134 (100.0)	0 (0.0)
	With Blue Light in Sign on the Far Side	-	-	109 (88.6)	14 (11.4)
NE US Grant Pl. EB at NE 33rd Ave.	Before	229 (99.1)	2 (0.9)	-	-
	With Blue Light in Backplate	185 (100.0)	0 (0.0)	-	-
	With Blue Light in Sign on the Far Side	192 (99.0)	2 (1.0)	-	-
NE 53 Ave. SB at NE Glisan St.	Before	-	-	105 (97.2)	3 (2.8)
	With Blue Light in Backplate	-	-	62 (98.4)	1 (1.6)
	With Blue Light in Backplate and Supplemental Sign	-	-	65 (97.0)	2 (3.0)
SW Terwilliger Blvd SB at SW Capitol Hwy	Before (1)	-	-	112 (100.0)	0 (0.0)
	Before (2)	-	-	75 (100.0)	0 (0.0)
	With Blue Light in Backplate	-	-	140 (99.3)	1 (0.7)
	With Blue Light in Backplate and Supplemental Sign	-	-	76 (100.0)	0 (0.0)
W 5th Ave EB and WB at Blair Blvd.	Before	32 (97.0)	1 (3.0)	67 (98.5)	1 (1.5)
	With Blue Light in Sign on the Far Side	32 (100.0)	0 (0.0)	53 (93.0)	4 (7.0)
Monroe Street NB and SB at 6th Ave.	Before	50 (92.6)	4 (7.4)	39 (81.3)	9 (18.8)
	With Blue Light in Sign on the Far Side	34 (79.1)	9 (20.9)	40 (93.0)	3 (7.0)

At the Portland sites, over 97% of the cyclists arrived on the street at all locations regardless of whether the blue light detection confirmation detection system was present or not except at NE Interstate Ave. and N Ainsworth St. WB, where the percent of cyclists arriving on the sidewalk after the installation of blue light in sign on the farside increased from 0.6% to 11.4%. Upon further examination of the data, all the sidewalk riders appeared to be children who were likely returning home from school. Except at the SW Terwilliger Blvd. and SW Capitol Hwy location where a bike lane was present, all other Portland locations had a shared approach. At the Eugene intersections, the arrival patterns were more variable. At W 5th Ave. and Blair Blvd intersection, the proportion of cyclists arriving on the sidewalk varied between 1.5% and 7%. Higher proportions of cyclists were observed arriving on the sidewalk at Monroe St. and W 6th Ave. with proportions varying between 7% and 21%, although the counts were small.

For subsequent analysis, only those cyclists that arrived on the street along the approach of interest were considered, as they would be in the best position to view the blue light feedback device after implementation.

5.2.1.2 Cyclist's Decision to Stop on Red Indication

The compliance behavior of cyclists arriving on a red indication was examined and the results are shown in Table 5.3. The compliance behavior was coded as yes (compliant), if the cyclist stopped and remain stopped until the green indication for left turn and through movements. For right turn movements, persons were coded as compliant if they stopped and proceeded only if a gap was found. Out of the total of 877 observed cyclists in the before and after conditions, 743 (85%) complied with the red indication. As found in previous research, bicyclist compliance with the traffic signal indications is highly site-specific. At three of the four locations in Portland and at the Monroe St at 6th Ave. intersection in Eugene, the overall proportion of cyclists who complied with the red indication was over 90%.

The observations for non-compliant cyclists are disaggregated by movement (either right turn or through/left turns). The through/left turn non-compliant movement has the potential to be a severe crash. While non-compliant, the right-turn without stopping has less safety impact. At most intersections, cyclists are turning into a bicycle lane. Figure 5.1 shows the frequency of these coded observations at the six farside locations (e.g. plots of the data in the table – note the x-axis starts at 40% and the numbers in the bars are frequency).

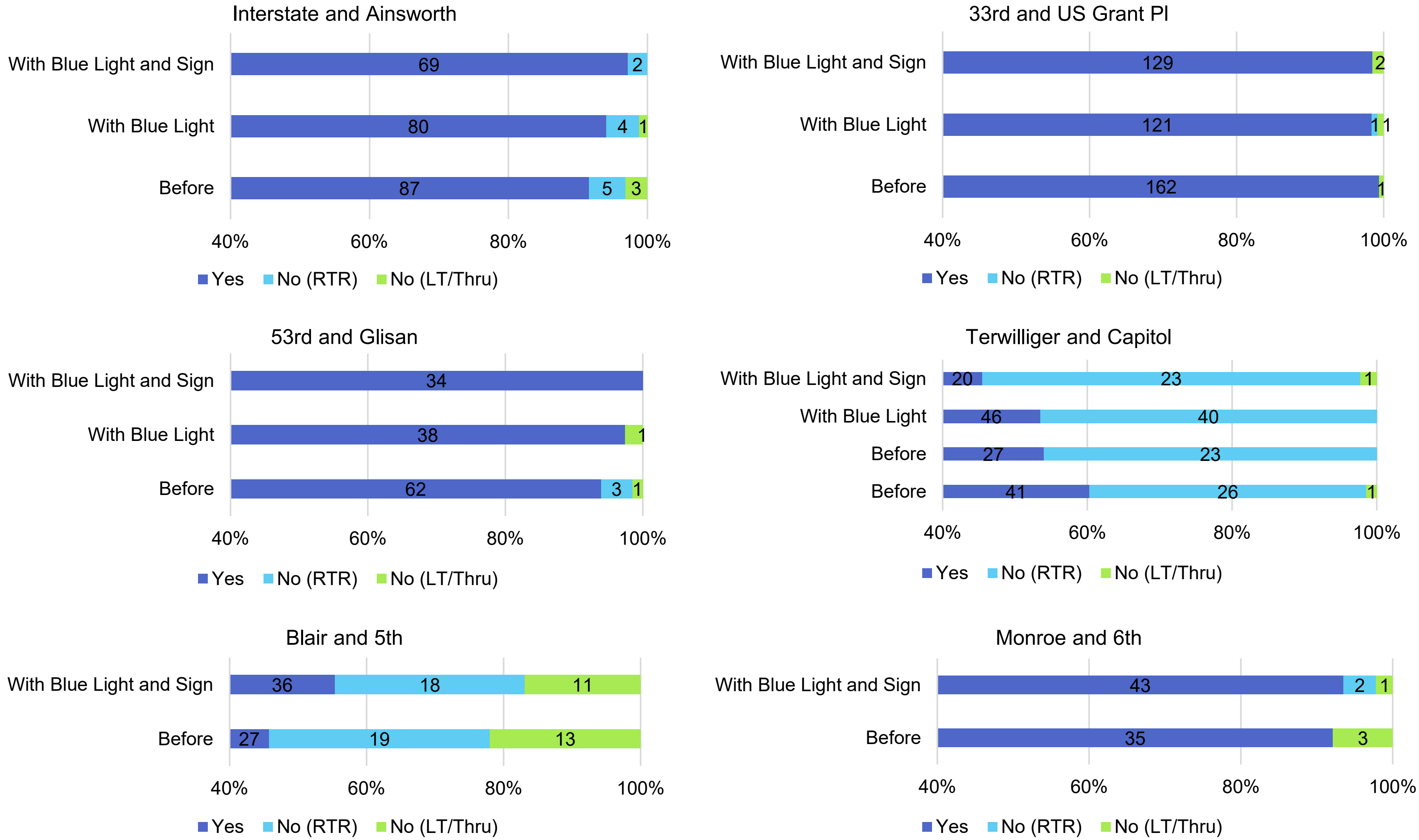
When comparing the compliance before and after the installation of the blue light detection systems, the results were site-specific. At three of the six locations (Interstate and Ainsworth, 53rd and Glisan, Blair and 5th) there was a small increase in the overall compliance (about 4%, 4%, and 8.2% respectively). At two locations (33rd and US Grant Pl and Monroe and 6th, there was a slight decrease in compliance (less than 1%). At the remaining location (Terwilliger and Capitol) there was a decrease in compliance (about 8%). None of the differences, however, were statistically significant.

It is noted that two locations (SW Terwilliger and Capitol and W 5th Ave. and Blair Blvd contribute the majority of non-compliant behaviors (175 of the 205 non-compliant observations). Most of these observations (150) are cyclists who did not stop for the red indication while making a right turn at SW Terwilliger. At the SW Terwilliger Blvd SB at SW Capitol Hwy location between 38% - 52% of the cyclists arriving on the red indication did not stop and turned right on red. These cyclists are travelling downhill and turning from a bike lane into the shoulder which is a bus bay and which connected to a bike lane going westbound, they probably felt comfortable doing so even on a red indication, perhaps due to the low propensity for conflicts. Similar cyclist behavior was also observed at the W5th Ave. at Blair Blvd intersection in Eugene. When cross traffic was light and gaps in traffic were available, cyclists undertook their movements without stopping for a red indication.

Table 5.3: Decision to Stop on Red Indication, Far Side Devices

Intersection	System Implementation	Yes (Compliant)		No (Does not Stop and Turns Right on Red)		No (Does not Stop and Turns Left/Thru on Red)	
		EB/NB n (%) *p-value*	WB/SB n (%) *p-value*	EB/NB n (%) *p-value*	WB/SB n (%) *p-value*	EB/NB n (%) *p-value*	WB/SB n (%) *p-value*
N Ainsworth St. WB at N Interstate Ave.	Before	-	87 (91.6)	-	5 (5.3)	-	3 (3.2)
	With Blue Light in Backplate	-	80 (94.1)	-	4 (4.7)	-	1 (1.2)
	With Blue Light in Sign on the Far Side	-	69 (97.2) *0.17*	-	2 (2.8) *0.52*	-	0 (0.0) *0.14*
NE US Grant Pl. EB at NE 33rd Ave.	Before	162 (99.4)	-	0 (0.0)	-	1 (0.6)	
	With Blue Light in Backplate	121 (98.4)	-	1 (0.8)	-	1 (0.8)	
	With Blue Light in Sign on the Far Side	129 (98.5) *0.47*	-	0 (0.0) -	-	2 (1.5) *0.44*	
NE 53 Ave. SB at NE Glisan St.	Before	-	62 (93.9)	-	3 (4.5)		1 (1.5)
	With Blue Light in Backplate	-	38 (97.4)	-	0 (0.0)		1 (2.6)
	With Blue Light in Backplate and Supplemental Sign	-	34 (100.0) *0.14*	-	0 (0.0) *0.21*		0 (0.0) *0.47*
SW Terwilliger Blvd SB at SW Capitol Hwy	Before (1)	-	41 (60.3)		26 (38.2)		1 (1.5)
	Before (2)	-	27 *(54.0)*		23 *(46.0)*		0 *(0.0)*

	With Blue Light in Backplate	-	46 (53.5)	-	40 (46.5)		0 (0.0)
	With Blue Light in Backplate and Supplemental Sign	-	20 (45.5) *0.12* *0.41*	-	23 (52.3) *0.14* *0.54*		1 (2.3) *0.42* *0.28*
W 5th Ave. EB and WB at Blair Blvd.	Before	13 (59.1)	14 (37.8)	4 (18.2)	15 (40.5)	5 (22.7)	8 (21.6)
	With Blue Light in Sign on the Far Side	17 (56.7) *0.88*	19 (54.3) *0.17*	5 (16.7) *0.93*	13 (37.1) *0.79*	8 (26.7) *0.74*	3 (8.6) *0.12*
Monroe Street NB and SB at 6th Ave.	Before	13 (100.0)	22 (95.7)	0 (0.0)	0 (0.0)	2 (13.3)	1 (4.3)
	With Blue Light in Sign on the Far Side	14 (100.0) *0.16*	29 (90.6) *0.47*	0 (0.0) -	2 (6.3) *0.22*	0 (0.0) *0.16*	1 (3.1) *0.81*



Note: Numbers in bars are frequency of observation, not percentage

Figure 5.1: Decision to stop on red, far side devices

5.2.1.3 Cyclist's Waiting Location during Red Indication

At the intersections where the blue light feedback systems were installed, stencil markings were present on the pavement to indicate to the cyclists where they should wait to be detected. . The waiting location of the cyclists who arrived on the red indication, when the stencil was not already occupied by a motor vehicle or other bicyclist, was observed before and after blue light and sign were installed. Results of the analysis are shown in Table 5.4. At three of the Portland intersections, the proportion of cyclists who were observed to wait on the stencil when arriving on red and the stencil was unoccupied is lower after the blue light and sign were installed than in the before condition. At N Ainsworth St. at N Interstate Ave., after the installation of blue light and sign, cyclists preferred waiting next to the curb near the pushbutton instead of waiting on the stencil which was placed in the center of the lane. The highest pushbutton use (30-47%) was observed at this location, which increased after the blue light and sign was installed compared to the before condition (40.5% before, 47.5% with blue light and sign, p-value 0.6). The pushbutton is situated near on the edge of the curb and is easy to press without having to dismount. At NE US Grant Pl. at NE 33rd Ave., there were two stencil markings that were visible after blue light and sign installation. The old marking was faded but still faintly visible and a new stencil marking was placed right next to the old marking. The new stencil marking was used to code the wait location in the post blue light and sign condition. Some cyclists still ended up waiting on the old stencil or waiting very close to the new stencil marking but not directly on it, which were coded as waiting off stencil. However, at SW Terwilliger Blvd at SW Capitol Hwy intersection, higher proportions of cyclists were observed to not stop on the red indication and made a right turn on red. As a result, a lower proportion of cyclists were observed to wait on the stencil marking. The difference in pushbutton use proportion between the second before condition (video data was collected twice in the before condition) and after blue light and sign was installed was also statistically significant.

At the W 5th Ave. and Blair Blvd intersection, the proportion of cyclists who arrived on red when the stencil was unoccupied and waited on the stencil increased for both eastbound and westbound directions after the blue light and sign were installed (EB 28.6% before, EB 37% with blue light and sign; WB 17.1% before, 34.3% with blue light and sign). However, these differences were not statistically significant. At the Monroe St and 6th Ave. intersection, the proportion of cyclists who arrived on red when the stencil was unoccupied and waited on the stencil increased for both northbound and southbound directions after the blue light and sign were installed (NB 28.6% before, NB 50% with blue light and sign; SB 30.8% before, 45.5% with blue light and sign), but these differences were not statistically significant. In both directions, the blue light activation was tied to a video detector and the detection zone was much larger than a traditional in-pavement loop. Therefore, the detection zone could have an impact on cyclists' waiting location, as the cyclist need not wait on the stencil marking for the blue light to be activated. Pushbutton use was low at both intersection in the before and after blue light and sign installation and statistically significant differences in pushbutton use were seen in the southbound direction at Monroe St and 6th Ave. between the before and after blue light and sign installation. Pushbutton usage was observed to have reduced post blue light and sign installation across both intersections, although the actual counts were small.

Table 5.4: Waiting Location of Cyclists Arriving on Red

Intersection	**Device Type**	**Total n**		**Stencil not Occupied. n (%)**		**Stencil not Occupied, Waited on Stencil n (%) p-value**		**Stencil not Occupied, Pressed the Pushbutton n (%)**	
		EB/NB	**WB/SB**	**EB/NB**	**WB/SB**	**EB/NB**	**WB/SB**	**EB/NB**	**WB/SB**
N Interstate Ave. at N Ainsworth St.	Before	-	93	-	37 (39.8)	-	14 (37.8)	-	15 (40.5)
	With Blue Light in Backplate	-	84	-	34 (40.5)	-	10 (29.4)	-	10 (29.4)
	With Blue Light in Sign on the Far Side	-	71	-	21 (29.6)	-	4 (19.0) *0.14*	-	10 (47.6) *0.60*
NE 33rd Ave. at NE US Grant Pl.	Before	166	-	78 (47.0)	-	49 (62.8)	-	4 (5.1)	-
	With Blue Light in Backplate	121	-	55 (45.5)	-	46 (83.6)	-	1 (1.8)	-
	With Blue Light in Sign on the Far Side	131	-	76 (58.0)	-	54 (71.1) *0.27*	-	2 (2.6) *0.42*	-
SW Terwilliger Blvd at SW Capitol Hwy	Before (1)	-	68	-	65 (95.6)	-	29 (44.6)	-	1 (1.5)
	Before (2)	-	54	-	54 (100.0)	-	26 (48.1)	-	0 (0.0)
	With Blue Light in Backplate	-	84	-	82 (97.6)	-	34 (41.5)	-	0 (0.0)
	With Blue Light in Backplate and Supplemental Sign	-	44	-	43 (97.7)	-	15 (34.9) *0.31* *0.19*	-	3 (7.0) *0.13* ***0.04****
W 5th Ave. EB and WB at Blair Blvd.	Before	22	37	21 (95.5)	35 (94.6)	6 (28.6)	6 (17.1)	2 (9.5)	0 (0.0)
	With Blue Light in Sign on the Far Side	30	35	27 (90.0)	35 (100.0)	10 (37.0) *0.54*	12 (34.3) *0.09*	1 (3.7) *0.41*	0 (0.0) -

Monroe Street NB & SB at 6th Ave.	Before	15	23	14 (93.3)	13 (56.5)	4 (28.6)	4 (30.8)	0 (0.0)	4 (30.8)
	With Blue Light in Sign on the Far Side	14	32	12 (85.7)	22 (68.8)	6 (50.0) *0.26*	10 (45.5) *0.39*	0 (0.0) -	1 (4.5) ***0.03****

*Statistically significant at the 95% confidence level

5.2.2 Nearside Blue Light Detection Confirmation

At the Corvallis location, the blue light detection confirmation system was installed along the northbound approach, for the cyclists on SW Brooklane Dr. As described previously, video data was collected during five different time periods. The following sections describe the collected metrics across all data collection periods.

5.2.2.1 Cyclists' Arrival Location

Table 5.5 summarizes the percentage of cyclists' arrival location for each of the data collection periods. The majority of cyclists were observed to arrive at the intersection on the sidewalk/path instead of the street across all the data collection periods. The proportion of cyclists arriving on the sidewalk varied between a high of 78.7 % observed two weeks after stencil installation to a low of 51.6% observed five weeks after blue light and sign installation. These percentages are expected as this intersection serves as a node to a shared-use path that runs along the south side of Philomath Blvd. Using the sidewalk to arrive at the intersection is reasonable. The proportion of cyclists' arriving on street, on the approach varied between a low of 12.9% observed two weeks after stencil installation to a high of 35.5% observed five weeks after blue light and sign installation. Additionally, cyclists were also observed to arrive on the northbound approach from the shared use path on the west and these are represented as other arrivals on street. Table 5.5 Only those cyclists that arrived on the street on the northbound approach were included for further analysis as these cyclists would be able to see the stencil, blue light, and sign clearly.

Table 5.5: Cyclists' Arrival Location

Installation	On Street (Approach) n (%)	On Street (Other) n (%)	Sidewalk n (%)
Before	20 (20.2)	3 (3.0)	76 (76.8)
With Stencil (2-wk)	20 (12.9)	13 (8.4)	122 (78.7)
With Stencil (4-wk)	19 (15.2)	11 (8.8)	95 (76.0)
With Stencil, Blue Light, and Sign (2-wk)	23 (14.8)	12 (7.7)	120 (77.4)
With Stencil, Blue Light, and Sign (5-wk)	22 (35.5)	8 (12.9)	32 (51.6)

5.2.2.2 Cyclist's Decision to Stop on Red Indication

Nearly all cyclists stopped for the red indication across all data collection time periods (83 compliant, 2 non-compliant). Table 5.6 summarizes the percentage of cyclists' decision to stop on red indication. Only three instances of cyclists not stopping for the red indication were observed and these occurred two weeks and four weeks post stencil installation, and five weeks post sign installation. During the post stencil period, two cyclists were observed to use an available gap in cross traffic and rode straight through the intersection. Post sign installation, one cyclist was observed to turn right without stopping. No statistically significant differences in proportions were found between cyclists stopping on the red indication before and with blue light and sign conditions after 5 weeks (100% before; 94% with stencil, blue light and sign, p-value 0.31). Similarly, no statistically significant differences were found between cyclists not stopping on red while turning right in the before and with blue light and sign conditions (0% before, 5.6% with blue light and sign, p-value 0.33), and for cyclists who did not stop on the red indication and either turned left and proceeded straight through the intersection (0% before; 0% with blue light and sign).

Table 5.6: Cyclists' Decision to Stop on Red Indication, Nearside Device

Installation	**Yes** **n** **(%)** ***p-value***	**No (Does not Stop and Turns Right on Red)** **n** **(%)** ***p-value***	**No (Does not Stop and Turns Left/Goes Thru on Red)** **n** **(%)** ***p-value***
Before	16 (100.0)	0 (0.0)	0 (0.0)
With Stencil (2-wk)	12 (92.3)	0 (0.0)	1 (7.7)
With Stencil (4-wk)	14 (93.3)	0 (0.0)	1 (6.7)
With Stencil, Blue Light, and Sign (2-wk)	18 (100.0)	0 (0.0)	0 (0.0)
With Stencil, Blue Light, and Sign (5-wk)	17 (94.4) *0.31*	1 (5.6) *0.33*	0 (0.0) -

5.2.2.3 Cyclist's Waiting Location during Red Indication

Table 5.6 shows the waiting location of the cyclists during the red indication. In the before condition, a stencil marking was located on the right, close to the curb. Following the before video data period, an additional stencil marking with a black background was added in the center of the lane. In the before condition, 100% of cyclists who arrived on the red indication when the stencil was not occupied were observed waiting on the old stencil. Two weeks after the new stencil was installed, 36.4% and 54.5% of the cyclists were observed to wait on both the old and new stencil markings, respectively. One cyclist was observed to not wait and went straight through. Four weeks after the stencil was installed, the proportion of cyclists observed using the new stencil increased to 73%, while 18% waited on the old stencil. Two weeks post sign installation, 55% were observed to wait on the new stencil while 27% waited on the old stencil. Eighteen (18%) percent of the cyclists were also observed to wait off the stencil markings ahead of the crosswalk, where they could better assess the gaps in cross traffic. Five weeks post sign installation, 25% were observed to wait on the old and new stencil markings. Forty two percent (42%) of the cyclists were observed to wait off the stencil markings ahead of the crosswalk, which presented them with greater visibility of the cross-traffic probably due to the steep grade on this approach, while one cyclist did not wait. Only 2 arriving cyclists were observed to use the pushbutton.

Table 5.7: Percentage of Cyclists' Waiting Location during Red Indication

Condition	Total n	Stencil not Occupied n (%)	Stencil not Occupied, Waited on Old Stencil n (%)	Stencil not Occupied, Waited on New Stencil n (%)	Stencil not Occupied, Pressed the Pushbutton n (%)
Before	16	12 (75.0)	12 (100.0)	-	0 (0.0)
With Stencil (2-wk)	13	11 (84.6)	4 (36.4)	6 (54.5)	1 (9.1)
With Stencil (4-wk)	15	11 (73.3)	2 (18.2)	8 (72.7)	0 (0.0)
With Stencil, Blue Light, and Sign (2-wk)	18	11 (61.1)	3 (27.3)	6 (54.5)	0 (0.0)
With Stencil, Blue Light, and Sign (5-wk)	18	12 (66.7)	3 (25.0) ***0.00****	3 (25.0)	1 (8.3) *0.31*

*statistically significant at the 95% confidence level

5.2.3 Nearside Countdown Timer

At the NE Broadway St. and N Williams Ave. intersection, a countdown timer was installed for cyclists in the westbound direction with video data being collected pre- and post-installation. The following sections describe the collected metrics across all the data collection periods.

5.2.3.1 Cyclists' Arrival Location

The majority of cyclists arrived at the intersection using the bike lane with 92% before and 88.5%after periods. In addition to the bike lane, a smaller proportion of cyclists (6.7% before; 8.8% after) were observed arriving at the intersection using other vehicular lanes on street. The arrival location is shown in Table 5.8. Additionally, 1.3% and 2.7% of the cyclists were observed arriving at the intersection on the sidewalk. Only those cyclists that arrived on the street using the bicycle lane were included for further analysis (as only these cyclists would be able to see the countdown timer clearly).

Table 5.8: Cyclists' Arrival Location

Installation	Street-Bike Lane (%)	Street – Other (%)	Sidewalk (%)
Before	138 (92.0)	10 (6.7)	2 (1.3)
After	200 (88.5)	20 (8.8)	6 (2.7)

5.2.3.2 Cyclist's Decision to Stop on Red Indication

The cyclists' decision to stop in response to the red indication is shown in Table 5.9. Compliance with the traffic signal indication is shown for three movements from the bicycle lane (turn left, proceed straight through, and turn right). In addition, three categories of compliance, coded – 1) stopped and remained stopped until green, 2) stopped initially but proceeded later on red, and 3) did not stop. For this location, there is a "No Right Turn on Red" sign that applies to all vehicles at the intersection, including bicycles. Thus, bicycles that turn right on red are considered non-compliant. All proportions were tested for statistical significance using the Z-test of proportions. The data for through movements and right-turn movements are plotted in Figure 5.2.

Overall, 62% (before) and 54% (after) of the cyclists in the after condition stopped and remained stopped until the green indication. The difference was not statistically significant using a (p-value 0.21). A total of 17% of the cyclists in the before condition and 18% of cyclists in the after condition initially stopped but were observed to proceed during the red indication (p-value 0.82). These cyclists found gaps in the lower pandemic conflicting traffic. Finally, 21% of cyclists (before) and 28% (after) did not stop at all (p-value 0.21). The difference is not statistically significant.

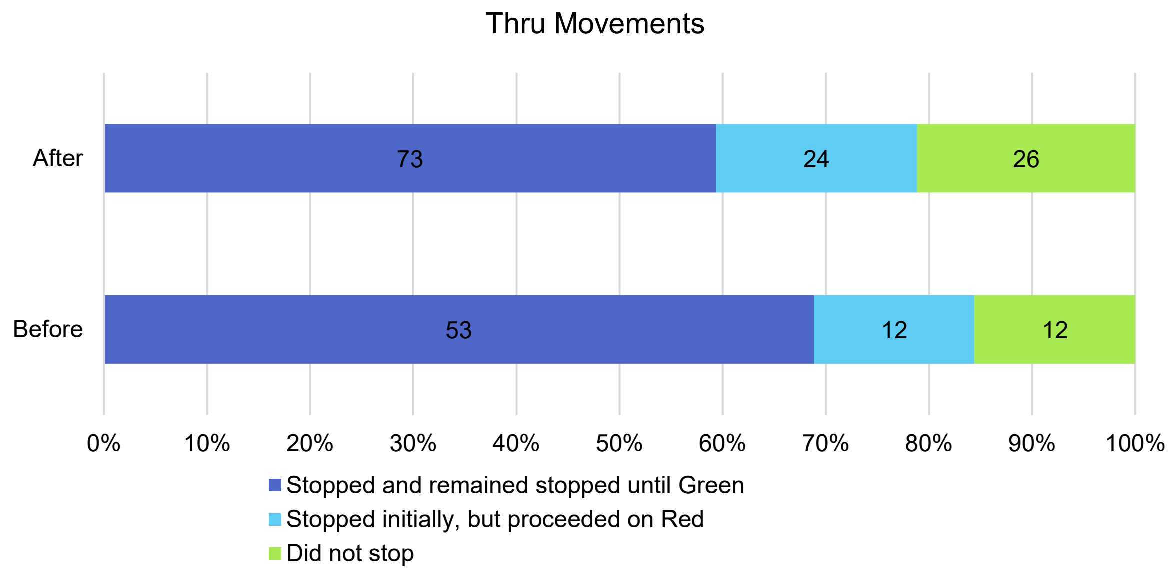
Person on bicycles who initially stopped but proceeded on the red indication or cyclists who did not stop at all either went straight through or turned right at the intersection. Even though the proportions of through cyclists who stopped initially but proceeded on red increased in the after condition compared to before condition (19.5% after; 15.6% before, p-value 0.48), these differences were not statistically significant. Similarly, the difference in proportions of cyclists who stopped initially on red but proceeded to turn right on the red indication in the before and after condition were not statistically significant (19% before, 13% after, p-value 0.58). No statistically significant differences were found between cyclists who did not stop but proceeded thru on the red indication (16% before; 21% after; p-value 0.33), and between cyclists who did not stop but turned right in the before and after condition (43% before, 57% after; p-value 0.33).

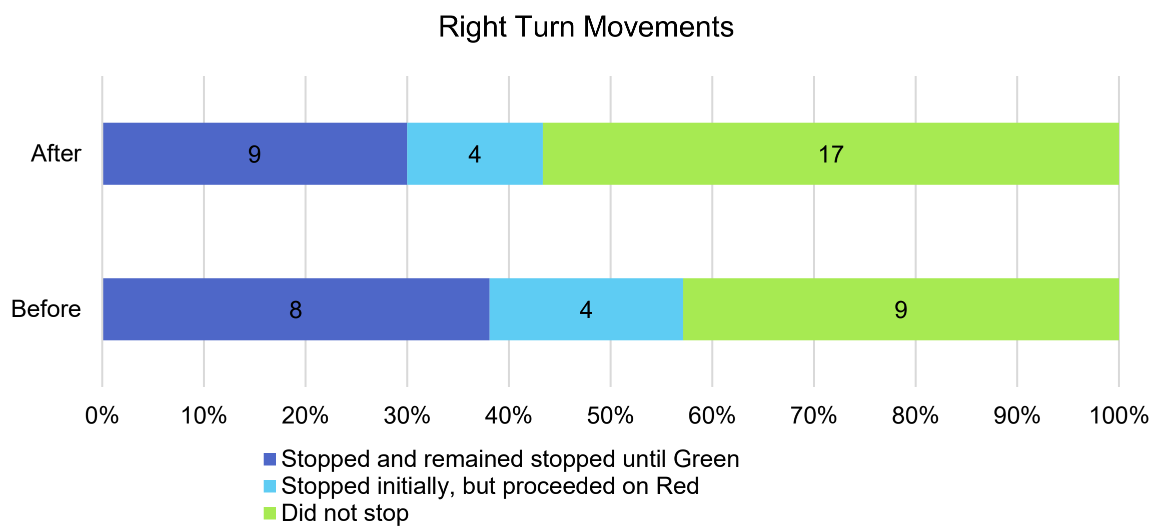
In summary, while the proportions of cyclists who did not comply with the signal indications increased after the countdown timer installation, these increases were not statistically significant. It is very likely that changes in compliance at this installation are not related to the information provided by the countdown timer but rather the reduced motor vehicle volumes of the COVID-19 pandemic. The research team was not able to quantify the differences in traffic volume due to data availability. A prior ODOT research project (SPR747) studied compliance at this same intersection using data from June 2011.

A total of 557 bicyclist were observed. Compliance was measured in more detail, but 42 cyclists accepted a gap during the red interval (7.5%) and 48 cyclist (7.5%) started to proceed through the intersection before the green interval ("signal jump). An additional 66 (11.8%) completed a right turn on red without stopping. Comparing these results to the data collected for this project during the pandemic, it is clear the pandemic conditions have influenced bicycle behaviors. Finally, it is worth noting that the signal phasing is set so that bicycles are displayed a red bicycle signal face during the adjacent dual right turn movement as well as the conflicting cross street volumes. With lower vehicle demand during the pandemic, there were often large conflict-free gaps for non-compliant cyclists to select that would not be present under typical traffic patterns.

Table 5.9: Cyclists' Decision to Stop on Red Indication, Countdown Timer

Condition	Stop on Red	Left n (%) p-value	Thru n (%) p-value	Right n (%) p-value	Total n (%) p-value
Before	Stopped and remained stopped until Green	0 (0.0)	53 (68.8)	8 (38.1)	61 (61.6)
	Stopped initially, but proceeded on Red	1 (100.0)	12 (15.6)	4 (19.0)	17 (17.2)
	Did not stop	0 (0.0)	12 (15.6)	9 (42.9)	21 (21.2)
After	Stopped and remained stopped until Green	0 (0.0) -	73 (59.3) *0.17*	9 (30.0) *0.55*	82 (53.6) *0.21*
	Stopped initially, but proceeded on Red	0 (0.0) -	24 (19.5) *0.48*	4 (13.3) *0.58*	28 (18.3) *0.82*
	Did not stop	0 (0.0) -	26 (21.1) *0.33*	17 (56.7) *0.33*	43 (28.1) *0.21*





Note: Numbers in bars are frequency of observation, not percentage

Figure 5.2: Decision to Stop on Red by Movement, Countdown Device

5.2.3.3 Cyclist's Waiting Location during Red Indication

Cyclists' waiting position during the red indication is presented in Table 5.10. The data presented includes only the cyclists who complied either partly or fully with the red signal indication. Of the cyclists arriving on red, 61.6% and 53.6% waited in street until green and 17.2% and 18.3% waited in the street initially but departed on red in the before and after conditions. No cyclists that arrived on the street were observed to wait on the sidewalk. Of the cyclists arriving on red, 33.3% and 37.9% were observed to use the pushbutton in the before and after conditions. The differences in proportions for waiting location and pushbutton usage are not statistically significantly different.

Table 5.10: Cyclists' Waiting Location during Red Indication

Installation	Total n	Arriving on Red			
		Waited in Street, until green (%) n (%)	Waited in Street initially, but departed on red n (%)	Waited on Sidewalk n (%)	Used the Pushbutton n (%)
Before	99	61 (61.6)	17 (17.2)	0 (0.0)	33 (33.3)
After	153	82 (53.6) *0.21*	28 (18.3) *0.82*	0 (0.0) -	58 (37.9) *0.46*

5.3 SUMMARY

This chapter summarized the findings of the three sets of field data collection whose objective was to understand a) how well cyclists comprehend and react to the use of a two-inch diameter circular LED blue light for detection confirmation either in back plate with supplemental sign or blue light in sign placed on the far side, b) how well cyclists comprehend and react to the use of a two-inch diameter circular LED blue light for detection confirmation in sign placed on near side and c) how well cyclists comprehend and react to the use of a countdown timer placed on near side.

For the farside installation, video data was collected at six intersections in Portland and Eugene using a before and after study (without blue light, with blue light in backplate, with blue light in backplate and supplemental sign or with blue light in sign located on the far side). Except for one location (SW Terwilliger Blvd at SW Capitol Hwy), the approaches were shared lanes with motor vehicles. The blue light detection confirmation systems provide positive confirmation to the person on a bicycle that they have been detected by the traffic signal. Assuming the detected cyclist understands the feedback system, the assumption is that they would be less likely to violate the traffic signal indication. Compliance was generally high except at W 5th Ave. and Blair Blvd and SW Terwilliger Blvd and SW Capitol Hwy. At both these locations, cyclists were generally observed to not stop and make a right turn on red. The noncompliance for cyclists going straight through or making a left turn was low across all locations. Overall, there was an increase in the compliance of cyclists after the blue light and sign were installed compared to the before condition at most intersections, however these decreases were not statistically significant.

At the nearside installation, the majority of cyclists were observed to be using the sidewalk which connects to a shared use path rather than the street. Compliance was very high across all data collection periods, and the handful of instances of noncompliance involved cyclists taking advantage of the gaps in cross traffic to either ride straight through the intersection or turn right without stopping. After the installation of the new stencil, cyclists were observed to wait both on the new and old stencil markings, while some cyclists waited ahead of the crosswalk.

At the countdown timer location, the majority of cyclists approached the intersection with a nearside countdown timer riding in the bike lane. The proportion of cyclists stopping partially and not stopping at all, increased in the after condition compared to the before condition, with higher proportions of cyclists turning red than going straight through, although the increases were not statistically significant. The noncompliance is likely related to cyclist culture and location rather than the device itself. Lower proportions of cyclists were observed to wait in the street until green after the countdown timer installation, but the reduction was not statistically significant. Pushbutton use increased after the countdown timer was installed than the before condition although the increase was not statistically significant.

6.0 INTERCEPT SURVEY

An intercept survey of cyclists was conducted to understand how well they comprehend the use of a two-inch diameter circular LED blue light for detection confirmation with an accompanying sign with both farside and nearside installations and a nearside countdown timer. Open-ended, multiple-choice, and Likert scale questions were developed to elicit each user's understanding and self-reported response to these devices. The intercept survey was administered to cyclists at six intersections (12 intersection approaches) and one intersection (one approach) for farside and nearside blue light detection confirmation system installations with sign in Oregon. The survey was also administered at a single approach at one intersection, where a nearside countdown timer was installed This chapter describes the development and administration of the survey and the results of the analysis.

6.1 FARSIDE BLUE LIGHT DETECTION CONFIRMATION

The objective of the intercept survey was to determine the cyclists' comprehension of the blue light detection confirmation device at traffic signals equipped with the accompanying sign. Two versions of the signs were designed – one in which the blue light was embedded in the sign, and the other where the blue light was in the signal backplate separate from the sign. The survey was designed to elicit common correct, incorrect, or partially incorrect interpretations of the blue light detection confirmation device meanings.

6.1.1 Design and Refinement

The first step in designing the survey was the development of questions that were designed to elicit cyclists' comprehension of the blue light detection confirmation device when combined with an accompanying sign. Two versions of the sign were developed for field installation – one where the blue light was static on the sign but instead embedded in the signal backplate (Figure 6.1) and another where the blue light was embedded as part of the sign itself (Figure 6.2).

Figure 6.1 Blue detection confirmation light in back plate with sign

Figure 6.2 Blue detection confirmation light embedded in sign

Table 6.1 shows the six intersection locations along with the 12 approaches where the blue light detection confirmation devices were installed along with the accompanying signs. The intercept survey was administered at these six intersections. Every effort was made to present questions neutrally, allowing respondents to provide meaningful answers reflecting their comprehension of the signal indications. Several rounds of review and refinement followed the internal development of the survey questions. Transportation graduate students at OSU and PSU tested a pilot survey and provided feedback for further improvements in the format and content of the survey questions. Once the project team was satisfied with the survey design, the survey was finalized.

Table 6.1 Blue Light Locations and Type of Accompanying Sign

Location	Approaches	City	Type	Letter Codes
N Ainsworth St. and N Interstate Ave.	N Ainsworth St. EB and WB	Portland	Embedded	AA
NE US Grant Pl. and NE 33rd Ave.	NE US Grant Pl. EB and WB	Portland	Embedded	BB
NE 53rd Ave. and NE Glisan St.	NE 53rd Ave. NB and SB	Portland	Separate	CC
SW Terwilliger Blvd and SW Capitol Hwy	SW Terwilliger Blvd NB and SB	Portland	Separate	DD
Monroe St. and W 6th Ave.	Monroe St. NB and SB	Eugene	Embedded	EE
W 5th Ave. and Blair Blvd	W 5th Ave. EB and WB	Eugene	Embedded	FF

6.1.2 Instrument

The survey consisted of 17 questions, which included a mix of open-ended and close-ended questions. The survey design included random branches so that open-ended questions could be presented in an unbiased manner. Figure 6.3 illustrates the organization and flow of the survey.

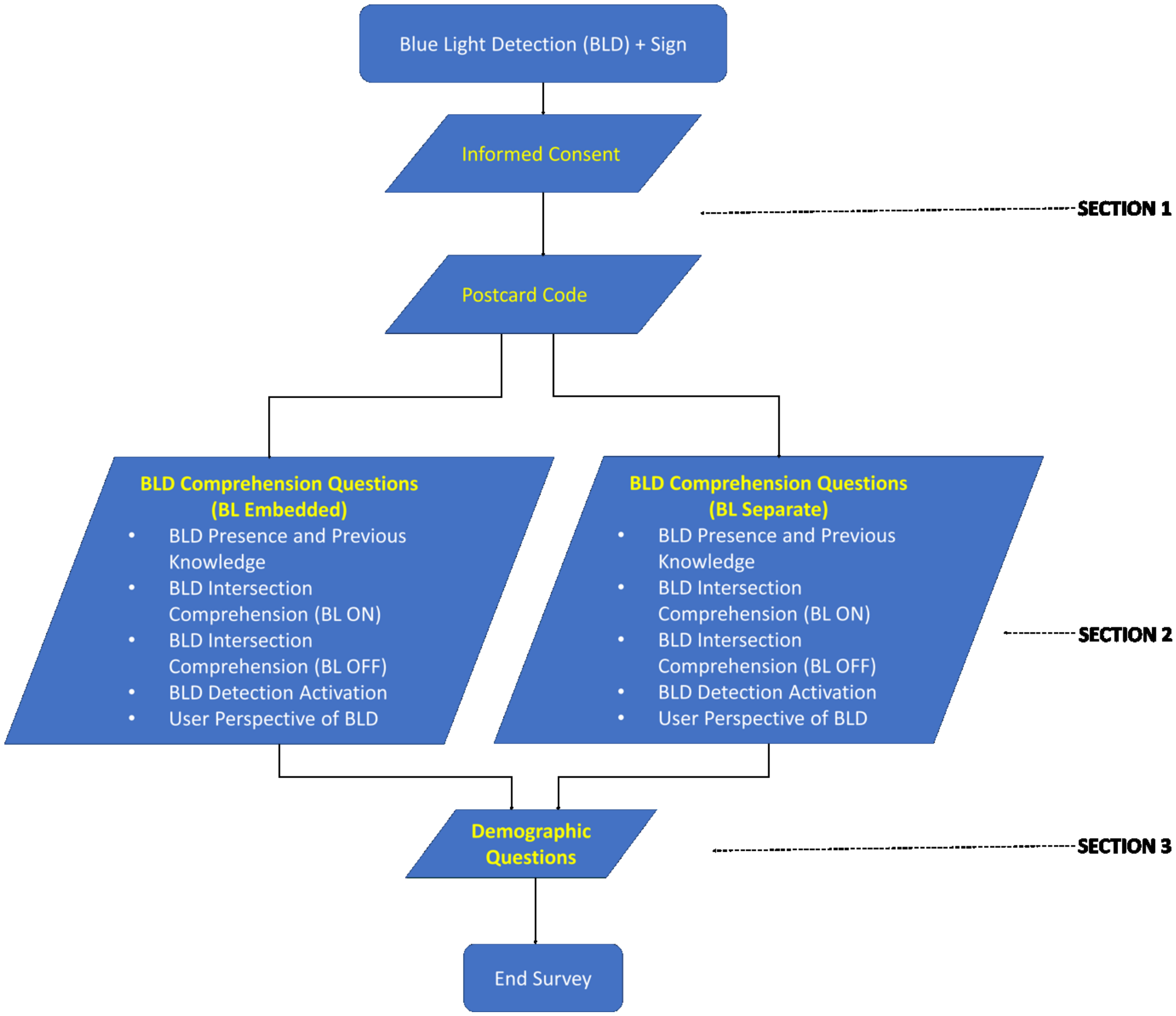


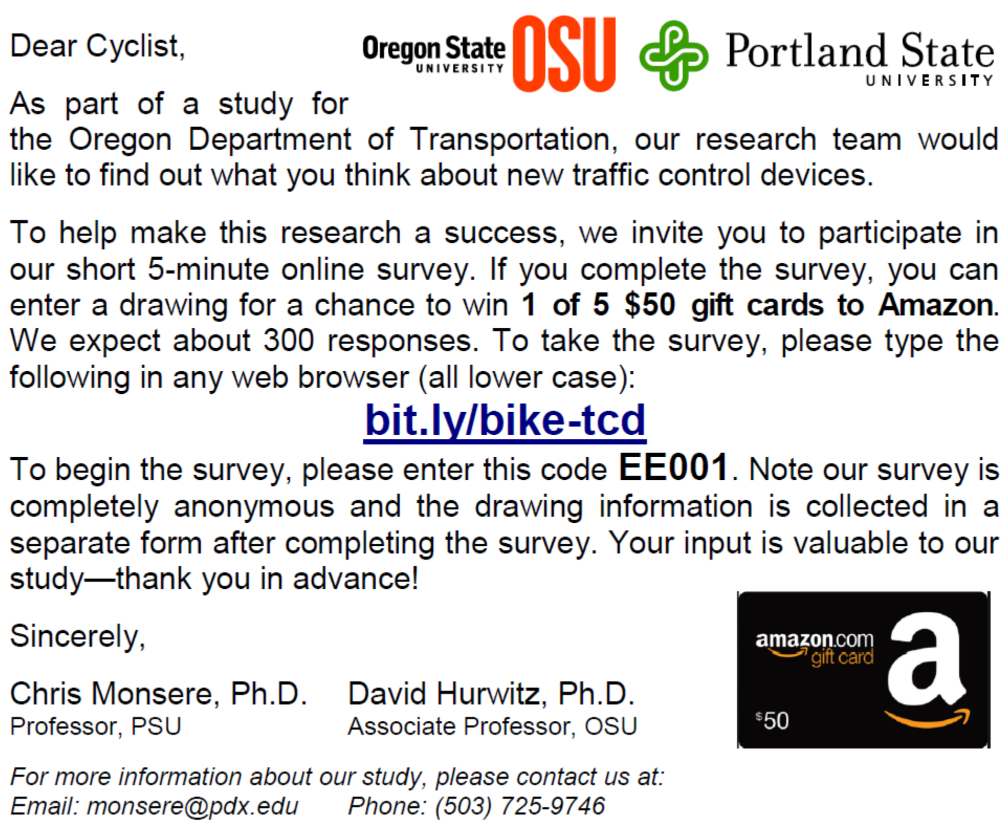
Figure 6.3 Intercept survey flow

Before being shown the questions, all respondents had to provide informed consent for the survey, certifying that they are over 18 years of age. Section 2 of the survey asked the respondents to first enter the letter and number code from the postcard that they were handed at the intersections. There were six-letter codes (AA – FF) corresponding to the six intersections along with number codes ranging from 001-300 as shown in Table 6.1.

Two branches of the survey were developed, depending on the letter code that was entered by the respondent. Letter codes AA, BB, EE, and FF corresponded to the embedded blue light version, where the respondents were shown pictures of the blue light embedded in the sign (Figure 6.1). Letter codes CC and DD corresponded to the version of the survey where the blue light was present separately from the sign in the traffic signal backplate (Figure 6.2). Within each of these branches, respondents were asked whether they had noticed or observed the blue light and sign at the intersections previously and whether they read any media articles about the blue lights. There were also a couple of open-ended questions, which asked respondents to report their understanding of a blue light indication when it was ON and OFF, with the supplemental sign included. Respondents were also asked to note how they could activate a blue light and their perspective regarding the inclusion of blue light devices at signalized intersections. Section 3 of the survey consisted of close-ended multiple-choice demographic questions on the respondent's income and education levels, cycling and driving habits, and eyesight. The entire survey instrument is included in Appendix B.

6.1.3 Administration

A recruitment postcard (Figure 6.4) containing pertinent information about the survey objectives, and the online link was handed out by researchers at PSU and OSU to cyclists as they approached and waited at six intersections where the blue lights were installed. Survey responses were never linked to the names of respondents answering the survey, thus ensuring the confidentiality of responses. Recipients were provided with the option of providing their contact information at the end of the online survey, to be entered into a drawing for one of five $100 Amazon.com gift cards.



Dear Cyclist,

Oregon State University OSU Portland State University

As part of a study for the Oregon Department of Transportation, our research team would like to find out what you think about new traffic control devices.

To help make this research a success, we invite you to participate in our short 5-minute online survey. If you complete the survey, you can enter a drawing for a chance to win **1 of 5 $50 gift cards to Amazon**. We expect about 300 responses. To take the survey, please type the following in any web browser (all lower case):

bit.ly/bike-tcd

To begin the survey, please enter this code **EE001**. Note our survey is completely anonymous and the drawing information is collected in a separate form after completing the survey. Your input is valuable to our study—thank you in advance!

Sincerely,

Chris Monsere, Ph.D.
Professor, PSU

David Hurwitz, Ph.D.
Associate Professor, OSU

amazon.com gift card $50

For more information about our study, please contact us at:
Email: monsere@pdx.edu Phone: (503) 725-9746

Figure 6.4: Recruitment postcard for the intercept surveys

These postcards contained unique codes by intersection so that the images displayed reflected the blue light detection confirmation system configuration they were exposed to at the intersection.

6.1.4 Response Rate

A total of 337 postcards were handed out at all six intersections as shown in Table 6.2. The response rate by location is also shown.

Table 6.2 Response Rates by Location

Location	City	Codes	Type	Handed Out	Responses	Response Rate
N Ainsworth St. and N Interstate Ave.	Portland	AA	Embedded	67	27	40%
NE US Grant Pl. and NE 33rd Ave.	Portland	BB	Embedded	107	53	50%
NE 53rd Ave. and NE Glisan St.	Portland	CC	Separate	44	23	52%
SW Terwilliger Blvd and SW Capitol Hwy	Portland	DD	Separate	13	9	69%
Monroe St. and W 6th Ave.	Eugene	EE	Embedded	51	22	43%
W 5th Ave. and Blair Blvd	Eugene	FF	Embedded	55	17	31%
Total				337	151	45%

A total of 156 responses were obtained, however five of the responses were incomplete and had to be discarded (i.e., respondents clicked the link and consented to take the survey but failed to complete the survey), resulting in a total of 151 complete responses. The overall response rate was 45%. The highest response rate was obtained at SW Terwilliger Blvd and SW Capitol Hwy, whereas the lowest response rate was obtained at W 5th Ave. and Blair Blvd.

6.1.5 Results

The following section describes the results obtained from the survey.

6.1.5.1 Demographic Summary

Table 6.3 presents demographic information for all survey respondents categorized by location. Proportions from the Census for Oregon are also provided in the table for comparison purposes. Older, educated white males were overrepresented as survey respondents compared to 2010 Census estimates for Oregon. Survey respondents were generally older than the general population, with larger representation in the 55–64 and 65+ years categories, for data collected from Oregon (60.78%) as compared to the census estimates (29.9%). The respondents were 89% White/Caucasian (vs. 77% reported in the Census). Proportions of higher-income respondents ($100,000 or greater) surveys were overrepresented (52.32%) when compared with census estimates (23.8%). Respondents with a bachelor's and higher (Masters and Doctorate) degrees were overrepresented as compared to the census proportions.

Table 6.4 summarizes the riding and driving behaviors of respondents. Overall respondents on average reported using the bicycle for 22 days in a month, with the highest use being reported at W5th Ave. and Blair Blvd intersection. Overall, 93% of respondents possessed a driver's license. 14% of the respondents reported that they did not drive a car for transportation, and 45% reported driving less than 5,000 miles in a year. A small percentage of respondents (1%) indicated that they were colorblind. Majority of the respondents indicated that they used corrective glasses or contacts for vision (58%).

Table 6.3 Demographic Comparisons between Survey Respondents across Locations

Category	Variable	Portland Embedded		Portland Separate		Eugene Embedded		Overall	Census
		AA	BB	CC	DD	EE	FF		
Gender	Male	55.6	62.3	87.0	66.7	54.5	76.4	65.6	49.5
	Female	40.7	37.7	13.0	33.3	45.4	11.8	32.5	50.5
	Prefer to self-describe	3.7	0.0	0.0	0.0	0.0	5.9	1.3	-
	Prefer not to answer	0.0	0.0	0.0	0.0	0.0	5.9	0.6	-
Age	18–24	0.0	3.8	0.0	0.0	0.0	0.0	1.3	12.7
	25–34	18.5	17.0	13.0	0.0	9.1	17.7	14.6	13.9
	35–44	48.1	35.8	34.8	33.3	22.7	17.6	33.8	13.1
	45–54	14.8	24.5	34.8	33.3	27.3	29.4	25.8	12.8
	55–64	11.1	13.2	13.0	33.4	22.7	17.7	15.9	13.5
	65+	7.4	5.7	4.4	0.00	18.2	17.6	8.6	16.4
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Race	American Indian or Alaska Native	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
	Asian	0.0	0.0	8.7	0.0	0.0	5.9	2.0	4.1
	Black or African American	0.0	1.9	0.0	0.0	9.1	0.0	2.0	1.8
	Hispanic or Latino/a	0.0	1.9	4.3	0.0	4.5	0.0	2.0	12.7
	White or Caucasian	100.0	86.8	87.0	88.9	81.8	88.2	88.7	76.5
	Other	0.0	1.9	0.0	11.1	0.0	0.0	1.3	4.1
	Prefer not to answer	0.0	7.5	0.0	0.0	4.5	5.9	4.0	-
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Income	Less than $25,000	0.0	1.9	0.0	0.0	18.2	52.9	9.3	21.3
	$25,000 – $50,000	3.7	7.5	13.0	0.0	22.7	5.9	9.3	23.5
	$50,000 – $75,000	7.4	7.5	17.4	11.1	18.2	5.9	10.6	18.5
	$75,000 – $100,000	22.2	11.3	8.7	0.0	9.09	0.0	10.6	12.9
	$100,000 – $200,000	51.9	49.1	39.1	44.4	18.2	23.5	40.4	18.8
	$200,000 or more	7.4	17.0	13.0	33.3	4.5	0.0	11.9	5.0
	Prefer not to answer	7.4	5.7	8.7	11.1	9.1	11.8	7.9	-
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Education	Some High school (grades 9–12, no degree)	0.0	1.9	0.0	0.0	0.0	5.9	1.3	6.0
	HS graduate (or equiv.)	0.0	1.9	0.0	0.0	4.5	0.0	1.3	23.4
	Some college (1–4 years, no degree)	0.0	5.7	8.7	0.0	4.5	23.5	6.6	25.8
	Trade/Vocational School	3.7	0.0	0.0	0.0	4.5	0.0	1.3	-
	Associate degree (incl. occup. or academic degrees)	0.0	3.8	4.3	0.0	18.2	11.8	6.0	8.7
	Four Year Degree (BA, BS, AB etc.)	63.0	41.5	43.5	22.2	27.3	35.3	41.7	20.1
	Master's degree (MA, MS, MENG, MSW, etc.)	33.3	41.5	30.4	55.6	31.8	11.8	34.4	12.2
	Doctorate degree (PhD, EdD, etc.)	0.0	3.8	13.0	22.2	9.1	11.8	7.3	
	Prefer not to answer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-

Table 6.4: Characteristics of Survey respondents

Category	Variable	Portland Embedded		Portland Separate		Eugene Embedded		Overall
		AA	BB	CC	DD	EE	FF	
Cycling Frequency	Number of days per month	21	23	20	19	21	27	22
Driver's license	Yes	96.3	98.1	100.0	100.0	72.7	82.4	92.7
	No	3.7	1.9	0.0	0.0	27.3	17.6	7.3
Miles driven per year	Don't drive a car for transportation	3.7	11.3	4.3	0.0	31.8	35.3	13.9
	Less than 5,000	59.3	47.2	43.5	33.3	31.8	41.2	45.0
	5,000 – 9,999	33.3	35.8	34.8	44.4	18.2	17.6	31.1
	10,000 – 14,999	0.0	5.7	17.4	22.2	13.6	5.9	8.6
	15,000 – 19,999	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Greater than 20,000	3.7	0.0	0.0	0.0	4.5	0.0	1.3
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Color blind	Yes	3.7	0.0	4.3	0.0	0.0	0.0	1.3
	No	96.3	100.0	95.7	100.0	100.0	100.0	98.7
	Don't want to provide this info/Don't Know	0.0	0.0	0.00	0.00	0.00	0.0	0.00
	Did not Respond	0.0	0.0	0.00	0.00	0.00	0.00	0.00
Corrective glasses or contacts	Yes	59.3	50.9	60.9	77.8	68.2	47.1	57.6
	No	40.7	49.1	39.1	22.2	31.8	52.9	42.4
	Don't want to provide this info/Don't Know	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0

6.1.5.2 Blue Light Observation and Media Familiarity

Respondents were shown a photo of an intersection similar to the one where they were handed the postcard and asked if they had noticed the blue light and the sign at the intersection that they traveled through. A follow-up question asked about their familiarity with media articles explaining the purpose of blue lights at intersections. Table 6.5 shows the responses. Overall, 84% of the respondents indicated that they had observed the blue light at the intersection and generally the percent of respondents who observed the blue light was higher at the Portland locations than Eugene locations except at the intersection of NE 53rd Ave. and NE Glisan St. Additionally, within the Portland locations, the percent of respondents who indicated that they had observed the blue light was higher at the locations where the blue light was embedded in the sign (AA, BB) than at locations where it was separate (CC and DD). Seventy percent (70%) of the respondents also did not read the media articles on blue light devices, although more respondents at the Portland locations read the articles compared to the respondents in the Eugene locations, possibly due to their familiarity with these devices and one of the major articles being published on bikeportland.org.

Table 6.5: Blue Light Observation and Media Familiarity

Category	Response	PDX Embedded		PDX Separate		Eugene Embedded		
		AA	BB	CC	DD	EE	FF	Overall
Observed Blue Light at Intersection	Yes	96.3	92.5	70.0	88.9	72.7	70.6	84.1
	No	3.7	7.5	30.0	11.1	27.3	29.4	15.9
Read Media Articles on Blue Lights	Yes	37.0	34.0	43.5	44.4	9.1	5.9	29.8
	No	63.0	66.0	56.5	55.6	90.9	94.1	70.2

6.1.5.3 Blue Light Comprehension

Since the survey contained open-ended questions designed to assess comprehension of the blue light display, the responses needed to be categorized for further analysis. The research team reviewed each open-ended response. Responses were coded as correct, partially correct, or incorrect based on established criteria shown in Table 6.6. The same coding convention was followed for coding both the responses for both open-ended questions (Blue light ON and OFF).

Table 6.6: Error Coding of Narrative

Display Indication	Correct	Partially Correct	Incorrect
Blue Light ON	Blue light indicates that either the car or bike has been "detected" at the intersection	Blue light indicates that a car or bike has been "detected" nearby or that that traffic signal has been triggered.	Anything else
Blue Light OFF	Blue light OFF indicates that either the car or bike has not been "detected" at the intersection	Blue light indicates that a car or bike has not been "detected" nearby or that that traffic signal has not been triggered.	Anything else

For the questions associated with the blue light being ON, responses were coded as correct if the respondents indicated that either the bicycle or vehicle has been "detected" at the intersection. A response was coded as partially correct, if the respondent indicated that there was some form of detection, but indicated that someone else was being detected or that the light cycle has been triggered (e.g., a vehicle or car has been detected nearby or indicating that the light cycle has been triggered to change). A response was coded as incorrect if the respondents indicated anything else. For the questions associated with the blue light being OFF, responses were coded as correct if the respondents indicated that either the bicycle or vehicle has NOT been "detected" at the intersection. A response was coded as partially correct if the respondent indicated that a bike or car was not detected nearby and that the traffic signal call was not placed. A response was coded as incorrect if the respondents indicated anything else.

Table 6.7: Blue Light Comprehension

Category	Response	Portland Embedded		Portland Separate		Eugene Embedded		Overall
		AA	BB	CC	DD	EE	FF	
Blue Light ON	Incorrect	3.7	5.7	4.4	11.1	4.5	23.5	7.3
	Partially Correct	3.7	3.8	13.0	11.1	18.2	17.7	9.3
	Correct	92.6	90.5	82.6	77.8	77.3	58.8	83.4
Blue Light OFF	Incorrect	11.1	3.7	4.3	0.0	13.6	29.4	9.2
	Partially Correct	11.1	3.8	8.7	33.3	9.1	11.8	9.3
	Correct	77.8	92.5	87.0	66.7	77.3	58.8	81.5

Overall the majority of the respondents understood the purpose of the blue light devices correctly and comprehension rates were high irrespective of whether the blue light was ON or OFF as seen in Table 6.7. . Comprehension was higher at the intersections of N

Ainsworth St. and N Interstate Ave. and NE US Grant Pl. and NE 33rd Ave. compared to the other locations when the blue light was ON.

Respondents were also asked if there was anything that they could do as a bicyclist to activate the blue light. Respondents who chose “yes” as their response were asked to describe the actions they would take. Sixty-six percent (66%) overall thought they could take actions to activate the blue light, while 33% were not sure (Table 6.8). A high percentage of respondents (92%) were sure that they could activate the blue light at the intersection of NE US Grant and NE 33rd Pl., possibly because they were familiar with the operation of a blue light device as it was already present at this location prior to the installation of the embedded blue light in the sign as part of this study.

Table 6.8: Blue Light Activation

Category	Response	Portland Embedded		Portland Separate		Eugene Embedded		Overall
		AA	BB	CC	DD	EE	FF	
Blue Light ON	Not Sure	44.4	5.7	39.1	44.4	59.1	52.9	33.1
	No	0.00	1.9	0.00	0.00	0.00	0.00	0.6
	Yes	55.6	92.4	60.9	55.6	40.9	47.1	66.3

The most common response from the people who said they could take actions to activate the blue light was to reposition their bicycle on/close to the bike pavement marking if present, or on/close to the loop detector.

6.1.5.4 Attitudes and Perceptions

Each respondent was asked to state their level of agreement with four multiple choice questions to explore their attitudes and perceptions regarding the visibility and utility of the blue light devices.

Table 6.9: Attitudes and Perceptions Regarding Blue Light Devices with Sign

Statement	Level of Agreement	Portland Embedded		Portland Separate		Eugene Embedded		Overall
		AA	BB	CC	DD	EE	FF	
The blue light and sign were clearly visible to me at the intersection	Strongly Disagree	3.7	13.2	8.7	0.0	9.1	11.8	9.3
	Somewhat Disagree	3.7	1.9	17.4	22.2	4.5	5.9	6.62
	Neither agree or disagree	3.7	0.0	17.4	0.0	4.5	17.6	6.0
	Somewhat Agree	29.6	7.5	21.7	33.3	22.7	29.4	19.9
	Strongly Agree	59.3	77.4	34.8	44.4	59.1	35.3	58.3
	Did not Respond	0.0	0.0	0.00	0.0	0.0	0.00	0.0
The meaning of the blue light and sign is easily understood at the intersection	Strongly Disagree	3.7	9.4	17.4	22.2	0.0	11.8	9.3
	Somewhat Disagree	11.1	9.4	17.4	0.0	27.3	23.5	14.6
	Neither agree or disagree	3.7	0.0	4.3	0.0	4.5	11.8	3.3
	Somewhat Agree	33.3	20.8	26.1	22.2	9.1	23.5	22.5
	Strongly Agree	48.1	60.4	34.8	55.6	59.1	23.5	49.7
	Did not Respond	0.0	0.0	0.0	0.0	0.0	5.9	0.7
I feel better about waiting on a bicycle at an intersection with the sign and blue light	Strongly Disagree	3.7	9.4	8.7	0.0	0.0	5.9	6.0
	Somewhat Disagree	0.0	3.8	8.7	0.0	4.5	5.9	4.0
	Neither agree or disagree	7.4	1.9	13.0	22.2	9.1	23.5	9.3
	Somewhat Agree	18.5	24.5	26.1	33.3	36.4	29.4	26.5
	Strongly Agree	70.4	60.4	43.5	44.4	50.0	35.3	54.3
	Did not Respond	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Having information that I have been detected by the traffic signal is useful to me	Strongly Disagree	3.7	9.4	4.3	11.1	0.0	11.8	6.6
	Somewhat Disagree	0.0	0.0	4.3	0.0	0.0	0.0	0.7
	Neither agree or disagree	0.0	1.9	13.0	0.0	4.5	5.9	4.0
	Somewhat Agree	14.8	11.3	26.1	33.3	18.2	41.2	19.9
	Strongly Agree	81.5	77.4	52.2	55.6	77.3	35.3	68.2
	Did not Respond	0.0	0.0	0.0	0.0	0.0	5.9	0.7

Overall, 78% of the respondents felt that the blue light and sign were clearly visible to them at the intersection. Two intersections NE 53rd Ave. and NE Glisan St. in Portland and W 5th Ave. and Blair Blvd had lower proportions of respondents stating that the blue light and sign were clearly visible, 57% and 64%, respectively. The level of disagreement (either somewhat or strongly disagree) with the statement that the blue light and sign were clearly visible varied between 7% and 26%.

Seventy-two percent (72%) of the respondents overall either somewhat or strongly agreed with the statement that the meaning of the blue light is easily understood at the intersection, while 24% somewhat or strongly disagreed. The highest levels of disagreement were seen at the intersections of NE 53rd Ave. and NE Glisan St. in Portland (35%) and W 5th Ave. and Blair Blvd in Eugene (35%).

Eighty-one percent (81%) of the respondents overall stated that they felt better about waiting at the intersection with the blue light and sign, while 10% either somewhat or strongly disagreed. The proportion of respondents who disagreed with this statement were highest at NE 53rd Ave. and NE Glisan St. in Portland (17%).

Eighty-eight percent (88%) of the respondents felt that having information that they have been detected by the traffic signal was useful, while 7% somewhat or strongly disagreed with the statement. The high levels of agreement with this statement across all intersections reveals that respondents like having feedback from the traffic signal regarding their detection status.

6.2 NEARSIDE BLUE LIGHT DETECTION CONFIRMATION

The objective of the intercept survey was to determine the cyclists' comprehension of the blue light detection confirmation device at traffic signals equipped with the accompanying sign placed nearside. The survey was designed to elicit common correct, incorrect, or partially incorrect interpretations of the blue light detection confirmation device meanings.

6.2.1 Design and Refinement

The first step in designing the survey was the development of questions that were designed to elicit cyclists' comprehension of the blue light detection confirmation device when combined with an accompanying sign. Also included in the survey were questions about cyclist' preference for the two stencil designs. At this location, an existing stencil (seen closer to the curb in Figure 6.5) was present in the before condition. A new stencil with the black background was added (as seen in the center of the lane in Figure 6.5). Finally, a blue light system was sign was added nearside.

Figure 6.5 Blue detection confirmation light embedded in sign, placed nearside

The intercept survey was administered at this intersection. Every effort was made to present questions neutrally, allowing respondents to provide meaningful answers reflecting their comprehension of the signal indications. Several rounds of review and refinement followed the internal development of the survey questions. Transportation graduate students at OSU and PSU tested a pilot survey and provided feedback for further improvements in the format and content of the survey questions. Once the project team was satisfied with the survey design, the survey was finalized.

6.2.2 Instrument

The survey consisted of 20 questions, which included a mix of open-ended and close-ended questions. Figure 6.6 illustrates the organization and flow of the survey.

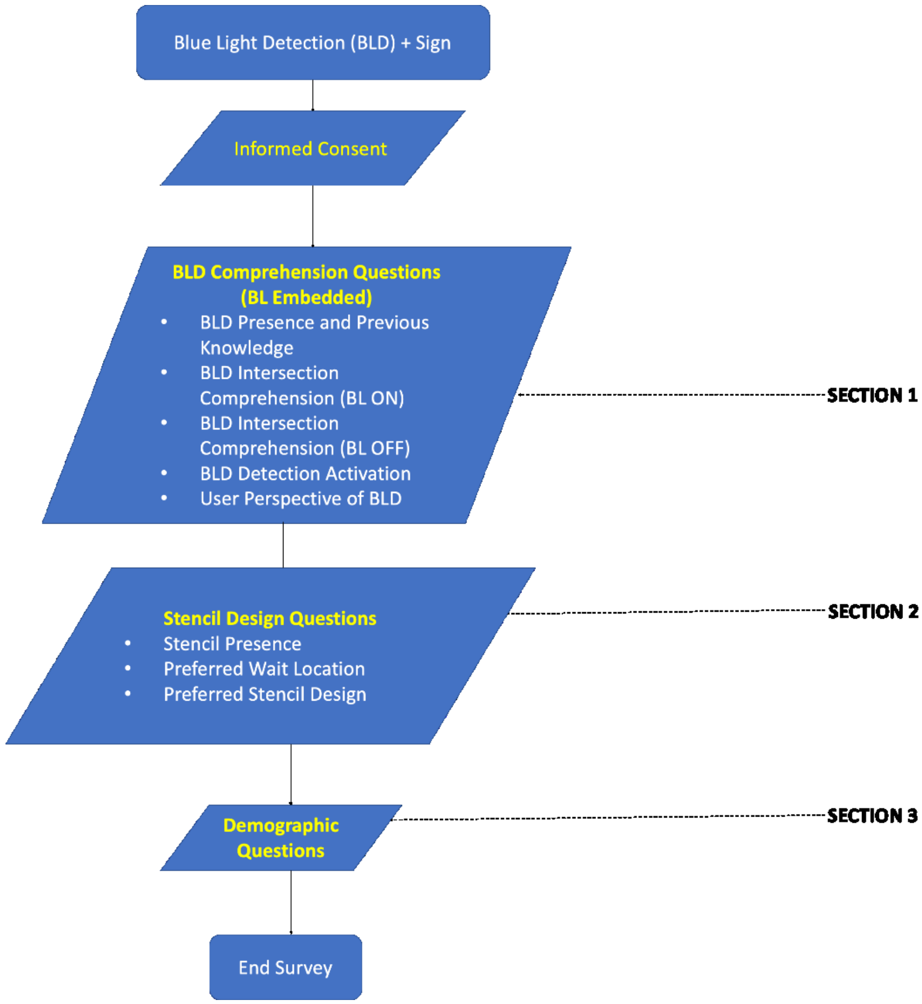


Figure 6.6 Nearside blue light detection confirmation system survey flow

Before being shown the questions, all respondents had to provide informed consent for the survey, certifying that they are over 18 years of age. Once consent was obtained, respondents were asked whether they had noticed or observed the blue light and sign at the intersections previously and whether they read any media articles about the purpose of blue light at intersections. There were also a couple of open-ended questions, which asked respondents to report their understanding of a blue light indication when it was ON and OFF, with the supplemental sign included. Respondents were also asked to note how they could activate a blue light. Respondents were also asked if they noticed the stencils on the pavement, their preferred wait location and their preference for stencil design based on the two options available at the intersection. They were also asked about their perspective regarding the inclusion of blue light devices at signalized intersections. The last section of the survey consisted of close-ended multiple-choice demographic questions on the respondent's income and education levels, cycling and driving habits, and eyesight. The entire survey instrument is included in Appendix C.

6.2.3 Administration

A recruitment postcard containing pertinent information about the survey objectives, and the online link was handed out by researchers at PSU and OSU to cyclists as they approached the intersection where the blue light was installed nearside (similar to Figure 6.4). Survey responses were never linked to the names of respondents answering the survey, thus ensuring the confidentiality of responses. Recipients were provided with the option of providing their contact information at the end of the online survey, to be entered into a drawing for one of three $100 Amazon.com gift cards.

6.2.4 Response Rate

A total of 93 postcards were handed out at this intersection. A total of 57 responses were obtained, however three of the responses were incomplete and had to be discarded (i.e., respondents clicked the link and consented to take the survey but failed to complete the survey), resulting in a total of 54 complete responses. The overall response rate was 58%.

6.2.5 Results

The following section describes the results obtained from the survey.

6.2.5.1 Demographic Summary

Table 6.10 presents demographic information for all survey respondents categorized by location. Proportions from the Census for Oregon are also provided in the table for comparison purposes. Older, educated white males were overrepresented as survey respondents compared to 2010 Census estimates for Oregon. Survey respondents were generally older than the general population, with larger representation in the 55–64 and 65+ year's categories, for data collected from Oregon (44.4%) as compared to the census estimates (29.9%). The respondents were 94% White/Caucasian (vs. 77% reported in the Census). Proportions of higher-income respondents ($100,000 or greater) surveys were overrepresented (33%) when compared with census estimates (24%). Respondents with a bachelor's and higher (Masters and Doctorate) degrees were overrepresented as compared to the census proportions.

Table 6.11 summarizes the riding and driving behaviors of respondents. Respondents on average reported using the bicycle for 16 days in a month. Ninety eight percent of respondents possessed a driver's license, 2% of the respondents reported that they did not drive a car for transportation, and 33% reported driving less than 5,000 miles in a year. A small percentage of respondents (4%) indicated that they were colorblind. Majority of the respondents indicated that they used corrective glasses or contacts for vision (52%).

Table 6.10: Demographic Comparisons between Survey Respondents and Census

Category	Variable	Overall (%)	Census (OR) (%)
Gender	Male	55.6	49.5
	Female	40.7	50.5
	Prefer to self-describe	3.7	-
	Prefer not to answer	0.0	-
Age	18–24	18.5	12.7
	25–34	18.5	13.9
	35–44	9.3	13.1
	45–54	9.3	12.8
	55–64	25.9	13.5
	65+	18.5	16.4
	Did not Respond	0.0	-
Race	American Indian or Alaska Native	0.0	0.9
	Asian	1.9	4.1
	Black or African American	0.0	1.8
	Hispanic or Latino/a	1.9	12.7
	White or Caucasian	94.4	76.5
	Other	1.9	4.1
	Prefer not to answer	0.0	-
	Did not Respond	0.0	-
Income	Less than $25,000	16.7	21.3
	$25,000 – $50,000	9.3	23.5
	$50,000 – $75,000	14.8	18.5
	$75,000 – $100,000	16.7	12.9
	$100,000 – $200,000	24.1	18.8
	$200,000 or more	9.3	5.0
	Prefer not to answer	9.3	-
	Did not Respond	0.0	-
Education	Some High school (grades 9–12, no degree)	0.0	6.0
	High-school graduate (or equivalent)	1.9	23.4
	Some college (1–4 years, no degree)	13.0	25.8
	Trade/Vocational School	0.0	-
	Associate degree (incl. occup. or academic degrees)	3.7	8.7
	Four Year Degree (BA, BS, AB etc.)	38.9	20.1
	Master’s degree (MA, MS, MENG, MSW, etc.)	27.8	12.2
	Doctorate degree (PhD, EdD, etc.)	13.0	
	Prefer not to answer	1.9	-
	Did not Respond	0.0	-

Table 6.11: Demographic Responses Survey Respondents across Locations

Category	Variable	Overall
Cycling Frequency	Number of days per month	16
Driver's license	Yes	98.1
	No	1.9
Miles driven per year	Don't drive a car for transportation	1.9
	Less than 5,000	33.3
	5,000 – 9,999	37.0
	10,000 – 14,999	22.2
	15,000 – 19,999	3.7
	Greater than 20,000	1.9
	Did not Respond	0.0
Color blind	Yes	3.7
	No	96.3
	Don't want to provide this information/Don't Know	0.0
	Did not Respond	0.0
Corrective glasses or contacts	Yes	51.9
	No	48.1
	Don't want to provide this information/Don't Know	0.0
	Did not Respond	0.0

6.2.5.2 Blue Light Observation and Media Familiarity

Respondents were shown a photo of an intersection similar to the one where they were handed the postcard and asked if they had noticed the blue light and the sign at the intersection that they traveled through. A follow-up question asked about their familiarity with media articles explaining the purpose of blue lights at intersections. Table 6.12 shows the responses. Forty eight percent (48%) of the respondents indicated that they had observed the blue light at the intersection. Eighty-seven (87%) of the respondents also did not read the media articles on blue light devices.

Table 6.12: Blue Light Familiarity

Category	Response	Overall
Observed Blue Light at Intersection	Yes	48.1
	No	51.9
Read Media Articles on Blue Lights	Yes	13.0
	No	87.0

6.2.5.3 Blue Light Comprehension

Since the survey contained open-ended questions designed to assess comprehension of the blue light display, the responses needed to be categorized for further analysis. The research team reviewed each open-ended response. Responses were coded as correct, partially correct, or incorrect based on established criteria shown in Table 6.13. The same coding convention was followed for coding both the responses for both open-ended questions (Blue light ON and OFF).

Table 6.13: Error Coding of Narrative

Display Indication	Correct	Partially Correct	Incorrect
Blue Light ON	Blue light indicates that either the car or bike has been "detected" at the intersection	Blue light indicates that a car or bike has been "detected" nearby or that that traffic signal has been triggered.	Anything else
Blue Light OFF	Blue light OFF indicates that either the car or bike has not been "detected" at the intersection	Blue light indicates that a car or bike has not been "detected" nearby or that that traffic signal has not been triggered.	Anything else

For the questions associated with the blue light being ON, responses were coded as correct if the respondents indicated that either the bicycle or vehicle has been "detected" at the intersection. A response was coded as partially correct, if the respondent indicated that there was some form of detection, but indicated that someone else was being detected or that the light cycle has been triggered (e.g., a vehicle or car has been detected nearby or indicating that the light cycle has been triggered to change). A response was coded as incorrect if the respondents indicated anything else. For the questions associated with the blue light being OFF, responses were coded as correct if the respondents indicated that either the bicycle or vehicle has NOT been "detected" at the intersection. A response was coded as partially correct if the respondent indicated that a bike or car was not detected nearby and that the traffic signal call was not placed. A response was coded as incorrect if the respondents indicated anything else.

Table 6.14: Blue Light Comprehension

Category	Response	Overall
Blue Light ON	Incorrect	25.9
	Partially Correct	14.8
	Correct	59.3
Blue Light OFF	Incorrect	27.8
	Partially Correct	20.4
	Correct	51.9

Overall, the 59.3% of the respondents understood the purpose of the blue light devices correctly, 14.8% responded partially incorrect and comprehension rates were higher when the blue light was ON compared to when it was OFF as seen in Table 6.14. Common incorrect responses were respondents indicating that they were not sure what the purpose of the blue light device was, or that it was either safe or not safe to cross the intersection.

Respondents were also asked if there was anything that they could do as a bicyclist to activate the blue light. Respondents who chose "yes" as their response were asked to describe the actions they would take. Fifty-six percent (56%) overall thought they could take actions to activate the blue light, while 44% were not sure (Table 6.15).

Table 6.15: Blue Light Activation

Category	Response	Overall
Blue Light ON	Not Sure	44.4
	No	0.0
	Yes	55.6

The most common response from the people who said they could take actions to activate the blue light was to reposition their bicycle on/close to the bike pavement marking, or on/close to the loop detector.

6.2.5.4 Bicycle Detector Stencil Familiarity

Respondents were shown a photo of an intersection similar to the one where they were handed the postcard and asked if they had noticed the bicycle detector stencil at the intersection that they traveled through. A follow-up question asked about preferred waiting location after drawing their attention to the original bicycle stencil with no black background which was located to the right of the travel lane and the new bicycle stencil with a black background, which was added to the center of the lane. Table 6.5 shows the responses. Eighty percent (80%) of the respondents indicated that they had observed the bicycle detector stencil at the intersection. Seventy percent (70%) of the respondents also indicated that they preferred to wait on the right, rather than the center of the lane. Eighty seven percent (87%) of the respondents also indicated that they preferred the stencil with the black background as compared to the one without.

Table 6.16: Bicycle Detector Stencil Familiarity

Category	Response	Overall
Observed Bicycle Detector Stencil at Intersection	Yes	79.6
	No	20.4
Preferred Waiting Location	Center of Lane	29.6
	On the Right	70.4
Stencil Preference	With Black Background	87.0
	Without Black Background	13.0

6.2.5.5 Attitudes and Perceptions

Each respondent was asked to state their level of agreement with four multiple choice questions to explore their attitudes and perceptions regarding the visibility and utility of the blue light devices. Table 6.17 shows the responses.

Table 6.17: Attitudes and Perceptions Regarding Nearside Blue Light Detection Confirmation Devices with Sign

Statement	Level of Agreement	Overall
The blue light and sign was clearly visible to me at the intersection	Strongly Disagree	9.3
	Somewhat Disagree	16.7
	Neither agree or disagree	20.4
	Somewhat Agree	20.4
	Strongly Agree	33.3
	Did not Respond	0.0
The meaning of the blue light and sign is easily understood at the intersection	Strongly Disagree	13.0
	Somewhat Disagree	14.8
	Neither agree or disagree	5.6
	Somewhat Agree	14.8
	Strongly Agree	51.9
	Did not Respond	0.0
I feel better about waiting on a bicycle at an intersection with the sign and blue light	Strongly Disagree	1.9
	Somewhat Disagree	7.4
	Neither agree or disagree	9.3
	Somewhat Agree	29.6
	Strongly Agree	51.9
	Did not Respond	0.0
Having information that I have been detected by the traffic signal is useful to me	Strongly Disagree	3.7
	Somewhat Disagree	5.6
	Neither agree or disagree	0.0
	Somewhat Agree	13.0
	Strongly Agree	77.8
	Did not Respond	0.0

Overall, 54% of the respondents felt that the blue light and sign were clearly visible to them (either somewhat or strongly agree) at the intersection. The level of disagreement (either somewhat or strongly disagree) with the statement that the blue light and sign were clearly visible was 26%, while 20% of the respondents did not agree or disagree.

Sixty-seven percent (67%) of the respondents overall either somewhat or strongly agreed with the statement that the meaning of the blue light is easily understood at the intersection, while 28% somewhat or strongly disagreed, while 5.6% neither agreed nor disagreed.

Eighty-one percent (81%) of the respondents overall stated that they felt better about waiting at the intersection with the blue light and sign, while 9% either somewhat or strongly disagreed. An additional 9% of respondents neither agreed nor disagreed about feeling better about waiting with the blue light and sign present at the intersection.

Ninety-one percent (91%) of the respondents felt that having information that they have been detected by the traffic signal was useful, while 9% somewhat or strongly disagreed with the statement. The high levels of agreement with this statement reveals that respondents like having feedback from the traffic signal regarding their detection status.

6.3 NEARSIDE COUNTDOWN TIMER

The objective of the intercept survey was to determine the cyclists' comprehension of the countdown timer at traffic signals placed nearside. The survey was designed to elicit common correct, incorrect, or partially incorrect interpretations of the countdown timer indication.

6.3.1 Design and Refinement

The first step in designing the survey was the development of questions that were designed to elicit cyclists' comprehension of the countdown timer, which was placed nearside as seen in Figure 6.7. The countdown timer display consisted of four signal lenses, with three of them showing the green, yellow and red indications through the use of a bicycle symbol. The fourth lens consisted of a STOP lettering along with white dots, whose movement indicated the countdown to the green indication.

Figure 6.7 Nearside countdown timer, Portland OR

The intercept survey was administered at this approach. Every effort was made to present questions neutrally, allowing respondents to provide meaningful answers reflecting their comprehension of the signal indications. Several rounds of review and refinement followed the internal development of the survey questions. Transportation graduate students at OSU and PSU tested a pilot survey and provided feedback for further improvements in the format and content of the survey questions. Once the project team was satisfied with the survey design, the survey was finalized.

6.3.2 Instrument

The survey consisted of 16 questions, which included a mix of open-ended and close-ended questions. Figure 6.8 illustrates the organization and flow of the survey.

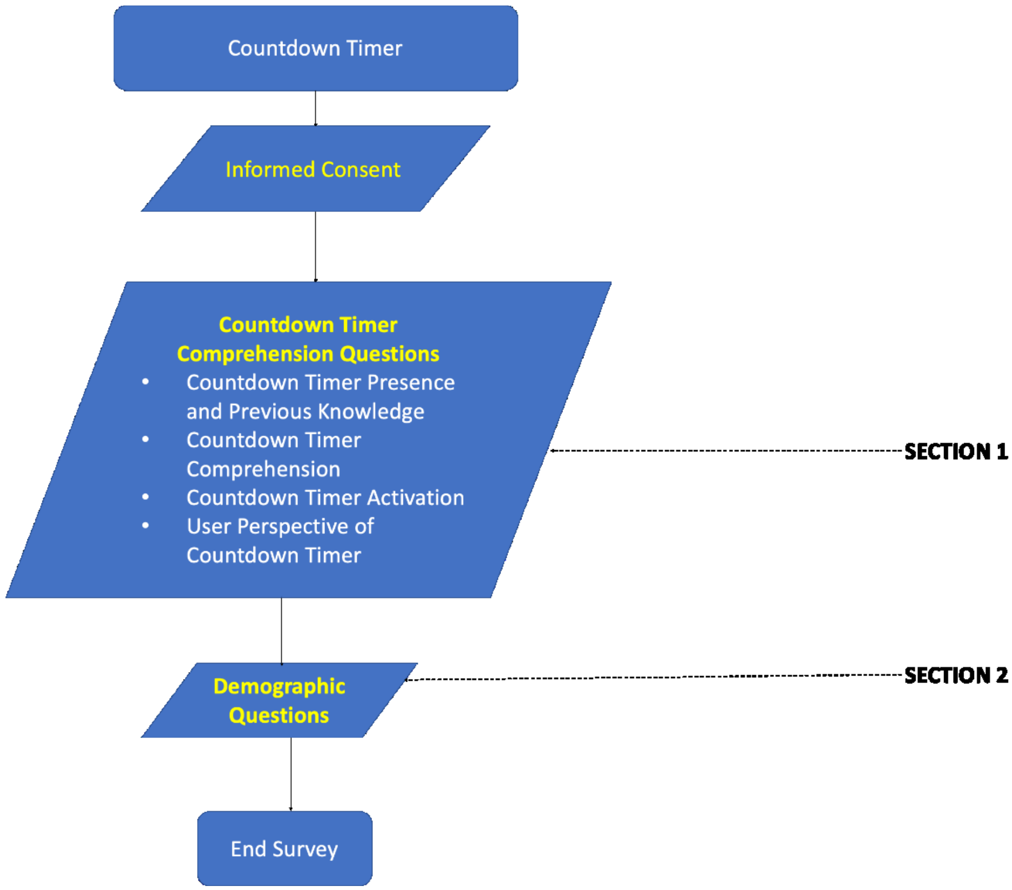


Figure 6.8 Nearside countdown timer survey flow

Before being shown the questions, all respondents had to provide informed consent for the survey, certifying that they are over 18 years of age. Once consent was obtained, respondents were asked whether they had noticed or observed the countdown timer at the intersection previously and whether they read any media articles about the purpose of the countdown timer at intersections. Next was an open-ended question, which asked respondents to report their understanding of the countdown timer display. Respondents were also asked to note if what actions they could take to activate the countdown timer as a bicyclist. They were also asked about their perspective regarding the inclusion of countdown timers at signalized intersections. The last section of the survey consisted of close-ended multiple-choice demographic questions on the respondent's income and education levels, cycling and driving habits, and eyesight. The entire survey instrument is included in Appendix D.

6.3.3 Administration

A recruitment postcard containing pertinent information about the survey objectives, and the online link was handed out by researchers at PSU to cyclists as they approached the intersection where the countdown timer was installed nearside ((similar to Figure 6.4)). Survey responses were never linked to the names of respondents answering the survey, thus ensuring the confidentiality of responses. Recipients were provided with the option of providing their contact information at the end of the online survey, to be entered into a drawing for one of three $100 Amazon.com gift cards.

6.3.4 Response Rate

A total of 87 postcards were handed out at this intersection. A total of 33 responses, out of which 4 were incomplete and therefore not included in the final analysis. A total of 29 responses were analyzed resulting in a response rate of 33%.

6.3.5 Results

The following section describes the results obtained from the survey.

6.3.5.1 Demographic Summary

Table 6.18 presents demographic information for all survey respondents categorized by location. Proportions from the Census for Oregon are also provided in the table for comparison purposes. Older, educated white males were overrepresented as survey respondents compared to 2010 Census estimates for Oregon. Survey respondents were overrepresented in the 35-44, 45-54, and 55-64 categories than the general population, with larger representation in the 55–64 and 65+ years categories, for data collected at the intersection with the countdown timer (82.7%) as compared to the census estimates (66.4%). The respondents were 90% White/Caucasian (vs. 77% reported in the Census). Proportions of higher-income respondents ($100,000 or greater) surveys were overrepresented (38%) when compared with census estimates (24%). Respondents with a bachelor's and higher (Masters and Doctorate) degrees were overrepresented as compared to the census proportions.

Table 6.19 summarizes the riding and driving behaviors of respondents. Respondents on average reported using the bicycle for 22 days in a month. Ninety three percent of respondents possessed a driver's license, 7% of the respondents reported that they did not drive a car for transportation, and 52% reported driving less than 5,000 miles in a year. A small percentage of respondents (3%) indicated that they were colorblind. Forty eight percent of the respondents indicated that they used corrective glasses or contacts for vision.

Table 6.18: Summary of Demographic Responses for Survey Respondents

Category	Variable	Overall	Census (Oregon)
Gender	Male	69.0	49.5
	Female	24.1	50.5
	Prefer to self-describe	3.4	-
	Prefer not to answer	3.4	-
Age	18–24	0.0	12.7
	25–34	3.4	13.9
	35–44	27.6	13.1
	45–54	31.0	12.8
	55–64	24.1	13.5
	65+	13.8	16.4
	Did not Respond	-	-
Race	American Indian or Alaska Native	0.0	0.9
	Asian	3.4	4.1
	Black or African American	0.0	1.8
	Hispanic or Latino/a	3.4	12.7
	White or Caucasian	89.7	76.5
	Other	0.0	4.1
	Prefer not to answer	3.4	-
	Did not Respond	0.0	-
Income	Less than $25,000	3.4	21.3
	$25,000 – $50,000	31.0	23.5
	$50,000 – $75,000	6.9	18.5
	$75,000 – $100,000	13.8	12.9
	$100,000 – $200,000	34.5	18.8
	$200,000 or more	3.4	5.0
	Prefer not to answer	6.9	-
	Did not Respond	0.0	-
Education	Some High school (grades 9–12, no degree)	3.4	6.0
	High-school graduate (or equivalent)	3.4	23.4
	Some college (1–4 years, no degree)	13.8	25.8
	Trade/Vocational School	0.0	-
	Associate degree (incl. occup. or academic degrees)	3.4	8.7
	Four Year Degree (BA, BS, AB etc.)	37.9	20.1
	Master’s degree (MA, MS, MENG, MSW, etc.)	24.1	12.2
	Doctorate degree (PhD, EdD, etc.)	13.8	
	Prefer not to answer	0.0	-
	Did not Respond	0.0	-

Table 6.19: Demographic Comparisons among Survey Respondents

Category	Variable	Overall
Cycling Frequency	Number of days per month	22
Driver's license	Yes	93.1
	No	6.9
Miles driven per year	Don't drive a car for transportation	6.9
	Less than 5,000	51.7
	5,000 – 9,999	31.0
	10,000 – 14,999	6.9
	15,000 – 19,999	3.4
	Greater than 20,000	0.0
	Did not Respond	0.0
Color blind	Yes	3.4
	No	96.6
	Don't want to provide this information/Don't Know	0.0
	Did not Respond	0.0
Corrective glasses or contacts	Yes	48.3
	No	51.7
	Don't want to provide this information/Don't Know	0.0
	Did not Respond	0.0

6.3.5.2 Countdown Timer Observation and Media Familiarity

Respondents were shown a photo of an intersection similar to the one where they were handed the postcard and asked if they had noticed the countdown timer at the intersection that they traveled through. A follow-up question asked about their familiarity with media articles explaining the purpose of countdown timers at intersections. Table 6.20 shows the responses. Sixty nine percent (69%) of the respondents indicated that they had observed the countdown timer at the intersection. The stop bar at this location is approximately 6 ft. ahead of the nearside countdown timer, so it is possible that cyclists did not notice the device. Ninety-seven (97%) percent of the respondents also did not read the media articles on countdown timer devices.

Table 6.20: Countdown Timer Familiarity

Category	Response	Overall
Observed Countdown Timer at Intersection	Yes	69.0
	No	31.0
Read Media Articles on Countdown Timers	Yes	3.4
	No	96.6

6.3.5.3 Countdown Timer Comprehension

Since the survey contained open-ended questions designed to assess comprehension of the countdown timer display, the responses needed to be categorized for further analysis.

The research team reviewed each open-ended response. Responses were coded as correct, partially correct, or incorrect based on established criteria shown in Table 6.21.

Table 6.21: Error Coding of Narrative

Display Indication	Correct	Partially Correct	Incorrect
Countdown Timer with STOP	The dots indicate the amount of time left until the bicyclist will be given the green signal. STOP indicates that the cyclist should stop and not proceed through the intersection on a red signal.	Stop and do not proceed or counts down the time until green but not both	Anything else

Responses were coded as correct if the respondents indicated that dots reflected the amount of time left until the green indication will be displayed and STOP indicates that the bicyclists need to stop and wait at the intersection until green is displayed. A response was coded as partially correct, if the respondent indicated that they needed to STOP or that the timer counts down until green but not both. A response was coded as incorrect if the respondents indicated anything else.

Table 6.22: Countdown Timer Comprehension

Category	Response	Overall
Countdown Timer	Incorrect	3.4
	Partially Correct	44.8
	Correct	51.7

Overall, 51.7% of the respondents understood the purpose of the countdown timers correctly and an additional 44.8% provided partially correct responses as seen in Table 6.22. For the partially correct responses, the respondents either stated that the countdown timer displayed the time remaining until green or stop and stay stopped until the green is displayed but not both. Only a small proportion of the respondents (3.4%) provided incorrect responses.

Respondents were also asked if there was anything that they could do as a bicyclist to activate the countdown timer. Respondents who chose "yes" as their response were asked to describe the actions they would take. Twenty-eight percent (28%) overall thought they could take actions to activate the countdown timer, while 66% were not sure (see Table 6.23: Countdown Timer Activation.

Table 6.23: Countdown Timer Activation

Category	Response	Overall
Countdown Timer	Yes	27.6
	No	6.9
	Not Sure	65.5

The most common response from the people who said they could take actions to activate the countdown timer was to use the pushbutton. Some of them also mentioned repositioning their bicycle on/close to the to the loop detector to activate the countdown timer display.

6.3.5.4 Attitudes and Perceptions

Each respondent was asked to state their level of agreement with five multiple choice questions to explore their attitudes and perceptions regarding the visibility and utility of the countdown timer displays. Table 6.24 shows the responses.

Table 6.24: Attitudes and Perceptions Regarding Countdown Timers

Statement	Level of Agreement	Overall
The countdown timer was clearly visible to me at the intersection	Strongly Disagree	17.2
	Somewhat Disagree	20.7
	Neither agree or disagree	10.3
	Somewhat Agree	27.6
	Strongly Agree	24.1
	Did not Respond	0.0
The meaning of the countdown timer is easily understood at the intersection	Strongly Disagree	6.9
	Somewhat Disagree	0.0
	Neither agree or disagree	6.9
	Somewhat Agree	41.4
	Strongly Agree	44.8
	Did not Respond	0.0
I can accurately estimate the time remaining to green from the countdown timer	Strongly Disagree	3.4
	Somewhat Disagree	0.0
	Neither agree or disagree	13.8
	Somewhat Agree	44.8
	Strongly Agree	37.9
	Did not Respond	0.0
I feel better about waiting on a countdown timer at an intersection with the sign and blue light	Strongly Disagree	3.4
	Somewhat Disagree	3.4
	Neither agree or disagree	27.6
	Somewhat Agree	41.4
	Strongly Agree	24.1
	Did not Respond	0.0
Having information that I have been detected by the traffic signal is useful to me	Strongly Disagree	3.4
	Somewhat Disagree	6.9
	Neither agree or disagree	17.2
	Somewhat Agree	48.3
	Strongly Agree	24.1
	Did not Respond	0.0

Overall, 52% of the respondents felt that the countdown timer display was clearly visible to them (either somewhat or strongly agree) at the intersection. The level of disagreement (either somewhat or strongly disagree) with the statement that the countdown timer display was clearly visible was 38%, while 10% of the respondents did not agree or disagree.

Eighty-six percent (86%) of the respondents overall either somewhat or strongly agreed with the statement that the meaning of the countdown timer display is easily understood at the intersection, while 7% strongly disagreed, and 7% neither agreed nor disagreed.

Eighty-three (83%) of the respondents overall stated that they can accurately estimate the amount of time remaining until green from the countdown timer display, while 3% strongly disagreed and 14% neither agreed nor disagreed.

Sixty-six percent (66%) of the respondents overall stated that they felt better about waiting at the intersection with the countdown timer display, while 7% either somewhat or strongly disagreed. An additional 28% of respondents neither agreed nor disagreed about feeling better about waiting with the countdown timer display present at the intersection.

Seventy-two percent (72%) of the respondents felt that having information that they have been detected by the traffic signal was useful, while 10% somewhat or strongly disagreed with the statement and 17% neither agreed nor disagreed. The high levels of agreement with this statement reveals that respondents like having feedback from the traffic signal regarding their detection status.

6.4 SUMMARY

Intercept surveys were conducted to understand how well cyclists comprehend blue light detection confirmation systems with an accompanying sign with far side and nearside implementations and a nearside countdown timer display. These surveys were conducted online with recruitment through postcards. For the intercept survey of blue light detection confirmation systems located far side, postcards were handed out at four intersections in Portland and two intersections Eugene, Oregon, four of which were equipped with blue light embedded in the sign and two with blue light in the signal back plate separate from the sign. For the intercept survey of blue light detection confirmation systems located nearside, postcards were handed out at one intersection in Corvallis, Oregon. For the nearside countdown timer intercept survey, postcards were handed out at one intersection in Portland, Oregon. The surveys generally consisted of a mix of open-ended, multiple-choice, and Likert-scale questions.

For the far side intercept surveys, a total of 337 postcards were handed out at the six intersections and a response rate of 45% was observed. Older, educated white males were overrepresented as survey respondents on the postcard survey compared to 2010 Census estimates for Oregon and the United States (US Census), and male respondents from the postcard survey had the highest overrepresentation. Overall, respondents on average reported using the bicycle for 22 days in a month, with the highest use being reported at W 5th Ave. and Blair Blvd intersection. Overall, 93% of respondents possessed a driver's license. Fourteen percent (14%) of the respondents reported that they did not drive a car for transportation, and 45% reported driving less than 5,000 miles in a year. A small percentage of respondents (1%) indicated that they were colorblind. Majority of the respondents indicated that they used corrective glasses or contacts for vision (58%). Overall, 84% of the respondents had observed the blue light and sign at the intersection and generally the percent of respondents who observed the blue light was higher at the Portland locations than Eugene locations barring one exception. This was likely due to the familiarity of Portland cyclists with the blue light devices. Additionally, within the Portland locations, the proportion of respondents who noticed the sign was higher at the embedded locations rather than at the locations where the blue light was separate from the sign. Although the sample size is small, this may indicate that the design where the blue light is embedded in the sign is more visible. Seventy percent (70%) of the respondents also did not read previous media articles on blue light devices, although more respondents at the Portland locations read the articles compared to the respondents in the Eugene locations, and possibly due to their familiarity with one of the major articles being published on bikeportland.org. The comprehension of the blue light device and sign was 83% and 81% respectively when the light was ON or OFF. The addition of a sign did indeed increase the comprehension rates significantly and was beneficial. Sixty-six percent (66%) overall thought they could take actions to activate the blue light, while 33% were not sure. The most common response from the people who said they could take actions to activate the blue light was to reposition their bicycle on/close to the bike pavement marking if present, or on/close to the loop detector. Regarding attitudes and perceptions, overall, 78% of the respondents felt that the blue light and sign were clearly visible to them at the intersection. Seventy-two percent (72%) of the respondents overall either somewhat or strongly agreed with the statement that the meaning of the blue light is easily understood at the intersection, while 24% somewhat or strongly disagreed. 81% of the respondents overall stated that they felt better about waiting at the intersection with the blue light and sign, while 10% either somewhat or strongly disagreed. Eighty-eight percent (88%) of the respondents felt that having information that they have been detected by the traffic signal was useful, while 7% somewhat or strongly disagreed with the statement.

For the nearside intercept survey, a total of 93 postcards were handed out at one Corvallis intersection and a response rate of 58% was observed. Similar to the online and far side intercept surveys, older, educated white males were overrepresented as survey respondents compared to 2010 Census estimates for Oregon. Proportions of higher-income respondents ($100,000 or greater) surveys were overrepresented (33%) when compared with census estimates (24%). Respondents with a bachelor’s and higher (Masters and Doctorate) degrees were overrepresented as compared to the census proportions. Respondents on average reported using the bicycle for 16 days in a month. Ninety eight percent of respondents possessed a driver’s license, 2% of the respondents reported that they did not drive a car for transportation, and 33% reported driving less than 5,000 miles in a year. A small percentage of respondents (4%) indicated that they were colorblind. Majority of the respondents indicated that they used corrective glasses or contacts for vision (52%). Forty eight percent (48%) of the respondents indicated that they had observed the blue light at the intersection. Eighty-seven (87%) of the respondents also did not read the media articles on blue light devices. Overall, 59% and 52% the respondents understood the purpose of the blue light devices correctly when it was ON and OFF respectively. The comprehension rates were higher when the blue light was ON compared to when it was OFF. Fifty-six percent (56%) overall thought they could take actions to activate the blue light, while 44% were not sure. The most common response from the people who said they could take actions to activate the blue light was to reposition their bicycle on/close to the bike pavement marking, or on/close to the loop detector. Eighty percent (80%) of the respondents indicated that they had observed the bicycle detector stencil at the intersection. Seventy percent (70%) of the respondents also indicated that they preferred to wait on the right, rather than the center of the lane where the new marking was present. Eight seven percent (87%) of the respondents also indicated that they preferred the stencil with the black background (new marking) as compared to the one without. Overall, 54% of the respondents felt that the blue light and sign were clearly visible to them (either somewhat or strongly agree) at the intersection. Sixty-seven percent (67%) of the respondents overall either somewhat or strongly agreed with the statement that the meaning of the blue light is easily understood at the intersection, while 28% somewhat or strongly disagreed, while 5.6% neither agreed nor disagreed. Eighty-one percent (81%) of the respondents overall stated that they felt better about waiting at the intersection with the blue light and sign. Ninety-one percent (91%) of the respondents felt that having information that they have been detected by the traffic signal was useful, while 9% somewhat or strongly disagreed with the statement.

For the nearside countdown timer intercept survey, a total of 87 postcards were handed out at this intersection and the resulting response rate was 33%. Survey respondents were overrepresented in the 35-44, 45-54, and 55-64 categories than the general population, with larger representation in the 55–64 and 65+ years categories, for data collected at the intersection with the countdown timer (82.7%) as compared to the census estimates (66.4%). The respondents were 90% White/Caucasian (vs. 77% reported in the Census). Proportions of higher-income respondents ($100,000 or greater) surveys were overrepresented (38%) when compared with census estimates (24%). Respondents with a bachelor's and higher (Masters and Doctorate) degrees were overrepresented as compared to the census proportions. Respondents on average reported using the bicycle for 22 days in a month. Ninety three percent of respondents possessed a driver's license, 7% of the respondents reported that they did not drive a car for transportation, and 52% reported driving less than 5,000 miles in a year. A small percentage of respondents (3%) indicated that they were colorblind. Forty eight percent of the respondents indicated that they used corrective glasses or contacts for vision. Sixty nine percent (69%) of the respondents indicated that they had observed the countdown timer at the intersection. Ninety-seven (97%) percent of the respondents also did not read the media articles on countdown timer devices. Overall, 51.7% of the respondents understood the purpose of the countdown timers correctly and an additional 44.8% provided partially correct responses, thus indicating a high comprehension of these devices. Twenty-eight percent (28%) overall thought they could take actions to activate the countdown timer, while 66% were not sure. The most common response from the people who said they could take actions to activate the countdown timer was to use the pushbutton. Some of them also mentioned repositioning their bicycle on/close to the loop detector to activate the countdown timer display.

Overall, 52% of the respondents felt that the countdown timer display was clearly visible to them (either somewhat or strongly agree) at the intersection. Eighty-six percent (86%) of the respondents overall either somewhat or strongly agreed with the statement that the meaning of the countdown timer display is easily understood at the intersection. Eighty-three (83%) of the respondents overall stated that they can accurately estimate the amount of time remaining until green from the countdown timer display. Sixty-six percent (66%) of the respondents overall stated that they felt better about waiting at the intersection with the countdown timer display. Seventy-two percent (72%) of the respondents felt that having information that they have been detected by the traffic signal was useful.

7.0 SYNTHESIS OF RESULTS AND RECOMMENDATIONS

This research sought to evaluate traffic control devices that can be used at signalized intersections to communicate to a person on a bicycle that they have been detected by the traffic signal and, in the case of countdown type devices, an estimate of the amount of waiting time remaining. Specifically, the objectives of this research were to:

- explore how well alternate designs for detection confirmation devices with or without supplemental signs are understood by the general public;
- establish quantitative information about the behavioral impacts of the confirmation devices from observations of the devices installed in the field;
- qualitatively study how the information provided by the detection confirmation device affect the overall cycling experience; and
- provide guidance to practitioners regarding the use of detection confirmation devices for bicycles.

To accomplish these objectives, the research team used a mixed methods approach. First, an online survey was conducted to understand the general public's comprehension of blue light detection confirmation device, supplemental sign options, and bicycle countdown timers. The survey sample was recruited through postcards that were mailed to 10,003 addresses in Oregon and through social media (i.e., Facebook advertisement) in Oregon and nationally. The survey consisted of 21 open-ended, multiple-choice, and Likert-scale questions. Of the 1,340 people who responded to the survey (568 postcard, 772 social media), a total of 1,084 responses were complete and useable for analysis (529 responses from the postcard survey and 555 responses from the social media survey). For the postcard recruitment, the calculated response rate was 5.8%. It is not possible to calculate a response rate for the social media recruitment.

In the online survey, respondents were randomly selected to be shown images from the perspective of a person on a bicycle or driving a car. The results from the surveys were then used to inform the design of a supplemental sign. The survey results also suggested that the countdown signal was another promising option to test. The following configuration of devices were installed in the field:

- At two intersections in Portland (one approach) and two intersections in Eugene (both approaches), the blue light was embedded in the sign on the farside signal mast arm or span wire;
- At two intersections in Portland, the blue light was in the signal backplate and the supplemental sign was on the farside signal mast arm or span wire;

- At one intersection in Corvallis, the blue light was embedded in the supplemental sign and placed nearside; and
- At one intersection in Portland, a countdown timer was placed nearside.

Video data was collected, before-and-after installation, to determine observable changes in cyclist's behavior. Finally, an intercept survey of cyclists was conducted at these same intersections asking many questions that aligned with the online survey as well as ones about the specific site. These surveys were administered online but recruitment was through postcards handed out at the intersections. For surveys of the devices placed on the farside, a total of 337 postcards were distributed at the six intersections. The response rate was 45% (151 responses). For the one intersection with the nearside blue light detection confirmation device, a total of 93 postcards were distributed and 54 responses received (response rate of 58%). For the nearside countdown timer intercept survey, a total of 87 postcards were handed out and 29 responses were received (response rate was 33%).

The following sections synthesize the research results that have been presented in the previous chapters that inform the objectives. Recommendations for practice follow.

7.1 COMPREHENSION

The surveys asked a number of questions to determine how well the blue light or countdown timers were understood. In the online survey, respondents were presented an image of an intersection approach with a blue light in the signal back plate. Analysis of the 1,084 open-ended responses to the question of "*What does the blue light mean to you?*" were coded as correct, partially correct, or incorrect. A primary result of the survey is that nearly all respondents (approximately 90%) indicated that they did not know what the blue light meant or provided a response that was not coded as correct. When a supplemental sign was added to the intersection image, comprehension rates increased. Table 7.1 presents the results of the postcard, social media (Oregon) and social media (USA) showing that correct or partially correct in the open-ended question responses were 58%, 38%, and 54%. Few respondents had any experience with a blue light in person. Only 14% in the postcard recruited pool and 3% in the social media (USA) respondents reported that they had experienced a blue light detection confirmation. Many more respondents in the Oregon social media respondents (30%) had experienced the blue light systems.

For the intercept survey respondents (who were all persons on bicycles), analysis of their open-ended response indicated much higher comprehension rates. Survey respondents were presented two images: 1) with the blue light "on" and 2) with the blue light "off". The farside embedded system elicited the highest correct and partially correct responses when the blue light detection confirmation system was on (90.6%), while the farside system where the blue light was separate from the sign elicited the highest correct and partially correct responses when the system was off (97.8%). Intercepted cyclists at the intersection with the devices placed farside elicited higher comprehension rates compared to the nearside system (though there is only a single nearside installation). Notably, though not shown in the table, 72% of intercept survey respondents at locations with farside placement strongly agreed or agreed with the statement that the meaning of the blue light and sign is easily understood at the intersection.

In summary, the meaning of the blue light when accompanied by a supplemental sign appears to be well understood. An average of 93% correct or partially correct responses by persons on bicycles in the intercept surveys, though the online survey was lower (average 50%). With respect to where the blue light should be placed, there was slightly lower comprehension of the embedded blue light sign placed farside (88% correct and partially correct) than the separate sign located farside (95% correct and partially correct). However, the Portland embedded locations on the farside had similar comprehension rates as Portland separate locations (94% vs. 95%) and far higher comprehension rates than the Eugene embedded locations (94% vs 82%). For the one location nearside with the embedded blue light detection confirmation, comprehension was lower (73%). While not shown in this summary table, the locations in Portland had higher comprehension that the Eugene or Corvallis locations which likely reflects both the longer learning period and familiarity with the device due to media articles and education efforts in Portland.

Table 7.1: Summary of Blue Light Comprehension Responses (Percentage)

Response	Online			Intercept					
	Sign with Symbol and Blue Dot			Farside (Embedded)		Farside (Separate)		Nearside (Embedded)	
	Postcard (OR)	Social Media (OR)	Social Media (USA)	Blue Light On	Blue Light Off	Blue Light On	Blue Light Off	Blue Light On	Blue Light Off
n	529	90	465	119	119	32	32	54	54
Correct	49.5	19.2	42.9	79.8	76.6	80.2	76.8	59.3	51.9
Partially Correct	8.2	19.2	11.8	10.8	8.9	12.1	21.0	14.8	20.4
Correct + Partially Correct	57.7	30.4	54.7	90.6	85.5	92.3	97.8	74.1	71.3
Incorrect	42.3	62.5	45.3	9.4	14.5	7.7	2.2	25.9	27.8
Experience blue light?	14.2	30.0	2.6	n/a					
Seen Media Articles?	n/a			21.4		44.0		13.0	

The survey scenarios with countdown timers elicited high proportions of correct responses. Table 7.2 shows the comparison of countdown timer comprehension responses for the online and intercept surveys. Comprehension measured online and by the intercepted cyclist were very high and nearly identical. Among the intercept survey respondents, the stated comprehension of the countdown timer was the highest (97%) though the sample of respondents was small.

Table 7.2: Summary of Survey Countdown Timer Comprehension Responses (Percentage)

Response	Online - Circular Disappearing Dots Option			Intercept
	Postcard (OR)	Social Media (OR)	Social Media (USA)	Nearside
n	529	90	465	29
Correct	42.6	51.4	38.0	51.7
Partially Correct	34.6	29.7	29.4	44.8
Correct + Partially Correct	77.2	81.1	68.7	96.6
Incorrect	22.8	18.9	31.3	3.4
Seen Media Articles?	n/a			3.4

7.2 BEHAVIOR

Cyclist behavior was observed using before and after video data collected at intersections equipped with detection confirmation systems (blue light and countdown timer). Bicycle volume, arrival location, signal status on arrival, waiting location and compliance were observed using the video data. The intercept survey also contained relevant comprehension questions.

An important context in evaluating the observed behavior change can be extracted from the intercept surveys. Table 7.3 summarizes the responses from the intercept surveys of these questions. In general, the percent of respondents who observed the blue light was higher at the Portland locations (94.4% embedded and 79.5% supplemental) than the Eugene locations (71.7% embedded). This was likely due to the familiarity of Portland cyclists with the blue light devices and the longer deployment. At the Portland locations, the proportion of respondents who noticed the blue light detection confirmation system was higher at the locations where the blue light was embedded in the sign. Although the sample size is small and there are many site-specific differences, these results suggest that the design where the blue light is embedded in the sign is more visible to cyclists. Finally, both nearside applications had the lowest number of persons observing the devices (48.1% Corvallis nearside, 69.0% Portland countdown).

Table 7.3: Summary of Cyclist Observation of Device (Percentage)

Question	Response	Portland Farside Blue Light Embedded	Portland Farside Blue Light Separate	Eugene Farside Blue Light Embedded	Corvallis Nearside Blue Light Embedded	Portland Nearside Countdown Timer
Observed Blue Light / Countdown at Intersection	Yes	94.4	79.5	71.7	48.1	69.0
	No	5.6	20.6	28.4	51.9	31.0
Blue Light / Countdown Clearly Visible	Strongly Agree or Agree	86.9	67.1	73.3	53.7	51.7

One possible behavior change given the additional information provided by the blue light detection confirmation systems is increased compliance with the red signal indication. Data on compliance were disaggregated by movement of the person on a bicycle. Table 7.4 synthesizes the comparison of cyclist compliance by device type and placement before and after the installation. As discussed in the video data analysis chapter, there are a number of site-specific details that influenced compliance. Nonetheless, these results are averaged for the similar devices for presentation in this chapter.

The embedded blue light devices placed on the farside show a small increase in the proportion of cyclists stopping and waiting through the entire red interval after the blue light detection confirmation device was installed (2.4% in Portland, 5.5% in Eugene). However, there was a 2.7% decrease in the proportion of cyclists stopping and waiting the entire red interval at the intersections with the blue light separate from the sign. As discussed in the video analysis chapter, both nearside devices were evaluated using video collected entirely during the COVID-19 pandemic. At the one location where the embedded blue light system was installed nearside there was an increase (2.0%) in cyclists stopping and waiting during the red interval. At the countdown timer location, there was an 8% decrease in compliance.

Overall, none of the changes observed were statistically significant. This does not mean that the differences do not exist but that with number of observations a statistical difference was not found. Future studies with larger sample sizes may be able to observe statistically significant differences. This result suggests that the detection feedback devices did not alter compliance behavior significantly. Previous research has shown that compliance is location specific and depends on cross street volumes, availability of gapes, and bicycling culture and risk-taking behavior (Thompson et al. 2013).

Table 7.4: Summary of Change in Cyclist Compliance Behavior

Type	Condition	Yes	No (Does not Stop and Turns Right on Red)	No (Does not Stop and Turns Left/Thru on Red)
Portland Blue Light Farside Embedded (2 locations)	Before	95.5	2.7	1.9
	With Blue Light in Sign	97.9	1.4	0.2
	Difference	**+2.4**	**-1.3**	**-1.7**
Portland Blue Light Far Side Separate (2 locations)	Before	75.5	23.3	1.2
	With Blue Light in Sign	72.8	26.2	1.2
	Difference	**-2.7**	**+2.9**	**0**
Eugene Blue Light Farside Embedded (2 locations)	Before	69.0	16.1	15.0
	With Blue Light in Sign	74.5	16.0	9.6
	Difference	**+5.5**	**-0.1**	-5.4
Corvallis Blue Light Nearside Embedded (1 location)	Before	95.2	0.0	4.8
	With Blue Light in Sign	97.2	2.8	0.0
	Difference	**+2.0**	**+2.8**	**0**
Portland Nearside Countdown (1 location)	Before	61.6	13.1	25.3*
	After	53.6	13.7	32.7*
	Difference	**-8.0**	**+0.6**	**+7.4**

* Includes persons on bicycle who stopped initially but did not wait until green indication

Another anticipated behavior change with positive detection confirmation would be persons on bicycles selecting waiting locations that would allow for their detection by the traffic signal. The installation of the countdown timer was not evaluated. Cyclists waiting location was coded for persons who arrived on the red indication when the stencil was not occupied. At the one of the Eugene locations and at the Corvallis location, video detection was being used and the detection zones for blue light activation were larger than the stencil markings. As context, while comprehension was good of the blue light detection confirmation systems, it is worth noting that only 66% of respondents indicated that thought they could take actions to activate the blue light.

Table 7.5 summarizes the synthesis of results for the proportion of observed cyclists waiting on stencil. At three of the Portland intersections (embedded and separate), the proportion of cyclists who were observed to wait on the stencil is lower after the blue light and sign were installed than in the before condition (50.3% before, 45.1% with blue light embedded in sign; 46.4% before, 34.9% with blue light separate from sign). These observed decreases were not statistically significant. At the two Eugene locations, the proportions of cyclists arriving on red and waiting on the stencil increased after the blue light and sign were installed (26.3% before, 41.7% with blue light in sign). Again, these results were not statistically significant. At the nearside blue light location in Corvallis, an additional stencil marking was added prior to the blue light installation and therefore the proportion of cyclists waiting on the old stencil marking showed a statistically significant decrease due to cyclists' waiting location being split between the two stencil markings (100.0% before, 26.1% with blue light in sign).

For the nearside devices, an important caveat is that the data comparison periods include both pre and post COVID-19 pandemic observations. While bicycle and vehicle traffic had somewhat returned to normal during the data collection effort, it is not possible to determine the impact of the pandemic on observed behaviors. It also should be noted that there are significant site-level variations in the data and drawing strong conclusions is challenging.

Table 7.5: Summary of Cyclist Waiting Behavior on Stencil

Type	Condition	Proportion of Cyclists Arriving on Red and Waited on Stencil
Portland Blue Light Farside Embedded (2 locations)	Before	50.3
	With Blue Light in Sign	45.1
	Difference	**-5.2**
Portland Blue Light Far Side Separate (1 location)	Before	46.4
	With Blue Light in Sign	34.9
	Difference	**-11.5**
Eugene Blue Light Farside Embedded (2 locations)	Before	26.3
	With Blue Light in Sign	41.7
	Difference	**+15.4**
Corvallis Blue Light Nearside Embedded (1 location)	Before	100.0
	With Blue Light in Sign	26.1
	Difference	**-73.9**

In summary, the blue light detection confirmation system embedded in the sign with the farside presentation was the most visible, was associated with a small increase in the proportion of cyclists stopping on the red indication after installation and but did not result in statistically significant difference in shifting the waiting location of the cyclists.

7.3 CYCLING EXPERIENCE

Another objective of the detection confirmation devices is to improve the waiting experience for the person on a bicycle at a traffic signal by giving positive confirmation of detection, and for the countdown timer, the expected waiting time. For all surveys, a question was asked about perceptions of waiting and whether the information was useful.

Table 7.6 shows the comparison of responses to the statement that the respondents feel better about waiting at an intersection equipped with a blue light detection confirmation system or countdown timer. Overall, the online respondents averaged about 60% strongly or somewhat agreeing about waiting on a bicycle at the blue light installations. For the intercepted cyclists, the response was considerably higher. At the blue light equipped locations about 80% agreed with this statement. At the countdown timer location, 65% agreed.

Table 7.7 presents the summary of responses for the intercepted cyclists who were asked for their level of agreement with a statement that the information that they have been detected is useful to them (this question was not asked of the online respondents). Overall, the intercept survey respondents averaged about 84% strongly or somewhat agreeing. Lastly, it is worth noting that in the online survey most responded agreed or somewhat agreed that they would support the use of blue light system at some intersections in their community (70% postcard, 84% social media (OR), 79% social media (USA)). In summary, the bicycle detection confirmation devices had the expected positive effect on the stated cycling experience based on the survey responses.

Table 7.6: Summary of Survey Responses to Question about Waiting (Percentage)

Response	Online		Intercept				
	I would feel better about waiting on a bicycle at an intersection if a blue light system was present.		*I feel better about waiting on a bicycle at an intersection with the sign and blue light*				
	Postcard (OR)	**Social Media (OR)**	**Social Media (USA)**	**Farside (Embedded)**	**Farside (Separate)**	**Nearside (Embedded)**	**Nearside (Countdown)**
n	529	90	465	119	32	54	29
Strongly Disagree	12.5	6.7	8.8	4.8	4.4	1.9	3.4
Somewhat Disagree	8.1	6.7	6.5	3.6	4.4	7.4	3.4
Neither agree or disagree	20.8	24.4	19.6	10.5	17.6	9.3	27.6
Somewhat Agree	24.2	28.9	30.5	27.2	29.7	29.6	41.4
Strongly Agree	33.6	33.3	33.8	54.0	44.0	51.9	24.1
Somewhat + Strongly Agree	57.8	62.2	64.3	81.2	73.7	81.5	65.5

Table 7.7: Summary of Survey Responses to Question about Useful Information (Percentage)

Response	Intercept			
	Having information that I have been detected by the traffic signal is useful to me			
	Farside (Embedded)	Farside (Separate)	Nearside (Embedded)	Nearside (Countdown)
n	119	32	54	29
Strongly Disagree	6.2	7.7	3.7	3.4
Somewhat Disagree	0	2.2	5.6	6.9
Neither agree or disagree	3.1	6.5	0.0	17.2
Somewhat Agree	21.5	29.7	13.0	48.3
Strongly Agree	67.9	53.9	77.8	24.1
Somewhat + Strongly Agree	89.4	83.6	90.8	72.4

7.4 RECOMMENDATIONS FOR PRACTICE

Based on the findings of this research, the following recommendations are made for the Oregon DOT to consider:

7.4.1 Embedded Farside Blue Light Detection Confirmation System with a Supplemental Sign

Figure 7.1: Blue detection confirmation light

The findings from the surveys (online and intercept) suggest that the blue light detection confirmation system provides useful information to cyclists and makes them feel better about waiting at the intersection. The detection confirmation system did not significantly change compliance or waiting locations of persons on bicycles on aggregate, although individual persons may change their behavior based on the information provided. The cost to install these systems are minor. As noted by Portland engineers, there are maintenance reason for installing the blue light as it can easily confirm detector outages and aid in placement of the waiting stencil. Overall, the evidence from this research suggests that blue light detection systems can be useful "tool in toolbox." The research suggests that careful consideration of candidate sites and placement of the system is required. Sites with significant bicycle traffic on shared lane roadways, such as neighborhood greenways are bicycle boulevards are strong candidates for the detection feedback devices.

A supplemental sign is required for comprehension - few respondents provided correct or partially correct responses without a supplemental sign in the surveys. The increase in comprehension rates with the addition of a supplemental sign was documented in the online and intercept surveys. The results suggest that for farside placements, the embedded design (where the blue light is placed within the sign) is preferred. While comprehension rates were overall slightly lower for the embedded design, farside presentation had slightly higher cyclist observation rates (83% for farside embedded systems, 79% for farside separate systems), greater visibility (80% for farside embedded systems, 67% for farside separate systems) and increased in compliance at the Eugene installations (69% before, 75% after). Because only one location had a nearside device and it was somewhat unique, this research cannot provide much guidance on the use of nearside devices. However, based on the findings from the farside device evaluation, it is expected that the nearside devices can also be beneficial to cyclists. If agencies want to consider nearside placement, placing the device where it is prominently visible to cyclists as they wait at the intersection is recommended.

Due to limitations of the survey length, the number of alternatives for the supplemental sign that were explored were limited. However, drawing on research for the MUTCD 9C-7 stencil, it is likely that the word "detected" is not well understood and sign comprehension could be further improved. There was debate about the appropriate sign legend and background by agency engineers. In Portland and Eugene, the supplemental signs were black and white. Agencies pointed to the other signs used for pedestrian and bicycle information at intersections (R10-4, R10-24, R10-26), or requesting bicycle green (R10-22) as support for the black and white design. Oregon DOT engineers concluded the sign was not regulatory, but rather guidance, and should be green lettering on white background. The research was not able to explore any difference on the effect of sign color on operations. Finally, as of publication of this final report, the draft MUTCD out for public comment includes a prohibition of using LEDs within the background area of a sign. Blue is also not listed as an approved color. If these changes are incorporated in the final MUTCD, an alternative to the embedded blue light may be to replace the blue LED with highly retroreflective circular blue symbol on the sign.

Finally, it is worth noting that for the farside detection confirmation systems, the detection of bicycles and motor vehicles was shared. Thus, at some locations the blue light is displayed when either a bicycle or motor vehicle was detected. While motor vehicle drivers in the field were not surveyed, it is possible that this display could cause confusion to some drivers as the sign used says "bicycle" detected but was not always a bicycle present. An improvement would be to separate detection so that only the bicycle is detected or use one of the alternate signs tested that state "vehicle detected". This was done at the Corvallis location using thermal and radar detection systems.

7.4.2 Bicycle Countdown Timer

Figure 7.2: Bicycle countdown timer

The nearside countdown timer installation explored in this study is the first instance of its kind in the U.S., although it is commonly used in Netherlands and other European countries. Although the intercept survey sample was small, the countdown timer elicited the highest correct and partially correct response rates (97%) among all the devices tested in this study. The high comprehension rates coupled with the perceptions of the respondents that the display was easily understood (86%) and that they felt better about waiting at an intersection with a countdown timer (66%) suggests that these devices could be candidates for nearside placement. Placement of these devices is also key as cyclists are generally accustomed to looking at the signal displays which are typically placed farside. Although, noncompliance increased post installation at the single location tested in this study, the increase was not statistically significant. The research does not conclude that the change in compliance was associated with the countdown timer. More likely, the change is due to traffic conditions present during the COVID-19 pandemic. In conclusion, since these devices are novel for U.S. cyclists, more research and testing may be needed prior to large scale adoption.

7.4.3 Education

Education of cyclists regarding the purpose and placement of the detection confirmation systems can help with increasing comprehension rates. In addition to cyclists, education of drivers can also help with safety improvements at the intersection as the drivers are alerted to the presence of a cyclist when these systems are activated, and the detection is separate. Education of cyclists and drivers across the country is recommended for successful adoption as the results of the online survey of respondents outside of Oregon showed poor comprehension rates.

7.5 LIMITATIONS OF RESEARCH

This research provides valuable insight on novel topics; however, there are some limitations with the research methods. The surveys were conducted in a stated-preference format, meaning that respondents were answering questions about hypothetical conditions. While stated preference surveys can be an easy way to collect data under an economically conscious method, there are limitations. Within stated-preference surveys, data is subject to the design of the survey and its questions; therefore, if a respondent reads or comprehends the question differently than the surveyor, then results could be askew. Additionally, the online survey was biased toward white, high-income, male respondents which does not accurately portray an overall census distribution.

Furthermore, as Portland currently has a population familiar with blue light detection confirmation systems, it is not clear if the results in this study would be transferrable to other contexts (though the online survey suggests they may).

The video data collection for the nearside bicycle countdown timer only observed 29 cyclists in one location. Due to the small sample size (i.e., should be more than one location, and greater than 30 observations with variability), conclusions cannot be made from the results, which limits the ability to provide robust recommendations. An important caveat is that the data comparison periods include both pre and post COVID-19 pandemic observations. In particular, the video observations for the before and after periods of the nearside devices and the intercept surveys at these locations were entirely during the COVID-19 pandemic. While bicycle and vehicle traffic and somewhat returned to normal during the data collection effort, it is not possible to determine the impact of the pandemic on observed behaviors. Additionally, in general, video data without validation (i.e., follow-up questions regarding behaviors made) results in ambiguous conclusions, with the researcher making assumptions about behaviors without validating whether those behaviors were made for a particular reason.

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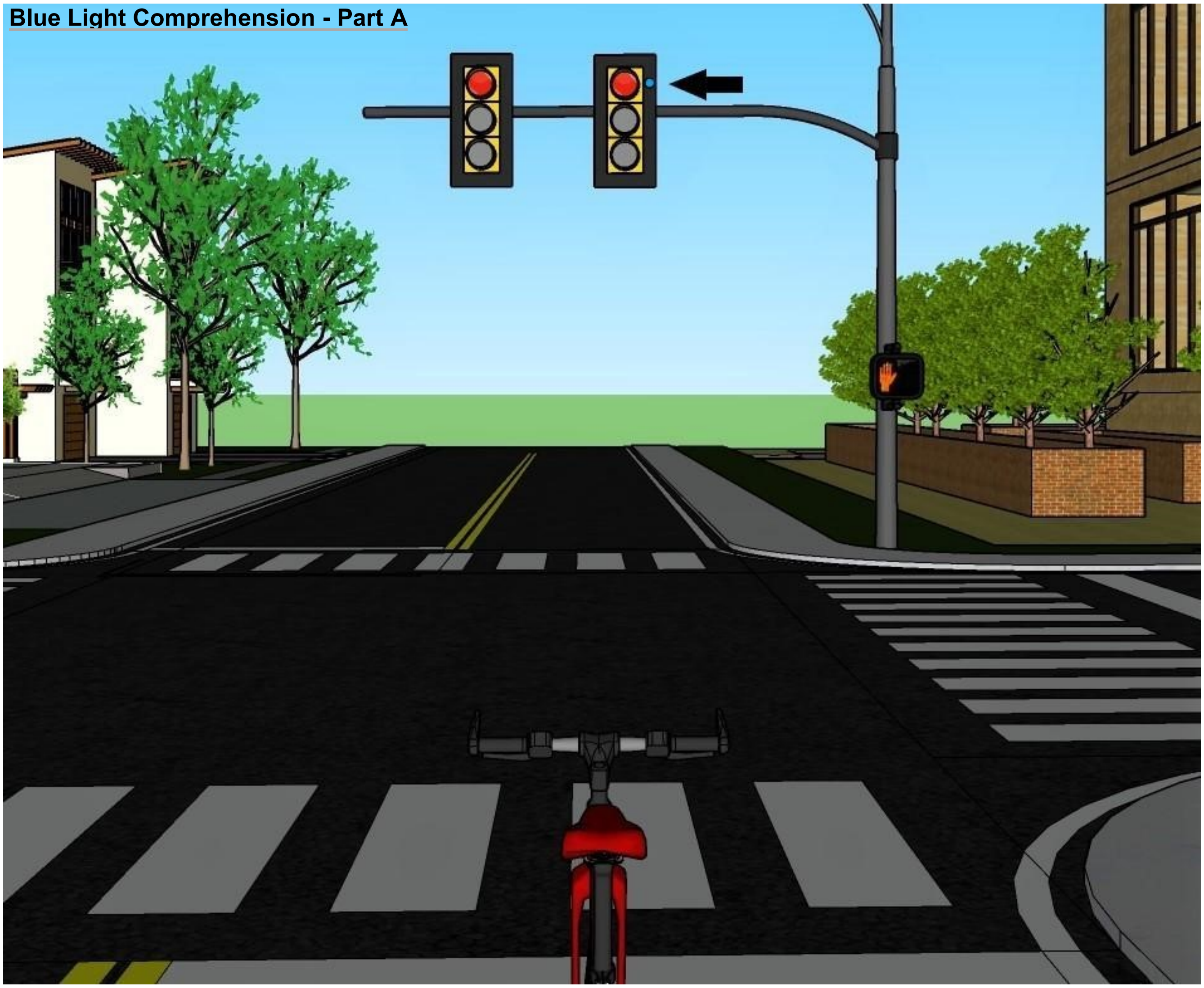
APPENDIX A ONLINE SURVEY QUESTIONNAIRE

Introduction and Informed Consent

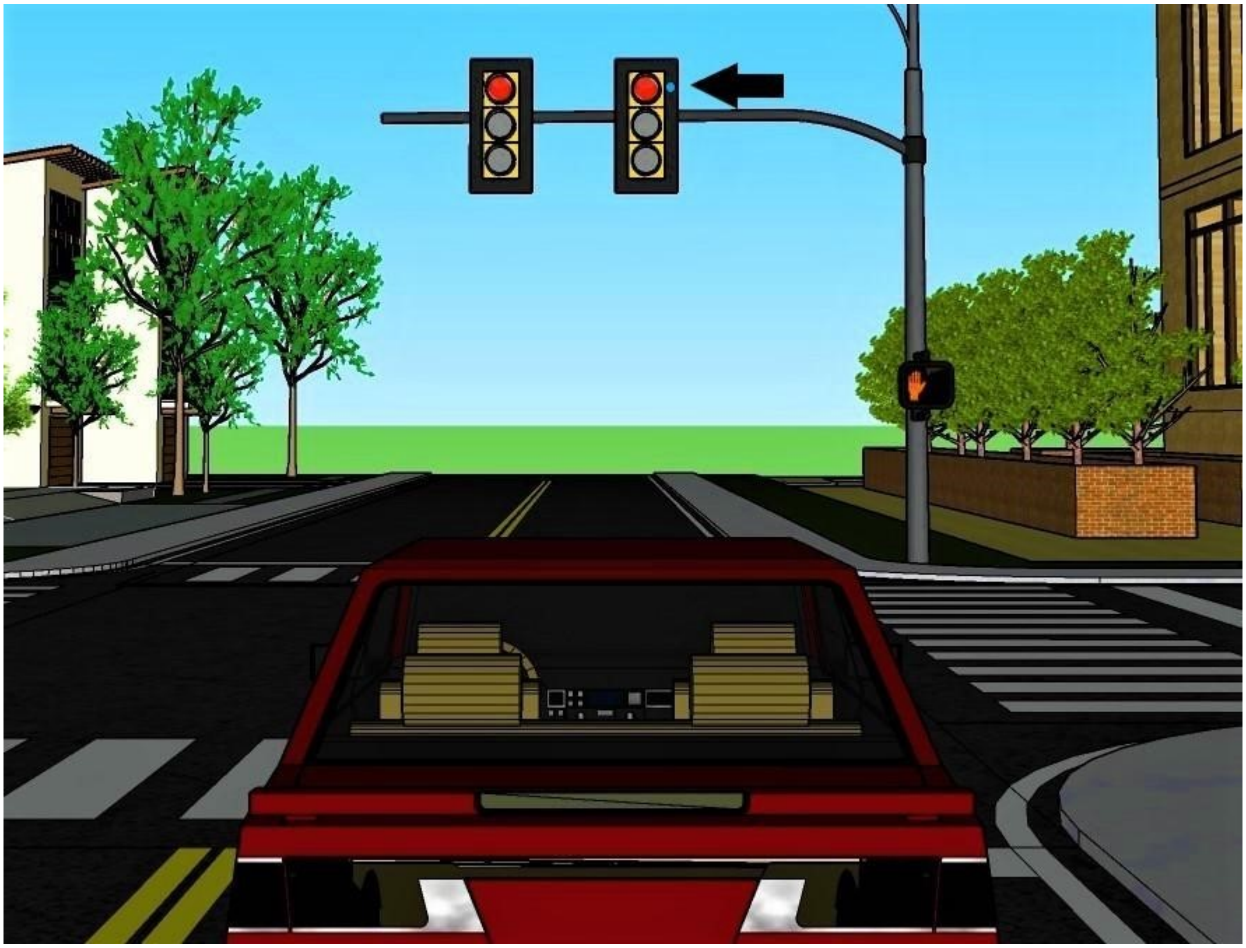
Interpretation of Traffic Displays and Signs

You are being asked to take part in a research study. The information in this Informed Consent document shows the main facts you need to know about this research for you to think about when making a decision about if you want to join in. Carefully look over the information in this form and ask questions about anything you do not understand before you make your decision. You must be 18 years or older to participate and there is no penalty if you choose not to join in or decide to stop. At the end of the survey, you will be redirected to another site to enter the drawing.

- ◘ **I AGREE** to take part in this study and certify that I am at least 18 years of age
- ◘ I **DO NOT AGREE** to take part in this study or I am not at least 18 years of age



Imagine that you are waiting at an intersection on a bicycle. What does the **BLUE LIGHT** (to the left of the arrow) mean to you? Please type your response in the box below and be as descriptive as possible.



Imagine that you are waiting at an intersection in a car. What does the **BLUE LIGHT** (to the left of the arrow) mean to you? Please type your response in the box below and be as descriptive as possible.

Blue Light Comprehension - Part B - Bike

There has been a sign added to the photo. Again, imagine that you are waiting at an intersection on a bicycle. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.

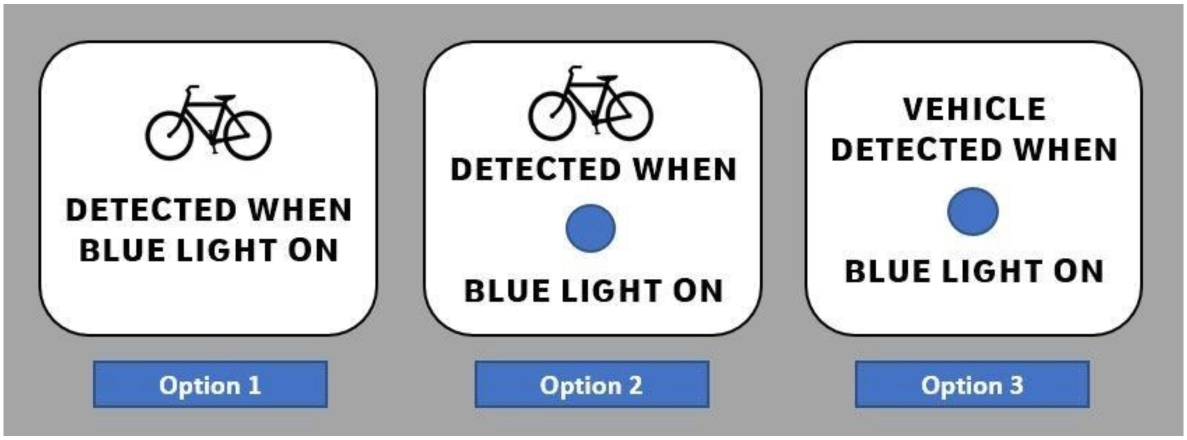
There has been a sign added to the photo. Again, imagine that you are waiting at an intersection on a bicycle. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.

There has been a sign added to the photo. Again, imagine that you are waiting at an intersection on a bicycle. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.

Blue Light Comprehension - Part C - Bike

The purpose of the **BLUE LIGHT** system is to let the person waiting at the intersection know that they have been detected by the sensors and that the traffic signal will soon provide a green light for them.

Below are three versions for the accompanying sign (you previously were shown one of them):



Which sign do you think best conveys the meaning of the blue light system?

- Option #1
- Option #2
- Option #3

Please explain **WHY** you chose this option as best.

Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Level of Agreement				
	Strongly Disagree	Disagree	Indifferent.	Agree	Strongly Agree

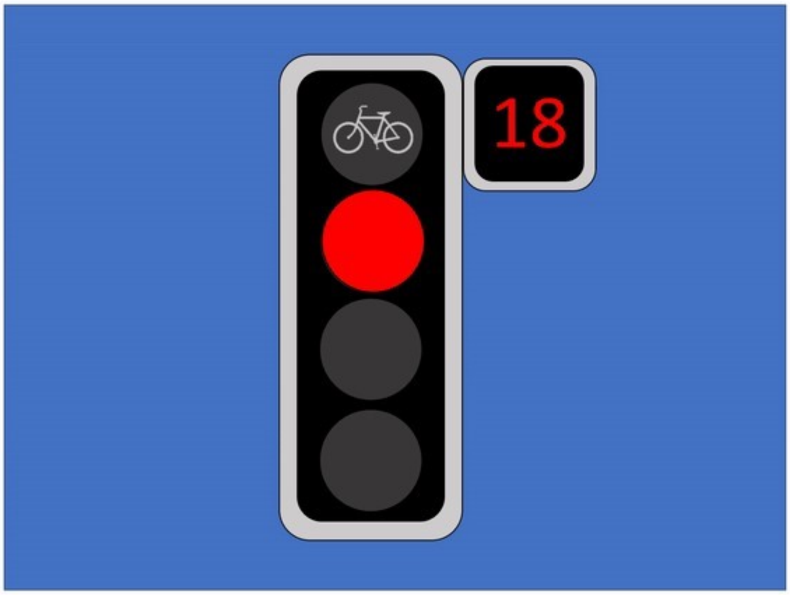
	Level of Agreement				
The addition of the sign helped with my understanding of the purpose of the blue light.	◘	◘	◘	◘	◘
I would support the use of a blue light system at some intersections in my community.	◘	◘	◘	◘	◘
I would feel better about waiting on a bicycle at an intersection if a blue light system was present.	◘	◘	◘	◘	◘

Have you experienced the **BLUE LIGHT** system at an intersection before?

◘ Yes
◘ No

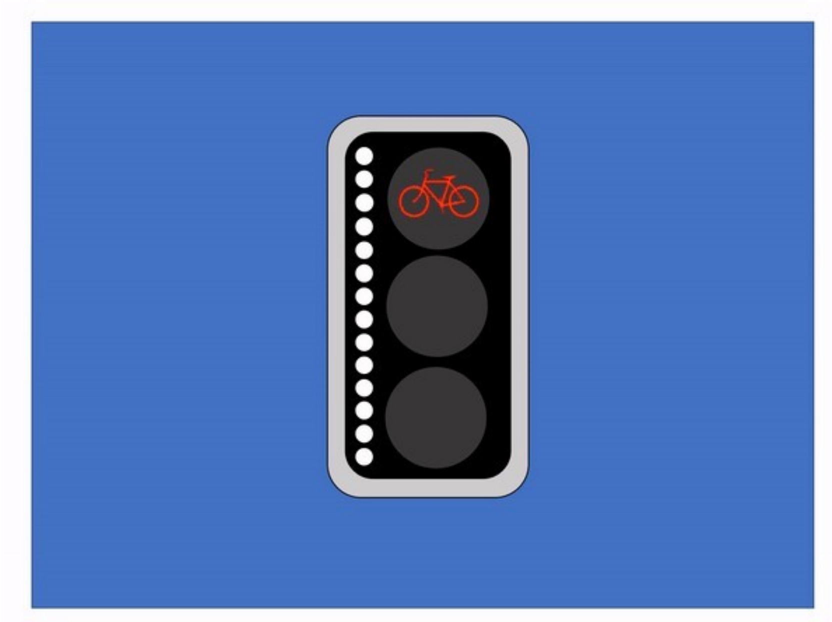
The following questions will ask you to imagine that you are stopped at an intersection on a bicycle while the traffic signal is red. You will be shown a new traffic signal just for persons on bicycles and asked some questions.

Countdown Timers - Part A



Imagine that you are stopped at an intersection on a bicycle on a red signal indication and you see the signal head above. What does the **DISPLAY** mean to you as a person on a bicycle? Please type your response in the box below and be as descriptive as possible.

Imagine that you are stopped at an intersection on a bicycle on a red signal indication and you see the signal head above. What does the **DISPLAY** mean to you as a person on a bicycle? Please type your response in the box below and be as descriptive as possible.

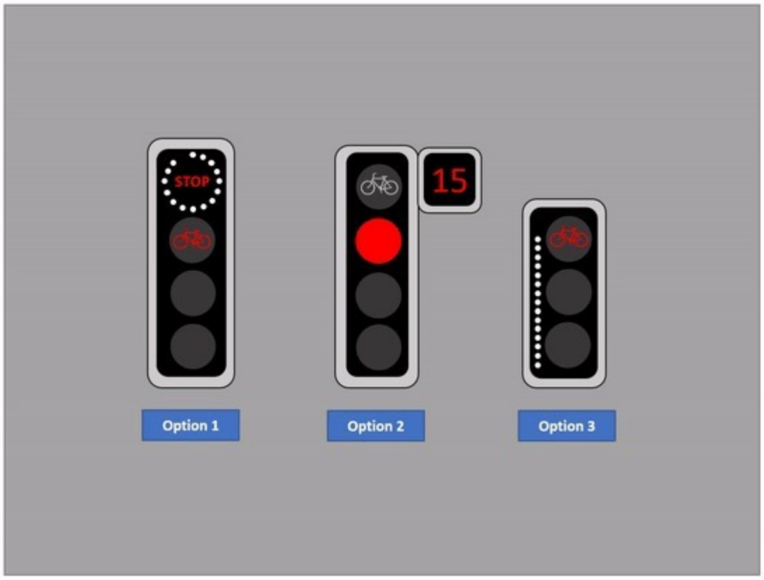


Imagine that you are stopped at an intersection on a bicycle on a red signal indication and you see the signal head above. What does the **DISPLAY** mean to you as a person on a bicycle? Please type your response in the box below and be as descriptive as possible.

Countdown Timer - Part B

The purpose of these traffic signals and the countdown timer is to indicate to the person on a bicycle the amount of time they have left to wait before the signal turns green for them to proceed safely through the intersection.

Below are three versions for the display (you previously were shown one of them):



What sign do you think best conveys the meaning of the countdown timer?

- Option #1
- Option #2
- Option #3

Please explain **WHY** you selected this option.

Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Level of Agreement				
	Strongly disagree	Disagree	Indifferent	Agree	Strongly Agree
The disappearing white dots makes sense to me as a way to display the countdown to green signal.	○	○	○	○	○
I prefer the display of the actual number of seconds as a countdown to green signal.	○	○	○	○	○
I would feel better about waiting at an intersection if a countdown timer (e.g., numeric countdown or disappearing dots) was present.	○	○	○	○	○

Demographics

Now you will be asked some questions regarding your demographics.

What is the **ZIP CODE** of your primary residence?

What is the **CITY** of your primary residence?

Do you have a **DRIVER'S LICENSE**?

- ○ Yes
- ○ No

How **LONG** have you had your driver's license?

- ○ 1 - 2 years
- ○ 3 - 5 years
- ○ 6 - 10 years
- ○ More than 10 years

On average, how many **MILES** do you drive per year?

- ○ Less than 5,000
- ○ 5,000 - 9,999
- ○ 10,000 - 14,999
- ○ 15,000 - 19,999
- ○ 20,000 or more

When the weather is nice, about how many days per month do you ride a bicycle?

When was the most recent time you rode a bicycle...?

	In the last month	In the last year	In the last five years	More than five years ago	Never
...primarily for fun or exercise?	☐	☐	☐	☐	☐
...primarily for transportation?	☐	☐	☐	☐	☐

What best describes your **GENDER**?

- ☐ Male
- ☐ Female
- ☐ Prefer not to answer
- ☐ Prefer to self-describe

What is your **AGE**?

What **RACE** do you consider yourself?

- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Hispanic or Latino/a
- ☐ White or Caucasian
- ☐ Other
- ☐ Prefer not to answer

What is your annual household **INCOME**?

- ☐ Less than $25,000
- ☐ $25,000 to less than $50,000
- ☐ $50,000 to less than $75,000
- ☐ $75,000 to less than $100,000
- ☐ $100,000 to less than $200,000
- ☐ $200,000 or more
- ☐ Prefer not to answer

What is the highest level of **EDUCATION** you have completed?

- Some high school or less
- High School diploma or GED
- Some college
- Trade/vocational school
- Associate degree
- Four Year degree
- Master's degree
- PhD Degree
- Prefer not to answer

Are you **COLOR BLIND**?

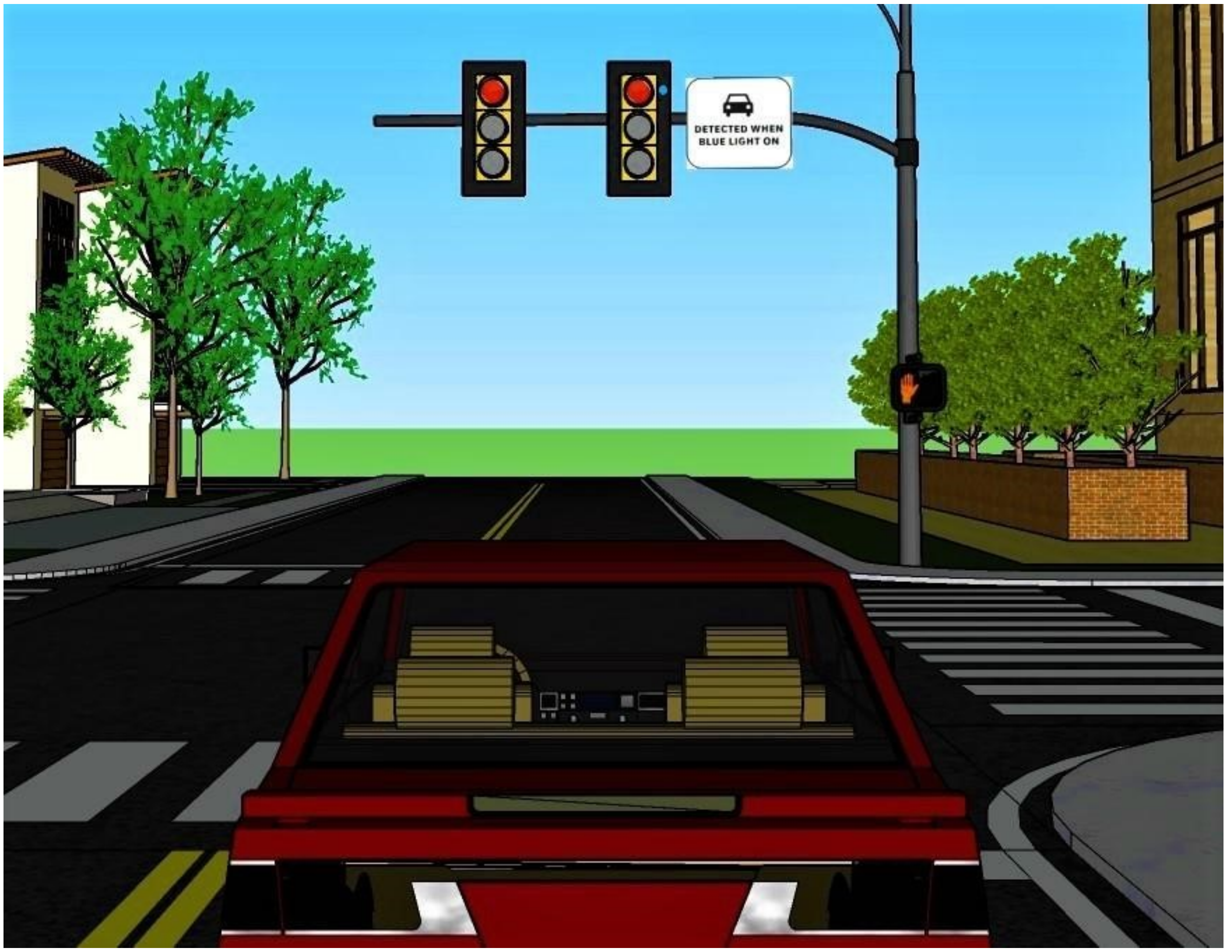
- Yes
- No
- Prefer not to answer

Do you currently wear **CORRECTIVE GLASSES** or **CONTACTS**?

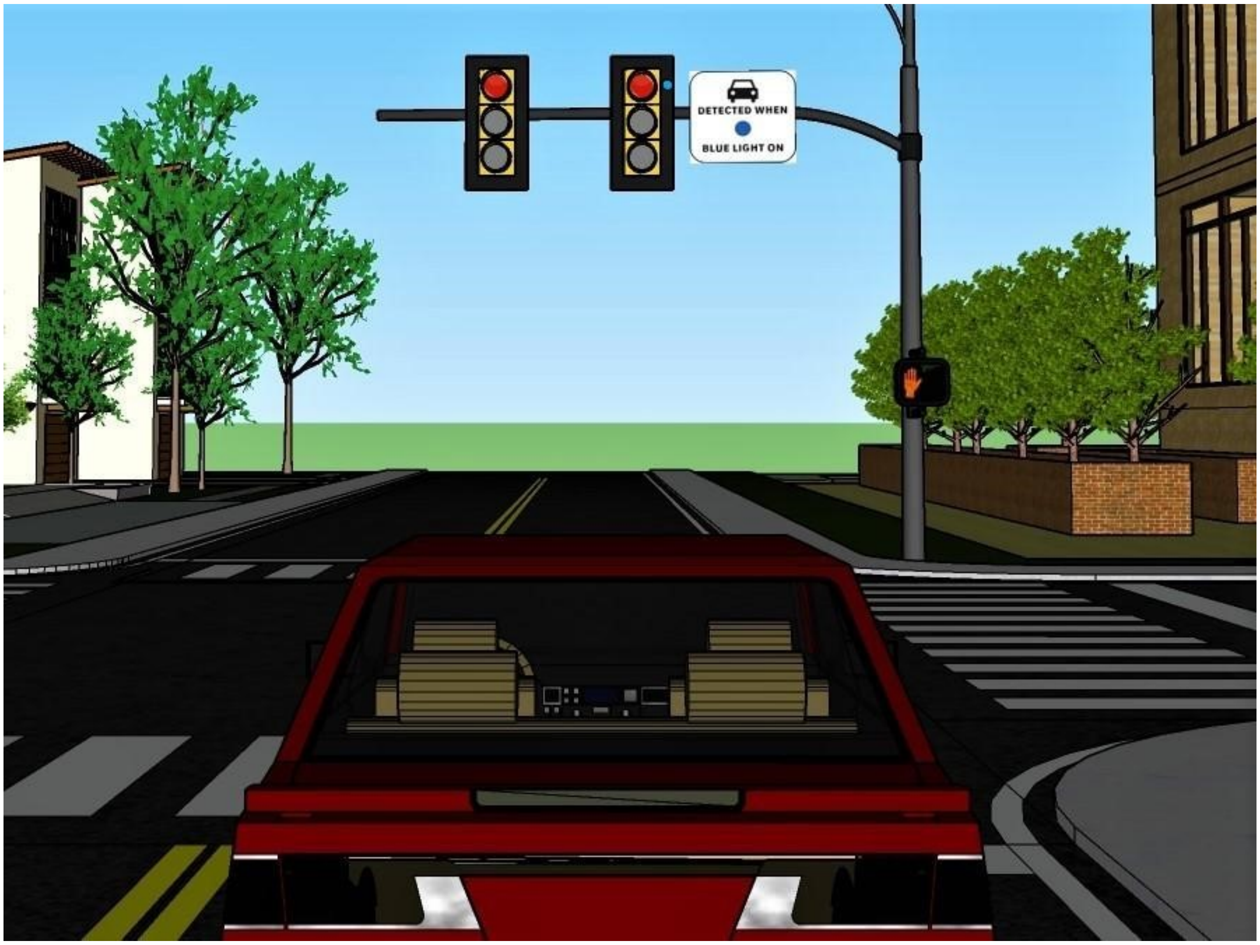
- Yes
- No
- Prefer not to answer

If there is anything else you want to tell us with respect to the survey, please let us know.

Blue Light Comprehension - Part B - Car



There has been a sign added to the photo. Again, imagine that you are waiting at an intersection in a car. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.



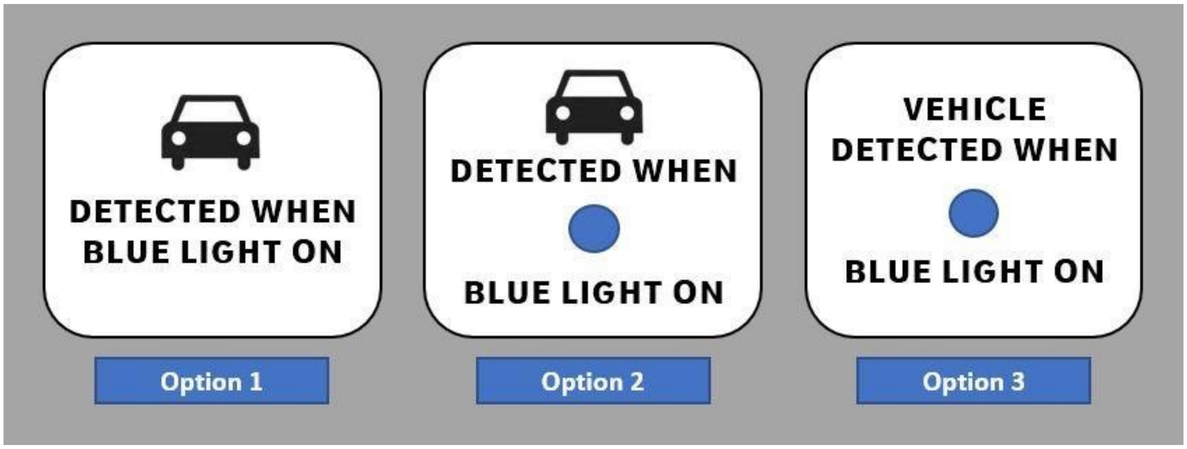
There has been a sign added to the photo. Again, imagine that you are waiting at an intersection in a car. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.

There has been a sign added to the photo. Again, imagine that you are waiting at an intersection in a car. What does the **BLUE LIGHT** mean to you now? Please type your response in the box below and be as descriptive as possible.

Blue Light Comprehension - Part C - Car

The purpose of the **BLUE LIGHT** system is to let the person waiting at the intersection know that they have been detected by the sensors and that the traffic signal will soon provide a green light for them.

Below are three versions for the accompanying sign (you previously were shown one of them):



What sign do you think best conveys the meaning of the blue light system?

- ◘ Option #1
- ◘ Option #2
- ◘ Option #3

Please explain **WHY** you selected this option.

Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Level of Agreement				
	Strongly Disagree	Disagree	Indifferent	Agree	Strongly Agree
The addition of the **SIGN** helped with my understanding of the purpose of the blue light.	◘	◘	◘	◘	◘
I would support the use of a **BLUE LIGHT** system at some intersections in my community.	◘	◘	◘	◘	◘
I would feel better about waiting in a vehicle at an intersection if a **BLUE LIGHT** system was present.	◘	◘	◘	◘	◘

APPENDIX B INTERCEPT SURVEY QUESTIONNAIRE FOR FARSIDE BLUE LIGHT FEEDBACK SYSTEMS

Interpretation of Traffic Displays and Signs

You are being asked to take part in a research study. The information in this linked informed consent document shows the main facts you need to know about this research for you to think about when making a decision about if you want to join in. Carefully look over the information in this form and ask questions about anything you do not understand before you make your decision. You must be 18 years or older to participate and there is no penalty if you choose not to join in or decide to stop. At the end of the survey, you will be redirected to another survey where you can enter our r**andom drawing to win one of 5 $50 Amazon gift cards**.

○ I **AGREE** to take part in this study, and I am at 18 years or older.

○ I **DO NOT AGREE** to take part in this study, or I am not 18 years or older.

Please select the first two letters that appear in the **CODE** from your postcard to begin the survey.

○ AA

○ BB

○ CC

○ DD

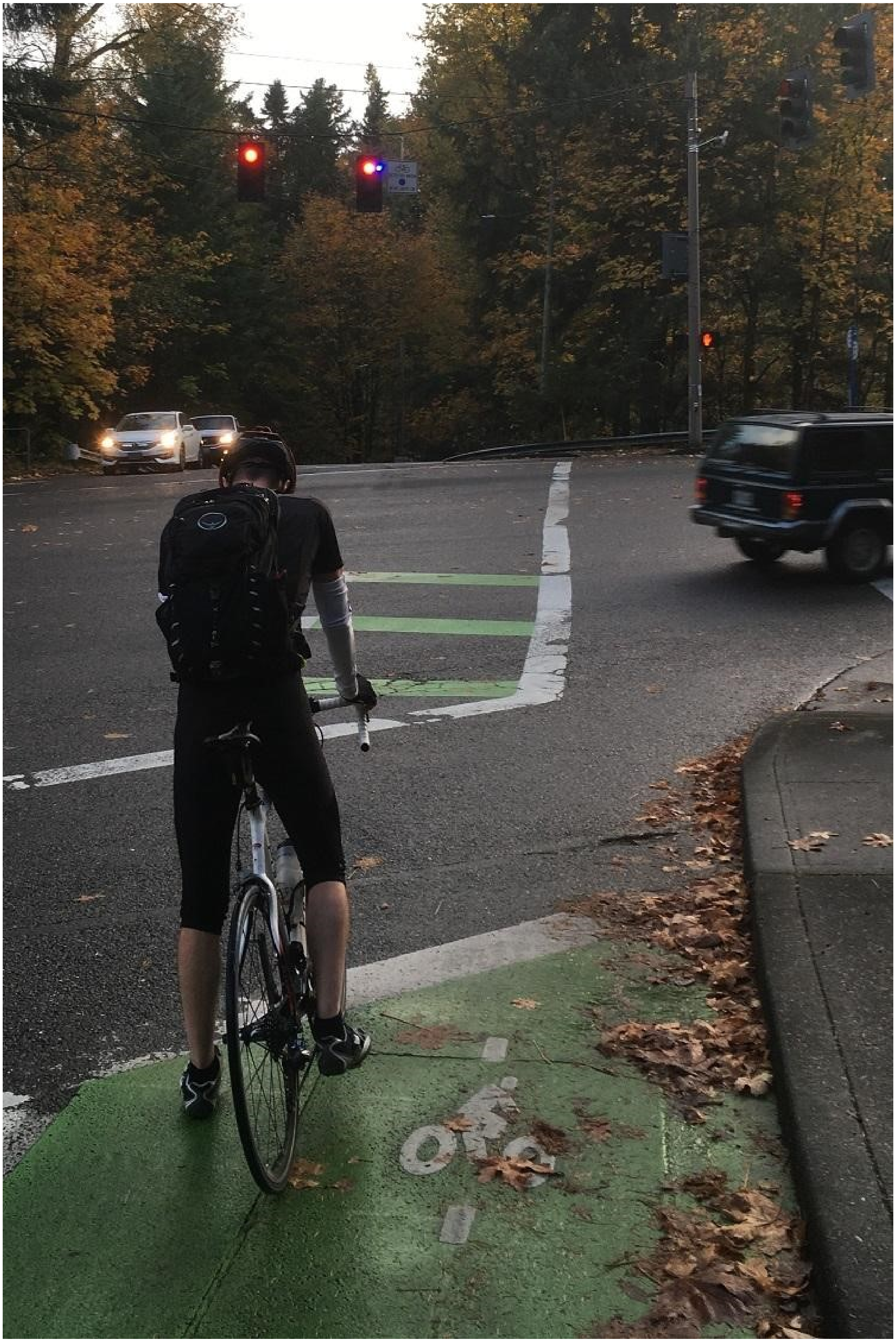
○ EE

○ FF

Please enter the numbers that follow the letters in the **CODE** from your postcard.

____

Blue Lights in Backplates



The photo above shows a view similar to the intersection where you were handed the postcard. Did you **notice or observe** the blue light and the sign at the intersection?

- ○ Yes
- ○ No

Have you previously read media articles or other materials explaining the blue light at intersections?

- ○ Yes
- ○ No

If you are waiting at the intersection and the blue light is **ON**, what does the sign pointed to by the red arrow mean to you?

Please type your response in the box below and be as descriptive as possible.

If you are waiting at the intersection and the blue light is **OFF** as shown in the photo, what does the sign pointed to by the red arrow mean to you?

Please type your response in the box below and be as descriptive as possible.

Is there anything you can do as a person on a bicycle to activate the blue light?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

What actions can you take to activate the blue light?

The purpose of the blue light is to let a person waiting know that they have been detected by the sensor and that the signal will soon provide a green signal. Bicycles need to be positioned in the lane correctly to be detected by aligning with the pavement marking.

Please indicate your level of agreement with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
The blue light and sign was clearly visible to me at the intersection.	○	○	○	○	○
The meaning of the blue light and sign is easily understood at the intersection.	○	○	○	○	○
I feel better about waiting on a bicycle at an intersection with the sign and blue light.	○	○	○	○	○
Having information that I have been detected by the traffic signal is useful to me.	○	○	○	○	○

Blue Light Embedded in Sign

The photo above shows a view similar to the intersection where you were handed the postcard. Did you **notice or observe** the blue light and the sign at the intersection?

○ Yes

○ No

Have you previously read media articles or other materials explaining the blue light at intersections?

○ Yes

○ No

If you are waiting at the intersection and the blue light is **ON**, what does the sign pointed to by the red arrow mean to you?

Please type your response in the box below and be as descriptive as possible.

____

____

____

____

____

If you are waiting at the intersection and the blue light is **OFF** as shown in the photo, what does the sign pointed to by the red arrow mean to you?

Please type your response in the box below and be as descriptive as possible.

Is there anything you can do as a person on a bicycle to activate the blue light?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

What actions can you take to activate the blue light?

____

____

____

____

____

The purpose of the blue light is to let a person waiting know that they have been detected by the sensor and that the signal will soon provide a green signal. Bicycles need to be positioned in the lane correctly to be detected by aligning with the pavement marking.

Please indicate your level of agreement with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
The blue light and sign was clearly visible to me at the intersection.	○	○	○	○	○
The meaning of the blue light and sign is easily understood at the intersection.	○	○	○	○	○
I feel better about waiting on a bicycle at an intersection with the sign and blue light.	○	○	○	○	○
Having information that I have been detected by the traffic signal is useful to me.	○	○	○	○	○

Demographics

Now you will be asked some questions regarding your transportation **activity** and demographics.

When the weather is nice, about how many days per month do you **RIDE** a bicycle?

____

Do you have a **DRIVER'S LICENSE**?

- ○ Yes
- ○ No

On average, how many **MILES** do you drive per year?

- ○ I don't drive a car for transportation
- ○ Less than 5,000
- ○ 5,000 - 9,999
- ○ 10,000 - 14,999
- ○ 15,000 - 19,999
- ○ 20,000 or more

What best describes your **GENDER**?

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer
- ◯ Prefer to self-describe ____

What is your **AGE**?

____

What **RACE** do you consider yourself?

- ◯ American Indian or Alaska Native
- ◯ Asian
- ◯ Black or African American
- ◯ Hispanic or Latino/a
- ◯ White or Caucasian
- ◯ Other
- ◯ Prefer not to answer

What is your annual household **INCOME**?

- Less than $25,000
- $25,000 to less than $50,000
- $50,000 to less than $75,000
- $75,000 to less than $100,000
- $100,000 to less than $200,000
- $200,000 or more
- Prefer not to answer

What is the highest level of **EDUCATION** you have completed?

- Some high school or less
- High School diploma or GED
- Some college
- Trade/vocational school
- Associate degree
- Four Year degree
- Master's degree
- PhD Degree
- Prefer not to answer

Are you **COLOR BLIND**?

- Yes
- No
- Prefer not to answer

Do you currently wear **CORRECTIVE GLASSES** or **CONTACTS**?

- Yes
- No
- Prefer not to answer

If there is anything else you want to tell us about the blue light and sign or the survey, please let us know. Otherwise, submit the survey to be redirected to the drawing.

APPENDIX C INTERCEPT SURVEY QUESTIONNAIRE FOR NEARSIDE BLUE LIGHT FEEDBACK SYSTEMS

You are being asked to take part in a research study. The information in this [linked informed consent] document shows the main facts you need to know about this research for you to think about when making a decision about if you want to join in. Carefully look over the information in this form and ask questions about anything you do not understand before you make your decision. You must be 18 years or older to participate and there is no penalty if you choose not to join in or decide to stop. At the end of the survey, you will be redirected to another survey where you can enter our random drawing to win one of 3 $50 Amazon gift cards.

O I **AGREE** to take part in this study and I am at 18 years or older. (1)

O I **DO NOT AGREE** to take part in this study or I am not 18 years or older. (2)

The photo above shows a view similar to the intersection where you were handed the postcard. Did you **NOTICE or OBSERVE** the blue light and sign at the intersection noted by the red arrow?

O Yes

O No

Have you previously **READ** media articles or other materials explaining the purpose of blue light at intersections?

○ Yes

○ No

If you are waiting at the intersection and the blue light is **ON**, what does the sign pointed to by the red arrow mean to you?
Please type your response in the box below and be as descriptive as possible.

____

If you are waiting at the intersection and the blue light is **OFF**, what does the sign pointed to by the red arrow mean to you?

Please type your response in the box below and be as descriptive as possible.

Is there anything you can do as a person on a bicycle to **ACTIVATE** the blue light?

- Yes
- No
- I'm not sure

What actions can you take to **ACTIVATE** the blue light?

The photo above shows the bicycle detector stencils on the pavement. Did you **NOTICE or OBSERVE** the bicycle detector stencils at the intersection?

O Yes

O No

The original bicycle stencil, with no black background, is located on the right side of the travel lane. A supplementary bicycle stencil, with black background, was added to the center of the lane.

Which location you **PREFER** to wait?

O Center of Lane

O On the Right

Do you **PREFER** the stencil without the black background (i.e., right side of the lane) or with the black background (i.e. center of the lane)

O Without Black Background

O With Black Background

The purpose of the blue light in the sign is to let the person waiting know that they have been detected and that the signal will soon provide a green signal. Bicycles need to be positioned in the lane correctly to be detected by aligning with either bicycle stencil.

Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
The blue light and sign was clearly visible to me at the intersection.	O	O	O	O	O
The meaning of the blue light and sign is easily understood at the intersection.	O	O	O	O	O
I feel better about waiting on a bicycle at an intersection with the sign and blue light.	O	O	O	O	O
Having information that I have been detected by the traffic signal is useful to me.	O	O	O	O	O

Now you will be asked some questions regarding your demographics.

When the weather is nice, about how many days per month do you **RIDE** a bicycle?
____

Do you have a **DRIVER'S LICENSE**?

O Yes

O No

On average, how many **MILES** do you drive per year?

- Less than 5,000
- 5,000 - 9,999
- 10,000 - 14,999
- 15,000 - 19,999
- 20,000 or more
- I don't drive

What best describes your **GENDER**?

- Male
- Female
- Prefer not to answer
- Prefer to self-describe

____

What is your **AGE**?

____

What **RACE** do you consider yourself?

- American Indian or Alaska Native
- Asian
- Black or African American
- Hispanic or Latino/a
- White or Caucasian
- Other

O Prefer not to answer

What is your annual household **INCOME**?

O Less than $25,000

O $25,000 to less than $50,000

O $50,000 to less than $75,000

O $75,000 to less than $100,000

O $100,000 to less than $200,000

O $200,000 or more

O Prefer not to answer

Q51 What is the highest level of **EDUCATION** you have completed?

O Some high school or less

O High School diploma or GED

O Some college

O Trade/vocational school

O Associate degree

O Four Year degree

O Master's degree

O PhD Degree

O Prefer not to answer

Are you **COLOR BLIND**?

O Yes

O No

O Prefer not to answer

Do you currently wear **CORRECTIVE GLASSES** or **CONTACTS**?

O Yes

O No

O Prefer not to answer

If there is anything else you want to tell us with respect to the survey, please let us know. Otherwise, submit the survey to be redirected to the drawing.

APPENDIX D INTERCEPT SURVEY QUESTIONNAIRE FOR NEARSIDE COUNTDOWN TIMER

You are being asked to take part in a research study. The information in this [linked informed consent] document shows the main facts you need to know about this research for you to think about when making a decision about if you want to join in. Carefully look over the information in this form and ask questions about anything you do not understand before you make your decision. You must be 18 years or older to participate and there is no penalty if you choose not to join in or decide to stop. At the end of the survey, you will be redirected to another survey where you can enter our random drawing to win one of 3 $50 Amazon gift cards.

○ I **AGREE** to take part in this study and I am at 18 years or older.

○ I **DO NOT AGREE** to take part in this study or I am not 18 years or older.

The photo above shows a view at the intersection where you were handed the postcard. Did you **NOTICE or OBSERVE** the bicycle signal (pointed to by the yellow arrow) at the intersection?

○ Yes

◯ No

Have you previously read media articles or other materials explaining the **PURPOSE** of this type of bicycle signal at intersections?

◯ Yes

◯ No

What does the display **with the word STOP and disappearing white dots** mean to you as a person on a bicycle when stopped at this intersection? Please type your response in the box below and be as descriptive as possible.

Is there anything you can do as a person on a bicycle to **ACTIVATE** the word STOP and white dots?

- ○ Yes
- ○ No
- ○ I'm not sure

What actions can you take to **ACTIVATE** the display?

The disappearing white dots are a countdown timer is to indicate to the person on a bicycle the amount of time they have left to wait before the signal turns green for them to proceed safely through the intersection.

Please indicate your **LEVEL OF AGREEMENT** with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
The countdown timer was clearly visible to me at the intersection.	○	○	○	○	○
The meaning of the countdown timer is easily understood at the intersection.	○	○	○	○	○

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I can accurately estimate of the time remaining to green from the countdown timer.	○	○	○	○	○
I feel better about waiting on a bicycle at an intersection with the countdown timer.	○	○	○	○	○
Having information that tells me how much time I have until given the green signal is useful to me.	○	○	○	○	○

Now you will be asked some questions regarding your demographics.

When the weather is nice, about how many days per month do you **RIDE** a bicycle?

____

Do you have a **DRIVER'S LICENSE**?

○ Yes

○ No

On average, how many **MILES** do you drive per year?

○ Less than 5,000

○ 5,000 - 9,999

- ◯ 10,000 - 14,999
- ◯ 15,000 - 19,999
- ◯ 20,000 or more
- ◯ I don't drive a vehicle

What best describes your **GENDER**?

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer
- ◯ Prefer to self-describe ____

What is your **AGE**?

____

What **RACE** do you consider yourself?

- ◯ American Indian or Alaska Native
- ◯ Asian
- ◯ Black or African American
- ◯ Hispanic or Latino/a
- ◯ White or Caucasian
- ◯ Other
- ◯ Prefer not to answer

What is your annual household **INCOME**?

- Less than $25,000
- $25,000 to less than $50,000
- $50,000 to less than $75,000
- $75,000 to less than $100,000
- $100,000 to less than $200,000
- $200,000 or more
- Prefer not to answer

What is the highest level of **EDUCATION** you have completed?

- Some high school or less
- High School diploma or GED
- Some college
- Trade/vocational school
- Associate degree
- Four Year degree
- Master's degree
- PhD Degree
- Prefer not to answer

Are you **COLOR BLIND**?

- Yes

○ No

○ Prefer not to answer

Do you currently wear **CORRECTIVE GLASSES** or **CONTACTS**?

○ Yes

○ No

○ Prefer not to answer

If there is anything else you want to tell us with respect to the survey, please let us know. Otherwise, submit the survey to be redirected to the drawing.

____
____
____
____
____